ABSTRACT

Background. As physical therapy gradually evolves into a more autonomous profession, physicians continue to play a major role in the clinical practice of physical therapists, particularly as a source of patient referral. The analysis of physicians’ referrals to physical therapy may be a practical and effective way to study the relationship between physicians and physical therapists.

Objectives. The objective of this study was to identify the primary reasons for physicians’ referrals to an outpatient physical therapy clinic and to determine whether further diagnosis by the physical therapist is necessitated prior to treatment.

Methods. Between January 1, 2001 and March 31, 2003, 544 consecutive physicians’ referrals were received in a rural physical therapy outpatient clinic. Physicians’ specialties, diagnosis on referral (or reason for referral, if diagnosis not provided), and prescribed orders on referral were all reviewed by the authors.

Results. One-third (33%) of the referrals were sent to physical therapy with no medical diagnosis (non-specified referrals – NSRs), and the most common reason for the referral in this NSR category was “pain” (88%). Commonly recommended treatments accompanying the NSRs included: evaluation & treatment (60%) and routine rehabilitation protocol (24%) for the relevant joints.

Conclusion. One-third (33%) of the referrals sent to physical therapy included no medical diagnosis, with the most common reason for the referral listed as “pain.” Evaluation and treatment was the most recommended treatment accompanying these non-specific referrals (almost 2/3). Physical therapists cannot properly manage patients based on a physician referred diagnosis of “pain,” therefore, it is necessary for physical therapists to make further diagnoses.

Key Words: physical therapy, decision-making, autonomy.

INTRODUCTION

Over 20 years ago, physicians played a dominant role in interaction between the physician and the physical therapist (PT). The PT functioned as a technician in a prescriptive role by following the order from the referring physician. The referring physician assumed the responsibilities and duties of evaluation, diagnosis, and determination of specific therapeutic interventions and modalities. Most physicians perceived the PT as a technician rather than a professional colleague. Physicians believed that the PT lacked the most complex criteria of medical professionalism: examination and evaluation skills and autonomy of judgment. However, the role of physical therapy has been changing rapidly in the past 5 to 10 years. In 2000, the American Physical Therapy Association (APTA) adopted Vision 2020, in which five key areas became the focus of the APTA to make physical therapy a more autonomous profession by the year 2020. These key areas include professionalism, direct access, the doctor of physical therapy degree, evidence-based practice, and the PT as the practitioner of choice. Achieving significant progress in these key areas will prepare and enable PTs to interact with physicians on a more collegial level and less as “subservient followers of orders.” Currently, the PT is assuming greater responsibility for initial assessment and management of musculoskeletal conditions. Actually, the PT has been functioning as the primary evaluator of neuromusculoskeletal conditions with success in the United States Army since the early 1970s. In reaction to this decades-long history of the PT
being the autonomous practitioner of choice in the Army, some researchers have suggested that the PT must demonstrate that they have the expertise in examination and treatment of musculoskeletal conditions to assume new roles in healthcare, to increase visibility within healthcare organizations, and to gain more autonomy as professionals.\(^1,9\)

Ritchey et al\(^11\) reported that the role expansion of physical therapy is not likely to occur easily because of the “turf battle” with physicians. The PT is seldom placed in a position to dispute or challenge a physician’s decision, or make a physician feel his/her competency is being questioned by subordinates.\(^11\)

While physical therapy has a long history of clinical practice with some level of autonomy regarding patient intervention, an equally long tradition of consulting with physicians also exists. Additionally, the cognitive and evaluative tasks the PT performs have tended to be secondary or supportive, if not supplementary, to a physician’s examination, evaluation, and diagnosis.

The American Medical Association and the American Academy of Orthopedic Surgeons oppose independent practitioner status for the PT because of concerns about improper diagnosis, inappropriate care, and the potential for increased costs.\(^12\) Ironically, several physician survey studies indicated that the majority of responding physicians did not know enough about physical therapy services.\(^2,3,13,14\) One study identified two areas that physicians lacked familiarity with physical therapy; the first being knowledge of how the PT evaluates their patients and the second being knowledge of modalities used by the PT and how such treatments are performed.\(^13\)

Recently, physicians’ knowledge of physical therapy was surveyed again revealing similar findings.\(^14\) These studies advocate for continuing education courses for physicians to increase their knowledge about physical therapy; suggestions that have been supported by the physician participants in the survey studies.\(^2,3,13,14\)

Recently, a trend has developed for states to pass laws allowing patients to have direct access to physical therapy. Also, an increasing number of physical therapy education programs in the United States are progressing to the doctor of physical therapy degree program. Physical therapy autonomy is becoming one of the most discussed issues related to daily physical therapy practice. According to the APTA Board of Directors, physical therapy autonomy is characterized by independent and self-determined professional judgment and action during practice.\(^15\) In other words, under direct access, the PT needs to be able to independently examine, evaluate, diagnose, and treat patients within their scope of practice.

All of these issues suggest there might be a “turf battle” between the PT and the physician, with one side trying to gain greater professional autonomy and role expansion and the other side opposing such expansion. Thus, analysis of physicians’ referrals to physical therapy may be a practical and effective way to study the relationship between the physician and the PT. The purpose of this study was to identify the primary reasons for physicians’ referrals to an outpatient physical therapy clinic and to determine whether further diagnosis by the PT is necessary prior to treatment.

**METHODS**

Between January 1, 2001 and March 31, 2003, 544 consecutive physicians’ referrals were received in a physical therapy outpatient clinic located between two metropolitan settings in the southeastern United States. For each referral, physician’s specialty, referral diagnosis (or reason for referral, if diagnosis was not provided), and prescribed orders on the referral were reviewed by the authors. No informed consent or institutional review board approval was required because the data collection did not require an intervention or an interaction with a living person and no identifiable private information was obtained or contained for this study in a form associateable with any individual(s).

**RESULTS**

**Specialty of the Physician**

Among 544 referrals from 78 physicians (67 medical doctors, 9 doctors of osteopathy, and 2 podiatrists), 59% of the referrals (321 of 544) were from orthopedists, and 32% (176 of 544) were from family or internal medicine practitioners.

Orthopedic surgeons, family physicians, and internal medicine physicians combined accounted for 91% of the total referrals. The remaining 9% of referrals came from physicians who specialized in neurology (2%), rehabilitation medicine (2%), pain management/anesthesiology (2%), podiatry (1%), general surgery (1%), and otolaryngology (1%).
Reason Provided on Referral

Out of the 544 referrals, 67% (367 of 544) included a specific medical diagnosis in the referral and for purposes of this study were categorized as specified referrals (SRs). (Table 1). The other 33% (177 of 544) did not include a specific medical diagnosis and were categorized as non-specified referrals (NSRs). Since these NSRs included symptoms (pain, dizziness, weakness) rather than a specific medical condition, these referrals are considered “reasons for referral” rather than diagnoses. Of these 177 NSRs, in 88% (156 of 177) the reason for referral was “pain” (knee pain, back pain, etc).

To further analyze the data, referrals specifically related to surgery were separated from non-surgical referrals. Among all referrals, 22% (118 of 544) specifically were related to post-surgery and had a specific diagnosis included in the referral. The most common post-surgical referrals were for knee arthroscopy, total knee replacement, and rotator cuff repair. In contrast, 78% of all referrals (426 of 544) were non-surgical related referrals.

Of the 426 non-surgery related referrals, 249 (58.4%) of them were referred with a specific medical diagnosis (SRs), and 177 (41.6%) were referred without any medical diagnosis (NSRs). Based on the anatomical location of the reason for the referral, the lower back, ankle-foot, shoulder, knee, and neck were the top five locations across all non-surgery related referrals (NSRs and SRs combined; Table 2). Among the 249 SRs, the lower back, ankle-foot, shoulder, knee, and neck were the top five sites of complaints. According to the medical diagnoses on the 249 SRs, lumbar strain, rotator cuff tendonitis/impingement, ankle sprain, cervical strain, and knee osteoarthritis were the top five diagnoses on the specified referrals. (Listed in Table 3 are the three most common physicians’ diagnoses for each anatomical location for the SRs.) Further analysis of the 177 NSRs revealed that the low back was the most frequent anatomic location for the reason for the referral. (Figure)

Prescribed Orders on Referrals

As seen in Table 4, the most commonly prescribed orders made by physicians on the 544 referrals were evaluation and treatment (47%), routine rehabilitation protocol (22%) for the relevant joints (i.e. routine knee rehab), strengthening and range of motion (15%), and specified modalities (13%). The most commonly recommended orders on the 177 NSRs included evaluation and treatment (60%), routine rehabilitation protocol (24%), and strengthening and range of motion (9%). Among those 22% (118 of 544) of referrals (including both SRs and NSRs) with routine rehabilitation protocol as the prescribed order, 11 of the 118 (9%) were accompanied with either a copy of the treatment protocol (9 of 11) or a reference to a published book or article (2 of 11). However, 107 of the 118 (91%) referrals presented no details of the treatment protocol. Of these 109 referrals, most came from orthopedists (51%) or family/internal medicine physicians (39%).

DISCUSSION

Physician Specialties

More and more states are passing direct access to physical therapy laws, but the long-standing trend continues to be that third parties such as Medicare, Medicaid, and private insurance companies reimburse physical therapy services only if the physical therapy service is prescribed by a physician.16 Therefore, physicians continue to play a major role in referral of patients to physical therapy and the prescription of physical therapy services seems to be determined, in part, by physician specialties and
patients’ insurance status. Namely, orthopedic surgeons, followed by general practitioners and internal medicine specialists, are still the main referral sources for physical therapy.\textsuperscript{11,17,18}

Likewise, this study showed similar results with orthopedists (59%) and family and internal medicine practitioners (32%) accounting for 91% of the total referrals.

Reason for Referral and Physical Therapy Autonomy

The physician members of the American Medical Association and the American Academy of Orthopedic Surgeons have traditionally opposed increased autonomy by physical therapists in the practice of physical therapy.\textsuperscript{12} Yet, as the primary source of referrals to physical therapy, their non-specified referrals from physicians are somewhat inconsistent with this viewpoint. This study identified pain, muscle weakness, and decreased range of motion (all of which are impairments/symptoms) as the three most common reasons physicians referred their patients to outpatient physical therapy. Interestingly, one-third (33%) of the referrals did not have a medical diagnosis with the most frequent location of the complaint being the lower back and the most frequent reason for the referral being “pain.” Clearly, additional skillful, independent examination and assessment of the patient by the PT is warranted in such instances. Two things may potentially be inferred from this finding. First, referring physicians may view the PT as a consultant/expert rather than as a subordinate with regard to management of some patients with musculoskeletal conditions. Secondly, a PT may be empowered to view him/herself more as a physician’s colleague rather than a technician or subordinate. Such ideals are also facilitated by the progression of physical therapy education to the doctor of physical therapy degree level, characterized by greater breadth and depth of content and instruction in skilled, proactive, and independent clinical decision making. Physical therapists do not identify disease in the sense of pathology, but they do identify clusters of signs, symptoms, and other relevant information from subjective and objective examination of the patient. These clusters can be labeled as classifications or diagnoses by the PT.\textsuperscript{19} Based on the present study, pain is the most common impairment that the PT encounters in an outpatient setting. Thus, the ability to understand and differentiate the multitude of signs and symptoms relevant to pain and then to be able to synthesize this information with data from patient history, and radiology and lab test results will greatly assist the PT in the management of their patients, especially in instances where medical diagnosis information from the referring physician is lacking.

Brogan\textsuperscript{17} reported that physicians probably do not recognize the extent to which their patients need phys-

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**TABLE 3. Categorization of Diagnoses on the Specified Referrals**

<table>
<thead>
<tr>
<th>Pain Area</th>
<th>Most Commonly Referred Diagnoses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>cervical strain, cervical degenerative disease, cervical disk hernia</td>
</tr>
<tr>
<td>Upper Back</td>
<td>trapezius spasm/strain, whiplash, thoracic strain</td>
</tr>
<tr>
<td>Low Back</td>
<td>lumbar strain, post disectomy (&gt; 1 year post-surgery), lumbar radiculopathy</td>
</tr>
<tr>
<td>Shoulder</td>
<td>rotator cuff tendonitis, impingement, humeral fracture, rotator cuff tear</td>
</tr>
<tr>
<td>Elbow</td>
<td>elbow tendonitis, radial head fracture</td>
</tr>
<tr>
<td>Wrist-Hand</td>
<td>cubital tunnel syndrome, fracture, tenosynovitis</td>
</tr>
<tr>
<td>Hip</td>
<td>trochanteric bursitis, ileal tuberosity bursitis, sacroiliac joint dysfunction</td>
</tr>
<tr>
<td>Knee</td>
<td>osteoarthritis, patellofemoral syndrome, patellar subluxation/dislocation</td>
</tr>
<tr>
<td>Ankle-Foot</td>
<td>ankle sprain, plantar fasciitis, achilles tendonitis</td>
</tr>
<tr>
<td>Systemic/Other</td>
<td>fibromyalgia, temporomandibular joint dysfunction, post-polio syndrome, rheumatoid arthritis</td>
</tr>
</tbody>
</table>
Physician referrals to physical therapy have been studied by others. Twenty years ago, physicians often did a physical therapy referral for patients with the assumption that the patient was not in need of any further assessment, evaluation, or decision-making by the PT. Several years later, Ritchey et al. found that 30% of physicians gave no diagnosis on the physical therapy referral, which is similar to results of this study (29%). Hulme et al. reported that although both physicians and physical therapists agreed that inclusion of the medical diagnosis on physical therapy referrals was a priority, many physical therapists reported the diagnosis was often omitted from referrals, was incomplete, or was a list of impairments/symptoms rather than a medical diagnosis. In the view of the PT, even a preliminary diagnosis was important for the purposes of serving as a starting point for the examination and evaluation and for assistance in excluding many pathological conditions that may cause the symptoms.

Further discussion regarding physician support of greater autonomy in physical therapy practice relates to decision-making regarding plan of care and interventions. According to this study, a substantial number of referrals state “evaluate and treat” (47% of all referrals). Among the NSRs, the percentage is 60% of NSR referrals. These observations seem to add additional support to the notion that greater autonomy of the PT, regarding all aspects of patient management, is being encouraged by physicians by the nature of their physical therapy referrals.

**Future Study**

In future research, data should be collected on a larger number of referrals from both rural and urban outpatient physical therapy clinical settings in different geographic areas of North America. Any association between physicians’ years of working experience and the frequency of specified and non-specified referrals should be investigated. Also, future research should focus on the relationship between physician specialty and any prescribed orders, recommended treatment duration, radiological or laboratory documentation, and treatment precautions stated on referrals. Such investigations, in combination with the results of the present study, will further assist both physicians and physical therapists in understanding their roles in the contemporary healthcare environment and may also serve to identify some continuing education needs of both professions.

**CONCLUSION**

Review of 544 physician referrals to a physical therapy outpatient clinic indicated that 1/3 (33%) of the referrals included no medical diagnosis. Within these non-specified referrals, “pain” was the reason listed most frequently (88%) and the low back was the most frequent location (40%). However, pain is a symptom/impairment rather than a medical diagnosis. Physical therapists cannot properly manage patients based on a referred diagnosis of “pain,” making it necessary for the PT to make further diagnoses. Greater independence and involvement in the diagnostic process, as well as patient management in general, is indirectly encouraged through non-specific physician referrals.
REFERENCES


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ABSTRACT

Glenohumeral joint instability is a common pathology encountered in the orthopaedic and sports medicine setting. A wide range of symptomatic shoulder instabilities exist ranging from subtle subluxations due to contributing congenital factors to dislocations as a result of a traumatic episode. Non-operative rehabilitation is utilized in patients diagnosed with shoulder instability to regain their previous functional activities through specific strengthening exercises, dynamic stabilization drills, neuromuscular training, proprioception drills, scapular muscle strengthening program and a gradual return to their desired activities. The specific rehabilitation program should be varied based on the type and degree of shoulder instability present and desired level of function. The purpose of this paper is to outline the specific principles associated with non-operative rehabilitation for each of the various types of shoulder instability and to discuss the specific rehabilitation program for each pathology type.

Keywords: Dynamic stabilization, neuromuscular control, shoulder joint

INTRODUCTION

Shoulder instability is a common pathology often seen in the orthopaedic and sports medicine setting. The glenohumeral joint allows tremendous amounts of joint mobility to function, thus, making the joint inherently unstable and the most frequently dislocated joint in the body. Due to the joint's poor osseous congruency and capsular laxity, it greatly relies on the dynamic stabilizers and neuromuscular system to provide functional stability. Therefore, differentiation between normal translation and pathological instability is often difficult to determine. A wide range of shoulder instabilities exist from subtle subluxations to gross instability. Often the success of the rehabilitation program is based on the recognition and treatment program designed to treat the specific type of instability present.

Non-operative rehabilitation is often implemented in patients diagnosed with a variety of shoulder instabilities. These instability patterns can range from congenital multidirectional instabilities to traumatic unidirectional dislocations. We have classified glenohumeral joint instabilities into two broad categories: traumatic and atraumatic. Based on the classification system of glenohumeral instability, as well as several other factors, a non-operative rehabilitation program may be developed. The purpose of this paper is to discuss and overview these factors along with the non-operative rehabilitation programs for the various types of shoulder instability in order to return the patient to their previous level of function.

TABLE. Seven key factors to consider in the rehabilitation of the unstable shoulder

1. Onset of the pathology
2. Degree of instability – subluxation vs. dislocation
3. Frequency of dislocation – chronic vs. acute
4. Direction of instability – anterior, posterior, multidirectional
5. Concomitant pathologies
6. End range neuromuscular control
7. Premorbid activity level
REHABILITATION FACTORS
Seven key factors should be considered when designing a rehabilitation program for a patient with an unstable shoulder (Table). These factors and their significance to the rehabilitation program will be presented.

Onset of Pathology
The first factor to consider in the rehabilitation of a patient with shoulder instability is the onset of the pathology. Pathological shoulder instability may result from an acute, traumatic event or chronic, recurrent instability. The goal of the rehabilitation program may vary greatly based on the onset and mechanism of injury. Following a traumatic subluxation or dislocation, the patient typically presents with significant tissue trauma, pain, and apprehension. The patient who has sustained a dislocation often exhibits more pain due to muscle spasm than a patient who has only subluxed their shoulder. Furthermore, a first-time episode of dislocation is generally more painful than the repeat event. Rehabilitation for the patient with a first-time traumatic episode will be progressed based on the patient’s symptoms with emphasis on early controlled range of motion, reduction of muscle spasms and guarding, and relief of pain.

Conversely, a patient presenting with atraumatic instability often presents with a history of repetitive injuries and symptomatic complaints. Often the patient does not complain of a single instability episode but, rather, a feeling of shoulder laxity or an inability to perform specific tasks. Rehabilitation for this patient should focus on early proprioception training, dynamic stabilization drills, neuromuscular control, scapular muscle exercises, and muscle strengthening exercises to enhance dynamic stability due to the unique characteristic of excessive capsular laxity and capsular redundancy in this type of patient.

Degree of Instability
The second factor is the degree of instability present in the patient and the effect on their function. Varying degrees of shoulder instability exist such as a subtle subluxation or gross instability. The term subluxation refers to the complete separation of the articular surfaces with spontaneous reduction. Conversely, a dislocation is a complete separation of the articular surfaces and requires a specific movement or manual reduction to relocate the joint, resulting in underlying capsular tissue trauma. The degree of trauma to the soft tissue of the glenohumeral joint with a shoulder subluxation is can be quite extensive. Speer et al3 has reported that in order for a shoulder dislocation to occur, a Bankart lesion and soft tissue trauma must be present on both sides of the glenohumeral joint capsule. Thus, in the situation of an acute traumatic dislocation, the anterior capsule may be avulsed off the glenoid (Bankart lesion) and the posterior capsule may be stretched, allowing the humeral head to dislocate. Warren et al4 refer to this damage to both the anterior and posterior capsule as the “circle stability concept.”

The rate of progression of the rehabilitation program will vary based upon the degree of instability and persistence of symptoms. For example, a patient with mild subluxations and muscle guarding may initially tolerate strengthening exercises and neuromuscular control drills more than a patient with a significant amount of muscular guarding.

Frequency of Dislocation
The next factor to influence the rehabilitation program is the frequency of dislocation or subluxation. The primary traumatic dislocation is most often treated conservatively with immobilization in a sling and early controlled passive range of motion (ROM) exercises, especially with first time dislocations. The incidence of recurrent dislocation ranges from 17-96% with a mean of 67% in patient populations between the ages of 21-30 years old. Therefore, the rehabilitation program should progress cautiously in young athletic individuals. It should be noted that Hovelius et al8,16,17 has demonstrated that the rate of recurrent dislocations is based on the patient’s age and not affected by the length of post-injury immobilization. Individuals between the ages of 19 and 29 years are the most likely to experience multiple episodes of instability. Hovelius et al8,16,17 noted patients in their 20’s exhibited a recurrence rate of 60%, whereas, patients in their 30’s to 40’s had less than a 20% recurrence rate. In adolescents, the recurrence rate is as high as 92%18 and 100% with an open physes.19

Chronic subluxations, as seen in the atraumatic, unstable shoulder may be treated more aggressively due to the lack of acute tissue damage and less muscular guarding and inflammation. Rotator cuff and periscapular strengthening activities should be initiated while ROM exercises are progressed. Caution is placed on avoiding excessive stretching of the joint capsule through aggressive ROM activities. The goal is to enhance strength, proprioception, dynamic stability and neuromuscular control, especially in the specific points of motion or direction which results in instability complaints.
Direction of Instability
The fourth factor is the direction of instability present. The three most common forms include anterior, posterior, and multidirectional. Anterior instability is the most common traumatic type of instability seen in the general orthopaedic population, representing approximately 95% of all traumatic shoulder instabilities. Following a traumatic event in which the humeral head is forced into extremes of abduction and external rotation, or horizontal abduction, the glenolabral complex and capsule may become detached from the glenoid rim resulting in anterior instability. This type of detachment is referred to as a Bankart lesion. Baker et al. have identified four types of Bankart lesions based on the size and degree of tissue involvement. Conversely, rarely will a patient with traumatic instability due to capsular redundancy dislocate their shoulder. It is the author’s opinion that these patients are more likely to repeatedly sublux the joint without complete separation of the humerus from the glenoid rim. Capsular avulsions can occur on the glenoid side (Bankart lesion) or on the humeral head side referred to as a HAGL lesion (humeral avulsion of the inferior glenohumeral ligament).

Posterior instability occurs less frequently, only accounting for less than 5% of traumatic shoulder dislocations. This type of instability is often seen following a traumatic event such as falling onto an outstretched hand or from a pushing mechanism. However, patients with significant atraumatic laxity may complain of posterior instability especially with shoulder elevation, horizontal adduction and excessive internal rotation due to the strain placed on the posterior capsule in these positions. In professional or collegiate football, the incidence of posterior shoulder instability appears higher than the general population. This is especially true in linemen. Mair et al. reported on nine athletes with posterior instability in which eight of nine were linemen and seven were offensive linemen. Often, these patients require surgery as Mair et al. also reported 75% required surgical stabilization. Kaplan et al. reported in a study of collegiate football players that 78% required surgical stabilization.

Multidirectional instability (MDI) can be identified as shoulder instability in more than one plane of motion. Patients with MDI have a congenital predisposition and exhibit ligamentous laxity due to excessive collagen elasticity of the capsule. Furthermore, Rodeo et al. reported that this type of patient turns over collagen at a faster rate. The authors consider an inferior displacement of greater than 8-10mm during the sulcus maneuver (Figure 2) with the arm adducted to the side as significant hypermobility, thus suggesting significant congenital laxity.

Due to the atraumatic mechanism and lack of acute tissue damage, ROM is often normal to excessive. Patients with recurrent shoulder instability due to MDI...
generally have weakness in the rotator cuff, deltoid muscle, and scapular stabilizers with poor dynamic stabilization and inadequate static stabilizers. Initially, the focus of the rehabilitation program is on maximizing dynamic stability, scapula positioning, proprioception, and improving neuromuscular control in mid ROM. Also, rehabilitation should focus on improving the efficiency and effectiveness of glenohumeral joint force couples through co-contraction exercises, rhythmic stabilization, and neuromuscular control drills. Isotonic strengthening exercises for the rotator cuff, deltoid muscle, and scapular muscles are also emphasized to enhance dynamic stability. Morris et al. reported the EMG activity of the rotator cuff and deltoid muscle in MDI and asymptomatic subjects. The authors noted the most significant difference was in the deltoid muscles compared to the rotator cuff muscles in their groups.

Concomitant Pathologies
The fifth factor involves considering other tissues that may have been affected and the premorbid status of the tissue. Disruption of the anterior capsulolabral complex from the glenoid commonly occurs during a traumatic injury resulting in an anterior Bankart lesion. Often osseous lesions may be present such as a concomitant Hill Sachs lesion caused by an impaction of the posterolateral aspect of the humeral head as it compresses against the anterior glenoid rim during relocation. This Hill Sachs lesion has been reported in up to 80% of dislocations. Conversely, a reverse Hill Sachs lesion may be present on the anterior aspect of the humeral head due to a posterior dislocation. Occasionally, a bone bruise may be present in individuals who have sustained a shoulder dislocation as well as pathology to the rotator cuff. In rare cases of extreme trauma, the brachial plexus may become involved as well. Common injuries in the unstable shoulder may involve the superior labrum (SLAP lesion) such as a type V SLAP lesion characterized by a Bankart lesion of the anterior capsule extending into the anterior superior labrum. These concomitant lesions may significantly slow down the rehabilitation program in order to protect the healing tissue.

Neuromuscular Control
The sixth factor to consider is the patient’s level of neuromuscular control, particularly at end range. Neuromuscular control may be defined as the efferent, or motor, output in reaction to an afferent, or sensory input. The afferent input is the ability to detect the glenohumeral joint position and motion in space with resultant efferent response by the dynamic stabilizers as they blend with the joint capsule to assist in stabilization of the humeral head. Injury with resultant insufficient neuromuscular control could result in deleterious effects to the patient. As a result, the humeral head may not center itself within the glenoid, thereby, compromising the surrounding static stabilizers. The patient with poor neuromuscular control may exhibit excessive humeral head migration with the potential for injury, an inflammatory response, and reflexive inhibition of the dynamic stabilizers.

Several authors have reported that neuromuscular control of the glenohumeral joint may be negatively affected by joint instability. Leiphart et al. compared the ability to detect passive motion and the ability to reproduce joint positions in patients with normal, unstable, and surgically repaired shoulders. The authors reported a significant decrease in proprioception following a shoulder dislocation. Blasier et al. reported a significant decrease in proprioception in patients with normal laxity. Zuckerman et al. noted that proprioception is affected by the patient’s age with older subjects exhibiting diminished proprioception than a comparably younger population. Thus, the patient presenting with traumatic or acquired instability may present with poor neuromuscular control.

Activity Level
The final factor to consider in the non-operative rehabilitation of the unstable shoulder is the arm dominance and the desired activity level of the patient. If the patient frequently performs an overhead motion or sporting activities such as a tennis, volleyball, or a throwing sport, then the rehabilitation program should include sport specific dynamic stabilization exercises, neuromuscular control drills, and plyometric exercises in the overhead position once full, pain free ROM and adequate strength has been achieved. Patients whose functional demands involve below shoulder level activities will follow a progressive exercise program to return full ROM and strength. The success rates of patients returning to overhead sports after a traumatic dislocation of their dominant arm are extremely low. Arm dominance can also significantly influence the successful outcome. The recurrence rates of instabilities vary based on age, activity level, and arm dominance. In athletes involved in
collision sports, the recurrence rates have been reported between 86-94%.6,40-42

**REHABILITATION GUIDELINES**

Patients may be classified into two common forms of shoulder instability - traumatic and atraumatic. Specific guidelines to consider in the rehabilitation of each patient population will be outlined. A four-phase rehabilitation program will be discussed for traumatic shoulder instability, followed by an overview of variations and key rehabilitation principles for atraumatic shoulder instability (congenital and acquired laxity).

**Traumatic Shoulder Instability**

**Phase I-Acute Phase**

Following a first time traumatic shoulder dislocation or subluxation, the patient often presents in considerable pain, muscle spasm, and an acute inflammatory response. The patient usually self-limits their motion by guarding the injured extremity in an internally rotated and adducted position against the side of their body to protect the injured shoulder. The goals of the acute phase are to 1) diminish pain, inflammation, and muscle guarding 2) promote and protect healing soft tissues, 3) prevent the negative effects of immobilization, 4) re-establish baseline dynamic joint stability, and 5) prevent further damage to glenohumeral joint capsule. (Appendix 1)

Immediate limited and controlled motion is allowed following a traumatic dislocation in patients between the ages of 18-28 years but immobilize patients between the ages of 29-54 years old. However, motion is restricted so as to not to cause further tissue attenuation. A short period of immobilization in a sling to control pain and to allow scar tissue to form for enhanced stability may be necessary for 7-14 days although no long-term benefits regarding recurrence rates and immobilization have been made in younger patients between the ages of 18-28 years old.8,43 Individuals above the age of 28 are usually immobilized for 24 weeks to allow scarring of the injured capsule. Potential complications with immobilization may include a decrease in joint proprioception, muscle disuse and atrophy, and a loss of ROM in specific age groups. Therefore, prolonged use of immobilization following a traumatic dislocation may not be recommended in all patients.

The ideal position to immobilize the glenohumeral has traditionally been in internal rotation with the arm close to the body. Recent studies by Itoi et al44,45 examined positional differences of immobilization and compared the rates of recurrent dislocations. The authors concluded that immobilization in external rotation significantly reduced the recurrence rate of instability in chronic and first-time dislocators. Itoi et al46 has recommended immobilization with the arm in 30 degrees of abduction and external rotation, compared to a group of patients immobilized in internal rotation. The results indicated a 0% recurrence rate in external rotation and 30% incidence of instability in the group immobilized in internal rotation. The authors stated that the resultant Bankart lesion had improved coaptation to the glenoid rim with immobilization in external rotation versus conventional immobilization in a sling.

Passive ROM is initiated in a restricted and protected range based on the patient's symptoms. The early motion is intended to promote healing, enhance collagen organization, stimulate joint mechanoreceptors, and aid in decreasing the patient's pain through neuromuscular modulation.14,46-48 Painfree active-assisted ROM exercises such as pendulums and external/internal rotation at 45 degrees of abduction using an L-bar (Breg Corp. Vista, CA) may also be initiated. Passive ROM exercises are also performed in a painfree arc of motion. Modalities such as ice, transcutaneous electrical nerve stimulation (TENS), and high voltage stimulation may also be beneficial to decrease pain, inflammation, and muscle guarding.

Strengthening exercises are initially performed through submaximal, painfree isometric contractions to initiate muscle recruitment and retard muscle atrophy. Electrical stimulation of the posterior cuff musculature may also be incorporated to enhance the muscle fiber recruitment process early on in the rehabilitation process and also in the next phase when the patient initiates isotonic strengthening activities. (Figure 3) Reinold et al49 believe that the use of electrical stimulation may improve force production of the rotator cuff particularly the external rotators immediately after an acute injury.

Dynamic stabilization exercises are also performed to re-establish dynamic joint stability. The patient maintains a static position as the rehabilitation specialist performs manual rhythmic stabilization drills to facilitate muscular co-contractions. These manual rhythmic stabilization drills are performed for the shoulder internal and external rotators in the scapular plane at 30 degrees of abduction and are performed at painfree angles which do not compromise the healing capsule. Rhythmic stabilization for flexion and extension may also be performed with the shoulder at 100 degrees of flexion and 10 degrees of horizontal abduction. Strengthening exercises are also
performed for the scapular retractors and depressors to reposition the scapula in its proper position. Scapula strengthening is critical for successful rehabilitation. Closed kinetic chain exercises such as weight shifting on a ball are performed to produce a co-contraction of the surrounding glenohumeral musculature and to facilitate joint mechanoreceptors to enhance proprioception. Weight shifts are usually able to be performed immediately following the injury unless posterior instability is present.

Phase II-Intermediate phase
During the intermediate phase, the program emphasizes regaining full ROM along with progressing strengthening exercises of the rotator cuff, and re-establishing muscular balance of the glenohumeral joint, scapular stabilizers, and surrounding shoulder muscles. Before the patient enters Phase II, certain criteria must be met which include diminished pain and inflammation, satisfactory static stability, and adequate neuromuscular control.

To achieve the desired goals of this phase, passive ROM is performed to the patient’s tolerance with the goal of attaining nearly full ROM. Active-assisted ROM exercises using a rope and pulley along with flexion and external/internal rotation exercises at 90 degrees of abduction using an L-bar may be progressed to tolerance without stressing the involved tissues. External rotation at 90 degrees of abduction is generally limited to 65-70 degrees to avoid over stressing the healing anterior capsuloligamentous structures for approximately 4-8 weeks but eventually increasing ROM to full motion as the patient tolerates.

Isotonic strengthening exercises are also initiated during this phase. Emphasis is placed on increasing the strength of the internal and external rotators and scapular muscles to maximize dynamic stability. The ultimate goal of the strengthening phase is to re-establish muscular balance following the injury. Kibler1 noted that scapular position and strength deficits have been shown to contribute to glenohumeral joint instability. Exercises initially include external and internal rotation with exercise tubing at 0 degrees of abduction along with sidelying external rotation and prone rowing. During the latter part of this phase, isotonic exercises are progressed to emphasize rotator cuff and scapulothoracic muscle strength. Manual resistive exercises such as sidelying external rotation and prone rowing may also prove beneficial by having the clinician vary the resistance throughout the ROM. Incorporating manual concentric and eccentric manual exercises and rhythmic stabilization drills at end range to enhance neuromuscular control and dynamic stability is also recommended.

Closed kinetic chain exercises are progressed to include a hand on the wall stabilization drills in the plane of the scapular at shoulder height as the patient tolerates. (Figure 5) Push-ups are performed first with hands on a table then progressed to a push-up on a ball or unstable surface while the rehabilitation specialist performs rhythmic stabilization to the involved and uninvolved upper extremity along with the trunk to integrate dynamic stability and core strengthening (tilt board, ball, etc.). (Figure 6) Caution should be placed while performing closed kinetic chain exercises in patients with posterior instability for 6-8 weeks at allow for adequate healing and strength gains. Furthermore, patients with significant scapular winging should perform push-ups until adequate scapular strength is accomplished. Core stabilization drills should also be performed to enhance scapular control. Additionally, strengthening exercises may be advanced in regards to resistance, repetitions, and sets as the patient improves. End range rhythmic stabilization drills with the arm at 0 degrees of adduction or at 45 degrees of abduction are also performed. Exercises such as tubing with manual resistance and end range rhythmic stabilization drills are also performed. (Figure 7) The goal of these exercise drills is to improve proprioception and neuromuscular control at end range.

Phase III- Advanced Strengthening
In the advanced strengthening phase, the focus is on...
improving strength, dynamic stability, and neuromuscular control near end range through a series of progressive strengthening exercises for a gradual return to the patient’s activity. Criteria to enter this phase include: 1) minimal pain and tenderness, 2) full range of motion, 3) symmetrical capsular mobility, 4) good (at least 4/5 manual muscle test) strength, endurance and dynamic stability of the scapulothoracic and upper extremity musculature.

Muscle fatigue has also been associated with a decrease in neuromuscular control. Carpenter et al.50 observed the ability to detect passive motion of shoulders positioned at 90 degrees of abduction and 90 degrees of external rotation. The investigators reported a decrease in both the detection of external and internal rotation movement following an isokinetic fatigue protocol. Therefore, exercises designed to enhance endurance in the upper extremity such as using low resistance and high repetitions (20-30 repetitions per set) are incorporated during this phase. Also, exercise sets utilizing time may be incorporated, such as 30 second or 60 second exercise bouts. These exercises may include tubing external and internal rotation, plyoball wall dribbling, and submaximal manual resistance drills.

Aggressive upper body strengthening through the continuation of a progressive isotonic resistance program is recommended. A gradual increase in resistance as well as a progression to a more functional position by performing tubing exercises at 90 degrees of abduction to strengthen the external and internal rotators is also recommended. Additionally, more aggressive isotonic strengthening exercises such as bench press, seated row, and latissimus pulldowns may be incorporated in a protected range of motion during this phase. During bench press and seated rows, the patient is instructed to not extend the upper extremities beyond the plane of the body to minimize stress on the shoulder capsule. Latissimus pulldowns are performed in front of the head and the patient is instructed to avoid full extension of the arms to minimize the amount of traction force applied to the shoulder joint. Also during this phase, the patient continues to perform rhythmic stabilization drills with the rehabilitation specialist and gradually progresses to a position of apprehension utilizing tubing at 90 degrees of abduction with end range rhythmic stabilization drills to enhance dynamic stability.

A patient wishing to return to athletic participation may be instructed to perform plyometric exercises for the upper extremity. These activities are incorporated to regain any remaining functional ROM as well as improving neuromuscular control and to train the extremity to produce and dissipate forces. Initially, 2-handed drills close to the body such as chest pass, side-to-side and overhead soccer throws (Figure 8) using a 3-5 pound medicine ball may be performed to enhance dynamic stabilization of the glenohumeral joint. Exercises are initiated with 2-hand drills close to the center of gravity and gradually progressed to longer lever arms away from the patient’s body. Drills are progressed to challenge the dynamic stabilizers of the shoulder.

After approximately two weeks of pain free 2-handed drills, the athlete progresses to 1-handed plyometric drills using a small medicine ball (1-2 lbs) and throwing into a plyoback. Plyoball wall dribbles in the 90/90 position (Figure 9) to improve overhead muscle endurance may also be incorporated.
Phase IV- Return to Activity Phase
In the return to activity phase, the goal is to increase, gradually and progressively, the functional demands on the shoulder in order for the patient to return to unrestricted, sport or daily activities. Other goals of this phase are to maintain the patient's muscular strength and endurance, dynamic stability and functional range of motion. The criteria to progress into this phase include: 1) full functional ROM, 2) adequate static stability, 3) satisfactory muscular strength and endurance, 4) adequate dynamic stability, and 5) a satisfactory clinical exam.

The general orthopaedic patient continues to perform a maintenance program to improve strength, dynamic stability, and neuromuscular control as well as maintaining full, functional and painfree ROM. The athlete continues to perform aggressive strengthening exercises such as plyometrics, proprioceptive neuromuscular facilitation drills, and isotonic strengthening. In addition, the athlete may begin functional sport activities through an interval return to sport program. These activities are designed to gradually return motion, function, and confidence in the upper extremity by progressing through graduated sport-specific activities. These interval sport programs are set up to minimize the chance of re-injury while training the patient for the demands of each individual sport. Each program should be individualized based on the patient's injury, skill level, and goals. The duration of each program is based on several factors including the extent of the injury, the sport and level of play, along with the time of season. The athlete is allowed to return to unrestricted sports activities after completion of an appropriately designed rehabilitation program and a successful clinical exam including full ROM, strength along with adequate dynamic stability and neuromuscular control.

We routinely perform a combination of isokinetic testing for our overhead athletes, which we refer to as the “Thrower's Series.” Criteria to begin an interval sport program includes an external rotation/internal rotation strength ratio of 66-76% or higher at 180º/second, an external rotation to abduction ratio of 67-75% or higher at 180º/second. Patients returning to contact sports such as hockey, football, rugby, etc may be required to wear a shoulder stability brace (Don-Joy) for the initiation of the sport return.

Rehabilitation for Atraumatic Shoulder Instability
Rehabilitation of the patient with congenital shoulder instability poses a significant challenge for the rehabilitation specialist. The patient typically presents with several episodes of instability which limits them from performing certain tasks which may include daily work tasks as well as recreational or sports activities. This type of instability may arise from several factors including excessive redundancy and capsular laxity, poor osseous configuration such as a flattened glenoid fossa, or weakness in the glenohumeral and scapular musculature resulting in poor neuromuscular control. Any of these factors, individually or in combination, may contribute to pathological glenohumeral instability.

The focus of the rehabilitation program for the patient with atraumatic instability is similar to the traumatically
unstable shoulder, however, this program involves a slower progression with careful consideration to avoid excessive stretching to the capsular tissue. Furthermore, early goals include improving proprioception, dynamic stability, neuromuscular control, and scapular muscle strengthening to gradually return the patient to functional activities without limitations. As previously mentioned, the early phase of rehabilitation involves reducing shoulder pain and muscular inhibition while abstaining from activities that cause apprehension.

Shoulder muscle activation has been shown to differ in patients with congenital laxity versus in a normal, stable shoulder. Normal force coupling that exists to dynamically stabilize the gleno-humeral joint is altered resulting in excessive humeral head migration and a feeling of subluxation by the patient. Rockwood and Burkhead found that an exercise program was effective in the management of 80% of atraumatic instability. A recent study by Misamore et al. found improved results in 49% (28 of 59) of patients in a long term follow up study of atraumatic, athletic patients.

The rehabilitation program (Appendix 2) for the patient with atraumatic instability involves regaining full ROM without excessive stress to the involved tissues. The patient often presents with excessive ROM, therefore, passive ROM activities are not the focus of the rehabilitation program. Special attention is placed to avoid excessive stretches to the involved tissues. Modalities such as cryotherapy, phonophoresis, high voltage stimulation, and TENS may be used to minimize pain and inflammation. The reduction of shoulder pain may also be accomplished through gentle motion activities to neuromodulate pain, NSAIDs prescribed by the physician and abstaining from painful arcs of active and passive ROM.

The focus of the early phase of the rehabilitation program is to minimize any further muscle atrophy and reflexive inhibition resulting from disuse, repeated subluxation episodes, and pain. Isometric contraction exercises may be performed for the gleno-humeral muscles particularly the rotator cuff. Rhythmic stabilization drills may also be performed to facilitate a muscular co-contraction/co-activation to improve neuromuscular control and enhance the sensitivity of the afferent mechanoreceptors. The goal is to create a more efficient agonist/antagonist co-contraction to improve force coupling and joint stability during active movements.

The authors of this paper believe that exercises such as rhythmic stabilization drills and closed kinetic chain exercises to promote a co-contraction and an improvement in proprioception are beneficial for this patient population. Axial compression exercises are progressed from standing weight shifts on a table top to then include the quadruped and tripod positions (Note - this position should be avoided if posterior instability is present). Rhythmic stabilization of the involved extremity as well as at the core and trunk may be applied during these closed kinetic chain drills to further challenge the patient’s dynamic stability and neuromuscular control. Unstable surfaces such as tilt boards, foam, large exercise balls, and the Biodex stability system (Biodex Corp., Shirley, NY) may be incor-
Porated to further challenge the patient’s dynamic stability while in the closed chain position to further promote a co-activation or cocontraction of the surrounding musculature. (Figure 12)

Patients with congenital laxity often present with significant rotator cuff and scapular strength deficits, particularly the external rotators, scapular retractors, and scapular depressors. A progressive isotonic strengthening program may be initiated to improve rotator cuff and scapular musculature strength, endurance, and dynamic stability. Proper scapula stability and movement is vital for asymptomatic function. Scapula strengthening will improve proximal stability and therefore enable distal segment mobility for the patient’s functional tasks. These exercises may include external rotation at 0 degrees of abduction, sidelying external rotation, standing external rotation at 90 degrees of abduction, prone external rotation, prone rowing, prone extension and prone horizontal abduction at 100 degrees with external rotation. Other scapular training exercises commonly incorporated include supine serratus punches and a dynamic hug for serratus anterior strengthening. Bilateral external rotation with scapular retraction and table lifts may also be performed to strengthen the lower trapezius. Neuromuscular control drills are performed for the scapular musculature by having the rehabilitation specialist manually resist scapula movements. The goal of these drills is to enhance strength, endurance, and scapula proprioception.

The function of neuromuscular control system must not be overlooked in this patient population. Functional exercise drills that include positions of instability to induce a reflexive muscular response may protect against future injury or recurring episodes of instability. \(^2\) Active joint repositioning tasks, proprioceptive neuromuscular facilitation (PNF) and plyometric exercises may be beneficial as well to evoke a neuromuscular response.

Once sufficient strength of the scapular stabilizers and posterior cuff has been achieved, the patient is encouraged to use the shoulder only in the most stable positions; those in the plane of the scapular during humeral elevation. Activities that promote a feeling of joint instability with or without subluxation or dislocation should be avoided. Only when coordination and confidence are achieved through progressive strengthening should the patient attempt activities in an intrinsically unstable position. Bracing of the glenohumeral joint for return to sporting activities may also be necessary to provide immobilization or controlled ROM to protect against further injury.

The primary focus of the rehabilitation program for the congenitally unstable shoulder patient is to enhance strength and balance in the rotator cuff, improve scapular position and core stability, along with improved proprioception and neuromuscular control. Once symptoms have subsided and sufficient strength has been achieved, the patient may resume normal shoulder function, which may include sport activities.

CONCLUSION

The glenohumeral joint is an inherently unstable joint that relies on the interaction of the dynamic and static stabilizers to maintain stability. Disruption of this interplay or poor development of any of these factors may result in instability, pain, and a loss of function. Rehabilitation will vary based on the type of instability present and the key principles described. A comprehensive program designed to establish full range of motion, balance capsular mobility, along with maximizing muscular strength, endurance, proprioception, dynamic stability and neuromuscular control is essential. A functional approach to rehabilitation using movement drills to promote a co-contraction and improve dynamic stability

Figure 11

Figure 12

Axial compression drill on an unstable surface while the rehabilitation performs rhythmic stabilizations to the patient’s involved shoulder and trunk.
patterns and sport specific positions along with an interval sport program will allow a gradual return to athletics. The focus of the program should minimize the risk of re-injury and ensure that the patient can safely produce and dissipate forces at the glenohumeral joint.

REFERENCES


References continued on page 30
**Appendix 1. Traumatic dislocation protocol**

## NON-OPERATIVE REHABILITATION

### TRAUMATIC DISLOCATION OF THE SHOULDER

The program will vary in length for each individual depending on several factors:

- Severity and onset of symptoms
- Degree of instability symptoms
- Direction of instability
- Concomitant pathologies
- Age and activity level of patient
- Arm dominance
- Desired goals and activities

### I. PHASE I - ACUTE MOTION PHASE

**Goals:**
- Protect healing capsular structures
- Re-establish non-painful range of motion
- Decrease pain, inflammation, and muscular spasms
- Retard muscular atrophy / Establish voluntary muscle activity
- Re-establish dynamic stability
- Improve proprioception

Note: During the early rehabilitation program, caution must be applied in placing the capsule under stress until dynamic joint stability is restored. It is important to refrain from activities in extreme ranges of motion early in the rehabilitation process.

**Decrease Pain/Inflammation:**
- Sling or ER brace for comfort and depending on age of patient (MD preference)
- Therapeutic modalities (ice, TENS, etc.)
- NSAIDs
- Gentle joint mobilizations (grade I-II) for pain neuromodulation
  * Do not stretch injured capsule

**Range of Motion Exercises:**
- Gentle ROM only, no stretching
- Pendulums
- Rope & Pulley
  - Elevation in scapular plane to tolerance
- Active-assisted ROM L-Bar to tolerance
  - Flexion
  - Internal Rotation with arm in scapular plane at 30 degrees abduction
  - External Rotation with arm in scapular plane at 30 degrees abduction
  - Motion is performed in Non-Painful arc of motion only *

★ **DO NOT PUSH INTO ER OR HORIZONTAL ABDUCTION with anterior instability**
★ **Avoid excessive IR or horizontal adduction with posterior instability**

**Strengthening/Proprioception Exercises:**
- Isometrics (performed with arm at side)
- Flexion
- Abduction

### II. Phase II - Intermediate Phase

**Goals:**
- Regain and improve muscular strength
- Normalize arthrokinematics
- Enhance proprioception and kinesthesia
- Enhance dynamic stabilization
- Improve neuromuscular control of shoulder complex

**Criteria to Progress to Phase II:**
- Nearly full to full passive ROM (ER may be still limited)
- Minimal pain or tenderness
- “Good” MMT of IR, ER, flexion, and abduction
- Baseline proprioception and dynamic stability

**Progress range of motion activities at 90 degrees abduction to tolerance (painfree)**

**Initiate isotonic strengthening**

**Emphasis on external rotation and scapular strengthening**
- ER/IR Tubing
- Scaption raises (full can)
- Abduction to 90 degrees
- Sidelying external rotation to 45 degrees
- Standing ER with tubing with manual resistance
- Hand on ball against wall resistance stabilization
- Prone extension to neutral
- Prone horizontal adduction
- Prone rowing
- Lower and middle trapezius
- Sidelying neuromuscular exercise drills
- Push-ups onto table
- Seated manual scapular resistance
- Biceps curls
- Triceps pushdowns

★ **Electrical muscle stimulation may be used to ER during exercises**

**Improve Neuromuscular control of Shoulder Complex**
- Initiation of proprioceptive neuromuscular facilitation
- Rhythmic stabilization drills
- ER/IR at 90 degrees abduction (limit degree of ER)
Appendix 1 (cont’d). Traumatic dislocation protocol

- Flexion/Extension/Horizontal at 100 degrees flexion, 10 degrees horizontal abduction
- Progress to mid and end range of motion
- Progress OKC program
- PNF
- Manual resistance ER (supine + sidelying /E eccentrics), prone row
- ER/IR tubing with stabilization
- Progress CKC exercises with rhythmic stabilizations
- Wall stabilization on ball
- Hand on wall – wall circles for rotator cuff endurance
- Hand on wall – side to side motion for scapular muscles and deltoid
- Static holds in push-up position on ball
- Push-ups on tilt board
- Core
- Abdominal strengthening
- Trunk strengthening / Low back
- Gluteal strengthening

Continue Use of Modalities (as needed)
- Ice, electrotherapy modalities

III. Phase III - ADVANCED Strengthening Phase

Goals:
• Improve strength/power/endurance
• Improve neuromuscular control
• Enhance dynamic stabilizations
• Prepare patient/athlete for activity

Criteria to Progress to Phase III:
• Full non-painful range of motion
• No palpable tenderness
• Continued progression of resistive exercises
• Good – normal muscle strength, dynamic stability, neuromuscular control

Continue use of modalities (as needed)

Continue isotonic strengthening (progress resistance)
- Continue Thrower’s Ten
- Progress to end range stabilization drills
- Progress to full ROM strengthening
- Progress to bench press in restricted ROM (restrict horizontal abduction ROM)
- Progress to flat & incline chest press (weighted) restrict motion
- Program to seated rowing and lat pull down (in front) in restricted ROM

Emphasize PNF
Manual D2 with RS at 45, 90, & 145 degrees

Advanced neuromuscular control drills (for athletes)
- Ball flips on table
- ER tubing at 90 deg abduction with manual resistance & RS at end range

- Push-ups on ball/rocker board with rhythmic stabilizations
- Manual scapular neuromuscular control drills
- Initiate perturbation activities (ER with exercise tubing with end range rhythmic stab)

Endurance training
- Timed bouts of exercises - 30-60 seconds
- Increase number of repetitions (sets of 15/20 reps)
- Multiple bouts throughout day (3x)

Initiate plyometric training
- 2-hand drills:
  - Chest pass throw
  - Side to side throw
  - Overhead soccer throw
- Progress to 1-hand drills:
  - 90/90 baseball throws
  - Wall dribbles
  - 90/90 baseball throws against wall

★ Continue to avoid excessive stress on joint capsule

IV. Phase IV - RETURN TO ACTIVITY PHASE

Goals:
• Maintain optimal level of strength/power/endurance
• Progressively increase activity level to prepare patient/athlete for full functional return to activity/sport

Criteria to Progress to Phase IV:
• Full ROM
• No pain or palpable tenderness
• Satisfactory isokinetic test
• Satisfactory clinical exam

Continue all exercises as in Phase III

Progress isotonic strengthening exercises
Resume normal lifting program (Physician will determine)
Initiate interval sport program (as appropriate)
Continue modalities- ice, e-stim, etc. (as needed)
Consider GH joint stabilizing brace for contact sports

FOLLOW-UP
• Isokinetic test (ER/IR & Abd/Add)
• Progress interval program
• Maintenance of exercise program
Appendix 2. Atraumatic Instability protocol

Non-operative Rehabilitation for Atraumatic Instability
This multi-phased program is designed to allow the patient/athlete to return to their previous functional level as quickly and safely as possible. Each phase will vary in length for each individual depending upon the severity of injury, ROM/strength deficits, and the required activity demands of the patient.

PHASE I - ACUTE PHASE

Goals:
• Decrease pain/inflammation
• Re-establish functional range of motion
• Establish voluntary muscular activation
• Re-establish muscular balance
• Improve proprioception
• Decrease Pain/Inflammation
  - Therapeutic modalities (ice, electrotherapy, etc.)
  - NSAIDs
  - Gentle joint mobilizations (Grade 1 and II) for neuromodulation of pain

Range of Motion Exercises
• Gentle ROM exercises – no stretching
• Pendulum exercises
• Rope and pulley
• Elevation to 90 degrees, progressing to 145/150 degrees flexion
• L-Bar
• Flexion to 90 degrees, progressing to full ROM
• Internal rotation with arm in scapular plane at 45 degrees abduction
• External rotation with arm in scapular plane at 45 degrees abduction
• Progressing arm to 90 degrees abduction

Strengthening Exercises
• Isometrics (performed with arm at side)
• Flexion
• Abduction
• Extension
• External rotation at 0 degrees abduction
• Internal rotation at 0 degrees abduction
• Scapular isometrics
• Biceps
• Retraction/protraction
• Elevation/depression
• Weight shifts with arm in scapular plane (closed chain exercises)
• Rhythmic stabilizations (supine position)
• External/internal rotation at 30 degrees abduction
• Flexion/extension at 45 and 90 degrees flexion

★ Note: It is important to refrain from activities and motion in extreme ranges of motion early in the rehabilitation process in order to minimize stress on joint capsule.

PHASE II - INTERMEDIATE PHASE

Goals:
• Normalize arthrokinematics of shoulder complex
• Regain and improve muscular strength of glenohumeral and scapular muscle
• Improve neuromuscular control of shoulder complex
• Enhance proprioception and kinesthesia

Criteria to Progress to Phase II:
• Full functional ROM
• Minimal pain or tenderness
• “Good” MMT

Initiate Isotonic Strengthening
• Internal rotation (sidelying dumbbell)
• External rotation (sidelying dumbbell)
• Scaption to 90 degrees
• Abduction to 90 degrees
• Prone horizontal abduction
• Prone rows
• Prone extensions
• Biceps
• Lower trapezius strengthening

Initiate Eccentric (surgical tubing) Exercises at Zero Degrees Abduction
• Internal rotation
• External rotation

Improve Neuromuscular Control of Shoulder Complex
• Rhythmic stabilization drills at inner, mid, and outer ranges of motion (ER/IR, and Flex/Ext)
• Initiate proprioceptive neuromuscular facilitation
• Scapulothoracic musculature
• Glenohumeral musculature
• Open kinetic chain at beginning and mid ranges of motion
• PNF
• Manual resistance
• External rotation
• Begin in supine position progress to sidelying
• Prone rows
• ER/IR tubing with rhythmic stabilization
• Closed kinetic chain
• Wall stabilization drills
  - Initiated in scapular plane
  - Progress to stabilization onto ball
• Weight shifts had on ball

Proprioception/Kinesthesia
Active joint reposition drills for ER/IR
Appendix 2.(cont'd)  Atraumatic Instability protocol

- Initiate core stabilization drills
  - Abdominal
  - Erect spine
- Gluteal strengthening

Continue Use of Modalities (as needed)
- Ice, electrotherapy

PHASE III – ADVANCED STRENGTHENING PHASE

Goals:
- Enhance dynamic stabilization
- Improve strength/endurance
- Improve neuromuscular control
- Prepare patient for activity

Criteria to Progress to Phase III:
- Full non-painful ROM
- No pain or tenderness
- Continued progression of resistive exercises
- Good to normal muscle strength

Continue Use of Modalities (as needed)

Continue Isotonic Strengthening (PRE’s)
- Fundamental shoulder exercises II

Continue Eccentric Strengthening

Emphasize PNF Exercises (D2 pattern) With Rhythmic Stabilization Hold

Continue to Progress Neuromuscular Control Drills
- Open kinetic chain
- PNF and manual resistance exercises at outer ranges of motion
- Closed kinetic chain
- Push-ups with rhythmic stabilization
- Progress to unsteady surface

- Medicine ball
- Rocker board
- Push-ups with stabilization onto ball
- Wall stabilization drills onto ball

Program Scapular Neuromuscular Control Training
- Sidelying manual drills
- Progress to rhythmic stabilization and movements (quadrant)

Emphasize Endurance Training
- Time bouts of exercise 30-60 sec
- Increase number of reps
- Multiple bouts bouts during day

PHASE IV – RETURN TO ACTIVITY PHASE

Goals:
- Maintain level of strength/power/endurance
- Progress activity level to prepare patient/athlete for full functional return to activity/sport

Criteria to Progress to Phase IV:
- Full non-painful ROM
- No pain or tenderness
- Satisfactory isokinetic test
- Satisfactory clinical exam

Continue all exercises as in Phase III

Initiate Interval Sport Program (if appropriate)

Patient Education


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RETURNING TO SPORTS AFTER PERIACETABULAR OSTEOTOMY FOR DEVELOPMENTAL DYSPLASIA OF THE HIP

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ABSTRACT

Background: A periacetabular osteotomy, indicated for adults or adolescents requiring correction of congruency and containment of the femoral head, is a common surgical procedure to address developmental dysplasia of the hip.

Objectives: To describe developmental hip dysplasia, a surgical procedure performed to address the condition, as well as therapeutic exercise and functional progression principles utilized to return a patient to tennis following periacetabular osteotomy.

Case Description: The patient was a 14 year-old female who underwent a Ganz periacetabular osteotomy of the right pelvis due to developmental dysplasia of the hip. Post-operative outpatient physical therapy consisted of strengthening of the hip, thigh, and core musculature, as well as activities to increase muscular and cardiovascular endurance, anaerobic conditioning, lower extremity proprioception, and soft tissue length. A functional progression program to return to tennis was also provided.

Outcomes: The patient was seen in outpatient physical therapy for a total of 34 visits over the course of 42 weeks. Results of a Lower Extremity Functional Scale (LEFS) indicated that heavy activities of daily living, as well as recreational and sporting activities, were improved following the post-operative rehabilitation program.

Discussion: The role of the physical therapist is vital in prescribing and progressing activity levels to facilitate return of function following this periacetabular osteotomy. Surgery that is technically well performed followed by a comprehensive rehabilitation program can allow for resumption of pre-morbid activities, enhancement of the quality of life, and return to sports activities.

Key Words: functional progression, tennis, congenital hip dysplasia.

INTRODUCTION

Hip problems in the developing youngster can be congenital or acquired and are frequently encountered by the physical therapist. Sports physical therapists may be comfortable in dealing with acquired hip conditions in active youth, but not as familiar with treating congenital hip dysfunction. On the other hand, pediatric physical therapists may be at ease addressing congenital hip issues but not as well versed in caring for acquired macro or microtrauma of the hip in active, normally developing youngsters. The generalist physical therapist may be somewhere in between these two extremes. The purpose of this case report is to describe developmental hip dysplasia, a surgical procedure performed to address this condition, as well as therapeutic exercise and functional progression principles utilized to return a patient to tennis following periacetabular osteotomy.

Developmental Dysplasia of the Hip

Conditions involving the hip joint in the skeletally immature youngster range from joint dysplasia to joint subluxation and dislocation. Traditionally, all of these conditions have been collectively referred to as congenital dysplasia of the hip; however, the term developmental dysplasia of the hip (DDH) has become more acceptable.1 Developmental dysplasia of the hip more accurately describes situations when hip problems that may not be noticed at birth, become apparent as a child matures and begins to bear weight in a standing position.

The epidemiology, etiology, examination and treatment of DDH are well documented.14 In addition to the clinical physical examination, standard anterior-posterior plain film radiographs of the...
pelvis are helpful in the diagnosis of DDH. Abnormal findings on plain film radiographs suggestive of DDH include the delayed appearance of ossification centers of the hip and pelvis beyond six months, as well as an abnormal relationship between the developing femoral neck and pelvis. As the younger matures, in addition to the traditional anterior-posterior view of the pelvis, a weight bearing view with the pelvis rotated 25° toward the x-ray beam (faux profile view) may also be helpful in quantifying the relationship between the developing femoral head and the acetabulum.

Surgical Intervention for DDH
Many individuals with DDH develop through childhood and adolescence without symptoms. Hip pain when present is typically due to high stresses on the acetabular rim resulting in articular cartilage damage with subsequent increased stresses on underlying subchondral bone. When infants with DDH are not diagnosed until late, or when previous treatment attempts in diagnosed infants are not successful, surgical intervention is indicated. Untreated acetabular dysplasia is the second most common cause of secondary osteoarthritis with degenerative joint disease from pathological joint-loading forces becoming symptomatic before the age of 50 in 25% to 50% of patients with DDH.10 Surgical options entail capsulorrhaphy, femoral derotation and varisation osteotomy, periacetabular osteotomy, or shelf arthroplasty, of the pelvis. The primary goal of the various procedures is to provide coverage of the developing femoral head.11-18

The Ganz triple osteotomy, also known as the Bernese osteotomy, is a common surgical procedure to address DDH. The Ganz procedure provides for the large bony corrections required to cover the femoral head in all needed directions including lateral rotation, anterior rotation, and medialization of the hip center.13 Ganz first performed his periacetabular osteotomy in 1983.16 The Ganz osteotomy is indicated in adults or adolescents with closed physes who have dysplastic hips requiring correction of congruency and containment of the femoral head. In most cases, the opening of the acetabulum lies in excessive anteversion from the sagittal plane.

The purpose of the Ganz procedure is to reorient the position of the acetabulum anteriorly and laterally to gain greater coverage of the femoral head and bring the roof of the acetabulum from an oblique position to a more horizontal position through a series of cuts in the innominate bones (Figure 1). Advantages of this periacetabular osteotomy include using only one approach, the potential for significant correction in all directions (including medial and lateral planes), the posterior column of the hemipelvis remains mechanically intact which allows immediate crutch walking with minimal internal fixation, the shape of the true pelvis is unaltered permitting a normal child delivery later in life, and retaining the hip’s center of rotation. Complications of the Ganz procedure include interarticular extension of the osteotomy, temporary femoral nerve palsy, insufficient or excessive overcorrection, secondary subluxation of the femoral head, osteonecrosis, nonunion, heterotopic ossification, vascular compromise or loss of fixation.6,15,18

CASE DESCRIPTION
History
At the time of the initial physical therapy visit the patient was 15 years old, 68 inches tall, and weighed 129 pounds. The patient was an incoming freshman at a local high school and had previously been involved in recreational and competitive tennis, participating in both singles and doubles.

At the age of five months, the patient was diagnosed with bilateral DDH with no occurrence of hip dislocation. Initial treatment for the DDH was via a hip spica cast which was removed at one year of age. Due to complaints of persistently painful clicking in the right hip during childhood the patient underwent a surgical release of the psoas at age ten. The patient was followed by her family

Figure 1
Two-dimensional view of acetabular re-positioning before (A) and after (B) Ganz osteotomy. Note: the roof of the acetabulum has moved more horizontally to cover the femoral head.
physician and local orthopedists but her condition worsened. She was subsequently referred to a regional orthopaedic specialist due to complaints of constant lateral hip pain. Upon reviewing her condition and past history, the surgeon recommended and performed a Ganz periacetabular osteotomy for the right hip. Figures 2 and 3 demonstrate pre- and post-operative radiographs.

Post-Operative Intervention
The patient had an uneventful hospital stay and after five days was discharged partial weight bearing (PWB) with axillary crutches and a home exercise program of active hip range of motion and gentle isometric hamstring and quadriceps muscle sets. Serial radiographs taken between surgery and the initial physical therapy visit demonstrated normal post-operative findings.

Post-Operative - Week Four
Four weeks following the osteotomy the surgeon referred the patient for outpatient physical therapy for three visits per week for six weeks. Physician orders were to advance weight bearing up to 40 pounds on the involved right lower extremity, strengthening, and range of motion work.

At the initial physical therapy visit, the patient had subjective complaints of minimal hip pain at rest and did note numbness in the thigh. The patient was ambulating PWB with an appropriate gait pattern using axillary crutches. In the sitting position she lacked full knee extension by five degrees due to quadriceps weakness. During the exam, the patient could not transfer from sitting to a supine position on the treatment table without manually assisting the involved leg. Observation of the patient in the supine position revealed quadriceps atrophy and an inability to initiate a straight leg raise. The patient was also unable to initiate gravity resisted abduction in the side-lying position. In the standing position hip abduction was with immediate substitution palpated in the quadratus lumborum. Active range of motion of the hips was measured and these values are found in Table 1. In addition, the patient filled out the Lower Extremity Functional Scale. This scale and the results are reported in the Outcomes Section of this case study.

Treatment in the outpatient clinic included hip flexor strengthening, open kinetic chain and closed kinetic chain quadriceps strengthening, and functional electrical stimulation for the quadriceps. Open kinetic chain quadriceps work was performed at terminal extension to address her extension lag. Closed kinetic chain strengthening was performed on the Shuttle (Contemporary Design Company, Glacier, WA). The Shuttle is a horizontal sliding carriage that allows the patient to perform closed chain activities in a gravity eliminated position. Added resistance from 25 to 200 pounds can be applied to the Shuttle by a series of elastic cords. Added resistance to strengthening activities on the Shuttle for the current patient did not exceed 50 pounds. Efforts to strengthen the gluteus medius were increased with manual resistance and resisted isotonic exercise in the supine position.

Post-Operative - Week Eight
After four weeks of rehabilitation (eight weeks after surgery), the patient returned to the physician. At that time the patient’s active standing hip flexion had increased to 90º. Hip extensor strength had increased and the patient was able to perform single leg bridging activities. Quadriceps atrophy persisted (one and one-quarter inch difference eight inches proximal to the knee joint line). However, the patient could actively extend the knee completely, and open chain terminal knee extensions were up to seven pounds of resistance. The patient could inconsistently initiate a straight leg raise but did so with a knee extension lag of...
greater than 30º. Gait was still PWB with axillary crutches.

After the visit to the surgeon, orders were received to continue outpatient treatment twice a week for six weeks with an emphasis on strengthening (especially with hip extension and abduction) and to increase weight bearing to 60 pounds. Crutch use was to be discontinued before the next scheduled visit with the surgeon in approximately twelve weeks.

Rehabilitation now focused on longer lever arm strengthening of the hip musculature with assisted and substitution free straight leg raises (SLR) and gravity resisted gluteus medius strengthening. Hip flexor stretching was initiated. Core strengthening of the abdominals and paravertebral muscles consisting of crunches, assisted leg lowering, diagonal crunches, and prone body weight resisted extension were instituted and progressed. Lower extremity strengthening and gait activities were begun in waist deep water.

The patient was instructed to progress to full weight bearing (FWB) ambulation with crutches at nine weeks following surgery. The patient admitted she was non-compliant with appropriate weight bearing status and had started to ambulate occasionally at home without crutches. During this time, the patient went on a family vacation and did some swimming and more walking than she had done since surgery. At this time the patient noted an inconsistent non-painful popping in the anterior hip, especially after prolonged weight bearing. It was also during this time that the patient noted increased pain at rest and an inability to lie comfortably on the affected side. The patient denied night pain. Decreased weight bearing restrictions were implemented and enforcement of consistent use of crutches. Strengthening efforts in the clinic and at home were de-emphasized. With these restrictions in activity and consistent use of the crutches, the pain at rest was eliminated. No imaging was performed at this time.

During the course of the next two weeks the patient was able to ambulate FWB with two crutches and was gradually weaned from the crutches to begin full weight bearing gait without an assistive device. The patient demonstrated a slight gluteus maximus lurch with slight trunk extension at heel strike. Gait training along with weight bearing strengthening and balance were instituted. Aerobic and anaerobic conditioning efforts were instituted on the recumbent bike.

**Post-Operative - Week Eighteen**

At the time of the surgeon’s follow-up visit three and a half months post-operatively, despite the increased quadriceps strength, the patient still could not consistently initiate a SLR. No extension lag was present with the eccentric SLR from 90º to 0º, but a lag of five degrees was present from 60º to 0º. The surgeon suggested another month of strengthening prior to allowing a return to tennis and scheduled the patient for a return visit in three months. Clinic visits focused on core and lower extremity strengthening, early functional progression activities, and progressing the functional progression program. Table 2 summarizes the rehabilitation program.

**Functional Progression**

Functional progression is a series of sport-specific, basic movement patterns graduated according to difficulty of the skill and the athlete’s tolerance. The end goal of functional progression is an athlete’s timely and safe return to competition. From post-operative week 24 to week 42, the patient was progressed along a continuum of increasingly more difficult activities culminating in her playing tennis.

At week 24, lower extremity efforts began with bilateral non-support activities, jumping side-to-side and front-to-back. Transition to unilateral non-support activities (hopping) was initially performed at a single point until the contralateral hip did not drop indicating adequate dynamic gluteus medius muscle strength. Jumping was followed by alternating single leg hopping on the involved extremity and uninvolved extremity upon command and in place. Again, once this activity was performed without substitution, progression was allowed to hopping side-to-side and front-to-back.

Since no healing time concerns existed for the patient’s upper extremities, upper extremity tennis drills (forehand and backhand ground, overhead returns, serves) could be progressed quickly. Effective power generation for all of these upper extremity movements, however, require force generation and force coupling from the lower extremities.
The patient was right hand dominant, so forehand ground strokes involving a neutral pelvis transitioning to hip extension and internal rotation were instituted. Backhand ground strokes involving more hip internal rotation followed by right trunk rotation over the fixed pelvis followed. Both of these strokes began with gentle volleys from mid court and were progressed to the baseline. Overhand returns and serves to incorporate more hip extension were also stressed. Emphasis was placed on a neutral spine while minimizing excessive trunk flexion due to concerns of gluteus maximus weakness and fatigue.

Extremities and the trunk. From post-operative weeks 26 to 32, figure-of-eights were progressed from full court to half court beginning with a jog and progressing to full speed. Acceleration and deceleration activities in the half court forwards, backwards, and side shuffling were then stressed from weeks 32 to 40 (Figure 4). Once the patient progressed through the acceleration and deceleration drills, she was then instructed to incorporate either a forehand or backhand stroke into the dynamic drills. After the patient was fluid in the acceleration/deceleration activities with twisting strokes, she began to play teammates, first doubles and then singles. When the coach and athlete were comfortable with her level of performance, the patient was allowed to compete. The functional progression program is summarized in Table 3.

**Table 2: Rehabilitation Summary**

<table>
<thead>
<tr>
<th>Immediate Post-Op</th>
<th>Pre-Full Weight Bearing</th>
<th>Post-Full Weight Bearing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-Op: Week 4-8</td>
<td>Post-Op: Week 8-12</td>
<td>Post-Op: Week 12</td>
</tr>
</tbody>
</table>

- **Strengthening**
  - Gluteus maximus isometrics
  - Quadriceps isometrics
  - Supine bilateral hip bridging
  - Standing hip abduction

- **Range of Motion**
  - Heel slides

- **Gait**
  - PWB with crutches

- **Strengthening**
  - Functional SLR’s
  - Open chain terminal knee extension
  - Shuttle closed chain bilateral support
  - Abdominals
  - Gravity resisted hip adduction
  - Standing hip abductor
  - Standing hip flexion
  - Unilateral bridging
  - Bilateral bridging with hip abduction

- **Gait**
  - Progress to FWB

- **Aquatics**
  - Pre-gait activities
  - Hip strengthening

- **Conditioning**
  - Aerobic recumbent bike
  - Anaerobic recumbent bike

**Figure 4**
Forward and backward acceleration/deceleration drills on the tennis court. Diagonal sprinting to the net and backpedaling to the backcourt.

**Outcome**
Forty-two weeks transpired from the time of surgery to completion of the functional progression and a return to tennis competition. During this time the patient was seen a total of 34 physical therapy visits. At the time of discharge the patient was performing at a level that allowed her to play number two doubles on her high school tennis team. The patient was also participating in singles tennis at a level the coach rated subjectively superior to before the surgery.

Prior to surgery and at the end of the physical therapy intervention, the patient completed the Lower Extremity Functional Scale (LEFS). The LEFS is used to qualitatively assess individual’s functional status during 20 specific functional tasks on a scale from 0 (unable to perform actively) to 4 (no difficulty). The maximum score of the assessment test is 80. Binkley et al have reported the LEFS to be reliable, valid, and sensitive to change.

The LEFS was administered to the patient to document perceived function prior to surgery with a resultant score of 63% (50 out of 80 points). The LEFS was also administered to the patient to document perceived function at the termination of postoperative rehabilitation with a resultant score of 83% (66 out of 80 points) (See Table 4).

All parameters of the LEFS to assess simple activities of daily living did not present
problems for the patient prior to surgery or following rehabilitation after surgery. Heavy activities around the house presented moderate difficulty prior to surgery and following the post-operative course these activities no longer presented any difficulty. Prolonged activities such as walking two blocks and standing for an hour, negotiating stairs, and sitting for an hour presented only a little bit of difficulty after post-operative rehabilitation. At a more strenuous level, walking a mile, recreational activities, sporting events, and squatting also caused the patient a little bit of difficulty following post-operative rehabilitation. Running on even and uneven ground, along with making sharp turns while running still presented moderate difficulty after post-operative rehabilitation.

### Table 3: Function Progression Summary

<table>
<thead>
<tr>
<th>Activity</th>
<th>Dosage</th>
<th>Onset</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bilateral non-support</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single plane front-to-back</td>
<td>3 sets – 2 minutes</td>
<td>Week 24</td>
</tr>
<tr>
<td>Single plane side-to-side</td>
<td>3 sets – 2 minutes</td>
<td></td>
</tr>
<tr>
<td>Serving</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline ground strokes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Unilateral non-support</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stationary</td>
<td>3 sets – 1 minute</td>
<td>Week 25</td>
</tr>
<tr>
<td>Stationary alternating legs</td>
<td>3 sets – 1 minute</td>
<td></td>
</tr>
<tr>
<td>Single plane front-to-back</td>
<td>3 sets – 1 minute</td>
<td></td>
</tr>
<tr>
<td>Single plane side-to-side</td>
<td>3 sets – 1 minute</td>
<td></td>
</tr>
<tr>
<td>Serving</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline ground strokes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Figure-eights</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full court jog</td>
<td>10 repetitions</td>
<td>Week 26</td>
</tr>
<tr>
<td>Full court half-sprint</td>
<td>10 repetitions</td>
<td>Week 27</td>
</tr>
<tr>
<td>Full court sprint</td>
<td>10 repetitions</td>
<td>Week 28</td>
</tr>
<tr>
<td>Half court jog</td>
<td>10 repetitions</td>
<td>Week 29</td>
</tr>
<tr>
<td>Half court half-sprint</td>
<td>10 repetitions</td>
<td>Week 30</td>
</tr>
<tr>
<td>Half court sprint</td>
<td>10 repetitions</td>
<td>Week 31</td>
</tr>
<tr>
<td>Light volleys</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Acceleration/deceleration (sagittal)</strong></td>
<td>10 repetitions</td>
<td>Week 32</td>
</tr>
<tr>
<td>Jog, no racquet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half-sprint, no racquet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full sprint, no racquet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jog, racquet, swing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Half-sprint, racquet, swing</td>
<td>10 repetitions</td>
<td>Week 33</td>
</tr>
<tr>
<td>Full sprint, racquet, swing</td>
<td>10 repetitions</td>
<td></td>
</tr>
<tr>
<td>Volleys</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Acceleration/deceleration (lateral)</strong></td>
<td>10 repetitions</td>
<td>Week 40</td>
</tr>
<tr>
<td>As above</td>
<td></td>
<td>Week 40</td>
</tr>
<tr>
<td>Doubles tennis</td>
<td></td>
<td>Week 42</td>
</tr>
<tr>
<td>Singles tennis</td>
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</tbody>
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**DISCUSSION**

The rehabilitation of the patient after periacetabular osteotomy for DDH is much like that of a stable fracture following open reduction and internal fixation with similar healing time constraints and weight bearing restrictions. Range of motion in this case returned quickly as there were no significant intra-articular concerns of the hip joint. Specific strengthening of the affected hip musculature along with strengthening of the core for proximal stability was paramount. Restricted weight bearing until bony healing had occurred can limit closed kinetic chain strengthening. However, weight bearing strengthening activities on a device like the Shuttle provides safe and functional loading. Since core strength is vital in the translation of lower extremity power to the upper body and shoulder, core strengthening can and should commence early. Cardiovascular endurance activities also must progress according to weight bearing restrictions.

Long lever arm function of the hip is limited in activities of daily living and in many sports including tennis. It is vital, however, to assure that function of the rectus femoris, a primary muscle responsible for long lever arm function is recovered. Isolated function and control of the rectus femoris was delayed after the periacetabular osteotomy. In this patient, potential contributing factors to the temporary rectus femoris weakness may be due to involvement of the femoral nerve and a change of the length tension relationship from detachment and reattachment of the muscle during surgery. Although the patient did demonstrate transient sensory changes following surgery, transient motor involvement cannot be ruled out.

Transient gait deviations, specifically a slight gluteus maximus lurch at heel strike, was also a concern. It is difficult to ascertain how much of this problem with gait was due to the patient's gait prior to surgery. Even though gluteal strength gains occurred quickly and gains were subsequently sufficient enough to approximate the contralateral side, slight deviations occurred and were more pronounced at faster gait speeds. Walking backwards (retro-walking) in the clinic with and without external resistance from rubber cords and retro-walking in the pool were helpful in correcting gait deviations.

Exercise dosage and activity modification can be difficult to prescribe. In a young and otherwise healthy individual, the tendency is for the patient to be overzealous. As the patient began to move about better, she did not feel the
need to utilize crutches as instructed. This increased weight bearing with concomitant advancement of a therapeutic exercise regime may result in excessive stress on the healing tissue. This was the case in managing this patient. Muscle discomfort immediately following workouts were common and to be expected. As the patient was allowed to do more in one area (weight bearing, exercise) another area was de-emphasized. When the patient became more aggressive in performing the prescribed exercises, when she increased her overall level of activity and disregarded the consistent use of crutches, she became symptomatic at rest. Symptoms at rest are when activities needed to be significantly restricted to allow the healing areas to accommodate to the added stress.

### CONCLUSION

This case study describes the rehabilitation program employed following periacetabular osteotomy in a 14 year-old female tennis player. The role of the physical therapist is vital in prescribing and progressing activity levels to facilitate return of function following this surgical procedure. Goals of the periacetabular osteotomy were to allow resumption of pre-morbid activities and enhance the patient's quality of life and prevent early osteoarthritic changes in the hip. Surgery that is technically well performed followed by a comprehensive rehabilitation program allowed for a return to sports activities following periacetabular osteotomy.

<table>
<thead>
<tr>
<th>Activities</th>
<th>0 Points</th>
<th>1 Point</th>
<th>2 Points</th>
<th>3 Points</th>
<th>4 Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Usual work, housework or school activities</td>
<td>▲</td>
<td></td>
<td></td>
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<tr>
<td>Usual hobbies, recreational, sporting activities</td>
<td>▲</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Getting into or out of bath</td>
<td>▲</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking between rooms</td>
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<td></td>
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<td></td>
<td></td>
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<tr>
<td>Putting on shoes or socks</td>
<td>▲</td>
<td></td>
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<tr>
<td>Squatting</td>
<td>▲</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifting objects from the floor</td>
<td>▲</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light activities around the house</td>
<td>▲</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heavy activities around the house</td>
<td>▲</td>
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<td></td>
<td></td>
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<tr>
<td>Getting in or out of the car</td>
<td>▲</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking two blocks</td>
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<td></td>
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<tr>
<td>Walking a mile</td>
<td>▲</td>
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<tr>
<td>Ascending/descending a flight of stairs</td>
<td>▲</td>
<td></td>
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<td></td>
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<tr>
<td>Standing for an hour</td>
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</tr>
<tr>
<td>Sitting for an hour</td>
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<td></td>
</tr>
<tr>
<td>Running on even ground</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Running on uneven ground</td>
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</tr>
<tr>
<td>Making sharp turns while running fast</td>
<td>▲</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hopping</td>
<td>▲</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Rolling over in bed</td>
<td>▲</td>
<td></td>
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</tr>
</tbody>
</table>

▲ Score prior to surgery  
★ Score at physical therapy discharge
REFERENCES


CORRESPONDENCE

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ABSTRACT
Background. A pre-event static stretching program is often used to prepare an athlete for competition. Recent studies have suggested that static stretching may not be an effective method for stretching the muscle prior to competition.

Objective. The intent of this study was to compare the immediate effect of static stretching, eccentric training, and no stretching/training on hamstring flexibility in high school and college athletes.

Methods. Seventy-five athletes, with a mean age of 17.22 (+/- 1.30) were randomly assigned to one of three groups – thirty-second static stretch one time, an eccentric training protocol through a full range of motion, and a control group. All athletes had limited hamstring flexibility, defined as a 20° loss of knee extension measured with the femur held at 90° of hip flexion.

Results. A significant difference was indicated by follow up analysis between the control group (gain = -1.08°) and both the static stretch (gain = 5.05°) and the eccentric training group (gain = 9.48°). In addition, the gains in the eccentric training group were significantly greater than the static stretch group.

Discussion and Conclusion. The findings of this study reveal that one session of eccentrically training through a full range of motion improved hamstring flexibility better than the gains made by a static stretch group or a control group.

INTRODUCTION
Most experts consider aerobic conditioning, strength training, and flexibility to be the three key components of a conditioning program. By definition, flexibility is the ability of a muscle to lengthen and allow one joint (or more than one joint in a series) to move through a range of motion, and the loss of flexibility is a decrease in the ability of a muscle to perform. Reduced injury risk, pain relief, and improved athletic performance are reasons provided for incorporating flexibility training into a training program.

Static stretching, defined as elongation of a muscle to tolerance and sustaining the position for a length of time, is considered the gold standard in flexibility training. Some authors have questioned the importance of using static stretching to help reduce injuries and to improve athletic performance. Recent studies have found that static stretching is not an effective way to reduce injury rates and may actually inhibit athletic performance. Murphy made a compelling argument against the use of static stretching. Although static stretching is often used as a part of preactivity preparation, Murphy argued that the nature of static stretching is passive and does nothing to warm a muscle; further, although the hamstring muscle is the most frequently stretched muscle, it is also the most commonly strained.

A better option for increasing flexibility, according to Murphy, would be an activity that is more dynamic by nature. Murphy therefore, introduced what is referred to as “dynamic range of motion.” To dynamically stretch a muscle, the antagonist group is contracted thus allowing the agonist to elongate naturally in a relaxed state. The dynamic nature of the activity, in theory, would cause a warming effect in the muscle, and the mus-
cle would be more pliable and accommodating to the stretch, leading to an increase in the flexibility of the muscle.

In contrast to the belief of Murphy, Bandy et al compared the flexibility gains made by subjects participating in a dynamic range of motion program with gains subjects achieved using a static stretching program. The gains achieved by the group in the static stretching program were greater than those achieved with dynamic range of motion.

More recently, Nelson and Bandy investigated a flexibility program which consisted of eccentrically training a muscle through a full range of motion. Previous literature suggests that most injuries occur in the eccentric phase of activity. For example, the hamstring muscles are most commonly injured when working eccentrically while decelerating or landing. Eccentrically training a muscle through a full range of motion, theoretically, could reduce injury rates, improve athletic performance, and improve flexibility. Nelson and Bandy compared the flexibility gains made over a six week period of time by a control group, a static stretch group, and a group who eccentrically trained the muscle through a full range of motion. The findings of the study were a significant increase in flexibility in the static stretch group (12.05º) and in the group who trained eccentrically through a full range of motion (12.79º) over the control group (a 1.17º change). The difference in the flexibility gained between the static stretch group and the eccentric training group was not significantly different. This study offers compelling evidence to incorporate eccentric training into any training program.

While it has been found that eccentrically training a muscle through a full range of motion will improve flexibility over a period of six weeks as well as static stretching, no study has been conducted to determine the immediate effects of one bout of eccentric training compared to one bout of static stretching and comparing both with a control. A pre-event stretching program is often used by coaches to prepare an individual for athletic competitions. Some of the goals of pre-event flexibility training program include decreasing the chances the individual will sustain an injury, warming the muscle, and improving the flexibility of the muscle in preparation for the activity. Theoretically, eccentric training will decrease injury rates and warm a muscle, but no study has been performed to determine the effects a single bout of eccentric training has on flexibility. Therefore, the purpose of the study is to determine if one bout of eccentric training through a full range of motion will improve flexibility and to compare the results with one bout of static stretching and a control group.

METHODS

Subjects

Eighty-seven subjects were recruited on a voluntary basis to participate in the study. The authors felt attrition would be low given the design of the study. By recruiting eighty-seven subjects this ensured the study would have the appropriate number needed when complete. Subjects were high school football players at Texarkana, Arkansas High School and Liberty Eylau High School, and college baseball players at Texarkana Community College. Subjects over the age of 18 signed an informed consent form. Subjects under 18 years of age had a parent or guardian sign the informed consent form and the minor signed an informed assent form. This study was approved by the Institutional Review Board of the University of Central Arkansas.

Volunteers for the study had to meet three requirements. The first requirement was the test extremity must have had no impairment to the hip, knee, thigh, or the low back for the previous year. The second requirement was the test extremity had to exhibit hamstring tightness. A deficit of 20º from full knee extension with the hip at 90º was defined as tight hamstrings. The subjects were also all high school and college athletes between the ages of 15 and 21 years.

Equipment

A double-armed transparent plastic goniometer was used for measuring hamstring flexibility. The protractor portion of the goniometer was divided into one-degree increments. The goniometer arms were 12 inches in length. A bubble was removed from a carpenter’s level and fixated to the goniometer to help ensure maintenance of the hip at a 90º angle.

Procedures

Measurement of hamstring flexibility was performed using the 90º test for hamstring flexibility described by Reese and Bandy. The subjects were positioned in supine with the hip and knee flexed to 90º. The
researchers palpated the lateral epicondyle of the femur and centered the goniometer over that landmark. The greater trochanter of the femur and the lateral malleolus of the tibia were marked. The goniometer was aligned with the lateral malleolus and the greater trochanter and centered over the lateral epicondyle. (Figure 1)

The markings on the goniometer were concealed with a piece of paper. While one researcher held the goniometer the other researcher moved the leg passively toward terminal extension. The point at which the researcher felt a firm resistance was defined as terminal extension. When the subject reached terminal extension the researcher holding the goniometer made sure proper alignment was maintained. An assisting examiner read and recorded the measurements on the blinded goniometer. Full hamstring flexibility was zero degrees on the goniometer. The subjects had no warm-up before data collection.

Since reliability had been established previously in the study by Nelson and Bandy,16 and the same researchers were performing the measurement, the reliability study was not replicated. A pretest measurement was taken on 87 males using the procedures using the 90/90 test for hamstring flexibility described. While 87 subjects were measured, 75 males met the criteria that had been established for the study. The subjects were randomly assigned to one of three groups.

The control group consisted of 24 subjects and was measured and then later re-measured. The length of time between the two measurements of the control group was similar to those in the study group. The subjects in the control group performed no stretching before being re-measured.

The eccentric training group (n=25) was measured then performed full range of motion eccentric training for the hamstring muscles. The subject lay supine with the left lower extremity fully extended. A 3 foot (0.91 m) piece of black theraband was held by the ends in each hand with the mid-section of the band wrapped around the right heel. The exercise started with the right knee locked in full extension and the hip in 0 degrees of extension. (Figure 2) The subject then pulled the hip into full flexion by pulling on the ends of the band with the arms. (Figure 3) The subject was to stop when he felt a gentle stretch. The position where the subject felt the gentle stretch was defined as full hip flexion. As the subject pulled the leg into hip flexion he was to resist the flexion motion by eccentrically contracting the hamstring muscles. The subject gave enough resistance to slow the hip flexion moment to take five seconds to complete. The eccentric activity was performed six times for a total stretch time of 30 seconds.

The static stretch group (n=26) performed a single 30 second static stretch using methods described by Bandy et al.1,15 The subject performed the hamstring stretch by standing erect with the left foot on the ground, toes pointed forward. (Figure 4) The heel of the right foot was on the seat of a chair or on a box. The subject’s toes on the right lower extremity were pointed toward the ceiling. The subject flexed forward at the hips while maintaining a neutral spine. The subject was instructed to keep the right knee fully extended. The subject flexed forward at the hips until a gentle stretch was felt in the posterior thigh. The position of stretch was held for 30 seconds.

**Data Analysis**

Means (and standard deviation) for all groups and all measurements were calculated. A 3 (group) x 2 (test) analysis of variance (ANOVA) with repeated measures on one variable (test) was used to analyze the data. Since an interaction was found, appropriate post hoc tests were performed to interpret the findings and are described in the results section. An alpha level of p<.05 was considered appropriate for the level of significance.
RESULTS
Seventy-five male subjects, with mean age of 17.22 years (SD = 1.30), completed all requirements for this study. Twenty-four subjects, with a mean age of 17.18 years (SD = 1.84) served the control group. The static group consisted of 26 subjects with a mean age of 17.22 years (SD = .76) and statically stretched the hamstrings muscles. Twenty-five subjects comprised the eccentric group and had a mean age of 17.27 years (SD = 0.96). The mean values for the pretest and posttest measurements of the control group for the degrees of knee extension were 31.42 degrees (SD = 9.97) and 32.50 degrees (SD = 10.19), respectively. The ICC (3,2) value calculated for pretest-posttest knee extension data of the control group was .95.

The Table presents the means for pretest and posttest measurements and gain scores for each group. Results of the two-way ANOVA (group x test) indicated a significant difference for test (df = 1,72; F = 59.16; p < .05), group (df = 2,72; F = 1.034; p < .05) and interaction (df = 2,72; F = 25.59; p < .05).

In order to interpret the group x test significant interaction, three follow-up statistical analyses were performed. First, three dependent t tests were calculated on the pretest to posttest change for each group. Using a Bonferroni correction to avoid inflation of the alpha level due to the use of multiple t tests, the alpha level was adjusted to p < .015. The dependant t tests indicated significant increases in hamstring flexibility in the group statically stretching (df = 25; t = 5.66; p < .015) and the eccentric group (df = 24; t = 6.85; p < .015), but no significant change in hamstring flexibility in the control group (df = 23; t = 1.83; p > .015).

Second, a one-way ANOVA was calculated to assess whether any significant differences existed in the pretest scores across the three groups. Results of these analyses indicated no significant difference (df = 2,72; F = .47; p > .05). A one-way ANOVA was calculated to assess if any difference existed across the posttest scores of the three groups. Results indicated a significant difference (df = 2,72; F = 5.15; p < .05). Tukey HSD post hoc analyses indicated that the mean posttest score of the static group (mean =25.77, SD = 9.15) was significantly different from the posttest score for the control group (mean = 32.50, SD = 10.19). Also, the posttest score for the eccentric group (mean = 24.12, SD = 9.66) was significantly different from the posttest score for the control group. The static and eccentric groups did not differ from each other.

Finally, in an attempt to summarize the data, an additional analysis using a one-way ANOVA on gain scores was calculated, revealing a significant difference between groups (df =2; F = 25.585; p < .05). Post hoc analysis using a Tukey HSD test indicated a significant difference between the gain in the static stretch group (mean = 5.50, SD = 4.50) and the control group (mean = -1.08, SD = 2.90), and the eccentric group (mean = 9.48, SD = 6.92) and the control group. Finally, the eccentric group showed a significantly greater gain than the static stretch group.

DISCUSSION
The groups performing one bout of static stretching and one bout of eccentric training showed significantly greater gains in flexibility than the control group. The group performing one bout of eccentric training showed a significantly greater gain in flexibility than the static stretch group. To date, this is the only study to compare
the immediate effects of one bout of eccentric training on changes in muscle flexibility. The results support the theory that the immediate effect of performing eccentric training through a full range of motion is an increase in muscle flexibility.

Eccentric training has been shown to improve flexibility not only from one bout of training as in this study, but also over a six week training program. The gains achieved by a six week program of static stretching and a six week program of eccentric training were very similar. Static stretching gained 12.04° and eccentric training gained 12.79° over the six week training program. Comparing the gains made over six weeks with the gains made with one bout of stretching or training, the gains were less with the single bout of training or stretching. While the gains were less with only one bout of activity, the gains were still significant when compared with a control.

No studies to date have examined the use of eccentric training to reduce injury rates, but the SAID (Specific Adaptation to Imposed Demand) principle states that a muscle will adapt to the imposed demands. If the muscle adapts to the imposed demand of eccentrically training, theoretically, injury rates would be lower since most injuries occur during the eccentric phase of activity.

Strength gains from eccentrically training a muscle would, theoretically, also improve performance. The need to use a resistance band does make eccentric training more difficult than static stretching, but the author of this study believes the benefits achieved outweigh the added complexity of using resistance bands.

Important clinical implications exist for eccentric training through a full range of motion. In many cases, the goal for clinicians and patients is a restoration of normal functional motion. Normal motion requires the patient to have the flexibility and the strength to perform the movement. Strengthening through a full range of motion will increase the likelihood that the patient will not only maintain the range achieved but will help ensure that the patient is able to use the range functionally. Eccentrically training through a full range of motion, theoretically, will improve the functional ability of the extremity by improving not only the flexibility but also the strength in that range.

A patient with weakness around a particular joint may not move the joint through a full range and structures around the area will often shorten leaving the patient with limited mobility. While static stretching has been proven to improve flexibility, the ability of static stretching to strengthen through and entire range of motion is

**Table.** Mean and standard deviation scores (in degrees) for pretest, posttest, and gain scores (in degrees) of knee flexion for each level of group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Control (n = 24)</th>
<th>Static (n = 26)</th>
<th>Eccentric (n = 25)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\bar{x}$</td>
<td>SD</td>
<td>$\bar{x}$</td>
</tr>
<tr>
<td>Pretest</td>
<td>31.42</td>
<td>9.97</td>
<td>31.27</td>
</tr>
<tr>
<td>Posttest</td>
<td>32.50</td>
<td>10.19</td>
<td>25.77</td>
</tr>
<tr>
<td>Gain (difference)</td>
<td>-1.08</td>
<td>2.90</td>
<td>5.50</td>
</tr>
</tbody>
</table>
doubtful. Eccentric training is strengthening the muscle by having it contract as it lengthens. A patient eccentrically training through a full range of motion will be gaining range of motion and strength at the same time, thus, making the activity more functional. This type of training could also save time by combining the strengthening and flexibility components into one activity.

More research is needed to determine if tangible gains can be made in strength, injury reduction, and performance enhancement through the use of eccentric training. In addition, future studies should address the effects of eccentric training on individuals across a diverse age group and include females.

CONCLUSION
In high school and college aged male athletes, hamstring flexibility gains made from one bout of eccentric training (as measured by hip flexion range of motion gains) were significantly better than the gains made by a static stretch group and a control group. This study provides evidence that when dealing with the immediate effects of stretching, flexibility programs may actually be enhanced by replacing static stretching with eccentric training.

REFERENCES
INVITED CLINICAL COMMENTARY

PRE-PARTICIPATION SCREENING: THE USE OF FUNDAMENTAL MOVEMENTS AS AN ASSESSMENT OF FUNCTION – part 1

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ABSTRACT

To prepare an athlete for the wide variety of activities needed to participate in their sport, the analysis of fundamental movements should be incorporated into pre-participation screening in order to determine who possesses, or lacks, the ability to perform certain essential movements. In a series of two articles, the background and rationale for the analysis of fundamental movement will be provided. In addition, one such evaluation tool that attempts to assess the fundamental movement patterns performed by an individual, the Functional Movement Screen (FMS™), will be described. Three of the seven fundamental movement patterns that comprise the FMS™ are described in detail in Part I: deep squat, hurdle step, and in-line lunge. Part II of this series, which will be published in the August issue of NAJSPT, will provide a brief review of the analysis of fundamental movements, as well a detailed description of the four additional patterns that complement those presented in Part I (to complete the total of seven fundamental movement patterns which comprise the FMS™): shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability.

The intent of this two part series is to introduce the concept of the evaluation of fundamental movements, whether it is the FMS™ system or a different system devised by another clinician. Such a functional assessment should be incorporated into pre-participation screening in order to determine whether the athlete has the essential movements needed to participate in sports activities with a decreased risk of injury.

Key Words. pre-participation screening, performance tests, function

INTRODUCTION

Over the last 20 years, the profession of sports rehabilitation has undergone a trend away from traditional, isolated assessment and strengthening toward an integrated, functional approach, incorporating the principles of proprioceptive neuromuscular faciliation (PNF), muscle synergy, and motor learning.1 However, it is difficult to develop and refer to protocols as “functional” when a functional evaluation standard does not exist. In many situations, rehabilitation professionals in sports settings are far too anxious to perform specific isolated, objective testing for joints and muscles. Likewise, these clinicians often perform sports performance and specific skill assessments without first examining functional movement. It is important to inspect and understand common fundamental aspects of human movement realizing that similar movements occur throughout many athletic activities and applications. The rehabilitation professional must realize that in order to prepare individuals for a wide variety of activities, fundamental movements should be assessed.

In the traditional sports medicine model, pre-participation physicals are followed by performance assessments. This systematic process doesn’t seem
to provide enough baseline information when assessing an individual’s preparedness for activity. Commonly, the medical pre-participation or rehabilitation examination includes only information that will exclude an individual from participating in certain activities. The perception of many past researchers is that no set standards exist for determining who is physically prepared to participate in activities. Recently, numerous medical societies have collaborated and attempted to establish more uniformity in this area, however, only suggestions for baseline medical parameters required for participation were provided. Ideally, collaboration should also occur among professionals to determine what the baseline for fundamental movement should be and if individuals should be allowed to participate if they are unable to perform movements at a basic level.

In the typical pre-participation screening exam, once the pre-participation medical examination is performed the active individual is then asked to complete performance tests. Commonly recommended performance tests include sit-ups, push-ups, endurance runs, sprints, and agility activities. In many athletic and occupational settings these performance activities become more specific to the tasks needed for defined areas of performance.

Performance tests function to gather baseline quantitative information and then attempt to make recommendations and establish goals. The recommendations are based on standardized normative information, which may not be relative to the individual’s specific needs. Likewise, in many cases, performance tests provide objective information that fails to evaluate the efficiency by which individuals perform certain movements. Little consideration is given to functional movement deficits, which may limit performance and predispose the individual to micro-traumatic injury.

Prescribed strength and conditioning programs often work to improve agility, speed, and strength without consideration for perfection or efficiency of underlying functional movement. An example would be a person who has an above average score on the number of sit-ups performed during a test but is performing very inefficiently by compensating and initiating the movement with the upper body and cervical spine as compared to the trunk. Compare this person to an individual who scores above average on the number of sit-ups, but is performing very efficiently and doesn’t utilize compensatory movements to achieve the sit-up. These two individuals would each be deemed “above average” without noting their individual movement inefficiencies. The question arises: If major deficiencies are noted in their functional movement patterns, then should their performance be judged as equal? These two individuals would likely have significant differences in functional mobility and stability; however, without assessing their functional mobility and stability it is inappropriate to assume differences.

The main goal in performing pre-participation or performance screenings is to decrease injuries, enhance performance, and ultimately improve quality of life. Currently, the research is inconsistent on whether the pre-participation or performance screenings and standardized fitness measures have the ability to achieve this main goal. A reason for the lack of predictive value of screenings is that the standardized screenings do not provide individualized, fundamental analysis of an individual’s movements. The authors of this clinical commentary suggest that analysis of fundamental movements should be incorporated into pre-season screening in order to determine who possesses, or lacks, the ability to perform certain essential movements.

THE FUNCTIONAL MOVEMENT SCREEN™

The Functional Movement Screen (FMS)™ is one evaluation tool that attempts to assess the fundamental movement patterns of an individual. This assessment tool fills the void between the pre-participation/pre-placement screenings and performance tests by evaluating individuals in a dynamic and functional capacity. A screening tool such as this offers a different approach to injury prevention and performance predictability. When used as a part of a comprehensive assessment, the FMS™ will lead to individualized, specific, functional recommendations for physical fitness protocols in athletic and active population groups.

The FMS™ is comprised of seven fundamental movement patterns that require a balance of mobility and stability. These fundamental movement patterns are designed to
provide observable performance of basic locomotor, manipulative, and stabilizing movements. The tests place the individual in extreme positions where weaknesses and imbalances become noticeable if appropriate stability and mobility is not utilized. It has been observed that many individuals who perform at very high levels during activities are unable to perform these simple movements. These individuals should be considered to be utilizing compensatory movement patterns during their activities, sacrificing efficient movements for inefficient ones in order to perform at high levels. If compensations continue, then poor movement patterns are reinforced leading to poor biomechanics and ultimately the potential of micro- or macro-traumatic injury.

The FMS™ tests were created based on fundamental proprioceptive and kinesthetic awareness principles. Each test is a specific movement, which requires appropriate function of the body’s kinetic linking system. The kinetic link model, used to analyze movement, depicts the body as a linked system of interdependent segments. These segments often work in a proximal-to-distal sequence, in order to impart a desired action at the distal segment. An important aspect of this system is the body’s proprioceptive abilities. Proprioception can be defined as a specialized variation of the sensory modality of touch that encompasses the sensation of joint movement and joint position sense. Proprioceptors in each segment of the kinetic chain must function properly in order for efficient movement patterns to occur.

During growth and development, an individual’s proprioceptors are developed through reflexive movements in order to perform basic motor tasks. This development occurs from proximal to distal, the infant learning to first stabilize the proximal joints in the spine and torso and eventually the distal joints of the extremities. This progression occurs due to maturation and learning. The infant learns fundamental movements by responding to a variety of stimuli, through the process of developmental motor learning. As growth and development progresses, the proximal to distal process becomes operational and has a tendency to reverse itself. The process of movement regression slowly evolves in a distal to proximal direction. This regression occurs as individ-

Application Examples

Firefighters initially train through controlled, voluntary movements. Then, through repetition, the movement becomes stored centrally as a motor program. The motor program eventually requires fewer cognitive commands leading to improved subconscious performance of the task. This subconscious performance involves the highest levels of central nervous system function, known as cognitive programming. In this example, problems would arise when the movements and training being “learned” are performed incorrectly, inefficiently, or asymmetrically.

A sport-specific example is a football lineman entering preseason practice who does not have the requisite balance of mobility or stability to perform a specific skill such as blocking. The athlete may perform the skill utilizing compensatory movement patterns in order to overcome the stability or mobility inefficiencies. The compensatory movement pattern will then be reinforced throughout the training process. In such an example, the individual creates a poor movement pattern that will be subconsciously utilized whenever the task is performed. Programmed altered movement patterns have the potential to lead to further mobility and stability imbalances, which have previously been identified as risk factors for injury.

An alternative explanation for development of poor movement patterns is the presence of previous injuries. Individuals who have suffered an injury may have a decrease in proprioceptive input, if untreated or treated inappropriately. A disruption in proprioceptive performance will have a negative effect on the kinetic linking system. The result will be altered mobility, stability, and asymmetric influences, eventually leading to compensatory movement patterns. This may be a reason why prior injuries have been determined to be one of the more significant risk factors in predisposing individuals to repeat injuries.

Determining which risk factor has a larger influence on injury, previous injuries or strength/flexibility imbal-
ances, is difficult. In either case, both lead to deficiencies in functional performance. It has been determined that these functional deficits lead to pain, injury, and decreased performance. Cholewicki et al demonstrated that limitations in stability in the spine led to muscular compensations, fatigue, and pain. Gardner-Morse et al determined that spinal instabilities result in degenerative changes due to the muscle activation strategies, which may be disrupted due to previous injury, stiffness, or fatigue. In addition, Battie et al demonstrated that individuals with previous low-back pain performed timed shuttle runs at a significantly lower pace than individuals who did not have previous low-back pain.

Therefore, an important factor in preventing injuries and improving performance is to quickly identify deficits in mobility and stability because of their influences on creating altered motor programs throughout the kinetic chain. The complexity of the kinetic linking system makes the evaluation of weaknesses using conventional, static methods difficult. For that reason, utilizing functional tests that incorporate the entire kinetic chain need to be utilized to isolate deficiencies in the system. The FMS™ is designed to identify individuals who have developed compensatory movement patterns in the kinetic chain. This identification is accomplished by observing right and left side imbalances and mobility and stability weaknesses. The seven movements in the FMS™ attempt to challenge the body’s ability to facilitate movement through the proximal-to-distal sequence. This course of movement in the kinetic chain allows the body to produce movement patterns more efficiently. The correct movement patterns were initially formed during growth and development. However, due to a weakness or dysfunction in the kinetic linking system, a poor movement pattern may have resulted. Once an inefficient movement pattern has been isolated by the FMS™, functional prevention strategies can be instituted to avoid problems such as imbalance, micro-traumatic breakdown, and injury.

**Scoring the Functional Movement Screen™**
The scoring for the FMS™ consists of four possibilities. The scores range from zero to three, three being the best possible score. The four basic scores are quite simple in philosophy. An individual is given a score of zero if at any time during the testing he/she has pain anywhere in the body. If pain occurs, a score of zero is given and the painful area is noted. A score of one is given if the person is unable to complete the movement pattern or is unable to assume the position to perform the movement. A score of two is given if the person is able to complete the movement but must compensate in some way to perform the fundamental movement. A score of three is given if the person performs the movement correctly without any compensation. Specific comments should be noted defining why a score of three was not obtained.

The majority of the tests in the FMS™ test right and left sides respectively, and it is important that both sides are scored. The lower score of the two sides is recorded and is counted toward the total; however it is important to note imbalances that are present between right and left sides.

Three tests have additional clearing screens which are graded as positive or negative. These clearing movements only consider pain, if a person has pain then that portion of the test is scored positive and if there is no pain then it is scored negative. The clearing tests affect the total score for the particular tests in which they are used. If a person has a positive clearing screen test then the score will be zero.

All scores for the right and left sides, and those for the tests which are associated with the clearing screens, should be recorded. By documenting all the scores, even if they are zeros, the sports rehabilitation professional will have a better understanding of the impairments identified when performing an evaluation. It is important to note that only the lowest score is recorded and considered when tallying the total score. The best total score that can be attained on the FMS™ is twenty-one.

**DESCRIPTION OF THE FMS™ TESTS**
The following are descriptions of three of the seven specific tests used in the FMS™ and their scoring system. Each test is followed by tips for testing developed by the authors as well as clinical implications related to the findings of the test.
Deep Squat

Purpose. The squat is a movement needed in most athletic events. It is the ready position and is required for most power movements involving the lower extremities. The deep squat is a test that challenges total body mechanics when performed properly. The deep squat is used to assess bilateral, symmetrical, functional mobility of the hips, knees, and ankles. The dowel held overhead assesses bilateral, symmetrical mobility of the shoulders as well as the thoracic spine.

Description. The individual assumes the starting position by placing his/her feet approximately shoulder width apart and the feet aligned in the sagittal plane. The individual then adjusts their hands on the dowel to assume a 90-degree angle of the elbows with the dowel overhead. Next, the dowel is pressed overhead with the shoulders flexed and abducted, and the elbows extended. The individual is then instructed to descend slowly into a squat position. The squat position should be assumed with the heels on the floor, head and chest facing forward, and the dowel maximally pressed overhead. As many as three repetitions may be performed. If the criteria for a score of III is not achieved, the athlete is then asked to perform the test with a 2x6 block under their heels. (Figures 1-4)

Tips for Testing:
- When in doubt, score the subject low.
- Try not to interpret the score while testing.
- Make sure if you have a question to view individual from the side.

Clinical Implications for Deep Squat

The ability to perform the deep squat requires closed-kinetic chain dorsiflexion of the ankles, flexion of the knees and hips, extension of the thoracic spine, and flexion and abduction of the shoulders.

Poor performance of this test can be the result of several factors. Limited mobility in the upper torso can be attributed to poor glenohumeral and thoracic spine mobility. Limited mobility in the lower extremity including poor closed-kinetic chain dorsiflexion of the ankles or poor flexion of the hips may also cause poor test performance.

When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by using standard goniometric measurements. Previous testing has identified that when an athlete achieves a score of II, minor limitations most often exist either with closed-kinetic chain dorsiflexion of the ankle or extension of the thoracic spine. When an athlete achieves a score of I or less, gross limitations may exist with the motions just mentioned, as well as flexion of the hip.

III

- Upper torso is parallel with tibia or toward vertical
- Femur below horizontal
- Knees are aligned over feet
- Dowel aligned over feet

Figure 1. Deep squat anterior view.  Figure 2. Deep squat lateral view.
Hurdle Step

Purpose. The hurdle step is designed to challenge the body’s proper stride mechanics during a stepping motion. The movement requires proper coordination and stability between the hips and torso during the stepping motion as well as single leg stance stability. The hurdle step assesses bilateral functional mobility and stability of the hips, knees, and ankles.

Description. The individual assumes the starting position by first placing the feet together and aligning the toes touching the base of the hurdle. The hurdle is then adjusted to the height of the athlete’s tibial tuberosity. The dowel is positioned across the shoulders below the neck. The individual is then asked to step over the hurdle and touch their heel to the floor while maintaining the stance leg in an extended position. The moving leg is then returned to the starting position. The hurdle step should be performed slowly and as many as three times bilaterally. If one repetition is completed bilaterally meeting the criteria provided, an III is given. (Figures 5-8)

Tips for Testing:
• Score the leg that is stepping over the hurdle
• Make sure the individual maintains a stable torso
• Tell individual not to lock knees of the stance limb during test
• Maintain proper alignment with the string and the tibial tuberosity
• When in doubt score subject low
• Do not try to interpret the score when testing

Clinical Implications for Hurdle Step
Performing the hurdle step test requires stance-leg stability of the ankle, knee, and hip as well as maximal closed-kinetic chain extension of the hip. The hurdle step also requires step-leg open-kinetic chain dorsiflexion of the ankle and flexion of the knee and hip. In addition, the athlete must also display adequate balance because the test imposes a need for dynamic stability.
Poor performance during this test can be the result of several factors. It may simply be due to poor stability of the stance leg or poor mobility of the step leg. Imposing maximal hip flexion of one leg while maintaining hip extension of the opposite leg requires the athlete to demonstrate relative bilateral, asymmetric hip mobility.

When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by using standard goniometric measurements of the joints as well as muscular flexibility tests such as Thomas test or Kendall’s test for hip flexor tightness. Previous testing has identified that when an athlete achieves a score of II, minor limitations most often exist with ankle dorsiflexion and hip flexion with the step leg. When an athlete scores a I or less, relative asymmetric hip immobility may exist, secondary to an anterior tilted pelvis and poor trunk stability.

### III
- Hips, knees and ankles remain aligned in the sagittal plane
- Minimal to no movement is noted in lumbar spine
- Dowel and string remain parallel

![Figure 5. Hurdle step anterior view.](image5)

![Figure 6. Hurdle step anterior view.](image6)

### II
- Alignment is lost between hips, knees, and ankles
- Movement is noted in lumbar spine
- Dowel and string do not remain parallel

![Figure 7. Hurdle step anterior view.](image7)

![Figure 8. Hurdle step anterior view.](image8)

### I
- Contact between foot and string occurs
- Loss of balance is noted
In-Line Lunge

Purpose. The in-line lunge attempts to place the body in a position that will focus on the stresses as simulated during rotational, decelerating, and lateral type movements. The in-line lunge is a test that places the lower extremities in a scissor style position challenging the body's trunk and extremities to resist rotation and maintain proper alignment. This test assesses hip and ankle mobility and stability, quadriceps flexibility, and knee stability.

Description. The tester attains the individual's tibia length, by either measuring it from the floor to the tibial tuberosity or acquiring it from the height of the string during the hurdle step test. The individual is then asked to place the end of their heel on the end of the board or a tape measure taped to the floor. The previous tibia measurement is then applied from the end of the toes of the foot on the board and a mark is made. The dowel is placed behind the back touching the head, thoracic spine, and sacrum. The hand opposite to the front foot should be the hand grasping the dowel at the cervical spine. The other hand grasps the dowel at the lumbar spine. The individual then steps out on the board or tape measure on the floor placing the heel of the opposite foot at the indicated mark. The individual then lowers the back knee enough to touch the surface behind the heel of the front foot and then returns to starting position. The lunge is performed up to three times bilaterally in a slow controlled fashion. If one repetition is completed successfully then a three is given for that extremity (right or left). (Figures 9-12)

Tips for Testing:
• The front leg identifies the side being scored
• Dowel remains in contact with the head, thoracic spine, and sacrum during the lunge
• The front heel remains in contact with the surface and back heel touches surface when returning to starting position
• When in doubt score the subject low
• Watch for loss of balance
• Remain close to individual in case he/she has a loss of balance.

Clinical Implications for In-Line Lunge
The ability to perform the in-line lunge test requires stance leg stability of the ankle, knee, and hip as well as apparent closed kinetic-chain hip abduction. The in-line lunge also requires step-leg mobility of hip abduction, ankle dorsiflexion, and rectus femoris flexibility. The athlete must also display adequate balance due to the lateral stress imposed.

Poor performance during this test can be the result of several factors. First hip mobility may be inadequate in either the stance leg or the step leg. Second, the stance-leg knee or ankle may not have the required stability as the athlete performs the lunge. Finally, an imbalance between relative adductor weakness and abductor tightness in one or both hips may cause poor test performance. Limitations may also exist in the thoracic spine region which may inhibit the athlete from performing the test properly.

When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by using standard goniometric measurements of the joints as well as muscular flexibility tests such as Thomas test or Kendall’s test for hip flexor tightness.

Previous testing has identified that when an athlete achieves a score of II, minor limitations often exist with mobility of one or both hips. When an athlete scores a I or less, a relative asymmetry between stability and mobility may occur around one or both hips.
III
- Dowel contacts remain with lumbar spine extension
- No torso movement is noted
- Dowel and feet remain in sagittal plane
- Knee touches board behind heel of front foot

II
- Dowel contacts do not remain with lumbar spine extension
- Movement is noted in torso
- Dowel and feet do not remain in sagittal plane
- Knee does not touch behind heel of front foot

I
- Loss of balance is noted
SUMMARY
The research related to movement-based assessments is extremely limited, mainly because only a few movement-based quantitative assessment tests are being utilized. According to Battie et al., the ultimate test of any pre-employment or pre-placement screening technique is its effectiveness in identifying individuals at the highest risk of injury. If the FMS™, or any similarly developed test, can identify at risk individuals, then prevention strategies can be instituted based on their scores. A proactive, functional training approach that decreases injury through improved performance efficiency will enhance overall wellness and productivity in many active populations.

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ABSTRACT

Background. Codman’s pendulum exercises are commonly prescribed after shoulder surgery and injury to provide grade I and II distraction and oscillation resulting in decreased pain, increased flow of nutrients into the joint space, and early joint mobilization. Many shoulder protocols suggest that weight may be added to these pendulum exercises as rehabilitation progresses, however, very few guidelines exist to stipulate how much weight should be added.

Objectives. To determine if added weight affected the subject’s ability to relax the shoulder musculature during pendulum exercises.

Methods. Twenty-six participants, ages 20 to 56 years old (mean 32.26, ± 8.51 years) were divided into two groups, nine pathological and 17 non-pathological. The muscle activity (EMG) of four variations of Codman’s pendulum exercises 1) wrist suspended 1.5 kg weighted-ball, 2) hand-held 1.5 kg dumbbell, 3) hand-held 1.5 kg weighted-ball, and 4) no weight were recorded in each muscle.

Results. When grouped across all patients and all other factors included in the ANOVA, the type of pendulum exercise did not have a significant effect on shoulder EMG activity regardless of patient population or muscle tested. Generally, the supraspinatus/upper trapezius muscle activity was significantly higher than the deltoid and infraspinatus activity – especially in the patients with pathological shoulders.

Conclusion. Performing the exercises with added weight did not result in significant increased shoulder EMG activity for the deltoid and infraspinatus muscles in subjects with and without shoulder pathology. However, patients with shoulder pathology had greater difficulty relaxing their supraspinatus/upper trapezius muscle group during Codman’s pendulum exercises than healthy subjects.

Key Words: Codman, passive motion, distraction, muscle activity

INTRODUCTION

Early joint mobilization plays an important role in the rehabilitation of the injured shoulder for the return of normal kinematics and shoulder function. Prolonged immobilization may predispose patients to muscle atrophy and poor neuromuscular control. The use of early joint motion can help prevent adhesions and contractures, especially pertaining to the periarticular connective tissue. Passive range of motion is typically prescribed during postoperative care and early rehabilitation of the injured shoulder to initiate early joint motion. The goal of an early rehabilitation protocol is to provide motion at the glenohumeral joint, while
maintaining relative inactivity of the repaired or injured muscles and tendons. These goals also aim to minimize excessive tension at the suture line, or site of injury, and prevent adverse effects on already injured musculature.\textsuperscript{1-6} Codman’s pendulum exercises are commonly prescribed after shoulder pathology to provide grade I and II distraction and oscillation resulting in decreased pain, increased flow of nutrients into the joint space, and early joint mobilization.\textsuperscript{5,6} Shoulder protocols, as well as Codman\textsuperscript{5} himself, suggest that weight may be added to these pendulum exercises as rehabilitation progresses, however, very few guidelines exist to stipulate when, and how much weight should be added.\textsuperscript{6}

The use of a continuous passive motion device (CPM) is not always available or appropriate after a shoulder injury or surgery, but the replication of the motion without the activation of the injured or sutured muscles is crucial for safe rehabilitation of the injured or post surgical shoulder. Typically, patients after shoulder injury or surgery have a difficult time relaxing the shoulder musculature and performing Codman’s pendulum exercises correctly. Dockery et al\textsuperscript{2} evaluated the different rehabilitation protocols using electromyographic (EMG) analysis of the rotator cuff muscles to determine if different protocols promoted passive motion and how much rotator cuff activation occurred. Using a sample size of ten healthy volunteers, the authors tested various exercises commonly used postoperatively following shoulder surgery using surface electrodes. They concluded that therapist assisted exercises and Codman’s pendulum exercises showed activity that was not significantly different from that of a CPM machine. The authors further concluded that these exercises are similar in safety to the CPM for obtaining early passive range of motion without disrupting the rotator cuff.

In a similar study, McCann et al\textsuperscript{1} used intramuscular fine wire EMG electrodes to examine shoulder muscle activity during passive, active, and resistive rehabilitation exercises. Passive exercises included Codman’s pendulum exercises and EMG activity was categorized as: 1. minimal - if less than 20% of the muscle activity needed to raise a 2.25kg weight into abduction was elicited, 2. moderate - if 20%-50% of abduction activity was elicited, and 3. maximal - if greater than 50% was elicited. The results indicated that only the Codman’s pendulum exercise demonstrated minimal muscle activity.

Very few studies have been conducted regarding this frequently used shoulder exercise during the early stages of rehabilitation. The purpose of this study was to determine if shoulder muscle activity increased with the addition of weight to Codman’s pendulum exercises and if a difference was present in the muscle activation between the pathological shoulder and the healthy shoulder. Additionally, this study examined various methods of performing Codman’s exercises and the effect on the activity of the shoulder musculature.

**METHODS**

Twenty six participants (14 females, 12 males), ages 20± to 56 years old (mean age 32.3 ± 8.5 years) were recruited. Upon review and approval by the Lenox Hill Hospital Institutional Review Board, informed consent was obtained from each participant. Interested volunteers were asked a series of questions in order to categorize the participants into either the pathological or non-pathological grouping. Nine participants who had pathological shoulders (mean age 39.3 ±12.5) and seventeen participants with non-pathological shoulders (mean age 30.4 ± 6.2) made up the two groups. Participants in the pathological group were classified as having a shoulder dysfunction and/or pain within the first 6 weeks of onset or were in their first 6 weeks postoperatively. The group of pathological shoulders consisted of two patients with superior labral anterior posterior repairs (SLAP), two with shoulder dislocations, one acromial clavicular joint (AC) decompression, one coracoclavicular ligament reconstruction, one shoulder impingement, one post surgical capsular shift and acromioplasty, and one post-surgical thermal shrinkage. Participants in the non-pathological group were classified as anyone who did not have a shoulder dysfunction, surgery, or pain within the past year.

Surface electrodes were positioned on the supraspinatus/upper trapezius, infraspinatus, and middle deltoid following standard surface electrode placement.\textsuperscript{7} The EMG sites were prepared according to standard protocol using a razor to remove hair, an alcohol pad to clean the skin, and an abrasive pad to abrade the skin.\textsuperscript{8} Two surface electrodes were placed 2.54cm (1 inch) apart on each of the targeted muscles to prevent the electrodes from touching
with motion. The placement of the electrodes was determined by referencing the work of the Delagi and Perotto. The infraspinatus electrode placement was the midway point of the spine of the scapula and measuring two finger widths posteriorly and inferiorly from the middle of the spine. The supraspinatus/upper trapezius electrode placement was determined by palpation of the middle portion of the spine of the scapula, then moving superiorly two finger widths in the supraspinatus fossa. The middle deltoid placement was halfway between the acromion and the deltoid tubercle. A ground electrode was placed on the olecranon process of the arm being tested. Muscle activity output was checked prior to the initiation of testing by having the participant contract each muscle to ensure correct electrode placement.

The EMG signals were band pass filtered from 10 to 500 Hz and sampled at 1000 Hz, with a common-mode rejection ratio of 130 dB (Telemyo, Noraxon, Scottsdale, AZ). A maximum voluntary isometric contraction (MVIC) for each muscle was performed for normalizing muscle activity during the Codman exercises. The MVIC was taken with the patient positioned in the standard manual muscle position for the best isolation of the targeted muscle. Shoulder abduction for the deltoid and supraspinatus/upper trapezius was recorded with the arm starting at the participants side, standing 30° away from a pillow held on the wall. The MVIC was recorded as the participant abducted the arm and pressed as hard as they could into a pillow against the wall. External rotation for the infraspinatus was recorded with the subject standing near a pillow held against a wall with elbow flexed 90° and shoulder held in 0° abduction and maximally pushing the wrist outward into the wall externally rotating the arm. Participants in the pathological group were asked to perform the MVIC on the uninvolved shoulder to avoid complications with the increased muscle activity of the involved shoulder musculature, while participants in the non-pathological group were asked to perform the MVIC on the shoulder being tested.

Participants in both the pathological and non-pathological groups were instructed to perform four variations of Codman’s pendulum exercises; suspended ball weight of 1.5 kg (3.3 lbs) (Figure 1), hand-held dumbbell of 1.5 kg (Figure 2), hand-held ball weight of 1.5 kg (Figure 3), and no weight (Figure 4). The participant was randomly assigned an order of exercises.

Participants were positioned with the non-tested arm resting on a table and the upper extremity to be tested hanging down for free movement. Trunk flexion at the hips was kept at a 75-degree angle from the upright vertical position as measured using a standard
goniometer. The degree to which the trunk was flexed at the hips was modified from the traditional protocol of 90 degrees to allow for ground clearance of the suspended weight as it dangled from the arm. The “pendulum” or swinging motion was initiated by having the participant move their trunk slightly back and forth until motions of internal circumduction and then external circumduction were achieved. A circle was placed on the floor for guidance to control for the amount of circumduction that the participant would achieve during the testing. Shoulder range of motion limits were set to the minimum ability of the most involved shoulder pathology to avoid any possible complications. The speed of the arm swing was controlled for each participant using a loud beat on an electric metronome set at 40 beats per minute. Three trials for each parameter were performed to allow participants to become comfortable with the motion and the testing procedure. The third trial was used for data collection. Each participant performed five clockwise and five counter clockwise circles for each of the four parameters tested.

The EMG signals were acquired using the Noraxon TeleMyo telemetered EMG system (Noraxon USA, Scottsdale, AZ). The signals were low pass filtered at 500 Hz and high pass filtered at 10Hz. The EMG readings were sampled at 1kHz and analyzed using Noraxon Myosoft software. A 100ms moving average RMS function was applied to the raw EMG signal. The average RMS for the duration of the trial was computed by integrating the RMS and dividing the area by the time, thereby, producing the average amplitude. This process was conducted for all activity during the last trial and expressed as a percent of that particular muscle’s MVIC. Internal and external circumduction were calculated for the non-pathological group since both arms were tested (i.e., left shoulder internal circumduction compared to right arm external circumduction). Internal and external circumduction were also calculated for each arm individually for the non-pathological group to verify the related muscle firing pattern was not different. The pathological group did not require these calculations since only the contralateral arm was tested.

Data Analysis
The effect of the different types of Codman exercises on muscle activity was examined using a 4x3x2 (exercise type x shoulder muscle group x pathology group) mixed model analysis of variance (ANOVA) with Bonferroni corrections for pairwise comparisons. Separate exercise type vs pathological group ANOVAs were performed on each muscle separately to further examine the data. Greenhouse-Geisser corrections were applied to significant ANOVAs that did not meet Mauchly’s sphericity assumption in order to reduce the likelihood of a type I error. An alpha of 0.05 was set a priori.

RESULTS
When grouped across all patients and all other factors included in the ANOVA, the type of pendulum exercise did not have a significant effect on shoulder EMG activity regardless of patient population or muscle tested (effect of exercise type - p=0.79, exercise type by shoulder muscle interaction - p=0.72). Generally, supraspinatus/upper trapezius muscle activity (17% MVIC) was significantly higher than deltoid (6%) and infraspinatus activity (7%) (muscle effect – p=0.001).

When each muscle was analyzed separately for the effect of added weight distraction during Codman’s pendulum exercises (comparing the three weighted conditions to the non-weighted condition), no significant increase in shoulder muscle activity occurred for any of the weighted conditions in the infraspinatus (Figure 5; p=0.39), supraspinatus/upper trapezius (Figure 6; p=0.36) and two of the exercise conditions for the deltoid. However, deltoid activity was increased during the pendulum exercise with a dumbbell (Figure 7; p=0.04).

Further analysis indicated that the pathological group had significantly greater muscle activity in the infraspinatus (Figure 5; p= 0.041) and supraspinatus/upper trapezius (Figure 6; p= 0.03) compared with the non-pathology group. No such significant difference between the pathological and non-pathological groups occurred in the deltoid group (Figure 7; p= 0.11).

DISCUSSION
Passive shoulder motion is regarded as standard early rehabilitation in patients postoperatively, as well as patients not undergoing surgery. Early joint mobilization plays an important role in the rehabilitation of the patient with an injured shoulder for the return of normal kinematics and shoulder function. Dockery et al

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tigated the different shoulder rehabilitation protocols using surface EMG analysis of the rotator cuff muscles to determine how much rotator cuff activity the protocols promoted. The authors concluded that shoulder muscle activity during Codman’s pendulum exercises was not significantly different from that of a continuous passive motion (CPM) machine. The study conducted by Dockery et al. used similar methodology (including the use of surface EMG) and found similar results as this present study.

In a similar study, McCann et al. used intramuscular fine wire EMG electrodes to examine shoulder muscle activity during passive, active, and resistive rehabilitation exercises. Only the pendulum exercise consistently showed minimal shoulder muscle activity defined as eliciting less than 20% of the muscle activity needed to raise a 2.25kg weight in abduction. The results of the present study are in agreement with the study of McCann et al., indicating that the type of pendulum exercise minimally affects shoulder muscle activity. A small increase in deltoid activity occurred in the group with shoulder pathology compared to the group without pathology during the pendulum exercise performed with the dumbbell but the infraspinatus and supraspinatus/upper trapezius did not show a similar effect. In comparing the pendulum exercises within each muscle with no weight to the three pendulum exercises performed with weight it was apparent that the added distraction force by the addition of weight did not increase shoulder muscle activity. All muscle activity - for each type of exercise and for pathological and non-pathological shoulders exercise - was less than 20% MVIC except for the supraspinatus/upper trapezius in the pathological group. Therefore, the majority of the Codman’s pendulum exercise for early shoulder rehabilitation fell below the minimal category established by McCann et al.

The other clinically relevant finding was that the supraspinatus/upper trapezius and infraspinatus muscle activity were significantly higher in the group with shoulder pathology compared to the group without pathology. However, although a significant difference was found between the group with pathology and the group without pathology for the infraspinatus muscles, the percent of muscle activity was below 15% for all types of exercise in both groups. Therefore, the infraspinatus muscle appears to be able to relax during pendulum exercises.

The only muscle group that appeared to be unable to relax during the pendulum exercises was the supraspinatus/upper trapezius. The magnitude of muscle activity in the group with shoulder pathology indicated that these subjects were not able to sufficiently relax their supraspinatus/upper trapezius muscle. Mean supraspinatus/upper trapezius activity was 39% MVIC for the pendulum exercise performed without a weight, 20% when performed with a suspended weight, 25% when...
performed with a grip weight, and 30% when performed with a dumbbell. Corresponding values in the group without pathology were 10%, 13%, 12%, and 11% (Table 1). This response may reflect a guarding response in patients with pathology. Biofeedback training may be necessary to facilitate relaxation in the supraspinatus/upper trapezius muscles during the pendulum exercises.

Since the results of this present study were largely negative with respect to the effect added weight on muscle relaxation it is important to assess whether this effect might have been subject to a type II error. Therefore, post hoc analyses were performed to determine the magnitude of difference in EMG activity that could be detected as significant (p<0.05) with 80% power. Based on the standard deviation of the difference in EMG activity (%) between the different types of pendulum exercises these detection thresholds were 5% for the supraspinatus/upper trapezius and 2.5% for the infraspinatus and deltoid. These analyses indicate that there was sufficient power to detect clinically relevant differences in EMG activity between the different types of pendulum exercises.

Limitations of the study include use of surface EMG to measure muscle activity, especially in the supraspinatus muscle. To say that the muscle activity of the supraspinatus was isolated without interference from the upper trapezius and possibly the posterior deltoid is problematic. Therefore, the category of supraspinatus/upper trapezius was used. Despite this limitation, we believe that this study still provides valuable information related to muscle activity during the performance of Codman’s pendulum exercises when adding weight. An additional limitation was the sample size. A larger sample size, especially in the group with pathological shoulders, would have been nice to compare to the control group.

**CONCLUSION**

The results of this present study indicate that adding a 1.5kg weight had no significant impact on shoulder muscle activity (as demonstrated by EMG analysis) during pendulum exercises for the deltoid and infraspinatus muscles for subjects with or without shoulder pathology. However, the supraspinatus/upper trapezius muscle group was clearly not relaxed in patients with shoulder pathology during any of the pendulum exercise.

**REFERENCES**


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ABSTRACT

Background. The relative importance and asymmetric loading of the trunk muscles in golf (slow rotation backswing followed by high velocity downswing) may cause side-to-side imbalances in axial rotation strength and endurance characteristics amongst elite players who frequently play and practice. Such imbalances may further be compounded by the presence of low back pain.

Objective. To establish and compare trunk rotation strength and endurance of healthy individuals who do not play golf and those that are highly skilled at the sport. Additionally, a smaller group of elite golfers with non-debilitating low back pain (LBP) were also evaluated and compared to their healthy counterparts.

Methods. Forty healthy non-golfing control subjects, 32 healthy elite golfers, and 7 golfers with LBP participated in this study. Bilateral trunk rotation strength and endurance was assessed using the Biodex System III Isokinetic Dynamometer with torso rotation attachment. Strength and endurance data was analyzed using 2-way ANOVA.

Results. No significant differences in peak torque were found within or between groups. However, golfers with LBP demonstrated significantly less endurance in the non-dominant direction (the follow-through of the golf swing) than either healthy group. No significant difference in endurance was found between the non-golfing controls and the healthy elite golfers.

Conclusions. Trunk rotation endurance in golfers with LBP might be more important than strength alone in the prevention and treatment of LBP. The results from this study provide useful information on possible risk factors associated with low back pain in golfers (decreased endurance) and allow for sport-specific clinical intervention strategies to be developed.

Key Words: spinal rotation, injury, golf

INTRODUCTION

The effective execution of the golf swing not only requires rapid movement of the extremities but also substantial strength and power of the trunk muscles. The torso rotates away from the target (to the right for a right handed player) at approximately 85 deg/sec on the backswing while the powerful downswing involves trunk velocities approaching 200 deg/sec. Pink et al. demonstrated relatively high and constant activity in the abdominal oblique muscles throughout most parts of the golf swing of skilled amateur players. In a similar study using professional golfers, Watkins et al. measured muscle activity in the erector spinae, abdominal oblique, and rectus abdominis. These authors established that all trunk muscles were relatively active during the acceleration phase of the golf swing with the trail-side abdominal oblique muscles showing the highest level of activity.

Given the relative importance of the trunk muscles in golf, particularly in terms of generating powerful axial rotation on the downswing, repetitive play and practice might contribute to enhanced rotational strength and endurance amongst these athletes. Furthermore, this asymmetric pattern of trunk rotation during the golf swing (slow rotation...
backswing followed by high velocity downswing) may cause side-to-side imbalances in rotational strength and endurance characteristics amongst elite players who frequently play and practice. These potential imbalances may contribute to an increased susceptibility of developing low back pain. Lindsey and Horton\(^4\) have shown side-to-side maximum trunk rotation flexibility imbalances in elite golfers with and without low back pain (LBP).

The authors of this study are aware of only six peer-reviewed, non golf-related research studies that have evaluated strength and endurance characteristics of the trunk muscles during axial rotation movements.\(^5\)\(^\text{-}\)\(^10\) Three of these studies\(^5\)\(^\text{-}\)\(^6\)\(^,\)\(^9\) have reported isokinetic trunk rotation strength measures, while the others attempted to assess trunk muscle characteristics with electromyography (EMG) during repeated trunk rotations. Five different studies have investigated strength and or endurance parameters during trunk flexion and extension motions.\(^11\)\(^\text{-}\)\(^15\) A limitation of most of these studies was they used custom made equipment to collect data. Kumar\(^5\) reported that the scarcity of data for trunk rotation is directly attributable to the lack of suitable, accurate, standardized, and affordable devices to permit such measurement. Consequently, gaps in the literature exist regarding trunk rotation strength and endurance capabilities in the general population. Furthermore, no previous studies have investigated trunk rotation strength and endurance in golfers.

Suter and Lindsay\(^16\) compared static trunk extensor endurance and inhibition of the quadriceps in low handicap golfers with LBP and healthy age-matched controls who did not golf. The authors were unable to show any significant differences in static holding times or decline in the EMG median frequency between groups. However, golfers with the lowest trunk extensor endurance were found to have significant quadriceps muscle inhibition compared to golfers with higher trunk endurance. It was postulated the inhibition of the quadriceps might be a direct result of abnormal afferent input to the muscle due to irritation of the spinal structures which innervate that specific region. No such association was observed for the normal subjects.

Considering the role of trunk rotation during the golf swing and the possible relationship between trunk muscle strength and endurance and low back pain, the purposes of the proposed exploratory research project were the following: 1) To establish normative data by measuring trunk rotational strength and endurance in healthy individuals who do not play golf. 2) To measure trunk rotation strength and endurance in age-matched elite golfers without LBP. (Collection of this data would permit comparisons between non-golfing control subjects and healthy golfers. This would also establish whether the repetitive and asymmetric nature of the golf swing leads to side-to-side differences in trunk rotation strength and endurance.) 3) To measure trunk rotation strength and endurance in elite golfers with non-debilitating LBP to determine if these individuals have less rotation strength and endurance compared to healthy elite golfers.

Owing to the scarcity of data associated with isokinetic trunk rotation testing, a number of secondary purposes were also investigated. In particular, whether subjects' torque and work results were influenced by trunk rotation range of motion (ROM) or body weight. The reliability and technical error associated with isokinetic strength testing was also examined.

**METHODS**

**Subject Recruitment**

Healthy male volunteer subjects that did not play golf were recruited via mass e-mail advertisements to University of Calgary faculty, staff, and students. Advertisements were faxed to golf professionals in the Alberta Professional Golf Association to recruit male professional and elite amateur golfers with and without LBP. Advertisements were also faxed to physical therapy clinics in the Calgary area to recruit elite male golfers with LBP.

Potential subjects were initially asked to complete a screening questionnaire regarding history of LBP (location, duration, frequency, and treatment) and the effects of playing golf and practicing on LBP. Those individuals who had not played golf more than twice per year in the past 5 years and had not experienced LBP in the previous 12 months were considered to be control normals. Elite golfers were defined as those playing and practicing at least 50 times per year and carrying a sanctioned handicap of 10 or less. Elite golfers who “never” or “rarely” experienced pain in the lumbar region of their back after practicing or playing during the golf season prior to completion of the questionnaire were classified as control normals.
golfers. Those players who “always” or “often” experienced pain in the lumbar region of their back after practicing or playing during the season preceding the questionnaire were classified as golfers with LBP.

Individuals were excluded from participating in the study if they were older than 49 years of age or had previously undergone surgery or other medically invasive procedures (nerve blocks or ablation, prolotherapy, cortisone injections) for LBP. Individuals over the age of 49 years were excluded based on published reports that both isometric and dynamic strength declines after age 50. Furthermore, potential golfers with LBP were excluded if they had experienced golf-related LBP for less than six months prior to the commencement of the study. Those golfers with LBP who met the inclusion criteria were individuals who had experienced LBP for some time and continued to play golf in spite of this pain. These inclusion criteria restrictions made it more difficult to recruit eligible subjects resulting in a lower sample than in the other groups.

Subjects
Forty healthy control normals (27.9 ± 4.8 yrs; 78.1 ± 8.2 kg; 176.5 ± 5.4 cm), 32 control golfers (30.0 ± 6.0 yrs; 79.1 ± 8.8 kg; 176.0 ± 5.7 cm), and 7 golfers with LBP (33.3 ± 9.6 yrs; 83.4 ± 10.9 kg; 178.7 ± 5.4 cm) participated in this study. All subjects completed a physical activity readiness questionnaire (PAR-Q) and signed an informed consent form prior to any testing procedures. Ethical approval was granted by the University of Calgary’s Faculty of Medicine Conjoint Health Research Ethics Board.

Testing Procedures
Subjects were required to visit the University of Calgary Sport Medicine Centre on one occasion for testing. Prior to any testing procedures, subjects completed a low back pain and disability questionnaire (Oswestery Pain Questionnaire). Height and weight measurements were made followed by a short five-minute warm-up on a stationary bicycle. Following the warm-up, subjects were required to perform a series of standard stretches for the abdominal, back, hip, and leg muscles. An explanation of the testing procedures was then given verbally. Subjects were asked to sit in the chair of the Biodex System III Isokinetic Torso Rotation Attachment (Biodex Medical Systems, Inc., Shirley, New York) in an upright position so that the axis of rotation of the Torso Rotation Attachment was aligned with the long axis of the subject’s spine (Figure 1). Once adjustments to the Torso Rotation Attachment were made to suit each individual, leg straps and hip pads were tightened to restrict lower body movement. A strap was then tightened around the back so the upper body was as tight as possible against the chest pad without causing discomfort. Once the apparatus was properly adjusted, subjects were given an opportunity to perform slow practice repetitions of trunk rotation to become familiar with the desired movement. All subjects were experiencing minimal or no low back pain on the day of testing. Subjects then underwent isokinetic axial rotation strength and endurance testing as per the following consistent protocol:

Strength Testing
Subjects were initially asked to turn as far as possible (without discomfort) in both directions to determine total ROM and to set limits in right and left rotation. After setting the ROM limits, subjects were required to perform practice repetitions at 90 deg/sec at a moderate intensity to become accustomed to the required speed of movement for the strength test. Shortly after this, subjects performed five bilateral concentric trunk rotations at 90 deg/sec. Ninety degrees per second has been shown to
be highly reliable for strength testing using the Biodex Isokinetic Dynamometer. Subjects were instructed to concentrate on using the trunk muscles rather than the arms or shoulders to perform the axial rotation movements; to start with moderate effort rotations; to gradually increase their effort so the last three repetitions were of maximal effort; to give equal effort in both directions of rotation; to keep breathing throughout the test (each subject determined their own pattern of breathing); and to stop the test if they felt any discomfort. All subjects were given verbal encouragement during the test.

**Endurance Testing**

Subjects were given a five-minute rest period between the strength and endurance tests. Five minutes is regarded as adequate time for replenishment of ATP and phosphocreatine stores in muscle following short-term maximal exercise. Range of motion limits were again set in the same manner as the strength testing protocol. Subjects were then required to perform moderate effort practice trunk rotations at a speed of 180 deg/sec. Following the practice repetitions and a brief rest, subjects performed 25 bilateral maximal trunk rotations at the 180 deg/sec speed. This velocity approximates the trunk rotation velocities reported for adult golfers and is an accepted velocity for endurance testing with isokinetic dynamometers. Subjects were instructed to perform the endurance test beginning with maximal effort and to maintain that intensity as long as possible throughout the duration of the test until 25 repetitions were completed. Subjects were given verbal encouragement throughout the test.

**Strength Test Reliability**

In addition to the strength and endurance testing for this research study, reliability of the strength test was assessed with a sub-group of 12 control normal subjects. These subjects performed the strength test three times with a 5-minute rest between tests. These same subjects repeated the same testing procedure 3-5 days following the initial testing session.

**Data Analysis**

To allow data from both left and right-handed subjects to be collected and interpreted in a consistent manner, right and left rotation values were categorized as “dominant” or “non-dominant.” Right torso rotation for a right-handed subject was categorized as “dominant” rotation while left rotation was referred to as “non-dominant” rotation. Right rotation for a left handed subject was categorized as “non-dominant” rotation.

**Strength Test Reliability**

Repeated measures analysis of variance (ANOVA) was used to determine significant differences between the six strength tests, while test-retest reliability was assessed by intraclass correlation coefficients (ICCs) as described by Baumgartner. A Technical Error Measurement (TEM) was also used to determine error of method due to biological and technical factors as per the following equation:

$$\text{Absolute TEM} = \sqrt{\frac{\sum d_i^2}{2n}}$$

Where $d = \text{The difference of one measure to the next; } i = \text{Number of individuals; } 2n = \text{number of samples x 2.}$

**Rotational Strength Data**

The peak torque of dominant and non-dominant trunk rotation during any of the test repetitions was used to represent trunk rotation strength. Peak torque (Nm) was calculated by the Biodex System III software and provided in a printout format. A 2-way ANOVA (groups X sides) was used to determine significant differences in strength measures between groups and between dominant and non-dominant sides.

**Rotational Endurance Data**

The total work (Joules) performed by subjects in both dominant and non-dominant trunk rotation over 25 repetitions was calculated by the Biodex System III software and provided in a printout format. A 2-way ANOVA (groups X sides) was used to determine significant differences in endurance measures between groups and between dominant and non-dominant sides.

**Range of Motion of Torso Rotation**

Total ROM (from dominant to non-dominant limit) was calculated by the Biodex System III software and provided in a printout format. An ASCI file for each subject was imported into Microsoft Excel to determine dominant ROM and non-dominant ROM.
Correlation Analyses
The ROM and strength data from control normals and control golfers were combined (n=72) to determine a potential association between the ROM achieved during the test procedure and peak torque (Nm) (whether individuals with higher ROM were able to generate more trunk rotation torque). A Pearson Product Correlation was performed to investigate an association between ROM and peak torque. This calculation was done independently for dominant and non-dominant rotation data. The ROM and endurance data were also treated in this same manner to determine a potential association between the ROM achieved during the test procedure and work performed (Joules) (i.e., whether individuals with higher ROM were able to perform more work in rotation).

Body weight data and rotational strength data from control normals and control golfers were combined (n=72) and a Pearson Product Correlation performed to determine if there was an association between body weight (kg) and peak torque (Nm). This calculation was done independently for dominant and non-dominant data. The body weight and endurance data was also treated in this same manner to investigate a potential association between subject weight and the work performed (Joules).

RESULTS
Strength Test Reliability
Mean values (±SD) of the 12 subjects for each of the six strength tests are presented in Table 1. No significant differences in peak torque were found between the six strength tests for left or right rotation (p>0.05). Intraclass correlation coefficients for both dominant and non-dominant rotation were found to be 0.93. The Technical Error of Measurement was found to be 7.70 (5.82%) for dominant rotation and 8.12 (6.01%) for non-dominant rotation.

Rotational Strength Testing
No significant differences in peak torque for non-dominant rotation were found between groups (df=2,76; F=0.51; p=0.6) (Table 2). A significant difference between groups was found for dominant rotation (df=2,76; F=3.15; p=0.048). However, using a Sheffé post hoc test, there was evidence that the control normals and golfers with LBP were different though this fell just outside statistical significance (p=0.056). No significant differences in peak torque between dominant and non-dominant rotation were found within any group (control normals: df=1,78; F=0.30; p=0.59; control golfers: df=1,62; F=1.30; p=0.26; golfers with LBP: df=1,12; F=1.46; p=0.25).
Rotational Endurance Testing
Significant differences in total work performed were found between groups for non-dominant (df=2.76; F=5.49; p=0.006) but not dominant rotation (df=2.76; F=2.78; p=0.07) (Table 3). Using a Sheffé post hoc test, it was found that there were significant differences for non-dominant rotation between control normals and golfers with LBP (p=0.009), and between control golfers and golfers with LBP (p=0.009). No significant differences in total work were found between control normals and control golfers (p=0.99). No significant differences in total work were found between dominant and non-dominant rotation in any group (control normals: df=1.78; F=0.79; p=0.38; control golfers: df=1.62; F=0.57; p=0.45; golfers with LBP: df=1.12; F=0.2; p=0.66).

Association Between ROM and Torque and Work
A poor correlation was found between the amount of ROM and the amount of torque produced in both dominant (r=-0.29) and non-dominant rotation (r=-0.17). A poor correlation was also found between the amount of ROM and the amount of work performed in both dominant (r=0.16) and non-dominant rotation (r=0.36).

Association Between Body Weight and Torque and Work
A moderate correlation existed between bodyweight and the amount of torque produced in both dominant (r = 0.44) and non-dominant rotation (r = 0.44). A poor correlation was found between body weight and the amount of work performed in both dominant (r = 0.34) and non-dominant rotation (r = 0.28).

DISCUSSION
The resultant ICC of greater than 0.90 for the test-retest data collected from 12 control normals on two different days indicated that the strength and endurance test protocol used in the present study were reliable measures of peak torque. The Technical Error of Measurement indicates that approximately 6% of the measured values obtained from this method of data collection were potentially due to apparatus error (technical error) or other biological factors. This finding means that if the same device were used in a future intervention study, more than 10% change in performance would be necessary to determine a significant effect from the intervention.

One of the purposes of this study was to establish normative trunk rotation strength and endurance data in healthy individuals who do not play golf. This was necessary as there is very limited data available pertaining to axial rotation.5-7 The studies by Kumar et al.5-7 investigating trunk rotation are difficult to reproduce since the measuring device used was developed in their laboratory. In comparison to other published trunk rotation strength data using commercially available equipment (Cybex II), the control normal values from the present study (Table 2) were slightly higher than the control values reported by Newton et al.9 (Table 4). The control normals in the present study were predominantly obtained from an active University population and, therefore, may have had a more athletic background than the control subjects in the study by Newton et al.9

The results from Table 2 showed there were no significant differences in trunk rotation torque either between or within the control normals and control golfers groups. Although the original hypothesis that elite golfers would exhibit greater side-to-side differences than control subjects was not statistically supported, it was interesting to note that a slight and consistent trend in asymmetry was
noticed in both control normals and control golfers. In both groups, the non-dominant direction produced the higher values. A possible reason for slightly higher non-dominant rotation strength in control normals might be related to the many recreational activities that involve rotation to the non-dominant side (left trunk rotation for right-handed throw/swing in baseball or racquet sports). It was expected that the golfers would demonstrate an overall higher amount of trunk rotation strength as well as a more pronounced side-to-side difference than control normals due to the power and frequency that a highly skilled golfer would perform asymmetrical axial rotation motions. However, since powerful eccentric contractions on the dominant side are also required to decelerate the torso during the follow-through of a golf swing, it is possible these eccentric forces help facilitate concentric strength development of the same muscles.

An additional finding from Table 2 was that trunk rotation strength in golfers with LBP was lower, but not to a significant degree, than the values recorded from the control normals and control golfers. Although statistical significance was not observed, the lower strength values recorded from golfers with LBP might have clinical significance which could be related to LBP. It is not clear whether trunk muscle weakness causes LBP or whether LBP leads to muscle dysfunction and hence weakness. However, results from the back pain questionnaire administered prior to testing indicated that golfers with LBP were typically only affected by LBP after and not before golfing. Golf has been shown to create considerable shear and compressive loads on the lumbar spine. It seems reasonable to suggest that golfers lacking trunk muscle strength may not be able to control these stresses as well as healthy golfers and thus be more likely to experience LBP when swinging the golf club.

The authors of this study were unable to locate any previously published normative data on isokinetic trunk rotation endurance. The findings from the current study showed no significant side-to-side differences in trunk rotation endurance between any of the groups (Table 3). However, significant differences in rotational endurance were found between control normals and golfers with LBP and between control golfers and golfers with LBP in the non-dominant direction. Non-dominant rotation for a golfer (left rotation for a right handed player) occurs at great velocity as the player attempts to accelerate their body towards the target to create maximum clubhead speed. Since this powerful movement is repeated throughout the game or practice session, decreased endurance could lead to premature fatigue and increased injury risk to the trunk region. The importance of trunk endurance in preventing LBP has been discussed by McGill and appears to be supported by the results of this study. Furthermore Suter and Lindsay found associations in a population of golfers between poor static trunk extensor endurance and increased quadriceps inhibition. Quadriceps inhibition was postulated to be reflective of irritation to the lumbar structures. Clinical ramifications from the present study suggest that muscular endurance exercises focusing on rotation of the trunk should be an important component of rehabilitation programs targeting golfers with LBP.

A secondary purpose of this study was to investigate whether trunk rotation ROM influenced the amount of muscle strength.
torque and work produced by subjects. The relatively poor correlations indicate that ROM did not appear to influence the amount of torque and work performed by subjects. These findings may have interesting implications for the golf swing, particularly in terms of the amount of trunk rotation on the backswing and the subsequent clubhead speed developed on the downswing. The results from the present study seem to support findings by Neighbors who was able to demonstrate that golfers could generate just as much clubhead velocity using a shortened backswing involving considerably less trunk rotation. Decreasing the amount of trunk rotation ROM during the golf swing has been suggested as important for reducing LBP in individuals that golf.

Another secondary purpose was to investigate whether overall body weight influenced torque and work. Results showed that a moderate correlation existed between body weight and peak torque. These findings support those of Newton et al suggesting that rotational strength and endurance data can be presented in absolute terms (not normalized) when making between-subject comparisons.

**Limitations**

Limitations exist in the interpretation of the results from this study. It has been suggested that isokinetic performance does not provide a valid measure of actual muscle strength or deficit. Rather, isokinetic performance measures what patients are doing with their muscles in a controlled environment at pre-determined constant speeds and in isolated movement directions. It is not known how accurately the test procedure incorporated in this study represents the trunk rotation performance associated with swinging a golf club.

The validity of the extrapolation of results from a cross-sectional study is very dependent on the representativeness of the sample. An inherent limitation of most observational studies is that the sample is not representative of the population. The strict inclusion criteria made it more difficult to recruit elite golfers with LBP. The relatively low number of subjects in the golfers with LBP group makes true associations less clear than would have been observed with a larger subject pool. Another limitation of cross-sectional studies is determining cause or effect. This study did not permit conclusions about the cause or effect relationship between trunk rotation strength and endurance and LBP.

Future studies should establish normative data for different samples than 18 to 49 year old males (females, seniors). Eccentric trunk rotation strength and endurance parameters should also be investigated considering the important deceleration role this type of contraction plays in the golf swing. Furthermore, it would be worthwhile to conduct a prospective study with an exercise intervention to improve trunk rotation strength and endurance in golfers with LBP with the goal to decrease pain symptoms. Similarly, an exercise intervention could be implemented to increase trunk rotation strength and endurance in healthy golfers to investigate the effects on performance (clubhead speed).

**CONCLUSIONS**

Normative trunk rotation strength and endurance measures were established with the Biodex System III Isokinetic Dynamometer. As well, this study was the first to investigate isokinetic trunk rotation of elite male golfers with and without LBP. The hypothesis that elite golfers (control golfers) would exhibit greater overall strength and endurance as well as increased side-to-side differences compared to healthy control subjects (control normals) was not supported in this case.

The hypothesis that elite golfers with LBP (golfers with LBP) would demonstrate less rotational strength than control golfers was not supported, however, golfers with LBP did display significantly less torso rotation endurance in the non-dominant, or downswing direction, than control golfers. Trunk rotation endurance in golfers with LBP might be more important than strength alone in the prevention and treatment of LBP.

Another important finding from this study was that ROM used during the test did not appear to influence the amount of torque or work performed. This finding suggests that golfers may not need to employ maximum trunk rotation ROM on the backswing to generate a powerful downswing. Furthermore, the results support those of Newton et al suggesting that rotational strength and endurance data can be presented in absolute terms (not normalized) when making between-subject comparisons.
The importance of this study in establishing trunk rotation normative data is considerable especially when taking into account the immense popularity of the sport and high incidence of low back problems. The results from this study provide valuable information on possible risk factors associated with low back pain in golfers (decreased endurance) and allow for intervention strategies to be developed. Future studies should prospectively investigate the cause and effect relationships between LBP and trunk muscle function.

REFERENCES
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ABSTRACT
Rehabilitation of patients following anterior cruciate ligament (ACL) reconstruction has undergone remarkable improvements over the past two decades. During this time, ACL research has been at the forefront of many orthopaedic and sports physical therapy clinics. With over 20 years of ACL rehabilitation experience (senior author) and prior collaboration with accelerated ACL rehabilitation pioneer K. Donald Shelbourne, the authors wish to present a unique perspective on the evolution of ACL rehabilitation.

Prior to the classic article by Paulos et al in 1981, literature on ACL rehabilitation was quite sparse. The basis for ACL rehabilitation at this time was founded in basic science studies conducted with animal models. In an effort to protect the graft, emphasis was placed on immobilization, extension limitation, restricted weight bearing, and delayed return to activity. Despite achieving good ligamentous stability, patients often experienced a spectrum of complications.

In 1990, Shelbourne and Nitz proposed an accelerated rehabilitation protocol following ACL reconstruction based on clinical experience. Their program emphasized delayed surgery, earlier range of motion and weight bearing, and full extension. As a result, patients experienced better clinical outcomes while maintaining knee stability.

The rehabilitation program presented in this paper is still largely based on the principles of the accelerated protocol. As evidence-based practice and the call for prospective, randomized clinical research continues, the continued progress in treating patients with this injury will be enhanced. Furthermore, clinicians are urged not to lose sight of the clinical reasoning that helped evolve the ACL rehabilitation process where it is today.

Key words: anterior cruciate ligament, knee, postoperative, evidence-based practice.

INTRODUCTION
Rehabilitation of patients following anterior cruciate ligament (ACL) reconstruction has undergone remarkable improvements over the past two decades. In 1983, one author reported on “The Anterior Cruciate Ligament Problem,” indicating no ideal treatment for a patient with ACL disruption existed. Initial surgical treatment of ACL injuries resulted in a high incidence of complications, which led many authors to favor nonoperative treatment and conservative rehabilitation. As surgical techniques improved and surgical outcomes became more predictable, postoperative rehabilitation became the key variable in determining successful outcomes.

Prior to the classic article by Paulos et al, literature regarding ACL rehabilitation was scarce. Initial reports of rehabilitation of patients following ACL reconstruction consisted of a few general paragraphs at the end of an article regarding surgical procedures. From 1980 to 1985, ACL literature increased dramatically as the period produced more articles than the previous 80 years. Since this time, ACL research has been at the forefront of many orthopaedic and sports physical therapy clinics.

With over 20 years of ACL rehabilitation experience (senior author) and prior collaboration with accelerated ACL rehabilitation pioneer, K. D. Shelbourne MD, the authors wish to present a unique perspective on the evolution of ACL rehabilitation. The term
accelerated rehabilitation will be used for the context of this paper to refer to the concept of a rehabilitation progression designed to allow early, yet safe return to activities following ACL reconstruction. The term traditional rehabilitation will be used to describe the more conservative, time-based, protocols that were commonly used in the past. This commentary will provide a brief history of the basic science models that led to the traditional rehabilitation protocols, highlight rehabilitation models proposed by Paulos et al. and Shelbourne and Nitz, provide evidence for the principles behind the accelerated rehabilitation program following ACL reconstruction, and re-emphasize key points to successful rehabilitation outcomes following ACL reconstruction. Although the impact of surgical technique and graft selection on the rehabilitation process is important, such topics are beyond the scope of this paper.

**BASIC SCIENCE MODELS**

During the 1970’s, basic science studies conducted with animal models provided the framework for the traditional rehabilitation model. This data was extrapolated and applied to humans. Application of animal studies should be done with caution due to the differences between the species. Many authors openly stated this limited applicability to clinical human cases. However, clinicians acted on the best available evidence at the time.

Great uncertainty existed as to the role of the ACL in knee joint stability and the long-term effects of knee instability. A classic study by Marshall and Olsson transected the ACL in 10 dogs and two dogs were used as a control group. The dogs were followed for up to 23 months. Macroscopic, histological, and microangiographic examinations revealed osteophytes progressively increasing in size for up to one year as well as proliferative and degenerative changes in the articular tissues. A close relationship existed between instability evaluated by an anterior drawer test and articular changes. The authors concluded that early stabilization was indicated in cases of ACL rupture. A biomechanical study by Butler et al. sought to determine the importance of knee ligaments in resisting joint translation. They used 14 human cadaver knees secured to a load cell and moving actuator to measure the restraining forces against the anterior and posterior drawer tests. Ligaments were sectioned individually and the test repeated to determine the contribution to restraint. Test result indicated that the ACL provided up to 86% of restraint against anterior translation in the knee. As the function of the ACL and the need for stabilization became clearer, the number and type of surgical procedures increased.

Following ACL disruption and reconstruction or repair, immobilization for an extended period of time was the standard form of treatment. Noyes and colleagues reported the functional properties of ligaments in monkeys. Wild primates were immobilized for eight weeks in total body plaster prior to undergoing mechanical testing in tension to failure under high strain-rate conditions. The results of testing on 100 knee specimens showed a significant decrease in ligament strength and stiffness following 8-weeks of immobilization. Two subgroups of monkeys underwent 5 and 12 month reconditioning periods prior to testing. Results showed incomplete recovery of ligament properties 5 months after resumed activity and strength properties required up to 12 months to return to normal. As a result, they suggested delayed return to activity for an extended period of time following immobilization, delayed return to strenuous activity for 6 to 12 months, and prescribed protective measures during rehabilitation. The application to humans suggested an extended delay for return to activity rather than shortening the length of immobilization.

The vascular anatomy and healing process of the ACL were described in dogs. Arnoczky et al. utilized microangiography, histology, and tissue-clearing techniques to analyze the normal vascular anatomy in eight dogs. They reported that the central portion of a normal canine ACL had decreased vascularity. Eight weeks following complete ACL transaction, spontaneous healing had not occurred in one animal. Alm et al. studied the revascularization process following ACL reconstruction in 29 dogs. Through microangiography and histological study, they found that the original vascularization of the distal and middle portions of the patellar tendon graft were preserved. The proximal and middle parts of the graft where the suture was attached were initially devoid of functioning vessels and had revascularized by 2 months. The structure of the graft resembled a normal ligament at 4 to 5 months.

Clancy and coworkers studied the vascularity of the patellar tendon graft in monkeys at 2, 3, 6, 9, and 12 months following ACL reconstruction. Microangiographic and histologic examinations were performed on one animal at each of the follow-up periods. They found that patellar tendon grafts in monkeys were revascularized after 8 weeks and resembled a normal lig-
significant because Butler et al. had demonstrated that a reconstruction. The authors considered these results significant because Butler et al. had demonstrated that a reconstruction.

The transplanted graft had intrinsic vessels by 8 weeks, was completely vascularized by 20 weeks, and had the histological appearance of a normal ligament at one year. Amiel et al. studied the morphology of patellar tendon grafts in rabbits at 2, 3, 4, 6, and 30 weeks following ACL reconstruction. Histological and biochemical examination were performed on five animals at each of the follow-up periods. The authors described the graft undergoing phases of ischemic necrosis, revascularization, proliferation, and remodeling. The transplanted graft had intrinsic vessels by 8 weeks, was completely vascularized by 20 weeks, and had the histological appearance of a normal ligament at one year. Amiel et al. studied the morphology of patellar tendon grafts in rabbits at 2, 3, 4, 6, and 30 weeks following ACL reconstruction. Histological and biochemical examination were performed on five animals at each of the follow-up periods. The grafts demonstrated a gradual assumption of the microscopic properties of the normal ACL. By 30 weeks postoperatively, collagen concentrations of the graft were the same as the normal ACL and cell morphology appeared ligamentous. The authors referred to this gradual process as "ligamentization." The common theme during this time period was that vascularization of a transplanted graft required 8 weeks and ligamentization required up to one year.

Rougraff et al. performed arthroscopic and histologic analysis of patellar tendon autografts following ACL reconstruction. The knees of 23 patients underwent arthroscopy and biopsy from 3 weeks to 6.5 years postoperatively. They observed that human patellar tendon autografts were viable as early as 3 weeks with exception of the central biopsy at 3 weeks. They detected increased neovascularity, nuclear morphology, and fibroblastic activity in the human grafts as compared to the necrotic stage observed in animals. Ligamentization required up to 3 years to complete.

To determine the strength of an ACL substitute, researchers studied the mechanical properties of various graft sources. Clancy et al. studied the tensile strength of patellar tendon grafts in monkeys at 3, 6, 9, and 12 months postoperatively. Three animals at the first three follow-up periods and five animals at the final follow-up period underwent stress to failure testing. The results demonstrated patellar tendon grafts had regained 81% of their original tensile strength prior to transfer at 9 and 12 months following reconstruction and were 52% of the strength of the normal ACL at 12 months following reconstruction. The authors considered these results significant because Butler et al. had demonstrated that a third of the patellar tendon in humans had 191% of the strength of the ACL. Noyes et al. compared the mechanical properties of nine human ligament graft tissues obtained from young trauma victims (mean age 26 years). The tissues studied included the ACL, central and medial portions of the bone-patellar tendon-bone (BPTB), semitendinosus, fascia lata, gracilis, distal iliotibial tract, and the medial, central, and lateral portions of the quadriceps tendon-patellar retinaculum-patellar tendon. All tissues were subjected to high-strain-rate failure tests to determine strength and elongation properties. The BPTB graft was the strongest with a mean strength of 159% to 168% of that of an ACL. The strength of the substitute graft would theoretically affect the initiation of motion and strengthening activities during the rehabilitation process.

Controversy surrounded the safety of simple motion and other stresses as researchers attempted to identify strain imposed on the ACL during rehabilitation. Grood et al. studied the biomechanics of knee extension and the effect of cutting the ACL in human cadavers. They reported increased anterior tibial translation during knee extension from 30° flexion to full extension. Arons and colleagues studied ACL strain during knee ROM and simulated quadriceps contractions in human cadavers. Using a strain transducer, they showed that ACL strain decreased as the knee was passively flexed from 0° until 30°-35° where the ACL underwent minimal strain. Further flexion increased the strain to a maximum at 120 degrees. Isometric and eccentric quadriceps contractions significantly increased ACL strain through the first 45° of knee flexion while isometric contraction at flexion angles greater than 60° decreased ACL strain. Quadriceps activity beyond 60° was determined to be safe. The authors speculated that immobilization might not protect the graft if isometric quadriceps contractions occur. Henning et al. used an in vivo strain gauge to study the load-elongation of the ACL during rehabilitation exercises. Two subjects with acute grade II ACL sprains were utilized and the results were scaled to an 80-pound Lachman test. Cycling produced 7%, single leg half squat produced 21%, normal walking produced 36%, quadriceps contraction against 20 pounds of resistance at 45° produced 50% and at terminal extension produced 121%, and downhill running produced 125% as much elongation as an 80 pound Lachman test. The authors recommended that knee extension not be performed through a full ROM during the first year following ACL reconstruction. Strain data gave clinical insight to the stress produced on the ACL during various rehabilitation activities. Clinicians used this information to avoid certain exercises and thus protect the healing ACL.
However, there are no direct methods of knowing the limits of strain that are safe for a healing ligament or graft.

Rougraff and Shelbourne suggested that stresses to the healing tissue that remained below failure threshold would be beneficial and that rehabilitation programs designed to limit stresses may negatively affect ultimate outcome. This postulation was supported by Hannafin et al who performed an in vitro study on the effects of stress deprivation on canine tendon. Their results showed a significant decrease in tensile strength over 8 weeks. They suggested that stress may be necessary for optimal graft healing and collagen formation.

TRADITIONAL REHABILITATION
These basic science studies led to the belief that intra-articular graft healing was a long-term process that included a maturation phase in which the graft was necrotic and weak. In an effort to protect the graft, emphasis was placed on immobilization, extension limitation, restricted weight bearing, and delayed return to activity.

In 1981, Paulos et al published the specifics and rationale of their postoperative rehabilitation program for patients following ACL reconstruction (Figure 1). Although they openly stated that their rehabilitation program was based on preliminary findings, opinions and designed to protect all patients, many practicing clinicians quickly adopted this protocol. The rehabilitation program consisted of five phases that included maximum protection (12 weeks), moderate protection (24 weeks), minimum protection (48 weeks), return to activity (60 weeks), and activity and maintenance.

During the maximum protection phase, patients were placed in a cast, nonweight-bearing (NWB) for 6 weeks in 30° to 60° of flexion. Based on animal research, they estimated healing ligament strength at less than 50% by 12 weeks. Full weight-bearing (FWB) was not allowed prior to 16 weeks. Quadriceps activity was limited through the first 24 weeks to minimize risk to the ACL, while emphasis was placed on hamstring strengthening. Running began approximately 9 to 12 months after surgery when the operative leg achieved 75% strength of the normal leg. The authors recommended a minimum of 9 months to return to full activity with most patients requiring at least a year.

A 1980 international survey performed by Paulos et al revealed that 53% of responding knee experts initiated knee motion by 3 weeks. The authors were concerned that the early initiation of knee motion could disrupt attachment site fixation. Of those included in the survey, 75% recommended an immobilization position of 30-60 degrees. The mean time for FWB was 7.7 weeks. The authors cautioned progression to early weight-bearing due to animal studies that demonstrated early graft vascularization at 8 weeks. Full range of motion (ROM) was expected at 6 months by 88% of respondents and the mean time for maximum knee motion was 4.3 months. The majority (63% always, 22% sometimes) felt a brace should be used for protection. Most respondents allowed running by 6 months with the mean at 4.7 months. Mean time for return to full activity was 9.4 months.

TRENDS IN THE 1980'S
Many researchers continued to study graft remodeling and revascularization as graft integrity and viability following ACL reconstruction remained a concern. Studies challenged the standard treatment of immobilization following ACL reconstruction and showed the beneficial effects of immediate joint motion. In turn, authors reported performing motion exercises sooner following reconstruction. Noyes et al reported that utilization of early motion avoided knee stiffness and promoted full knee extension following ACL reconstruction. Their early motion program utilized continuous passive motion (CPM) during hospitalization. Upon discharge a knee splint was worn which allowed an immediate arc of 0° to 90° of flexion and the patient used the opposite leg to assist motion for 10 to 15 minutes every hour. In 1987, Noyes et al studied the effects of early knee motion following open and arthroscopic ACL reconstruction. Eighteen patients with acute and chronic ACL deficiencies were randomized into two groups prior to surgery. The motion group started knee motion on the second postoperative day while the delayed motion group initiated motion on the seventh postoperative day. All other aspects of the rehabilitation program were the same. Results showed that CPM performed on the second postoperative day did not increase joint effusion or result in stretching of the ligamentous reconstruction as measured by a KT-1000 arthrometer at 6 months postoperatively. Although not significant, the early motion group also achieved increased mean knee extension values measured at 1, 2, 3, 4, and 12 weeks postoperatively. Despite the apparent benefits of early motion following ACL reconstruction, the authors were still concerned that utilization of a CPM after reconstruction would disrupt or loosen the graft.
Figure 1. Comparison between traditional rehabilitation as described by Paulos et al.¹ and the Methodist Sports Medicine Center Rehabilitation program.
In 1986, Bilko et al. published the results of a questionnaire taken at the ACL Study Group meeting in 1984. The survey results were compared to the results of the 1980 international survey by Paulos et al. Analysis of 44 returned questionnaires indicated that more surgeons immobilized the knee between 30º and 60º of flexion, yet the length of time immobilized decreased. Of those who responded, 48% were immobilized between 1 and 3 weeks compared to 21% who were immobilized between 5 and 8 weeks. Isometric exercises were not prescribed as often during the 1st week postoperatively, while the use of electrical stimulation and isokinetics during rehabilitation occurred more frequently. The earliest time to full weight-bearing ranged from the 3 to 4 week period to 16 weeks. Less than 7% indicated regular use of continuous passive motion. Full ROM was expected at 3 months by 18% and 6 months by another 68% following ACL reconstruction. Only one surgeon responded that the minimum time for return to full activity was 6 months, while 95% reported return within 10 months postoperatively. All respondents allowed return to full activity by one year. Only 25% did not recommend a brace for return to play.

Despite achievement of good ligamentous stability, patients often experienced a spectrum of complications that included patellofemoral symptoms, quadriceps weakness, and limited ROM. From 1982 to 1986, Sachs et al. prospectively followed 126 patients who underwent ACL reconstruction and were immobilized in 30º of flexion for 3 weeks. At one-year follow-up, quadriceps weakness was defined as less than 80% bilaterally and was present in 65% of patients which correlated positively with flexion contracture and patellar irritability. Flexion contractures ≥ 5º were present in 24% of patients and patellofemoral pain occurred in 19% of patients. Sachs et al. also published results from the San Diego Kaiser review series of 390 patients with ACL surgeries between 1983 and 1988. One year follow-up statistics revealed 3% of patients with postoperative graft impingement, 7% required manipulation, 20% had flexion contractures, 19% experienced patellofemoral pain, 62% demonstrated quadriceps weakness, 12% exhibited an effusion, and 10% required a secondary procedure within 1 year. To decrease the incidence of joint stiffness and flexion contracture, the authors recommended full ROM and no swelling at the time of surgery as well as immobilization of patients at 0º for 10-14 days postoperatively.

Trends in ACL rehabilitation in the 1980’s revealed earlier ROM and weight bearing. Disagreement was predominately in regard to the initiation of weight-bearing, full ROM, rehabilitation exercises, and return to play. The complication rate remained high during this time but decreased with initiation of earlier motion. It is the senior author’s opinion that the rehabilitation programs which were published largely emphasized open kinetic chain (OKC) exercises and hamstring strengthening.

**ACCELERATED REHABILITATION**

Rehabilitation of patients following ACL surgery at Methodist Sports Medicine Center initially followed many of the trends begun in the 1980’s. In 1982, patients were placed in a cast for 6 weeks following ACL reconstruction. Due to flexion contractures, strict immobilization was replaced in 1983 with the immediate use of a CPM and a 30º removable splint. Like many clinics, the rehabilitation protocol was slightly modified from that used by Paulos et al. Patients did not weight bear until 6 weeks, attain full motion until 4 months, or return to activity until 9 to 12 months postoperatively. By 1985, patients were placed in a 0º postoperative splint. Consequently, motion problems decreased while stability remained unchanged. In 1985, the staff studied patient compliance and found that good clinical results, such as full ROM, strength, stability, and return to activity, were not necessarily correlated with subjectively reported patient compliance (unpublished data). In fact, patients who were noncompliant actually had better results than those who complied with the rehabilitation program. Subsequently, a new criterion-based rather than time-based rehabilitation protocol was adopted at Methodist Sports Medicine Center by the end of 1986.

In 1990, Shelbourne and Nitz published a clinically based article on accelerated rehabilitation of patients following autogenous bone-patellar tendon-bone (BPTB) ACL reconstruction. The accelerated program called for rapid advancement of goals and emphasized early full knee extension, quadriceps muscle leg control (Figure 1), soft tissue healing, and normalized gait pattern. Patients were not immobilized following surgery. On day 1, CPM was initiated and weight bearing as tolerated was allowed without crutches. Strengthening exercises were predominantly closed kinetic chain (CKC) and OKC quadriceps exercises were minimized. Patients typically returned to light sports activities by 2 months and full activity between 4 and 6 months following reconstruction. Subjective and objective follow-up evaluations were routinely performed, as were isokinetic and KT-1000 evaluations beginning 5 to 6 weeks postoperatively. Shelbourne and Nitz reported increased patient compli-
ance, earlier return to normal function, decreased frequency of patellofemoral symptoms, and a significant decrease in the number of procedures required to obtain full knee extension.

Shelbourne and Nitz\(^2\) reported a retrospective comparison of follow-up data on 138 patients who performed a traditional rehabilitation program following ACL reconstruction from 1984 to 1985 and 247 patients from 1987-1988 who performed the accelerated rehabilitation program following ACL reconstruction. Subjective knee ratings were similar for both groups from the time of reconstruction to 2-year follow-up. Isokinetic quadriceps strength tests revealed a quicker return of quadriceps strength in the accelerated group at each follow-up period from 4 months to 1 year. Likewise, analysis of KT-1000 scores revealed equal to or better scores than the traditional group at each follow-up comparison from 4 months to 1 year, which indicated no loss in knee stability. Furthermore, 12% of patients who performed the traditional rehabilitation program required surgical intervention to achieve full extension compared to 4% of patients in the accelerated program.

**TRENDS IN THE 1990’S: EVIDENCE FOR ACCELERATED REHABILITATION**

The accelerated program was met with much resistance in the literature. Many authors were concerned that “aggressive” rehabilitation would lead to graft failure,\(^14,38\) inappropriate graft strain,\(^39-43\) or adversely affect articular cartilage.\(^40\) Several authors cited that there was no evidence to support the safety of activities such as early FWB, jogging and agility drills by 5 to 6 weeks, return to sport at 4 to 6 months,\(^43-45\) and were alarmed by the lack of long-term follow-up.\(^38,39,43,46\) Devita et al\(^45\) reported that gait mechanics were abnormal following accelerated rehabilitation while Hardin et al\(^47\) suggested that individuals with hyperlaxity had an increased risk for instability following accelerated rehabilitation. Beynnon and Johnson\(^44\) questioned the safety of accelerated rehabilitation citing the retrospective nature and possible bias as caution for clinical use.

Accelerated rehabilitation has been previously described in detail.\(^2,48-52\) The Methodist Sports Medicine Center rehabilitation program outlined in Figure 1 was largely based on the principles of the accelerated protocol.\(^2\) The goal of the Methodist Sports Medicine Center rehabilitation protocol had always been to minimize postoperative complications and return the knee to a normal state as quickly and safely as possible. The protocol continued to be adapted and changed based on clinical experience and the current findings in the literature. With the emergence of evidence-based practice (EBP), much of the accelerated rehabilitation program following autogenous BPTB ACL reconstruction had been well supported in the literature. The term “accelerated” rehabilitation may no longer be appropriate or necessary due to the shift in rehabilitation trends over the past decade.

The Methodist Sports Medicine Center rehabilitation protocol was divided into 5 phases: preoperative, early postoperative, intermediate postoperative, advanced rehabilitation, and return to activity. The time frames presented with each phase were general in nature and based on clinical experience. Progression of patients between phases of rehabilitation were individualized decisions determined by achievement of goals and clinical reasoning.

**Phase I: Preoperative**

Phase I rehabilitation began immediately following ACL injury.\(^49\) The goals of the preoperative period were to reduce swelling and restore normal motion, gait, and strength prior to surgery. Common exercises for flexion ROM included heel slides (Figure 2), wall slides, and active/assistive flexion. Exercises for extension ROM included heel props (Figure 3), prone hangs, and towel extensions. Once full ROM with minimal swelling was obtained, CKC strengthening was begun with exercises such as leg press, squats, step downs (Figure 4), stationary bicycle, and step machines. This time frame also allowed for mental preparation and education of surgery and postoperative rehabilitation. Surgery was scheduled once these goals were attained. The patient underwent preoperative
testing for postoperative comparison that included bilateral ROM, KT-1000 ligament arthrometry, isokinetic strength evaluation, and a single leg hop test on the non-involved extremity.\textsuperscript{50-52}

De Carlo et al\textsuperscript{50} reported a retrospective study of 169 patients who underwent autogenous BPTB ACL reconstruction for acute ACL injury. Patients who had reconstruction within the first week after injury had a significantly increased incidence of arthrofibrosis compared to patients who had reconstruction delayed 21 days or more. Patients who had delayed reconstruction also had better ROM and isokinetic strength scores at 13 weeks following reconstruction. Shelbourne and Foulk\textsuperscript{53} performed a retrospective review of 143 patients who underwent autogenous BPTB ACL reconstruction within 3 months of injury. Patients were divided into two groups based on when they elected to have surgery. Group 1 delayed surgery a mean of 40 days after injury while group 2 had surgery a mean of 11 days after injury. Results of isokinetic testing determined that patients who delayed ACL reconstruction had significantly better quadriceps strength at 2 and 4 months postoperatively than those who underwent acute surgery. Cosgarea et al\textsuperscript{54} and Wasilewski et al\textsuperscript{55} have also confirmed earlier return of motion and strength following delayed ACL reconstruction. Two studies have reported that timing of surgery had no effect on extension loss.\textsuperscript{56,57} However, both authors defined full extension as 0° rather than the ROM prior to surgery.\textsuperscript{56,57} Regardless of the time from injury, the senior author believes the condition of the knee prior to reconstruction (minimal swelling, full hyperextension, near normal strength, and normal gait) were directly correlated with the ability to regain early motion and strength postoperatively.

Udry et al\textsuperscript{58} studied psychological readiness of the patient undergoing ACL reconstruction. They found that adolescents reported higher preoperative mood disturbance levels compared to adults. However, adolescents also reported higher levels of psychological readiness for surgery than adults. Shelbourne and Rask\textsuperscript{59} reported that patients who had a second ACL procedure for the opposite knee experienced a smoother transition following reconstruction than with the initial procedure. For this reason, a thorough preoperative education was incorporated for all patients. These factors are important to consider because of the effort, motivation, and understanding required of postoperative rehabilitation.

**Phase II: Early Postoperative**

Immediately following surgery, the reconstructed knee was placed in a cold compression cuff with the leg in a CPM machine. Range of motion, quadriceps control, and weight-bearing as tolerated were initiated the day of surgery. The goals for the first postoperative week were to control swelling, obtain full hyperextension, increase passive knee flexion to at least 110°, and establish good quadriceps leg control. The cold compression cuff remained on the knee at all times except when patients performed ROM exercises. The patient remained lying down as much as possible except when exercises were performed or for personal hygiene. Extension ROM exercises, such as heel props and towel extensions, were performed for 10 minutes hourly during the day. Flexion was initiated with the knee rested in the CPM machine set to 110° and held for 10 minutes, four times daily. Early leg control was accomplished with quadriceps setting, straight leg raises, and active knee hyperextension.
By the end of the second postoperative week, the patient should have been able to demonstrate normal gait, full passive extension, 130° of flexion, and good quadriceps leg control. During this week, patients added prone hangs (1-3 lbs could be added if extension was tight) to their daily ROM exercises. Patients were encouraged to stand with their weight over their reconstructed knee with the quadriceps contracted, which locked the knee into full hyperextension. Gait training was necessary if the patient ambulated with a limp or without a normal heel-to-toe pattern. If the patient had full knee hyperextension and ambulated normally, strengthening exercises could be initiated which included seated knee extension from 90° to full terminal knee extension and bilateral half squats.

Shelbourne et al performed a prospective trial which compared the effectiveness of different methods of postoperative cryotherapy to decrease pain in 400 patients following autogenous BPTB ACL reconstruction. Patients who used a cold compression device had a significantly shorter hospitalization stay compared to patients who used a thermal blanket or ice bag. They used significantly less oral and injectable narcotics compared to patients who used an ice bag. Noyes et al conducted a prospective study of early motion versus delayed motion exercises in 18 patients following ACL reconstruction. Subjects in the early motion group began CPM on the second postoperative day while subjects in the delay motion group were braced in 10° of extension and began CPM on the seventh postoperative day. The results showed no deleterious effects of early motion with regard to knee laxity, joint effusion, hemarthrosis, ROM, use of pain medication, and length of hospital stay. The use of cold compression, CPM, and early active motion allowed for elevation of the leg, patient comfort, and predictable return of motion.

Initially, many authors were hesitant to attain full extension in the early postoperative period. These concerns were based on biomechanical studies that showed maximal flexion and extension of the knee caused increased stress on the intact ACL. However, many authors had reported that gaining extension immediately postoperatively decreased the frequency of flexion contractures. Rubinstein et al reviewed the effects of restoring full knee hyperextension immediately following autogenous BPTB ACL reconstruction. Subjects were grouped according to the degree of hyperextension. Group 1 consisted of 97 patients who hyperextended an average of 10° (8°-15°) and group 2 consisted of 97 patients who hyperextended an average of 2° (0°-5°). No significant differences in KT-1000 arthrometer manual maximum side-to-side scores between groups were found. The authors determined that restored full knee hyperextension immediately postoperatively did not adversely affect stability of the knee.

Several authors had voiced concern that early weight-bearing may have caused excessive forces that harm the graft or fixation and suggested 4 to 6 weeks of crutches to allow for bone healing. However, Arnoczky reported that a biologic graft was the strongest the day it was placed inside the knee. A prospective study by Tyler et al sought to determine the effect of immediate weight-bearing after autogenous BPTB ACL reconstruction. Forty-nine subjects were randomized into two groups. Group 1 underwent imme-

### Lower Extremity Functional Progression for Court Sports

1. Heel raises 10 times (injured leg)
2. Walk at a fast pace full court
3. Jump on both legs 10 times
4. Jump on the injured leg 10 times
5. Jog in a straight line full court
6. Jog around the entire perimeter of the court two times
7. Sprint at 1/2, 3/4 and full speed from the baseline to half court
8. Run figure 8’s at 1/2, 3/4, and full speed from the baseline to half court
9. Triangle drills – sprint baseline to half court, backward run to the baseline, defensive slides along baseline, both directions
10. Cariocas (cross-over drill) completed at 1/2, 3/4, and full speed
11. Cutting completed full court at 1/2, 3/4, and full speed

Figure 5. Functional progressions specific to the patient’s sport are employed to establish whether or not the patient is ready to return to activity.
mediate weight-bearing as tolerated while group 2 was nonweight-bearing for 2 weeks. Results showed that immediate weight-bearing after ACL reconstruction resulted in a lower incidence of anterior knee pain, greater vastus medialis oblique electromyography activity, and no effect on knee stability at a mean follow-up of 7.3 months.

**Phase III: Intermediate Postoperative**

The third and fourth week following reconstruction was the intermediate postoperative phase. During this period, strengthening was initiated cautiously as full ROM was obtained. Strengthening progressed as long as minimal swelling and full ROM were maintained. Exercises were predominantly unilateral, high repetition/low resistance, and CKC exercise during this period and included step downs, leg press, leg extension, and half squats. At the end of 4 weeks, patients underwent passive ROM testing and completed their first postoperative isokinetic strength evaluation and KT-1000 ligament arthrometer tests.

Strain studies indicated that CKC exercises allowed increased muscle activity without subjecting the ACL to increased strain values. A prospective study by Bynum et al compared OKC versus CKC exercises during rehabilitation following autogenous BPTB ACL reconstruction. Ninety-seven patients were randomized to the OKC and CKC protocols. Results at a mean follow-up of 19 months demonstrated that CKC exercise following ACL reconstruction resulted in less patellofemoral pain and better subjective scores than OKC exercise. Subsequently, the authors reported using CKC exercise exclusively following ACL reconstruction. A prospective study by Mikkelsen et al compared CKC versus combined CKC and OKC exercise initiated 6 weeks after ACL reconstruction. Forty-four patients were randomized into the two groups. Follow-up at 6 months indicated that the addition of OKC exercise produced a significant improvement in quadriceps strength, earlier return to sport, and no increased KT-1000 measurements. Although caution was used with full arc OKC exercise, the Methodist Sports Medicine Center protocol included integration of both OKC and CKC exercises.

**Phase IV: Advanced Rehabilitation**

Weeks five through eight comprised the advanced rehabilitation phase. The emphasis of this phase was increased strength and initiation of early sports activities. The patient continued to maintain full ROM and advanced strengthening to low repetition/high resistance as indicated. Once patients demonstrated 70% quadriceps strength via isokinetic testing, they performed light agility drills and proprioceptive activity that included a running progression, lateral slides, crossovers, and single leg hopping. If a joint effusion was present, it was carefully monitored as activity increased. An activity-specific functional progression, such as shooting baskets or dribbling a soccer ball, was initiated near the end of this period. At the end of 8 weeks, the patients were evaluated to assess ROM, tested with the KT-1000 ligament arthrometer, performed an isokinetic strength evaluation, and completed a subjective questionnaire.

In 1993, Barber-Westin and Noyes reported serial KT-1000 measurements on 84 patients following BPTB allograft ACL reconstruction and controlled rehabilitation for chronic ACL deficiency. Arthrometer measurements were obtained on each patient for at least 2 years following surgery. Of those patients with abnormal anterior-posterior displacements greater than 2.5 mm, 86% were first detected during the intensive strength training or return to sports phases of rehabilitation. In 1999, Barber-Westin et al reported a subsequent observational study of 142 patients following ACL reconstruction that used a rehabilitation program similar to the previous study. However, this group of subjects used a BPTB allograft rather than an allograft. They found no association between abnormal displacements and the phase of rehabilitation.

Shelbourne and Davis followed 603 patients who underwent autogenous BPTB ACL reconstruction and participated in a sports agility program at a mean of 5.1 weeks. These patients were evaluated to determine if program effects knee stability. Patients were required to have full hyperextension, knee flexion to 120°, and at least 60% quadriceps strength compared to the normal leg. The KT-1000 manual maximum arthrometer scores revealed that 92.7% of patients at a mean of 5 weeks and 93.2% of patients at a mean follow-up of 24 weeks had displacement differences of 3 mm or less. The results showed that early return to sports agility activities did not compromise graft integrity measured 24 weeks following ACL reconstruction.

**Phase V: Return to Activity**

Return to activity was very individualized and was designed to match the patient’s goals. The patient continued to increase strength and increase the intensity and duration of athletic activities. A functional progres-
No joint space narrowing was seen in 94% of patients, to 3 mm and 98% of patients less than 5 mm of laxity. The mean manual maximum KT-1000 arthrometer difference was 2.0 mm with 90% of patients less than or equal to 2.06 mm at full ROM and 2.10 mm at a mean 2.7 year follow-up. In 1997, Shelbourne and Gray reported that more patients tore their normal, contralateral ACL (4.4%) than their reconstructed ACL (2.4%). They proposed that graft failure was not the result of a weakened graft, but rather the consequence of normal return to sport.

In 1995, Shelbourne et al. reported KT-1000 manual maximum difference scores in a 2 to 6 year follow-up of 209 patients who underwent autogenous BPTB ACL and accelerated rehabilitation. The mean KT-1000 score was 2.06 mm at full ROM and 2.10 mm at a mean 2.7 year follow-up. In 1997, Shelbourne and Gray reported objective data on 806 patients and subjective data on 948 patients in a 2 to 9 year follow-up after autogenous BPTB ACL reconstruction and accelerated rehabilitation. Of those patients who underwent acute reconstruction, the mean manual maximum KT-1000 arthrometer difference was 2.0 mm with 90% of patients less than or equal to 3 mm and 98% of patients less than 5 mm of laxity. No joint space narrowing was seen in 94% of patients, isokinetic quadriceps evaluation revealed 94% strength, mean motion was 5° of hyperextension and 140° of flexion, and mean subjective modified Noyes questionnaire score was 93.2 out of 100 possible. In 2000, Shelbourne and Gray reported on the effects of meniscus and articular cartilage status on autogenous BPTB ACL reconstruction and accelerated rehabilitation in a 5 to 15 year follow-up. Of those patients with both menisci present and normal articular cartilage at the time of surgery, 97% had normal or near normal radiographs. Based on these findings, evidence supported that accelerated rehabilitation following autogenous BPTB ACL reconstruction produced excellent long-term results without affecting long-term stability.

Trends in ACL rehabilitation in the 1990’s revealed remarkable changes compared to the 1980’s. Many authors began adopting protocols similar to the accelerated program. The rehabilitation programs were characterized by preoperative rehabilitation, immediate ROM and weight bearing, full passive knee extension, and functional exercise. Meanwhile, some authors continued to share concerns regarding the wide scale use of these new protocols, particularly in specific patient groups or with specific graft sources.

**ACL REHABILITATION IN THE 2000’S: EVIDENCE-BASED PRACTICE**

Recently, the buzzword in the physical therapy profession has been “evidence-based practice.” Evidence based practice is a very positive trend that may ultimately result in improved quality and effectiveness of patient care. Sackett et al defined EBP as “the integration of best research evidence with clinical expertise and patient values.” Evidence based practice could be the trend that defines ACL rehabilitation in the 2000’s.

Several authors have published well-conducted research on the strain behavior of the ACL during common rehabilitation activities. A comprehensive database has been compiled based on peak strain values in which the authors used to design rehabilitation programs to be compared in a prospective, randomized, double-blind trial. The results of these studies will help delineate rehabilitation programs that are safe for a healing ACL graft. A need exists for prospective, randomized, blinded clinical trials to compare accelerated rehabilitation with more conservative rehabilitation before accelerated rehabilitation can be considered safe and appropriate.

Recently, Beynnon et al reported the results of a prospective, randomized, double-blind study comparing accelerated versus nonaccelerated rehabilitation in 22 patients following BPTB ACL reconstruction. The rehabilitation programs were based on their previous work of ACL strain data during rehabilitation activities. Exercises that had been shown to produce significant
strain to the ACL were initiated earlier in the accelerated program and delayed in the nonaccelerated program. Exercises that did not produce significant ACL strain were initiated in both rehabilitation programs during the same time frame. The accelerated program, characterized by early unrestricted weight-bearing and early use of quadriceps-dominated exercises, lasted 19 weeks and return to sports was possible by 24 weeks while the nonaccelerated program lasted 32 weeks and return to sports was possible also at 32 weeks. At 2-year follow-up, their results demonstrated no difference in anterior knee laxity between accelerated and nonaccelerated rehabilitation. The authors also found that both programs produced the same outcomes in clinical assessment, patient satisfaction, functional performance, and articular cartilage metabolism. Furthermore, total compliance measured at the end of each program was significantly less in the nonaccelerated group.

Evidence based practice has not been limited to prospective, randomized, blinded clinical trials. While the authors agree that prospective, randomized, blinded clinical trials are the gold standard and large studies of this nature are required for best evidence practice, the difficulty most clinicians face in performance of such studies must be acknowledged. Prospective long-term outcome studies may also be conducted to gain insight into the effectiveness of clinical intervention.

To date no studies have been published that have determined conservative rehabilitation following ACL reconstruction to have produced better outcomes or long-term stability than those reported with accelerated rehabilitation. Therefore, the current evidence supports the use of the more physiologic progression following BPTB ACL reconstruction.

While research evidence has been a very important part of EBP, it is the senior author’s opinion that clinical expertise and patient values are equally important components of EBP for quality patient care. Salter reported that the biological concept of CPM for synovial joints was based on clinical observation and deduction. In 1970, the concept of CPM was introduced which was contrary to the initial thought process of joint immobilization for disease or injury. The evolution of the Methodist Sports Medicine Center rehabilitation protocol following ACL reconstruction was based on clinical experience and listening to patients. In 1990, accelerated rehabilitation was the antithesis of traditional rehabilitation following ACL reconstruction.

The clinician must utilize clinical reasoning skills and individualize the care of each patient. No specific exercises or parameters exist for exercise intensity or duration that have been proven to lead to successful outcomes. Guidelines for early application of strain to the healing ACL have not been published. The Methodist Sports Medicine Center rehabilitation protocol the authors have presented has adhered to the basic principles of rehabilitation. Patients increased activity if they had attained full ROM, exhibited minimal effusion and pain, had a normal gait, and demonstrated good leg strength measured isokinetically (quadriceps deficit of ≤30%). The condition of the knee dictated rehabilitation. Patients were not forced to return to activity. Only when the patient was physically and mentally ready was return to activity considered. In addition, the use of a functional progression program allowed the patient and the physical therapist, athletic trainer and, in rare instances, the coach to determine if an athlete was ready to advance.

**RE-EMPHASIS IN ACL REHABILITATION**

Many researchers have attempted to replicate the accelerated Methodist Sports Medicine Center rehabilitation protocol or currently utilize a similar protocol. For this reason, the authors felt that it was important to clear some misconceptions and re-emphasize some key points of the Methodist Sports Medicine Center rehabilitation protocol.

The preoperative period was vitally important for successful outcome following ACL reconstruction. Patients were required to have full ROM including hyperextension, minimal effusion, good quadriceps strength via isokinetic testing, and normal gait prior to reconstruction. Once these goals were met, surgery was scheduled at a time that was convenient for the patient to allow restricted activity during the first postoperative week.

The emphasis of the first postoperative week was the minimization of swelling. If swelling could be prevented, motion and strengthening would not be inhibited. Although immediate full weight bearing as tolerated with crutches was allowed, activity was not unrestricted. The patients were instructed to remain supine with the leg in the CPM machine except when performing exercises or personal hygiene. The ability to prevent swelling during the first postoperative week greatly impacted the progression of return to activity.
Restoration of motion should be aimed to achieve motion equal to the opposite extremity. Normal motion was often thought of as 0° to 135°. However, a study by De Carlo and Seln of 889 preseason athletes found that 96% of individuals demonstrated some degree of hyperextension. The mean ROM was 5° of hyperextension and 140° of flexion for males and 6° of hyperextension and 143° of flexion for females. If the patient had not achieved full ROM, especially hyperextension, equal to the opposite side, the return of normal gait, function, and knee biomechanics would have been inhibited. The importance of obtaining full hyperextension postoperatively has been well documented.

The Methodist Sports Medicine Center rehabilitation protocol was criterion-based. The time frames given were used as guidelines and were not absolute. Advancement to the next phase depended on the condition of the knee and completion of the goals of the previous phase. The initial phases of the program were very similar for all patients in an attempt to restore normal motion, gait, and strength. The latter phases of the program were much more individualized in an effort to return patients to their previous level of function.

CONCLUSION
Over the past two decades, rehabilitation of a patient after an ACL injury has made a dramatic shift toward better patient outcomes and quicker return to activity. In their respective times, the traditional and accelerated rehabilitation models have both given clinicians a sound framework for treating patients as well as stimulated further research. A solid base of evidence exists in the literature to support accelerated rehabilitation as both safe and effective. As EBP and the call for prospective, randomized clinical research continues, the continued progress in treating this injury is exciting. Furthermore, clinicians are urged not to lose sight of the clinical reasoning and deduction that assisted in the evolution of the current science of ACL rehabilitation.

REFERENCES


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ABSTRACT

Background. Arthrofibrosis is a frequent complication following rehabilitation of a patient with anterior cruciate ligament (ACL) reconstruction. Although prevention is the best treatment, little information exists within the literature regarding the management and rehabilitation intervention for arthrofibrosis. In this case report a rehabilitation program in the treatment of a patient with arthrofibrosis is described.

Objectives. To identify the importance of discrete measures of knee range of motion in the knee of a patient following ACL reconstruction in order to help prevent postoperative complications.

Case Description. The patient was an 18-year-old female who sustained an ACL and medial collateral ligament (MCL) injury in a basketball game and underwent an ACL reconstruction with an ipsilateral patellar tendon graft. The patient developed arthrofibrosis and, despite traditional physical therapy of therapeutic exercise and manual therapy, the patient continued to complain of pain, stiffness, limited activities of daily living, and the inability to participate in competitive sports. This patient used a knee extension device as part of her rehabilitation program.

Outcomes. The patient was able to obtain knee extension and flexion equal to her opposite normal knee. Upon completion of the rehabilitation program, the patient returned to full activities of daily living and competitive sports.

Discussion. Increasing and maintaining knee extension that is equal to the opposite normal knee is an important component in the successful outcome for the patient after ACL reconstruction. The use of a knee extension device may provide an effective rehabilitation intervention in the treatment of arthrofibrosis.

Key Words: arthrofibrosis, anterior cruciate ligament, rehabilitation

INTRODUCTION

Arthrofibrosis is an abnormal proliferation of fibrous tissue in and around a joint that can lead to loss of motion, pain, stiffness, muscle weakness, swelling, and limited activities of daily living. This condition can occur after an injury, or more commonly, after surgery. 

Arthrofibrosis remains a common postoperative complication after anterior cruciate ligament (ACL) reconstruction despite the choices of graft selection. Patellar tendon grafts, hamstring grafts, and allografts are the most commonly used grafts selected for ACL reconstruction, and arthrofibrosis has been found to occur after all three. While a greater incidence of arthrofibrosis occurs with a patellar tendon graft, this condition continues to be prevalent in patients who received hamstring grafts and allografts, as well.

Shelbourne et al classified different types of arthrofibrosis in the knee based on the loss of knee extension, flexion, or both; the location of scar tissue formation intra-articularly; and the mobility and location of the patella (Table 1). Prevention of arthrofibrosis is the preferred treatment and is possible with a structured rehabilitation program. However, once arthrofibrosis has occurred, the treatment approach widely varies. Numerous published surgical reports exist regarding the cause and treatment of arthrofibrosis, but the rehabilitation programs are poorly defined. 

For the physical therapist, even fewer guidelines exist with no consistent consensus among researchers as to the most effective treatment and postoperative...
The importance of obtaining and maintaining knee extension following ACL reconstruction is well documented in the literature. Most treatment approaches for arthrofibrosis include surgical intervention followed by extension casting and “aggressive” physical therapy. Published reports discuss the use of serial casting, “drop out” casts and daily physical therapy. This approach is often a time consuming event requiring daily cast changes and multiple visits to the clinic or hospital. However, the best treatment approach in achieving range of motion (ROM) after surgical intervention requires further investigation. Many times, patients with arthrofibrosis will undergo multiple surgeries and extended lengths of time in physical therapy, which can become very costly and time consuming.

The purpose of this case report is to describe the use of a knee extension device in the treatment of a patient with Type 3 arthrofibrosis. In this case a unique knee extension device was used as part of a home exercise program.

**CASE DESCRIPTION**

The patient was an 18-year-old female who tore her right ACL and medial collateral ligament during a basketball game on 10-28-03. She was evaluated by an orthopedic surgeon and placed in a knee brace that was locked at 30°. The patient was instructed by the physician to perform quadriceps muscle contractions and straight leg raise exercises. She underwent medial collateral ligament repair and ACL reconstruction using an ipsilateral patellar tendon graft on 12-09-03. After surgery, the patient’s knee was kept in extension by a knee brace and she was limited to toe touch weight bearing for four weeks.

The patient began formal physical therapy for ROM and patellar mobilization on 12-31-03 and was advised by her physician to continue to wear the knee brace locked at 0° to 90°. Due to the slow progress in ROM, the patient underwent a right knee manipulation and arthroscopy on 02-06-04. After surgery, the patient continued with physical therapy for ROM exercises and was prescribed methylprednisolone (steroid for inflammation). Over the next month, the patient had her knee aspirated twice, was placed on rofecoxib (non-steroidal anti-inflammatory – NSAID), and repeated a dose of methylprednisolone. The patient continued to complain of pain and stiffness in her right knee. As of 03-19-04, her right knee ROM was still significantly limited at 0-10-108°.

The patient underwent a second right knee manipulation and arthroscopy on 03-22-04 (Table 2). Postoperatively, the patient was placed on prednisone (steroid for inflammation) and issued a continuous passive motion (CPM) machine to assist with ROM. Upon follow up, the patient was diagnosed with arthrofibrosis. She was instructed to continue with physical therapy and placed on cyclobenzaprine, a muscle relaxer. She additionally received bupivacaine (analgesic for pain) injections prior to physical therapy appointments to help make her physical therapy more tolerable. She was attempting to run and bike but continued to have significant pain and stiffness. The patient was then referred to the Shelbourne Clinic at

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Methodist Hospital for a second opinion on examination and treatment of her knee on 05-25-04.

**Initial Physical Therapy Examination**

Physical examination showed that the patient had an antalgic gait and was walking with a bent right knee. She had right quadriceps atrophy. The patient’s knee had a mild effusion, good patella mobility in all directions, a negative Lachman test, negative posterior drawer; and negative varus and valgus laxity with testing. The patient felt no tenderness to palpation over the medial collateral ligament or the patellar tendon. She was able to perform a leg raise with a bent knee and significant extension lag. Plain radiographs were read as normal.

Range of motion measurements were taken using a goniometer as described by Norkin. ROM measurements were recorded as A-B-C, with A being the degrees of hyperextension, B indicating lack of extension from zero, and C documenting degrees of flexion. Her right knee ROM was 0-10-110° vs. her normal left knee 10-0-150°, which means she was lacking 20° of extension and 40° of flexion.

The International Knee Documentation Committee subjective knee form (IKDC) outcome instrument was used to assess the patient’s current condition. The initial score on the IKDC was 41/100 and is representative of a significant amount of disability.

The patient was diagnosed with Type 3 arthrofibrosis. The patient had been undergoing regular physical therapy in her home town three times per week since her ACL reconstruction. After discussing the details of the physical therapy sessions, it became apparent that the focus of the rehabilitation program had been on strengthening and not ROM. Therefore, the present focus was to try non-operative methods to maximize her knee ROM and restore knee symmetry.

The goals of physical therapy were to increase right knee ROM equal to her left knee, decrease swelling, restore a normal gait pattern, increase leg strength equal to her left knee, and return to normal activities of daily living and eventually full competitive basketball.

**Physical Therapy Intervention**

The loss in knee extension is more problematic and causes more limitations than a loss of knee flexion. Aglietti et al. showed that patients who have better knee ROM before surgery have a better prognosis and outcome after surgical intervention. Therefore, the initial plan of care focused on treating the knee extension loss. Paulos et al. showed that it is difficult to obtain and maintain both flexion and extension at the same time and achieving extension should be a priority. The treatment was initiated to focus on increasing knee extension only. Most uninjured, normal knees have some degree of hyperextension. De Carlo and Sell found normal knee extension to be 5° of hyperextension in males and 6° of hyperextension in females. Normal knee ROM is defined as ROM equal to that of the noninvolved limb to include the measurement for hyperextension. The patient’s normal, uninjured knee extension measured 10° of hyperextension. Therefore, our goal was to maximize knee extension equal to the opposite normal knee.

A knee extension device (Elite Seat, Kneebourne Therapeutics, Noblesville, IN) was used that would stretch the knee into hyperextension (Figure 1). The second author (KDS) is a part owner of Kneebourne Therapeutics which designed and developed the knee extension device. This device is patient controlled and provides a low load, long duration stretch. The patient was issued and instructed to use the extension device for 10 minutes 3-4 times per day followed by additional knee extension exercises. These exercises included a towel stretch and heel prop exercises and active terminal knee extension while standing. The towel stretch is an exercise that focuses on increasing extension and forcing the knee into knee hyperextension (Figure 2). The patient was advised in performing a heel prop and it was to be performed whenever the patient was sitting (Figure 3).

She was also instructed to stand on the involved extremity and attempt to extend the knee into a locked out posi-
tion by an active quadriceps contraction (Figure 4). This exercise assisted in maintaining the extension acquired from the previous exercises. All exercises were performed three times per day. The patient received instruction in gait training and was encouraged to walk full weight bearing with a normal, symmetrical gait pattern. Finally, she was issued and instructed in a cold/compression device (Cryo/Cuff, Aircast Inc., Summit, New Jersey, USA) to help control swelling and soreness.

Given that the patient lived approximately 5 hours of driving time from the clinic, she was set up on a home exercise program as described previously to focus on increasing and maximizing her involved extremity knee extension. Her progress was monitored through phone calls. Two weeks later she returned for a follow-up evaluation and presented with increased ROM. Her right involved knee measurement was 5-0-110° vs. 10-0-150º in the left normal knee. On physical examination, she was able to perform a straight leg raise and an active heel lift (Figure 5); however, this activity was not equal to the opposite knee. The patient’s knee had a mild effusion and she walked with a slightly bent knee. The patient reported that her knee was still very sore. The patient was advised to continue with her current home exercise program focusing on increasing her knee extension until she felt she was no longer making improvements.

The patient returned 2 weeks later (1 month after her initial visit) to check her progress following this new treatment. She felt she had maximized her knee extension at that time and was feeling most of her discomfort in the anterior aspect of the knee while using the knee extension device and performing the exercises. Upon physical examination, she continued to walk with a bent knee and had a mild effusion. Her ROM measured the same as her previous visit, still lacking both extension and flexion. She continued to have pain with walking, stairs and activities of daily living. The patient’s desire was to return to high-level sports and she planned on playing basketball at a college later that year. Given that her knee was still lacking ROM and she was having pain and difficulty with activities of daily living, the patient elected to undergo an arthroscopic scar resection as recommended by the physician.

**Surgical Intervention**

The patient underwent an arthroscopic scar resection on 07-19-04, approximately 6 weeks after her initial presentation to the present clinic (Table 3). Informed consent was obtained and the rights of the subject were protected for a study in the follow up of patients undergoing knee arthroscopy. She underwent the surgical procedure as described by Shelbourne et al10 for Type 3 arthrofibrosis.

The patient was kept overnight in the hospital and received intravenous Toradol for inflammation and pain control. An anti-embolism stocking was applied to the patient’s leg and the leg was elevated in a CPM machine to help prevent postoperative swelling. She was also placed in a CryoCuff (Aircast Inc., Summit, New Jersey, USA) to assist in preventing a hemarthrosis.
Post Surgical Physical Therapy Intervention and Examination

On the day of surgery, exercises for extension were immediately initiated. The knee extension device was used for 10 minutes, followed by 10 towel stretch exercises, and quadriceps activation to achieve and maintain an active heel lift. She followed this exercise with 10 straight leg raises to maintain good leg control and avoid quadriceps inhibition. These exercises for knee extension were performed six times per day. The patient was on bed rest for the first three days postoperatively to minimize swelling. Bed rest is an important concept after surgery since evidence exists that a hemarthrosis may contribute to an inhibitory effect on the quadriceps and hamstrings muscles resulting in muscle atrophy.

Early quadriceps muscle activation plays a key role in achieving and maintaining knee extension. Therefore, although the patient was on bed rest to minimize swelling, she was performing a regular exercise program to achieve and maintain full terminal hyperextension equal to the opposite knee. Full weight bearing with a normal gait pattern was emphasized and allowed for restroom privileges only.

The patient was discharged from the hospital to a nearby hotel. Prior to discharge, her ROM was 10-0-90° in the right involved knee versus 10-0-150° in the left knee. She had a moderate effusion and walked full weight bearing with a slightly antalgic gait pattern. The patient was discharged from the hospital with a home exercise program. She was to remain supine in the CPM with continuous use of the cold/compression device. Six times throughout the day, she took her leg out of the CPM machine, removed the cold/compression device and performed the exercise program, which included the extension device for 10 minutes, towel stretch exercises followed by active quadriceps muscle activation 10 times, and straight leg raise exercises 10 times. The patient then reapplied the cold/compression device and placed her leg back in the CPM machine. Full weight bearing and a normal gait pattern was encouraged and emphasized for restroom privileges only.

At three days postoperatively, she returned to the clinic to have her ROM and progress evaluated. She continued to achieve full passive terminal hyperextension equal to the opposite knee, an active heel lift, a straight leg raise, and her knee had a moderate effusion. Knee flexion exercises were instituted because she had excellent leg control and equal knee extension. She was instructed in heel slide and wall slide exercises and was told to discontinue flexion exercises if she noted any loss in knee extension. She was instructed to continue to use the extension device and perform all exercises 3 to 5 times per day. She was told to perform a heel prop exercise when sitting and to stand on the involved extremity forcing the knee locked out by an active quadriceps muscle contraction when standing.

At 10 days postoperatively she had maintained her full passive terminal hyperextension equal to the opposite normal knee, an active heel lift, and was walking with a normal gait. Her knee had a mild effusion and ROM measured as 10-0-125° in the right involved knee versus 10-0-150° in the left normal knee. She was instructed to continue to focus on perfect knee extension and to increase her knee flexion until she could sit on her heels equally and comfortably (Figure 6). No strengthening exercises were initiated so that the focus continued to be on achieving full knee ROM.

She returned 08-31-04, approximately six weeks postoperatively, and she
rated her knee at 60% and had returned to all normal activities of daily living including helping out on the family farm. She continued to perform the prescribed exercises four times per day. Her ROM on the right involved knee was 10-0-143° versus 10-0-150° in the left normal knee. She was able to sit on her heels but had an uncomfortable tilt. Her knee had a mild effusion and she had a normal gait, no tenderness, and an active heel lift that was not yet equal to the opposite normal knee. She was instructed to continue with her previous home exercise program but she could gradually decrease using the extension device to 1-2 times per day as long as she did not lose extension. Upon achieving full ROM symmetrically equal to the opposite knee, she was able to begin biking and elliptical cross trainer, single-leg press, single-leg extensions, and step down exercises. These exercises were performed one time per day, 3-5 times per week. Progression of the low-impact and strengthening program was allowed as long as no ROM was lost or compromised.

On 09-23-04, approximately two months after her surgery, she underwent isokinetic strength testing at 180° and 60° speeds and single-leg hop testing. These strength tests were repeated at four, six, and eight months postoperatively. At four months she was allowed to begin shooting baskets and light agility drills. At eight months postoperatively she was released to full participation (Table 3).

**OUTCOMES**

At four months postoperatively, the patient had symmetrical knee ROM including full equal hyperextension and full equal flexion. She had an equal active heel lift and was able to sit on her heels equally and comfortably. Isokinetic strength testing of the involved knee compared with the opposite normal knee revealed 79% strength at 180°/s speed and 66% strength at 60°/s speed. She rated her knee at 80%.

At one year postoperatively, the patient’s knee had symmetrical ROM including full equal hyperextension and full equal flexion. She had an equal active heel lift and

<table>
<thead>
<tr>
<th>EVENT</th>
<th>DATE</th>
<th>Right Knee ROM</th>
<th>STRENGTH 180°</th>
<th>STRENGTH 60°</th>
<th>ACTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Evaluation</td>
<td>05-25-04</td>
<td>0-10-110°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 weeks</td>
<td>06-09-04</td>
<td>5-0-110°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 weeks</td>
<td>07-06-04</td>
<td>5-0-110°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arthroscopic scar resection</td>
<td>07-19-04</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital Discharge</td>
<td>07-20-04</td>
<td>10-0-90°</td>
<td></td>
<td></td>
<td>Bed rest x 3 days</td>
</tr>
<tr>
<td>3 days PO</td>
<td>07-23-04</td>
<td>10-0-115°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 days PO</td>
<td>08-03-04</td>
<td>10-0-125°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 wks PO</td>
<td>08-31-04</td>
<td>10-0-143°</td>
<td></td>
<td></td>
<td>Low impact</td>
</tr>
<tr>
<td>2 mos PO</td>
<td>09-23-04</td>
<td>10-0-148°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 mos PO</td>
<td>11-16-04</td>
<td>10-0-150°</td>
<td>79%</td>
<td>66%</td>
<td>Shooting baskets</td>
</tr>
<tr>
<td>6 mos PO</td>
<td>01-12-05</td>
<td>10-0-150°</td>
<td>74%</td>
<td>75%</td>
<td>Agility drills</td>
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<tr>
<td>8 mos PO</td>
<td>03-09-05</td>
<td>10-0-150°</td>
<td>95%</td>
<td>83%</td>
<td>Return to basketball</td>
</tr>
<tr>
<td>1 yr PO</td>
<td>07-19-05</td>
<td>10-0-150°</td>
<td>89%</td>
<td>96%</td>
<td></td>
</tr>
</tbody>
</table>

PO = postoperatively
was able to sit on her heels equally and comfortably. Her quadriceps muscle strength was 89% of the opposite normal knee at 180°/s speed and 96% strength at 60°/s speed with isokinetic strength testing. She tested 101% on the single-leg-hop test. She rated her knee at 98% and her knee had a mild effusion. The patient’s IKDC score at one year postoperatively was 97/100, more than doubling the score she achieved on her initial visit. Additionally the patient returned to full athletic competition without pain or difficulty and was formally discharged from physical therapy at that time.

DISCUSSION
The treatment of arthrofibrosis is often a costly and time intensive treatment process. The focus of treatment in most published articles is in regards to surgical intervention with varying rehabilitation protocols. Authors of previously published papers state the importance of acquiring extension but no consensus exists on the best way to achieve this movement. Some authors have tried extension casts which require multiple visits to the clinic and can be very uncomfortable. In addition, a cast prevents the patient from being able to perform exercises in between visits. The use of the extension device used with the patient in this report allowed for a patient controlled intervention in increasing knee extension to include hyperextension.

Although most authors agree that restoration of normal knee ROM is a key tenant of treatment, disagreement exists as to what constitutes “normal” ROM. Other treatment programs to regain knee extension fail to take into account that most people have some degree of knee hyperextension. Many authors report they had achieved good ROM results by achieving zero degrees, however, these authors still did not have a good outcome. Achieving full hyperextension equal to the opposite normal knee was the focus of this rehabilitation utilizing the knee extension device. Previous attempts in physical therapy that utilized therapeutic exercises and manual therapy had failed. In this case report, full ROM equal to the opposite normal knee was achieved and it is the author’s opinion that this achievement of full extension was the most important factor in returning the patient to an active lifestyle, including competitive basketball.

Maximizing extension preoperatively may have helped in obtaining full extension postoperatively. Avoiding a hemarthrosis and subsequent quadriceps inhibition after surgery allowed for early quadriceps activation and the ability to maintain full terminal knee extension. Once the patient was able to maintain extension, flexion exercises were initiated followed by the rehabilitation program described earlier.

CONCLUSION
While prevention provides the best treatment for arthrofibrosis, a need exists for data on the best way to treat arthrofibrosis once it has occurred. This case is an example of a successful outcome in the treatment of Type 3 arthrofibrosis in which a knee extension device was utilized. The rehabilitation program described in this case study may assist physical therapists and physicians in the treatment of patients with arthrofibrosis.

REFERENCES


ABSTRACT
Part I of this two-part series (presented in the May issue of NAJSPT) provided the background, rationale, and a complete reference list for the use of fundamental movements as an assessment of function during pre-participation screening. In addition, Part I introduced one such evaluation tool that attempts to assess the fundamental movement patterns of an individual, the Functional Movement Screen (FMS)™, and described three of the seven fundamental movement patterns that comprise the FMS™.

Part II of this series provides a brief review of the analysis of fundamental movement as an assessment of function. In addition, four additional fundamental tests of the FMS™, which complement those described in Part I, will be presented (to complete the total of seven fundamental tests): shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability. These four patterns are described in detail, a grading system from 0-III is defined for each pattern, and the clinical implications for receiving a grade less than a perfect III are proposed.

By reading Part I and Part II, it is hoped that the clinician will recognize the need for the assessment of fundamental movements, critique current and develop new methods of functional assessment, and begin to provide evidence related to the assessment of fundamental movements and the ability to predict and reduce injury. By using such a screening system, the void between pre-participation screening and performance tests will begin to close.

Key Words: pre-participation screening, performance tests, function

INTRODUCTION
The assessment of fundamental movements is an attempt to pinpoint deficient areas of mobility and stability that may be overlooked in the asymptomatic active population. The ability to predict injuries is equally as important as the ability to evaluate and treat injuries. The difficulty in preventing injury seems to be directly related to the inability to consistently determine those athletes who are predisposed to injuries. In many situations, no way exists for knowing if an individual will fall into the injury or non-injury category – no matter what the individual’s risk factors are. Meeuwisse1 suggested that unless specific markers are identified for each individual, determining who is predisposed to injuries would be very difficult.

The inconsistencies surrounding the pre-participation physical and performance tests offer very little assistance in identifying individuals who are predisposed to injuries. These two evaluation methods do not offer predictable and functional tests that are individualized and may assist in identifying specific kinetic chain weaknesses. Numerous sports medicine professionals have suggested the need for specific assessment techniques that utilize a more functional approach in order to identify movement deficits.2-4

The Functional Movement System (FMS)™ is an attempt to capture movement pattern quality with a primitive grading system that begins the process of functional movement pattern assessment in normal individuals. It is not intended to be used for diagnosis, but rather to demonstrate limitations or
asymmetries with respect to human movement patterns and eventually correlate these limitations with outcomes, which may lead to an improved proactive approach to injury prevention.5

The FMS™ may be included in the pre-placement/pre-participation physical examination or be used as a stand-alone assessment technique to determine deficits that may be overlooked during the traditional medical and performance evaluations. In many cases, muscle flexibility and strength imbalances may not be identified during the traditional assessment methods. These problems, previously acknowledged as significant risk factors, can be identified using the FMS™. This movement-based assessment serves to pinpoint functional deficits (or biomarkers) related to proprioceptive, mobility and stability weaknesses.

Scoring the Functional Movement Screen™
The scoring for FMS™ was provided in detail in Part I. The exact same instructions for scoring each test are repeated here to allow the reader to score the additional tests presented in Part II without having to refer to Part I. The scores on the FMS™ range from zero to three; three being the best possible score. The four basic scores are quite simple in philosophy. An individual is given a score of zero if at any time during the testing he/she has pain anywhere in the body. If pain occurs, a score of zero is given and the painful area is noted. A score of one is given if the person is unable to complete the movement pattern or is unable to assume the position to perform the movement. A score of two is given if the person is able to complete the movement but must compensate in some way to perform the fundamental movement. A score of three is given if the person performs the movement correctly without any compensation. Specific comments should be noted defining why a score of three was not obtained.

The majority of the tests in the FMS™ test right and left sides respectively, and it is important that both sides are scored. The lower score of the two sides is recorded and is counted toward the total; however it is important to note imbalances that are present between right and left sides.

Three tests have additional clearing screens which are graded as positive or negative. These clearing movements only consider pain, if a person has pain then that portion of the test is scored positive and if there is no pain then it is scored negative. The clearing tests affect the total score for the particular tests in which they are used. If a person has a positive clearing screen test then the score will be zero.

All scores for the right and left sides, and those for the tests which are associated with the clearing screens, should be recorded. By documenting all the scores, even if they are zeros, the sports rehabilitation professional will have a better understanding of the impairments identified when performing an evaluation. It is important to note that only the lowest score is recorded and considered when tallying the total score. The best total score that can be attained on the FMS™ is twenty-one.

DESCRIPTION OF THE FMS™ TESTS
The following are descriptions of the final four specific tests used in the FMS™ and their scoring system. Each test is followed by tips for testing developed by the authors as well as clinical implications related to the findings of the test.

Shoulder Mobility
Purpose. The shoulder mobility screen assesses bilateral shoulder range of motion, combining internal rotation with adduction and external rotation with abduction. The test also requires normal scapular mobility and thoracic spine extension.

Description. The tester first determines the hand length by measuring the distance from the distal wrist crease to the tip of the third digit in inches. The individual is then instructed to make a fist with each hand, placing the thumb inside the fist. They are then asked to assume a maximally adducted, extended, and internally rotated position with one shoulder and a maximally abducted, flexed, and externally rotated position with the other. During the test the hands should remain in a fist and they should be placed on the back in one smooth motion. The tester then measures the distance between the two closest bony prominences. Perform the shoulder mobility test as many as three times bilaterally (Figures 1-3).

Tips for Testing:
• The flexed shoulder identifies the side being scored
• If the hand measurement is exactly the same as the distance between the two points then score the subject low
• The clearing test overrides the score on the rest of the test
• Make sure individual does not try to “walk” the hands toward each other
Clearing exam. A clearing exam should be performed at the end of the shoulder mobility test. This movement is not scored it is simply performed to observe a pain response. If pain is produced, a score of zero is given to the entire shoulder mobility test. This clearing exam is necessary because shoulder impingement can sometimes go undetected by shoulder mobility testing alone.

The individual places his/her hand on the opposite shoulder and then attempts to point the elbow upward (Figure 4). If there is pain associated with this movement, a score of zero is given. It is recommended that a thorough evaluation of the shoulder be done. This screen should be performed bilaterally.

Clinical Implications for Shoulder Mobility
The ability to perform the shoulder mobility test requires shoulder mobility in a combination of motions including abduction/external rotation, flexion/extension, and adduction/internal rotation. This test also requires scapular and thoracic spine mobility.

Poor performance during this test can be the result of several causes, one of which is the widely accepted explanation that increased external rotation is gained at the expense of internal rotation in overhead throwing athletes. In addition, excessive development and shortening of the pectoralis minor or latissimus dorsi muscles can cause postural alterations of forward or rounded shoulders. Finally, a scapulothoracic dysfunction may be present, resulting in decreased glenohumeral mobility secondary to poor scapulothoracic mobility or stability.

When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by using standard goniometric measurements of the joints as well as muscular flexibility tests such as Kendall’s test for pectoralis minor and latissimus dorsi tightness or Sahrmann’s tests for shoulder rotator tightness.

Previous testing has identified that when an athlete achieves a score of II, minor postural changes or shortening of isolated axio-humeral or scapulo-humeral muscles exist. When an athlete scores a I or less, a scapulothoracic dysfunction may exist.
Active Straight Leg Raise

Purpose. The active straight leg raise tests the ability to disassociate the lower extremity from the trunk while maintaining stability in the torso. The active straight leg raise test assesses active hamstring and gastroc-soleus flexibility while maintaining a stable pelvis and active extension of the opposite leg.

Description. The individual first assumes the starting position by lying supine with the arms in an anatomical position and head flat on the floor. The tester then identifies mid-point between the anterior superior iliac spine (ASIS) and mid-point of the patella, a dowel is then placed at this position perpendicular to the ground. Next, the individual is instructed to lift the test leg with a dorsiflexed ankle and an extended knee. During the test the opposite knee should remain in contact with the ground, the toes should remain pointed upward, and the head remain flat on the floor. Once the end range position is achieved, and the malleolus is located past the dowel then the score is recorded per the established criteria (explained later). If the malleolus does not pass the dowel then the dowel is aligned along the medial malleolus of the test leg, perpendicular to the floor and scored per the established criteria. The active straight leg raise test should be performed as many as three times bilaterally (Figures 5-7).

Tips for Testing:
• The flexed hip identifies the side being scored
• Make sure leg on floor does not externally rotate at the hip
• Both knees remain extended and the knee on the extended hip remains touching the ground
• If the dowel resides at exactly the mid-point, score low

Figure 5. Active SLR III
• Ankle/Dowel resides between mid-thigh and ASIS

Figure 6. Active SLR II
• Ankle/Dowel resides between mid-thigh and mid-patella/joint line

Figure 7. Active SLR I
• Ankle/Dowel resides below mid-patella/joint line

Clinical Implications for Active Straight Leg Raise
The ability to perform the active straight leg raise test requires functional hamstring flexibility, which is the flexibility that is available during training and competition. This is different from passive flexibility, which is more commonly assessed. The athlete is also required to demonstrate adequate hip mobility of the opposite leg as well as lower abdominal stability.

Poor performance during this test can be the result of several factors. First, the athlete may have poor functional hamstring flexibility. Second, the athlete may have inadequate mobility of the opposite hip, stemming from iliopsoas inflexibility associated with an anteriorly tilted pelvis. If this limitation is gross, true active hamstring flexibility will not be realized. A combination of these factors will demonstrate an athlete’s relative bilateral,
asymmetric hip mobility. Like the hurdle step test, the active straight leg raise test reveals relative hip mobility; however, this test is more specific to the limitations imposed by the muscles of the hamstrings and the iliopsoas.

When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by Kendall's sit-and-reach test as well as the 90-90 straight leg raise test for hamstring flexibility. The Thomas test can be used to identify iliopsoas flexibility.6

Previous testing has identified that when an athlete achieves a score of II, minor asymmetric hip mobility limitations or moderate isolated, unilateral muscle tightness may exist. When an athlete scores a I or less, relative hip mobility limitations are gross.

Trunk Stability Push-Up

Purpose. The trunk stability push-up tests the ability to stabilize the spine in an anterior and posterior plane during a closed-chain upper body movement. The test assesses trunk stability in the sagittal plane while a symmetrical upper-extremity motion is performed.

Description. The individual assumes a prone position with the feet together. The hands are then placed shoulder width apart at the appropriate position per the criteria described later. The knees are then fully extended and the ankles are dorsiflexed. The individual is asked to perform one push-up in this position. The body should be lifted as a unit; no “lag” should occur in the lumbar spine when performing this push-up. If the individual cannot perform a push-up in this position, the hands are lowered to the appropriate position per the established criteria (Figures 8-10).

Tips for Testing:
• Tell them to lift the body as a unit
• Make sure original hand position is maintained and the hands do not slide down when they prepare to lift
• Make sure their chest and stomach come off the floor at the same instance
• When in doubt score it low
• The clearing test overrides the test score

Figure 8. Trunk Stab Push Up III (male)

III
• Males perform one repetition with thumbs aligned with the top of the forehead
• Females perform one repetition with thumbs aligned with chin

Figure 9. Trunk Stab Push Up II (male)

II
• Males perform one repetition with thumbs aligned with chin
• Females perform one repetition with thumbs aligned with clavicle

Figure 10. Trunk Stab Push Up II (male)

I
• Males are unable to perform one repetition with hands aligned with chin
• Females are unable to perform one repetition with thumbs aligned with clavicle
Clearing exam. A clearing exam is performed at the end of the trunk stability push-up test. This movement is not scored; the test is simply performed to observe a pain response. If pain is produced, a score of zero is given for the entire push-up test. This clearing exam is necessary because back pain can sometimes go undetected during movement screening.

Spinal extension can be cleared by performing a press-up in the push-up position (Figure 11). If pain is associated with this motion, a zero is given and a more thorough evaluation should be performed.

Clinical Implications for Trunk Stability Push-up
The ability to perform the trunk stability push-up requires symmetric trunk stability in the sagittal plane during a symmetric upper extremity movement. Many functional activities in sport require the trunk stabilizers to transfer force symmetrically from the upper extremities to the lower extremities and vice versa. Movements such as rebounding in basketball, overhead blocking in volleyball, or pass blocking in football are common examples of this type of energy transfer. If the trunk does not have adequate stability during these activities, kinetic energy will be dispersed and lead to poor functional performance, as well as increased potential for micro traumatic injury.

Poor performance during this test can be attributed simply to poor stability of the trunk stabilizers. When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by using test by Kendall or Richardson et al. for upper and lower abdominal and trunk strength. However, the test by Kendall requires a concentric contraction while a push-up requires an isometric stabilizing reaction to avoid spinal hyperextension. A stabilizing contraction of the core musculature is more fundamental and appropriate than a simple strength test, which may isolate one or two key muscles. At this point, the muscular deficit should not necessarily be diagnosed. The screening exam simply implies poor trunk stability in the presence of a trunk extension force, and further examination at a later time is needed to formulate a diagnosis.

Rotary Stability
Purpose. The rotary stability test is a complex movement requiring proper neuromuscular coordination and energy transfer from one segment of the body to another through the torso. The rotary stability test assesses multi-plane trunk stability during a combined upper and lower extremity motion.

Description. The individual assumes the starting position in quadruped with their shoulders and hips at 90 degrees relative to the torso. The knees are positioned at 90 degrees and the ankles should remain dorsiflexed. The individual then flexes the shoulder and extends the same side hip and knee. The leg and hand are only raised enough to clear the floor by approximately 6 inches. The same shoulder is then extended and the knee flexed enough for the elbow and knee to touch. This is performed bilaterally for up to three repetitions. If a III is not attained then the individual performs a diagonal pattern using the opposite shoulder and hip in the same manner as described (Figures 12-16).

Tips for Testing:
• Scoring is identified by the upper extremity movement on the score sheet, but even if someone gets a three, both diagonal patterns must be performed and scored. The information should be noted
• Make sure the elbow and knee touch during the flexion part of the movement
• Provide cueing to let the individual know that he/she does not need to raise the hip and arm above 6 inches off of the floor
• When in doubt, score the subject low
• Do not try to interpret the score when testing
Figure 12. Rotary Stab Start III

Figure 13. Rotary Stab Finish III

III
- Performs one correct unilateral repetition while keeping spine parallel to surface
- Knee and elbow touch

Figure 14. Rotary Stab Start II

Figure 15. Rotary Stab Finish II

II
- Performs one correct diagonal repetition while keeping spine parallel to surface
- Knee and elbow touch

Figure 16. Rotary Stab Start I

I
- Inability to perform diagonal repetitions
Clearing exam. A clearing exam is performed at the end of the rotary stability test. This movement is not scored; it is simply performed to observe a pain response. If pain is produced, a score of zero is given to the entire rotary stability test. This clearing exam is necessary because back pain can sometimes go undetected by movement screening.

Spinal flexion can be cleared by first assuming a quadruped position and then rocking back and touching the buttocks to the heels and the chest to the thighs (Figure 17). The hands should remain in front of the body reaching out as far as possible.

**Figure 17. Spinal Flexion Clearing Test**

Clinical Implications for Rotary Stability
The ability to perform the rotary stability test requires asymmetric trunk stability in both sagittal and transverse planes during asymmetric upper and lower extremity movement. Many functional activities in sport require the trunk stabilizers to transfer force asymmetrically from the lower extremities to the upper extremities and vice versa. Running and exploding out of a down stance in football and track are common examples of this type of energy transfer. If the trunk does not have adequate stability during these activities, kinetic energy will be dispersed, leading to poor performance and increased potential for injury.

Poor performance during this test can be attributed simply to poor asymmetric stability of the trunk stabilizers. When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by using Kendall’s test for upper and lower abdominal strength.6

**SUMMARY**

The research related to movement-based assessments is extremely limited, mainly because only a few movement-based quantitative assessment tests are being utilized. According to Battie et al,4 the ultimate test of any pre-employment or pre-placement screening technique is its effectiveness in identifying individuals at the highest risk of injury. If the FMS™, or any similarly developed test, can identify at risk individuals, then prevention strategies can be instituted based on their scores. A proactive, functional training approach that decreases injury through improved performance efficiency will enhance overall wellness and productivity in many active populations.

**REFERENCES**


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The Functional Movement Screen™ is the registered trademark of FunctionalMovement.com with profits from the sale of these products going to Gray Cook and Lee Burton. The Editors of NAJSPT emphasize (and the authors concur) that the use of fundamental movements as an assessment of function is the important concept to be taken from Part I and Part II of this series and can be performed without the use of the trademarked equipment.
EDITORIAL

WANTED: A FEW GOOD AUTHORS!

Barbara Hoogenboom, PT, EdD, SCS, ATCa
Michael Voight, PT, DHSc, OCS, SCS, ATCb

Contrary to the title of this editorial—which is supposed to get your attention—we will accept all good authors. The demand for clinically relevant evidence in the profession of physical therapy has never been greater. Knowledgeable, intelligent, and evolving professionals, clinicians, educators, and students are continually seeking to advance their skills, justify treatment choices, and improve patient outcomes based on the available evidence. The North American Journal of Sports Physical Therapy (NAJSPT) is a peer-reviewed journal that reviews manuscripts that relate to all aspects of sports physical therapy for possible publication. NAJSPT publishes relevant, timely, and interesting papers that add to the existing evidence related to the practice of sports physical therapy. This editorial seeks to motivate and prepare the new or would-be author to go to the keyboard, and start writing!

Writing for publication in a peer-reviewed journal often appears a daunting process, one that is foreign to most clinicians and many beginning academicians. Scientific writing takes time above and beyond your regular work commitments. Few clinics or academic institutions provide time for writing! In addition to being costly in terms of time investment, scientific writing for publication is a venture fraught with possible pitfalls and rejection, so many excellent scholars and clinicians avoid it. To quote Jeffers, as quoted by Foreman in a similar editorial written in 2005, “Feel the fear and do it anyway!”

Many of you are experts in your area of practice. Many of you have ideas and thoughts to share. Many others conduct important clinical research in the context of your clinics. We would like to encourage you (any and all of you who spend time reading this editorial) to consider contributing to the evidence in sports physical therapy via the vehicle known as NAJSPT. We believe that many authors exist who have just not yet begun writing.

Begin the process with a topic in which you have interest. Perhaps with a clinical technique, research conducted in your clinic, a controversial protocol, or that Masters’ thesis or Doctoral dissertation that the world should know about...an idea is all that it takes!

Next, choose a type of paper you are going to write. NAJSPT provides a wide variety of outlets for your dissemination. Manuscripts submitted to the NAJSPT are reviewed under one of the following categories: Original Research Contribution, Review of Literature (Qualitative or Systematic), Clinical Commentary, Case Report, and Clinical Suggestion. Please review the pages at the end of the journal (and at the end of every journal) to see what is required for submission in each category.

Manuscript preparation: The writing phase. Remember that the best writing is preceded by planning. By knowing the guidelines for NAJSPT in the back of each journal, you can choose a type of paper and tailor your writing and citations accordingly. When writing, one of the hardest things to do is get started. We suggest that you write when you have a block of time with no distractions to dedicate to the project. (Kids and family commitments, laundry and household chores, email, and sports on TV always work to distract the authors of this editorial.)

When writing, we have found that saving the work often prevents frustrating losses of text that happen at the least opportune times. When ready, share your draft with a trusted colleague who can critique your work and suggest changes or help you clarify your writing. We find that what is “clear” to the original author may not be so clear to another reader, so this process of sharing and clar-
ilitation is helpful prior to submission. Our suggestion is to take 1-2 days to digest your trusted colleague’s advice before responding. Criticism may be tough in the short run, but in the long run, it will improve your manuscript. Remember to ask one question: Is the submission better? In most cases, the feedback makes for a better submission to a journal.

Also remember to cite frequently and make sure that your citations comply with the AMA style required by the NAJSPT. Abbreviations for journals should reflect the current practice as set by Index Medicus. We find that the use of a reference manager will help you avoid renumbering or redoing references in the event that an additional reference must be added when the manuscript is complete.

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Submission of your article. Most journals have a set format in which to submit manuscripts and any tables, figures, or pictures. The preferred method for the NAJSPT is electronic; however, authors can also put forward a paper submission. A copy of the manuscript on CD should accompany the paper submission.

The review and editorial process. All manuscripts submitted are peer-reviewed in a blind process by at least two members of the NAJSPT Editorial Board — who provide a recommendation for acceptance, revision, or rejection to one of the Associate Editors. The Associate Editor then summarizes the reviews and sends a recommendation to the Editor-in-Chief. The final decision concerning the publication of a manuscript is solely the responsibility of the Editor-in-Chief. Rarely does the review process result in a complete rejection of the manuscript with no feedback. Rather, the review should be seen as a form of peer feedback with assistance and comments that may make the manuscript more clear to the end reader or strengthen the results. As members of the editorial staff of NAJSPT, we will say that feedback from those who have undergone the review process is overwhelmingly positive, and the people submitting usually thank us even when the manuscript is rejected. To date, the NAJSPT has an acceptance rate approaching 70% with a submission to decision time of approximately four months.

Conclusion. We sincerely hope that this review of instructions to authors and considerations for writing contained in this editorial will help you get started on the writing track! The utility, clinical relevance, and timeliness of information to be shared with the sports rehabilitation community is up to you. You are the authors that will fill the pages of NAJSPT, the journal of which the Sports Physical Therapy Association is so proud. We hope that these thoughts and ideas inspire you to get off the fence and write!

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REFERENCES
Rehabilitation of patients following anterior cruciate ligament (ACL) reconstruction has undergone remarkable improvements over the past two decades. During this time, ACL research has been at the forefront of many orthopaedic and sports physical therapy clinics. With over 20 years of ACL rehabilitation experience (senior author) and prior collaboration with accelerated ACL rehabilitation pioneer K. Donald Shelbourne, the authors wish to present a unique perspective on the evolution of ACL rehabilitation.

Prior to the classic article by Paulos et al in 1981,1 literature on ACL rehabilitation was quite sparse. The basis for ACL rehabilitation at this time was founded in basic science studies conducted with animal models. In an effort to protect the graft, emphasis was placed on immobilization, extension limitation, restricted weight bearing, and delayed return to activity. Despite achieving good ligamentous stability, patients often experienced a spectrum of complications.

In 1990, Shelbourne and Nitz 2 proposed an accelerated rehabilitation protocol following ACL reconstruction based on clinical experience. Their program emphasized delayed surgery, earlier range of motion and weight bearing, and full extension. As a result, patients experienced better clinical outcomes while maintaining knee stability.

The rehabilitation program presented in this paper is still largely based on the principles of the accelerated protocol. As evidence-based practice and the call for prospective, randomized clinical research continues, the continued progress in treating patients with this injury will be enhanced. Furthermore, clinicians are urged not to lose sight of the clinical reasoning that helped evolve the ACL rehabilitation process where it is today.

Key words: anterior cruciate ligament, knee, postoperative, evidence-based practice.

INTRODUCTION

Rehabilitation of patients following anterior cruciate ligament (ACL) reconstruction has undergone remarkable improvements over the past two decades. In 1983, one author reported on “The Anterior Cruciate Ligament Problem,” indicating no ideal treatment for a patient with ACL disruption existed.3 Initial surgical treatment of ACL injuries resulted in a high incidence of complications, which led many authors to favor nonoperative treatment and conservative rehabilitation.3 As surgical techniques improved and surgical outcomes became more predictable, postoperative rehabilitation became the key variable in determining successful outcomes.

Prior to the classic article by Paulos et al,1 literature regarding ACL rehabilitation was scarce. Initial reports of rehabilitation of patients following ACL reconstruction consisted of a few general paragraphs at the end of an article regarding surgical procedures. From 1980 to 1985, ACL literature increased dramatically as the period produced more articles than the previous 80 years.4 Since this time, ACL research has been at the forefront of many orthopaedic and sports physical therapy clinics.

With over 20 years of ACL rehabilitation experience (senior author) and prior collaboration with accelerated ACL rehabilitation pioneer, K. D. Shelbourne MD, the authors wish to present a unique perspective on the evolution of ACL rehabilitation. The term
accelerated rehabilitation will be used for the context of this paper to refer to the concept of a rehabilitation progression designed to allow early, yet safe return to activities following ACL reconstruction. The term traditional rehabilitation will be used to describe the more conservative, time-based, protocols that were commonly used in the past. This commentary will provide a brief history of the basic science models that led to the traditional rehabilitation protocols, highlight rehabilitation models proposed by Paulos et al and Shelbourne and Nitz, provide evidence for the principles behind the accelerated rehabilitation program following ACL reconstruction, and re-emphasize key points to successful rehabilitation outcomes following ACL reconstruction. Although the impact of surgical technique and graft selection on the rehabilitation process is important, such topics are beyond the scope of this paper.

BASIC SCIENCE MODELS
During the 1970's, basic science studies conducted with animal models provided the framework for the traditional rehabilitation model. This data was extrapolated and applied to humans. Application of animal studies should be done with caution due to the differences between the species. Many authors openly stated this limited applicability to clinical human cases. However, clinicians acted on the best available evidence at the time.

Great uncertainty existed as to the role of the ACL in knee joint stability and the long-term effects of knee instability. A classic study by Marshall and Olsson transected the ACL in 10 dogs and two dogs were used as a control group. The dogs were followed for up to 23 months. Macroscopic, histological, and microcomputed examinations revealed osteophytes progressively increasing in size for up to one year as well as proliferative and degenerative changes in the articular tissues. A close relationship existed between instability evaluated by an anterior drawer test and articular changes. The authors concluded that early stabilization was indicated in cases of ACL rupture. A biomechanical study by Butler et al sought to determine the importance of knee ligaments in resisting joint translation. They used 14 human cadaver knees secured to a load cell and moving actuator to measure the restraining forces against the anterior and posterior drawer tests. Ligaments were sectioned individually and the test repeated to determine the contribution to restraint. Test result indicated that the ACL provided up to 86% of restraint against anterior translation in the knee. As the function of the ACL and the need for stabilization became clearer, the number and type of surgical procedures increased.

Following ACL disruption and reconstruction or repair, immobilization for an extended period of time was the standard form of treatment. Noyes and colleagues reported the functional properties of ligaments in monkeys. Wild primates were immobilized for eight weeks in total body plaster prior to undergoing mechanical testing in tension to failure under high strain-rate conditions. The results of testing on 100 knee specimens showed a significant decrease in ligament strength and stiffness following 8-weeks of immobilization. Two subgroups of monkeys underwent 5 and 12 month reconditioning periods prior to testing. Results showed incomplete recovery of ligament properties 5 months after resumed activity and strength properties required up to 12 months to return to normal. As a result, they suggested delayed return to activity for an extended period of time following immobilization, delayed return to strenuous activity for 6 to 12 months, and prescribed protective measures during rehabilitation. The application to humans suggested an extended delay for return to activity rather than shortening the length of immobilization.

The vascular anatomy and healing process of the ACL were described in dogs. Arnoczky et al utilized microangiography, histology, and tissue-clearing techniques to analyze the normal vascular anatomy in eight dogs. They reported that the central portion of a normal canine ACL had decreased vascularity. Eight weeks following complete ACL transaction, spontaneous healing had not occurred in one animal. Alm et al studied the revascularization process following ACL reconstruction in 29 dogs. Through microangiography and histological study, they found that the original vascularization of the distal and middle portions of the patellar tendon graft were preserved. The proximal and middle parts of the graft where the suture was attached were initially devoid of functioning vessels and had revascularized by 2 months. The structure of the graft resembled a normal ligament at 4 to 5 months.

Clancy and coworkers studied the vascularity of the patellar tendon graft in monkeys at 2, 3, 6, 9, and 12 months following ACL reconstruction. Microangiographic and histologic examinations were performed on one animal at each of the follow-up periods. They found that patellar tendon grafts in monkeys were revascularized after 8 weeks and resembled a normal lig-
Amiel et al.15 studied the morphology of patellar tendon grafts in rabbits at 2, 3, 4, 6, and 30 weeks following ACL reconstruction. Histological and biochemical examination were performed on five animals at each of the follow-up periods. The authors described the graft undergoing phases of ischemic necrosis, revascularization, proliferation, and remodeling. The transplanted graft had intrinsic vessels by 8 weeks, was completely vascularized by 20 weeks, and had the histological appearance of a normal ligament at one year. Amiel et al.15 studied the morphology of patellar tendon grafts in rabbits at 2, 3, 4, 6, and 30 weeks following ACL reconstruction. Histological and biochemical examination were performed on five animals at each of the follow-up periods. The grafts demonstrated a gradual assumption of the microscopic properties of the normal ACL. By 30 weeks postoperatively, collagen concentrations of the graft were the same as the normal ACL and cell morphology appeared ligamentous. The authors referred to this gradual process as “ligamentization.” The common theme during this time period was that vascularization of a transplanted graft required 8 weeks and ligamentization required up to one year.

Rougraff et al.16 performed arthroscopic and histologic analysis of patellar tendon autografts following ACL reconstruction. The knees of 23 patients underwent arthroscopy and biopsy from 3 weeks to 6.5 years postoperatively. They observed that human patellar tendon autografts were viable as early as 3 weeks with exception of the central biopsy at 3 weeks. They detected increased neovascularity, nuclear morphology, and fibroblastic activity in the human grafts as compared to the necrotic stage observed in animals. Ligamentization required up to 3 years to complete.

To determine the strength of an ACL substitute, researchers studied the mechanical properties of various graft sources. Clancy et al.13 studied the tensile strength of patellar tendon grafts in monkeys at 3, 6, 9, and 12 months postoperatively. Three animals at the first three follow-up periods and five animals at the final follow-up period underwent stress to failure testing. The results demonstrated patellar tendon grafts had regained 81% of their original tensile strength prior to transfer at 9 and 12 months following reconstruction and were 52% of the strength of the normal ACL at 12 months following reconstruction. The authors considered these results significant because Butler et al.17 had demonstrated that a third of the patellar tendon in humans had 191% of the strength of the ACL. Noyes et al.18 compared the mechanical properties of nine human ligament graft tissues obtained from young trauma victims (mean age 26 years). The tissues studied included the ACL, central and medial portions of the bone-patellar tendon-bone (BPTB), semitendinosus, fascia lata, gracilis, distal iliotibial tract, and the medial, central, and lateral portions of the quadriceps tendon-patellar retinaculum-patellar tendon. All tissues were subjected to high-strain-rate failure tests to determine strength and elongation properties. The BPTB graft was the strongest with a mean strength of 159% to 168% of that of an ACL. The strength of the substitute graft would theoretically affect the initiation of motion and strengthening activities during the rehabilitation process.

Controversy surrounded the safety of simple motion and other stresses as researchers attempted to identify strain imposed on the ACL during rehabilitation. Grood et al.19 studied the biomechanics of knee extension and the effect of cutting the ACL in human cadavers. They reported increased anterior tibial translation during knee extension from 30° of flexion to full extension. Arms and colleagues20 studied ACL strain during knee ROM and simulated quadriceps contractions in human cadavers. Using a strain transducer, they showed that ACL strain decreased as the knee was passively flexed from 0° until 30°-35° where the ACL underwent minimal strain. Further flexion increased the strain to a maximum at 120 degrees. Isometric and eccentric quadriceps contractions significantly increased ACL strain through the first 45° of knee flexion while isometric contraction at flexion angles greater than 60° decreased ACL strain. Quadriceps activity beyond 60° was determined to be safe. The authors speculated that immobilization might not protect the graft if isometric quadriceps contractions occur. Henning et al.21 used an in vivo strain gauge to study the load-elongation of the ACL during rehabilitation exercises. Two subjects with acute grade II ACL sprains were utilized and the results were scaled to an 80-pound Lachman test. Cycling produced 7%, single leg half squat produced 21%, normal walking produced 36%, quadriceps contraction against 20 pounds of resistance at 45° produced 50% and at terminal extension produced 121%, and downhill running produced 125% as much elongation as an 80 pound Lachman test. The authors recommended that knee extension not be performed through a full ROM during the first year following ACL reconstruction. Strain data gave clinical insight to the stress produced on the ACL during various rehabilitation activities. Clinicians used this information to avoid certain exercises and thus protect the healing ACL.
However, there are no direct methods of knowing the limits of strain that are safe for a healing ligament or graft.

Rougraff and Shelbourne\textsuperscript{22} suggested that stresses to the healing tissue that remained below failure threshold would be beneficial and that rehabilitation programs designed to limit stresses may negatively affect ultimate outcome. This postulation was supported by Hannafin et al\textsuperscript{23} who performed an in vitro study on the effects of stress deprivation on canine tendon. Their results showed a significant decrease in tensile strength over 8 weeks. They suggested that stress may be necessary for optimal graft healing and collagen formation.

TRADITIONAL REHABILITATION

These basic science studies led to the belief that intra-articular graft healing was a long-term process that included a maturation phase in which the graft was necrotic and weak. In an effort to protect the graft, emphasis was placed on immobilization, extension limitation, restricted weight bearing, and delayed return to activity.

In 1980, Paulos et al\textsuperscript{1} published the specifics and rationale of their postoperative rehabilitation program for patients following ACL reconstruction (Figure 1). Although they openly stated that their rehabilitation program was based on preliminary findings, opinions and designed to protect all patients, many practicing clinicians quickly adopted this protocol.\textsuperscript{22,23} The rehabilitation program consisted of five phases that included maximum protection (12 weeks), moderate protection (24 weeks), minimum protection (48 weeks), return to activity (60 weeks), and activity and maintenance.

During the maximum protection phase, patients were placed in a cast, nonweight-bearing (NWB) for 6 weeks in 30° to 60° of flexion. Based on animal research, they estimated healing ligament strength at less than 50% by 12 weeks. Full weight-bearing (FWB) was not allowed prior to 16 weeks. Quadriceps activity was limited through the first 24 weeks to minimize risk to the ACL, while emphasis was placed on hamstring strengthening. Running began approximately 9 to 12 months after surgery when the operative leg achieved 75% strength of the normal leg. The authors recommended a minimum of 9 months to return to full activity with most patients requiring at least a year.

A 1980 international survey performed by Paulos et al\textsuperscript{1} revealed that 53% of responding knee experts initiated knee motion by 3 weeks. The authors were concerned that the early initiation of knee motion could disrupt attachment site fixation. Of those included in the survey, 75% recommended an immobilization position of 30-60 degrees. The mean time for FWB was 7.7 weeks. The authors cautioned progression to early weight-bearing due to animal studies that demonstrated early graft vascularization at 8 weeks. Full range of motion (ROM) was expected at 6 months by 88% of respondents and the mean time for maximum knee motion was 4.3 months. The majority (63% always, 22% sometimes) felt a brace should be used for protection. Most respondents allowed returning by 6 months with the mean at 4.7 months. Mean time for return to full activity was 9.4 months.

TRENDS IN THE 1980’S

Many researchers continued to study graft remodeling and revascularization as graft integrity and viability following ACL reconstruction remained a concern. Studies challenged the standard treatment of immobilization following ACL reconstruction and showed the beneficial effects of immediate joint motion.\textsuperscript{25,26} In turn, authors reported performing motion exercises sooner following reconstruction. Noyes et al\textsuperscript{27} reported that utilization of early motion avoided knee stiffness and promoted full knee extension following ACL reconstruction. Their early motion program utilized continuous passive motion (CPM) during hospitalization. Upon discharge a knee splint was worn which allowed an immediate arc of 0° to 90° of flexion and the patient used the opposite leg to assist motion for 10 to 15 minutes every hour. In 1987, Noyes et al\textsuperscript{28} studied the effects of early knee motion following open and arthroscopic ACL reconstruction. Eighteen patients with acute and chronic ACL deficiencies were randomized into two groups prior to surgery. The motion group started knee motion on the second postoperative day while the delayed motion group initiated motion on the seventh postoperative day. All other aspects of the rehabilitation program were the same. Results showed that CPM performed on the second postoperative day did not increase joint effusion or result in stretching of the ligamentous reconstruction as measured by a KT-1000 arthrometer at 6 months postoperatively. Although not significant, the early motion group also achieved increased mean knee extension and flexion values measured at 1, 2, 3, 4, and 12 weeks postoperatively. Despite the apparent benefits of early motion following ACL reconstruction, the authors were still concerned that utilization of a CPM after reconstruction would disrupt or loosen the graft.\textsuperscript{29}
Figure 1. Comparison between traditional rehabilitation as described by Paulos et al.1 and the Methodist Sports Medicine Center Rehabilitation program.
In 1986, Bilko et al.30 published the results of a questionnaire taken at the ACL Study Group meeting in 1984. The survey results were compared to the results of the 1980 international survey by Paulos et al.1 Analysis of 44 returned questionnaires indicated that more surgeons immobilized the knee between 30º and 60º of flexion, yet the length of time immobilized decreased. Of those who responded, 48% were immobilized between 1 and 3 weeks compared to 21% who were immobilized between 5 and 8 weeks. Isometric exercises were not prescribed as often during the 1st week postoperatively, while the use of electrical stimulation and isokinetics during rehabilitation occurred more frequently. The earliest time to full weight-bearing ranged from the 3 to 4 week period to 16 weeks. Less than 7% indicated regular use of continuous passive motion. Full ROM was expected at 3 months by 18% and 6 months by another 68% following ACL reconstruction. Only one surgeon responded that the minimum time for return to full activity was 6 months, while 95% reported return within 10 months postoperatively. All respondents allowed return to full activity by one year. Only 25% did not recommend a brace for return to play.

Despite achievement of good ligamentous stability, patients often experienced a spectrum of complications that included patellofemoral symptoms, quadriceps weakness, and limited ROM.31-33 From 1982 to 1986, Sachs et al.34 prospectively followed 126 patients who underwent ACL reconstruction and were immobilized in 30º of flexion for 3 weeks. At one-year follow-up, quadriceps weakness was defined as less than 80% bilaterally and was present in 65% of patients which correlated positively with flexion contracture and patellar irritability. Flexion contractures ≥ 5º were present in 24% of patients and patellofemoral pain occurred in 19% of patients. Sachs et al.35 also published results from the San Diego Kaiser review series of 390 patients with ACL surgeries between 1983 and 1988. One year follow-up statistics revealed 3% of patients with postoperative graft impingement, 7% required manipulation, 20% had flexion contractures, 19% experienced patellofemoral pain, 62% demonstrated quadriceps weakness, 12% exhibited an effusion, and 10% required a secondary procedure within 1 year. To decrease the incidence of joint stiffness and flexion contracture, the authors recommended full ROM and no swelling at the time of surgery as well as immobilization of patients at 0º for 10-14 days postoperatively.

Trends in ACL rehabilitation in the 1980's revealed earlier ROM and weight bearing.36 Disagreement was predominant in regard to the initiation of weight-bearing, full ROM, rehabilitation exercises, and return to play. The complication rate remained high during this time but decreased with initiation of earlier motion. It is the senior author's opinion that the rehabilitation programs which were published largely emphasized open kinetic chain (OKC) exercises and hamstring strengthening.1,24,37

ACCELERATED REHABILITATION

Rehabilitation of patients following ACL surgery at Methodist Sports Medicine Center initially followed many of the trends begun in the 1980's. In 1982, patients were placed in a cast for 6 weeks following ACL reconstruction. Due to flexion contractures, strict immobilization was replaced in 1983 with the immediate use of a CPM and a 30º removable splint. Like many clinics, the rehabilitation protocol was slightly modified from that used by Paulos et al.1 Patients did not weight bear until 6 weeks, attain full motion until 4 months, or return to activity until 9 to 12 months postoperatively. By 1985, patients were placed in a 0º postoperative splint. Consequently, motion problems decreased while stability remained unchanged. In 1985, the staff studied patient compliance and found that good clinical results, such as full ROM, strength, stability, and return to activity, were not necessarily correlated with subjectively reported patient compliance (unpublished data). In fact, patients who were noncompliant actually had better results than those who complied with the rehabilitation program. Subsequently, a new criterion-based rather than time-based rehabilitation protocol was adopted at Methodist Sports Medicine Center by the end of 1986.

In 1990, Shelbourne and Nitz2 published a clinically based article on accelerated rehabilitation of patients following autogenous bone-patellar tendon-bone (BPTB) ACL reconstruction. The accelerated program called for rapid advancement of goals and emphasized early full knee extension, quadriceps muscle leg control (Figure 1), soft tissue healing, and normalized gait pattern. Patients were not immobilized following surgery. On day 1, CPM was initiated and weight bearing as tolerated was allowed without crutches. Strengthening exercises were predominantly closed kinetic chain (CKC) and OKC quadriceps exercises were minimized. Patients typically returned to light sports activities by 2 months and full activity between 4 and 6 months following reconstruction. Subjective and objective follow-up evaluations were routinely performed, as were isokinetic and KT-1000 evaluations beginning 5 to 6 weeks postoperatively. Shelbourne and Nitz2 reported increased patient compli-
ance, earlier return to normal function, decreased frequency of patellofemoral symptoms, and a significant decrease in the number of procedures required to obtain full knee extension.

Shelbourne and Nitz\(^2\) reported a retrospective comparison of follow-up data on 138 patients who performed a traditional rehabilitation program following ACL reconstruction from 1984 to 1985 and 247 patients from 1987-1988 who performed the accelerated rehabilitation program following ACL reconstruction. Subjective knee ratings were similar for both groups from the time of reconstruction to 2-year follow-up. Isokinetic quadriceps strength tests revealed a quicker return of quadriceps strength in the accelerated group at each follow-up period from 4 months to 1 year. Likewise, analysis of KT-1000 scores revealed equal to or better scores than the traditional group at each follow-up comparison from 4 months to 1 year, which indicated no loss in knee stability. Furthermore, 12% of patients who performed the traditional rehabilitation program required surgical intervention to achieve full extension compared to 4% of patients in the accelerated program.

**TRENDS IN THE 1990’S: EVIDENCE FOR ACCELERATED REHABILITATION**

The accelerated program was met with much resistance in the literature. Many authors were concerned that “aggressive” rehabilitation would lead to graft failure\(^14,38\), inappropriate graft strain\(^39-43\), or adversely affect articular cartilage\(^40\). Several authors cited that there was no evidence to support the safety of activities such as early FWB, jogging and agility drills by 5 to 6 weeks, return to sport at 4 to 6 months\(^43-45\), and were alarmed by the lack of long-term follow-up\(^38,39,43,46\). Devita et al\(^45\) reported that gait mechanics were abnormal following accelerated rehabilitation while Hardin et al\(^47\) suggested that individuals with hyperlaxity had an increased risk for instability following accelerated rehabilitation. Beynnon and Johnson\(^44\) questioned the safety of accelerated rehabilitation citing the retrospective nature and possible bias as caution for clinical use.

Accelerated rehabilitation has been previously described in detail\(^2,48-52\). The Methodist Sports Medicine Center rehabilitation program outlined in Figure 1 was largely based on the principles of the accelerated protocol\(^2\). The goal of the Methodist Sports Medicine Center rehabilitation protocol had always been to minimize postoperative complications and return the knee to a normal state as quickly and safely as possible. The protocol continued to be adapted and changed based on clinical experience and the current findings in the literature. With the emergence of evidence-based practice (EBP), much of the accelerated rehabilitation program following autogenous BPTB ACL reconstruction had been well supported in the literature. The term “accelerated” rehabilitation may no longer be appropriate or necessary due to the shift in rehabilitation trends over the past decade.

The Methodist Sports Medicine Center rehabilitation protocol was divided into 5 phases: preoperative, early postoperative, intermediate postoperative, advanced rehabilitation, and return to activity. The time frames presented with each phase were general in nature and based on clinical experience. Progression of patients between phases of rehabilitation were individualized decisions determined by achievement of goals and clinical reasoning.

**Phase I: Preoperative**

Phase I rehabilitation began immediately following ACL injury\(^49\). The goals of the preoperative period were to reduce swelling and restore normal motion, gait, and strength prior to surgery. Common exercises for flexion ROM included heel slides (Figure 2), wall slides, and active/assistive flexion. Exercises for extension ROM included heel props (Figure 3), prone hangs, and towel extensions. Once full ROM with minimal swelling was obtained, CKC strengthening was begun with exercises such as leg press, squats, step downs (Figure 4), stationary bicycle, and step machines. This time frame also allowed for mental preparation and education of surgery and postoperative rehabilitation. Surgery was scheduled once these goals were attained. The patient underwent preoperative...
testing for postoperative comparison that included bilateral ROM, KT-1000 ligament arthrometry, isokinetic strength evaluation, and a single leg hop test on the non-involved extremity.50-52

De Carlo et al50 reported a retrospective study of 169 patients who underwent autogenous BPTB ACL reconstruction for acute ACL injury. Patients who had reconstruction within the first week after injury had a significantly increased incidence of arthrofibrosis compared to patients who had reconstruction delayed 21 days or more. Patients who had delayed reconstruction also had better ROM and isokinetic strength scores at 13 weeks following reconstruction. Shelbourne and Foulk53 performed a retrospective review of 143 patients who underwent autogenous BPTB ACL reconstruction within 3 months of injury. Patients were divided into two groups based on when they elected to have surgery. Group 1 delayed surgery a mean of 40 days after injury while group 2 had surgery a mean of 11 days after injury. Results of isokinetic testing determined that patients who delayed ACL reconstruction had significantly better quadriceps strength at 2 and 4 months postoperatively than those who underwent acute surgery. Cosgarea et al54 and Wasilewski et al55 have also confirmed earlier return of motion and strength following delayed ACL reconstruction. Two studies have reported that timing of surgery had no effect on extension loss.56,57 However, both authors defined full extension as 0º rather than the ROM prior to surgery.56,57 Regardless of the time from injury, the senior author believes the condition of the knee prior to reconstruction (minimal swelling, full hyperextension, near normal strength, and normal gait) were directly correlated with the ability to regain early motion and strength postoperatively.

Udry et al58 studied psychological readiness of the patient undergoing ACL reconstruction. They found that adolescents reported higher preoperative mood disturbance levels compared to adults. However, adolescents also reported higher levels of psychological readiness for surgery than adults. Shelbourne and Rask59 reported that patients who had a second ACL procedure for the opposite knee experienced a smoother transition following reconstruction than with the initial procedure. For this reason, a thorough preoperative education was incorporated for all patients. These factors are important to consider because of the effort, motivation, and understanding required of postoperative rehabilitation.

Phase II: Early Postoperative

Immediately following surgery, the reconstructed knee was placed in a cold compression cuff with the leg in a CPM machine. Range of motion, quadriceps control, and weight-bearing as tolerated were initiated the day of surgery. The goals for the first postoperative week were to control swelling, obtain full hyperextension, increase passive knee flexion to at least 110º, and establish good quadriceps leg control. The cold compression cuff remained on the knee at all times except when patients performed ROM exercises. The patient remained lying down as much as possible except when exercises were performed or for personal hygiene. Extension ROM exercises, such as heel props and towel extensions, were performed for 10 minutes hourly during the day. Flexion was initiated with the knee rested in the CPM machine set to 110º and held for 10 minutes, four times daily. Early leg control was accomplished with quadriceps setting, straight leg raises, and active knee hyperextension.

Figure 3. A heel prop is used to allow the knee joint to hyperextend.

Figure 4. The step-down exercise is used to develop quadriceps strength.
By the end of the second postoperative week, the patient should have been able to demonstrate normal gait, full passive extension, 130º of flexion, and good quadriceps leg control. During this week, patients added prone hangs (1-3 lbs could be added if extension was tight) to their daily ROM exercises. Patients were encouraged to stand with their weight over their reconstructed knee with the quadriceps contracted, which locked the knee into full hyperextension. Gait training was necessary if the patient ambulated with a limp or without a normal heel-to-toe pattern. If the patient had full knee hyperextension and ambulated normally, strengthening exercises could be initiated which included seated knee extension from 90º to full terminal knee extension and bilateral half squats.

Shelbourne et al performed a prospective trial which compared the effectiveness of different methods of postoperative cryotherapy to decrease pain in 400 patients following autogenous BPTB ACL reconstruction. Patients who used a cold compression device had a significantly shorter hospitalization stay compared to patients who used a thermal blanket or ice bag. They used significantly less oral and injectable narcotics compared to patients who used an ice bag. Noyes et al conducted a prospective study of early motion versus delayed motion exercises in 18 patients following ACL reconstruction. Subjects in the early motion group began CPM on the second postoperative day while subjects in the delay motion group were braced in 10º of extension and began CPM on the seventh postoperative day. The results showed no deleterious effects of early motion with regard to knee laxity, joint effusion, hemarthrosis, ROM, use of pain medication, and length of hospital stay. The use of cold compression, CPM, and early active motion allowed for elevation of the leg, patient comfort, and predictable return of motion.

Initially, many authors were hesitant to attain full extension in the early postoperative period. These concerns were based on biomechanical studies that showed maximal flexion and extension of the knee caused increased stress on the intact ACL. However, many authors had reported that gaining extension immediately postoperatively decreased the frequency of flexion contractures.

Rubinstein et al reviewed the effects of restoring full knee hyperextension immediately following autogenous BPTB ACL reconstruction. Subjects were grouped according to the degree of hyperextension. Group 1 consisted of 97 patients who hyperextended an average of 10º (8º-15º) and group 2 consisted of 97 patients who hyperextended an average of 2º (0 - 5º). No significant differences in KT-1000 arthrometer manual maximum side-to-side scores between groups were found. The authors determined that restored full knee hyperextension immediately postoperatively did not adversely affect stability of the knee.

Several authors had voiced concern that early weight-bearing may have caused excessive forces that harm the graft or fixation and suggested 4 to 6 weeks of crutches to allow for bone healing. However, Arnoczky reported that a biologic graft was the strongest the day it was placed inside the knee. A prospective study by Tyler et al sought to determine the effect of immediate weight-bearing after autogenous BPTB ACL reconstruction. Forty-nine subjects were randomized into two groups. Group 1 underwent imme-

Lower Extremity Functional Progression for Court Sports

1. Heel raises 10 times (injured leg)
2. Walk at a fast pace full court
3. Jump on both legs 10 times
4. Jump on the injured leg 10 times
5. Jog in a straight line full court
6. Jog around the entire perimeter of the court two times
7. Sprint at 1/2, 3/4 and full speed from the baseline to half court
8. Run figure 8’s at 1/2, 3/4, and full speed from the baseline to half court
9. Triangle drills - sprint baseline to half court, backward run to the baseline, defensive slides along baseline, both directions
10. Cariocas (cross-over drill) completed at 1/2, 3/4, and full speed
11. Cutting completed full court at 1/2, 3/4, and full speed

Figure 5. Functional progressions specific to the patient’s sport are employed to establish whether or not the patient is ready to return to activity.
Intermediate weight-bearing as tolerated while group 2 was nonweight-bearing for 2 weeks. Results showed that immediate weight-bearing after ACL reconstruction resulted in a lower incidence of anterior knee pain, greater vastus medialis oblique electromyography activity, and no effect on knee stability at a mean follow-up of 7.3 months.

Phase III: Intermediate Postoperative
The third and fourth week following reconstruction was the intermediate postoperative phase. During this period, strengthening was initiated cautiously as full ROM was obtained. Strengthening progressed as long as minimal swelling and full ROM were maintained. Exercises were predominantly unilateral, high repetition/low resistance, and CKC exercise during this period and included step downs, leg press, leg extension, and half squats. At the end of 4 weeks, patients underwent passive ROM testing and completed their first postoperative isokinetic strength evaluation and KT-1000 ligament arthrometer tests.

Strain studies indicated that CKC exercises allowed increased muscle activity without subjecting the ACL to increased strain values. A prospective study by Bynum et al compared OKC versus CKC exercises during rehabilitation following autogenous BPTB ACL reconstruction. Ninety-seven patients were randomized to the OKC and CKC protocols. Results at a mean follow-up of 19 months demonstrated that CKC exercise following ACL reconstruction resulted in less patellofemoral pain and better subjective scores than OKC exercise. Subsequently, the authors reported using CKC exercise exclusively following ACL reconstruction. A prospective study by Mikkelson et al compared CKC versus combined CKC and OKC exercise initiated 6 weeks after ACL reconstruction. Forty-four patients were randomized into the two groups. Follow-up at 6 months indicated that the addition of OKC exercise produced a significant improvement in quadriceps strength, earlier return to sport, and no increased KT-1000 measurements. Although caution was used with full arc OKC exercise, the Methodist Sports Medicine Center protocol included integration of both OKC and CKC exercises.

Phase IV: Advanced Rehabilitation
Weeks five through eight comprised the advanced rehabilitation phase. The emphasis of this phase was increased strength and initiation of early sports activities. The patient continued to maintain full ROM and advanced strengthening to low repetition/high resistance as indicated. Once patients demonstrated 70% quadriceps strength via isokinetic testing, they performed light agility drills and proprioceptive activity that included a running progression, lateral slides, crossovers, and single leg hopping. If a joint effusion was present, it was carefully monitored as activity increased. An activity-specific functional progression, such as shooting baskets or dribbling a soccer ball, was initiated near the end of this period. At the end of 8 weeks, the patients were evaluated to assess ROM, tested with the KT-1000 ligament arthrometer, performed an isokinetic strength evaluation, and completed a subjective questionnaire.

In 1993, Barber-Westin and Noyes reported serial KT-1000 measurements on 84 patients following BPTB allograft ACL reconstruction and controlled rehabilitation for chronic ACL deficiency. Arthrometer measurements were obtained on each patient for at least 2 years following surgery. Of those patients with abnormal anterior-posterior displacements greater than 2.5 mm, 86% were first detected during the intensive strength training or return to sports phases of rehabilitation. In 1999, Barber-Westin et al reported a subsequent observational study of 142 patients following ACL reconstruction that used a rehabilitation program similar to the previous study. However, this group of subjects used a BPTB autograft rather than an allograft. They found no association between abnormal displacements and the phase of rehabilitation.

Shelbourne and Davis followed 603 patients who underwent autogenous BPTB ACL reconstruction and participated in a sports agility program at a mean of 5.1 weeks. These patients were evaluated to determine if program affected knee stability. Patients were required to have full hyperextension, knee flexion to 120°, and at least 60% quadriceps strength compared to the normal leg. The KT-1000 manual maximum arthrometer scores revealed that 92.7% of patients at a mean of 5 weeks and 93.2% of patients at a mean follow-up of 24 weeks had displacement differences of 3 mm or less. The results showed that early return to sports agility activities did not compromise graft integrity measured 24 weeks following ACL reconstruction.

Phase V: Return to Activity
Return to activity was very individualized and was designed to match the patient's goals. The patient continued to increase strength and increase the intensity and duration of athletic activities. A functional progres-
sion (Figure 5) that followed a half to three-quarter to full speed progression of sport-specific activities was incorporated in this phase. The patient achieved 85% quadriceps strength and completed a functional progression program prior to return to full athletic activity. While some patients returned to activity as early as 2 months, typically patients returned to full activity between 4 and 6 months after ACL reconstruction.

Many authors continued to base return to activity guidelines on histological studies that reported full maturation and required 12 months to complete. However, Rougraff et al reported that ligamentization could require up to 3 years to complete. Glasgow et al studied the effects of early (5 months) versus late (9 months) return to vigorous cutting activities on outcome in 64 patients following patellar tendon autograft ACL reconstruction. Return to vigorous activity was based on a minimum of 8 weeks postoperation, negative Lachman test, absence of effusion, and patient desire to return. At a mean follow-up of 46 months, no differences were found in KT-1000 scores, subjective evaluations, or isokinetic strength. Interestingly, in a review of 1288 patients who underwent autogenous BPTB ACL and accelerated rehabilitation, Shelbourne and Davis reported that more patients tore their normal, contralateral ACL (4.4%) than their reconstructed ACL (2.4%). They proposed that graft failure was not the result of a weakened graft, but rather the consequence of normal return to sport.

In 1995, Shelbourne et al reported KT-1000 manual maximum difference scores in a 2 to 6 year follow-up of 209 patients after autogenous BPTB ACL reconstruction and accelerated rehabilitation. The mean KT-1000 score was 2.06 mm at full ROM and 2.10 mm at a mean 2.7 year follow-up. In 1997, Shelbourne and Gray reported objective data on 806 patients and subjective data on 948 patients in a 2 to 9 year follow-up after autogenous BPTB ACL reconstruction and accelerated rehabilitation. Of those patients who underwent acute reconstruction, the mean manual maximum KT-1000 arthrometer difference was 2.0 mm with 90% of patients less than or equal to 3 mm and 98% of patients less than 5 mm of laxity. No joint space narrowing was seen in 94% of patients, isokinetic quadriceps evaluation revealed 94% strength, mean motion was 5º of hyperextension and 140º of flexion, and mean subjective modified Noyes questionnaire score was 93.2 out of 100 possible. In 2000, Shelbourne and Gray reported on the effects of meniscus and articular cartilage status on autogenous BPTB ACL reconstruction and accelerated rehabilitation in a 5 to 15 year follow-up. Of those patients with both menisci present and normal articular cartilage at the time of surgery, 97% had normal or near normal radiographs. Based on these findings, evidence supported that accelerated rehabilitation following autogenous BPTB ACL reconstruction produced excellent long-term results without affecting long-term stability.

Trends in ACL rehabilitation in the 1990’s revealed remarkable changes compared to the 1980’s. Many authors began adopting protocols similar to the accelerated program. The rehabilitation programs were characterized by preoperative rehabilitation, immediate ROM and weight bearing, full passive knee extension, and functional exercise. Meanwhile, some authors continued to share concerns regarding the wide scale use of these new protocols, particularly in specific patient groups or with specific graft sources.

**ACL REHABILITATION IN THE 2000’S: EVIDENCE-BASED PRACTICE**

Recently, the buzzword in the physical therapy profession has been “evidence-based practice.” Evidence based practice is a very positive trend that may ultimately result in improved quality and effectiveness of patient care. Sackett et al defined EBP as “the integration of best research evidence with clinical expertise and patient values.” Evidence based practice could be the trend that defines ACL rehabilitation in the 2000’s.

Several authors have published well-conducted research on the strain behavior of the ACL during common rehabilitation activities. A comprehensive database has been compiled based on peak strain values in which the authors used to design rehabilitation programs to be compared in a prospective, randomized, double-blind trial. The results of these studies will help delineate rehabilitation programs that are safe for a healing ACL graft. A need exists for prospective, randomized, blinded clinical trials to compare accelerated rehabilitation with more conservative rehabilitation before accelerated rehabilitation can be considered safe and appropriate.

Recently, Beynnon et al reported the results of a prospective, randomized, double-blind study comparing accelerated versus nonaccelerated rehabilitation in 22 patients following BPTB ACL reconstruction. The rehabilitation programs were based on their previous work of ACL strain data during rehabilitation activities. Exercises that had been shown to produce significant
strain to the ACL were initiated earlier in the accelerated program and delayed in the nonaccelerated program. Exercises that did not produce significant ACL strain were initiated in both rehabilitation programs during the same time frame. The accelerated program, characterized by early unrestricted weight-bearing and early use of quadriceps-dominated exercises, lasted 19 weeks and return to sports was possible by 24 weeks while the nonaccelerated program lasted 32 weeks and return to sports was possible also at 32 weeks. At 2-year follow-up, their results demonstrated no difference in anterior knee laxity between accelerated and nonaccelerated rehabilitation. The authors also found that both programs produced the same outcomes in clinical assessment, patient satisfaction, functional performance, and articular cartilage metabolism. Furthermore, total compliance measured at the end of each program was significantly less in the nonaccelerated group.

Evidence based practice has not been limited to prospective, randomized, blinded clinical trials. While the authors agree that prospective, randomized, blinded clinical trials are the gold standard and large studies of this nature are required for best evidence practice, the difficulty most clinicians face in performance of such studies must be acknowledged. Prospective long-term outcome studies may also be conducted to gain insight into the effectiveness of clinical intervention.

To date no studies have been published that have determined conservative rehabilitation following ACL reconstruction to have produced better outcomes or long-term stability than those reported with accelerated rehabilitation. Therefore, the current evidence supports the use of the more physiologic progression following BPTB ACL reconstruction.

While research evidence has been a very important part of EBP, it is the senior author’s opinion that clinical expertise and patient values are equally important components of EBP for quality patient care. Salter reported that the biological concept of CPM for synovial joints was based on clinical observation and deduction. In 1970, the concept of CPM was introduced which was contrary to the initial thought process of joint immobilization for disease or injury. The evolution of the Methodist Sports Medicine Center rehabilitation protocol following ACL reconstruction was based on clinical experience and listening to patients. In 1990, accelerated rehabilitation was the antithesis of traditional rehabilitation following ACL reconstruction.

The clinician must utilize clinical reasoning skills and individualize the care of each patient. No specific exercises or parameters exist for exercise intensity or duration that have been proven to lead to successful outcomes. Guidelines for early application of strain to the healing ACL have not been published. The Methodist Sports Medicine Center rehabilitation protocol the authors have presented has adhered to the basic principles of rehabilitation. Patients increased activity if they had attained full ROM, exhibited minimal effusion and pain, had a normal gait, and demonstrated good leg strength measured isokinetically (quadriceps deficit of ≤30%). The condition of the knee dictated rehabilitation. Patients were not forced to return to activity. Only when the patient was physically and mentally ready was return to activity considered. In addition, the use of a functional progression program allowed the patient and the physical therapist, athletic trainer and, in rare instances, the coach to determine if an athlete was ready to advance.

RE-EMPHASIS IN ACL REHABILITATION

Many researchers have attempted to replicate the accelerated Methodist Sports Medicine Center rehabilitation protocol or currently utilize a similar protocol. For this reason, the authors felt that it was important to clear some misconceptions and re-emphasize some key points of the Methodist Sports Medicine Center rehabilitation protocol.

The preoperative period was vitally important for successful outcome following ACL reconstruction. Patients were required to have full ROM including hyperextension, minimal effusion, good quadriceps strength via isokinetic testing, and normal gait prior to reconstruction. Once these goals were met, surgery was scheduled at a time that was convenient for the patient to allow restricted activity during the first postoperative week.

The emphasis of the first postoperative week was the minimization of swelling. If swelling could be prevented, motion and strengthening would not be inhibited. Although immediate full weight bearing as tolerated with crutches was allowed, activity was not unrestricted. The patients were instructed to remain supine with the leg in the CPM machine except when performing exercises or personal hygiene. The ability to prevent swelling during the first postoperative week greatly impacted the progression of return to activity.
Restoration of motion should be aimed to achieve motion equal to the opposite extremity. Normal motion was often thought of as 0° to 135°.46,56,57,66,89 However, a study by De Carlo and Sell16 of 889 preseason athletes found that 96% of individuals demonstrated some degree of hyperextension. The mean ROM was 5° of hyperextension and 140° of flexion for males and 6° of hyperextension and 143° of flexion for females. If the patient had not achieved full ROM, especially hyperextension, equal to the opposite side, the return of normal gait, function, and knee biomechanics would have been inhibited. The importance of obtaining full hyperextension postoperatively has been well documented.4,26,34,40,64

The Methodist Sports Medicine Center rehabilitation protocol was criterion-based.49 The time frames given were used as guidelines and were not absolute. Advancement to the next phase depended on the condition of the knee and completion of the goals of the previous phase. The initial phases of the program were very similar for all patients in an attempt to restore normal gait, function, and knee biomechanics would have been inhibited. The importance of obtaining full hyperextension postoperatively has been well documented.

2,16,27,34,54,64

CONCLUSION
Over the past two decades, rehabilitation of a patient after an ACL injury has made a dramatic shift toward better patient outcomes and quicker return to activity. In their respective times, the traditional and accelerated rehabilitation models have both given clinicians a sound framework for treating patients as well as stimulated further research. A solid base of evidence exists in the literature to support accelerated rehabilitation as both safe and effective. As EBP and the call for prospective, randomized clinical research continues, the continued progress in treating this injury is exciting. Furthermore, clinicians are urged not to lose sight of the clinical reasoning and deduction that assisted in the evolution of the current science of ACL rehabilitation.

REFERENCES


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ABSTRACT

Background. Arthrofibrosis is a frequent complication following rehabilitation of a patient with anterior cruciate ligament (ACL) reconstruction. Although prevention is the best treatment, little information exists within the literature regarding the management and rehabilitation intervention for arthrofibrosis. In this case report a rehabilitation program in the treatment of a patient with arthrofibrosis is described.

Objectives. To identify the importance of discrete measures of knee range of motion in the knee of a patient following ACL reconstruction in order to help prevent postoperative complications.

Case Description. The patient was an 18-year-old female who sustained an ACL and medial collateral ligament (MCL) injury in a basketball game and underwent an ACL reconstruction with an ipsilateral patellar tendon graft. The patient developed arthrofibrosis and, despite traditional physical therapy of therapeutic exercise and manual therapy, the patient continued to complain of pain, stiffness, limited activities of daily living, and the inability to participate in competitive sports. This patient used a knee extension device as part of her rehabilitation program.

Outcomes. The patient was able to obtain knee extension and flexion equal to her opposite normal knee. Upon completion of the rehabilitation program, the patient returned to full activities of daily living and competitive sports.

Discussion. Increasing and maintaining knee extension that is equal to the opposite normal knee is an important component in the successful outcome for the patient after ACL reconstruction. The use of a knee extension device may provide an effective rehabilitation intervention in the treatment of arthrofibrosis.

Key Words: arthrofibrosis, anterior cruciate ligament, rehabilitation

INTRODUCTION

Arthrofibrosis is an abnormal proliferation of fibrous tissue in and around a joint that can lead to loss of motion, pain, stiffness, muscle weakness, swelling, and limited activities of daily living. This condition can occur after an injury, or more commonly, after surgery. Arthrofibrosis remains a common postoperative complication after anterior cruciate ligament (ACL) reconstruction despite the choices of graft selection. Patellar tendon grafts, hamstring grafts, and allografts are the most commonly used grafts selected for ACL reconstruction, and arthrofibrosis has been found to occur after all three. While a greater incidence of arthrofibrosis occurs with a patellar tendon graft, this condition continues to be prevalent in patients who received hamstring grafts and allografts, as well.

Shelbourne et al classified different types of arthrofibrosis in the knee based on the loss of knee extension, flexion, or both; the location of scar tissue formation intra-articularly; and the mobility and location of the patella (Table 1). Prevention of arthrofibrosis is the preferred treatment and is possible with a structured rehabilitation program. However, once arthrofibrosis has occurred, the treatment approach widely varies. Numerous published surgical reports exist regarding the cause and treatment of arthrofibrosis, but the rehabilitation programs are poorly defined. For the physical therapist, even fewer guidelines exist with no consistent consensus among researchers as to the most effective treatment and postoperative
The importance of obtaining and maintaining knee extension following ACL reconstruction is well documented in the literature.1,4,10-12 Most treatment approaches for arthrofibrosis include surgical intervention followed by extension casting and “aggressive” physical therapy. Published reports discuss the use of serial casting, “drop out” casts and daily physical therapy.8,10 This approach is often a time consuming event requiring daily cast changes and multiple visits to the clinic or hospital. However, the best treatment approach in achieving range of motion (ROM) after surgical intervention requires further investigation. Many times, patients with arthrofibrosis will undergo multiple surgeries and extended lengths of time in physical therapy, which can become very costly and time consuming.

The purpose of this case report is to describe the use of a knee extension device in the treatment of a patient with Type 3 arthrofibrosis. In this case a unique knee extension device was used as part of a home exercise program.

### CASE DESCRIPTION

The patient was an 18-year-old female who tore her right ACL and medial collateral ligament during a basketball game on 10-28-03. She was evaluated by an orthopedic surgeon and placed in a knee brace that was locked at 30°. The patient was instructed by the physician to perform quadriceps muscle contractions and straight leg raise exercises. She underwent medial collateral ligament repair and ACL reconstruction using an ipsilateral patellar tendon graft on 12-09-03. After surgery, the patient’s knee was kept in extension by a knee brace and she was limited to toe touch weight bearing for four weeks.

The patient began formal physical therapy for ROM and patellar mobilization on 12-31-03 and was advised by her physician to continue to wear the knee brace locked at 0° to 90°. Due to the slow progress in ROM, the patient underwent a right knee manipulation and arthroscopy on 02-06-04. After surgery, the patient continued with physical therapy for ROM exercises and was prescribed methylprednisolone (steroid for inflammation). Over the next month, the patient had her knee aspirated twice, was placed on rofecoxib (non-steroidal anti-inflammatory – NSAID), and repeated a dose of methylprednisolone. The patient continued to complain of pain and stiffness in her right knee. As of 03-19-04, her right knee ROM was still significantly limited at 0-10-108°.

The patient underwent a second right knee manipulation and arthroscopy on 03-22-04 (Table 2). Postoperatively, the patient was placed on prednisone (steroid for inflammation) and issued a continuous passive motion (CPM) machine to assist with ROM. Upon follow up, the patient was diagnosed with arthrofibrosis. She was instructed to continue with physical therapy and placed on cyclobenzaprine, a muscle relaxer. She additionally received bupivacaine (analgesic for pain) injections prior to physical therapy appointments to help make her physical therapy more tolerable. She was attempting to run and bike but continued to have significant pain and stiffness. The patient was then referred to the Shelbourne Clinic at

### Table 1. Classification of Arthrofibrosis.

<table>
<thead>
<tr>
<th>TYPE</th>
<th>EXTENSION</th>
<th>FLEXION</th>
<th>PATELLAR MOBILITY</th>
</tr>
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<tbody>
<tr>
<td>Type 1</td>
<td>&lt;10° extension loss</td>
<td>Normal flexion</td>
<td>Normal</td>
</tr>
<tr>
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<td>&gt;10° extension loss</td>
<td>Normal flexion</td>
<td>Normal</td>
</tr>
<tr>
<td>Type 3</td>
<td>&gt;10° extension loss</td>
<td>&gt;25° flexion loss</td>
<td>Decreased</td>
</tr>
<tr>
<td>Type 4</td>
<td>&gt;10° extension loss</td>
<td>&gt;30° flexion loss</td>
<td>Decreased and patella infera</td>
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### Table 2. Order of events following previous treatment.

<table>
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<tr>
<th>EVENT</th>
<th>DATE</th>
<th>RIGHT KNEE ROM</th>
</tr>
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<tr>
<td>Date of Injury</td>
<td>10-28-03</td>
<td>0-0-45°</td>
</tr>
<tr>
<td>ACL Reconstruction</td>
<td>12-09-03</td>
<td>0-0-45°</td>
</tr>
<tr>
<td>Manipulation</td>
<td>02-06-04</td>
<td>0-3-90°</td>
</tr>
<tr>
<td>Manipulation</td>
<td>03-22-04</td>
<td>0-10-108°</td>
</tr>
<tr>
<td>Follow-up appointment</td>
<td>05-13-04</td>
<td>0-7-120°</td>
</tr>
</tbody>
</table>
Methodist Hospital for a second opinion on examination and treatment of her knee on 05-25-04.

**Initial Physical Therapy Examination**

Physical examination showed that the patient had an antalgic gait and was walking with a bent right knee. She had right quadriceps atrophy. The patient’s knee had a mild effusion, good patella mobility in all directions, a negative Lachman test, negative posterior drawer, and negative varus and valgus laxity with testing. The patient felt no tenderness to palpation over the medial collateral ligament or the patellar tendon. She was able to perform a leg raise with a bent knee and significant extension lag. Plain radiographs were read as normal.

Range of motion measurements were taken using a goniometer as described by Norkin. ROM measurements were recorded as A-B-C, with A being the degrees of extension from zero, and C documenting degrees of flexion. Her right knee ROM was 0-10-110° vs. her normal left knee 10-0-150º, which means she was lacking 20º of extension and 40º of flexion.

The International Knee Documentation Committee subjective knee form (IKDC) outcome instrument was used to assess the patient's current condition. The initial score on the IKDC was 41/100 and is representative of a significant amount of disability.

The patient was diagnosed with Type 3 arthrofibrosis. The patient had been undergoing regular physical therapy in her hometown three times per week since her ACL reconstruction. After discussing the details of the physical therapy sessions, it became apparent that the focus of the rehabilitation program had been on strengthening and not ROM. Therefore, the present focus was to try nonoperative methods to maximize her knee ROM and restore knee symmetry. The goals of physical therapy were to increase right knee ROM equal to her left knee, decrease swelling, restore a normal gait pattern, increase leg strength equal to her left knee, and return to normal activities of daily living and eventually full competitive basketball.

**Physical Therapy Intervention**

The loss in knee extension is more problematic and causes more limitations than a loss of knee flexion. Aglietti et al showed that patients who have better knee ROM before surgery have a better prognosis and outcome after surgical intervention. Therefore, the initial plan of care focused on treating the knee extension loss. Paulos et al showed that it is difficult to obtain and maintain both flexion and extension at the same time and achieving extension should be a priority. The treatment was initiated to focus on increasing knee extension only. Most uninjured, normal knees have some degree of hyperextension. De Carlo and Sell found normal knee extension to be 5º of hyperextension in males and 6º of hyperextension in females. Normal knee ROM is defined as ROM equal to that of the noninvolved limb to include the measurement for hyperextension. The patient's normal, uninvolved knee extension measured 10º of hyperextension. Therefore, our goal was to maximize knee extension equal to the opposite normal knee.

A knee extension device (Elite Seat, Kneebourne Therapeutics, Noblesville, IN) was used that would stretch the knee into hyperextension (Figure 1). The second author (KDS) is a part owner of Kneebourne Therapeutics which designed and developed the knee extension device. This device is patient controlled and provides a low load, long duration stretch. The patient was issued and instructed to use the extension device for 10 minutes 3-4 times per day followed by additional knee extension exercises. These exercises included a towel stretch and heel prop exercises and active terminal knee extension while standing. The towel stretch is an exercise that focuses on increasing extension and forcing the knee into knee hyperextension (Figure 2). The patient was advised in performing a heel prop and it was to be performed whenever the patient was sitting (Figure 3).

She was also instructed to stand on the involved extremity and attempt to extend the knee into a locked out posi-
tion by an active quadriceps contraction (Figure 4). This exercise assisted in maintaining the extension acquired from the previous exercises. All exercises were performed three times per day. The patient received instruction in gait training and was encouraged to walk full weight bearing with a normal, symmetrical gait pattern. Finally, she was issued and instructed in a cold/compression device (Cryo/Cuff, Aircast Inc., Summit, New Jersey, USA) to help control swelling and soreness.

Given that the patient lived approximately 5 hours of driving time from the clinic, she was set up on a home exercise program as described previously to focus on increasing and maximizing her involved extremity knee extension. Her progress was monitored through phone calls. Two weeks later she returned for a follow-up evaluation and presented with increased ROM. Her right involved knee measurement was 5-0-110° vs. 10-0-150° in the left normal knee. On physical examination, she was able to perform a straight leg raise and an active heel lift (Figure 5); however, this activity was not equal to the opposite knee. The patient’s knee had a mild effusion and she walked with a slightly bent knee. The patient reported that her knee was still very sore. The patient was advised to continue with her current home exercise program focusing on increasing her knee extension until she felt she was no longer making improvements.

The patient returned 2 weeks later (1 month after her initial visit) to check her progress following this new treatment. She felt she had maximized her knee extension at that time and was feeling most of her discomfort in the anterior aspect of the knee while using the knee extension device and performing the exercises. Upon physical examination, she continued to walk with a bent knee and had a mild effusion. Her ROM measured the same as her previous visit, still lacking both extension and flexion. She continued to have pain with walking, stairs and activities of daily living. The patient’s desire was to return to high-level sports and she planned on playing basketball at a college later that year. Given that her knee was still lacking ROM and she was having pain and difficulty with activities of daily living, the patient elected to undergo an arthroscopic scar resection as recommended by the physician.

**Surgical Intervention**

The patient underwent an arthroscopic scar resection on 07-19-04, approximately 6 weeks after her initial presentation to the present clinic (Table 3). Informed consent was obtained and the rights of the subject were protected for a study in the follow up of patients undergoing knee arthroscopy. She underwent the surgical procedure as described by Shelbourne et al. for Type 3 arthrofibrosis.

The patient was kept overnight in the hospital and received intravenous Toradol for inflammation and pain control. An anti-embolism stocking was applied to the patient’s leg and the leg was elevated in a CPM machine to help prevent postoperative swelling. She was also placed in a CryoCuff (Aircast Inc., Summit, New Jersey, USA) to assist in preventing a hemarthrosis.
Post Surgical Physical Therapy Intervention and Examination

On the day of surgery, exercises for extension were immediately initiated. The knee extension device was used for 10 minutes, followed by 10 towel stretch exercises, and quadriceps activation to achieve and maintain an active heel lift. She followed this exercise with 10 straight leg raise exercises to maintain good leg control and avoid quadriceps inhibition. These exercises for knee extension were performed six times per day. The patient was on bed rest for the first three days postoperatively to minimize swelling. Bed rest is an important concept after surgery since evidence exists that a hemarthrosis may contribute to an inhibitory effect on the quadriceps and hamstrings muscles resulting in muscle atrophy. Early quadriceps muscle activation plays a key role in achieving and maintaining knee extension. Therefore, although the patient was on bed rest to minimize swelling, she was performing a regular exercise program to achieve and maintain full terminal hyperextension equal to the opposite knee. Full weight bearing with a normal gait pattern was emphasized and allowed for restroom privileges only.

The patient was discharged from the hospital to a nearby hotel. Prior to discharge, her ROM was 100-0-90° in the right involved knee versus 100-0-150° in the left knee. She had a moderate effusion and walked full weight bearing with a slightly antalgic gait pattern. The patient was discharged from the hospital with a home exercise program. She was to remain supine in the CPM with continuous use of the cold/compression device. Six times throughout the day, she took her leg out of the CPM machine, removed the cold/compression device and performed the exercise program, which included the extension device for 10 minutes, towel stretch exercises followed by active quadriceps muscle activation 10 times, and straight leg raise exercises 10 times. The patient then reapplied the cold/compression device and placed her leg back in the CPM machine. Full weight bearing and a normal gait pattern was encouraged and emphasized for restroom privileges only.

At three days postoperatively, she returned to the clinic to have her ROM and progress evaluated. She continued to achieve full passive terminal hyperextension equal to the opposite knee, an active heel lift, a straight leg raise, and her knee had a moderate effusion. Knee flexion exercises were instituted because she had excellent leg control and equal knee extension. She was instructed in heel slide and wall slide exercises and was told to discontinue flexion exercises if she noted any loss in knee extension. She was instructed to continue to use the extension device and perform all exercises 3 to 5 times per day. She was told to perform a heel prop exercise when sitting and to stand on the involved extremity forcing the knee locked out by an active quadriceps muscle contraction when standing.

At 10 days postoperatively she had maintained her full passive terminal hyperextension equal to the opposite normal knee, an active heel lift, and was walking with a normal gait. Her knee had a mild effusion and ROM measured as 100-0-125° in the right involved knee versus 100-0-150° in the left normal knee. She was instructed to continue to focus on perfect knee extension and to increase her knee flexion until she could sit on her heels equally and comfortably (Figure 6). No strengthening exercises were initiated so that the focus continued to be on achieving full knee ROM.

She returned 08-31-04, approximately six weeks postoperatively, and she
rated her knee at 60% and had returned to all normal activities of daily living including helping out on the family farm. She continued to perform the prescribed exercises four times per day. Her ROM on the right involved knee was 10-0-143° versus 10-0-150° in the left normal knee. She was able to sit on her heels but had an uncomfortable tilt. Her knee had a mild effusion and she had a normal gait, no tenderness, and an active heel lift that was not yet equal to the opposite normal knee. She was instructed to continue with her previous home exercise program but she could gradually decrease using the extension device to 1-2 times per day as long as she did not lose extension. Upon achieving full ROM symmetrically equal to the opposite knee, she was able to begin biking and elliptical cross trainer, single-leg press, single-leg extensions, and step down exercises. These exercises were performed one time per day, 3 - 5 times per week. Progression of the low-impact and strengthening program was allowed as long as no ROM was lost or compromised.

On 09-23-04, approximately two months after her surgery, she underwent isokinetic strength testing at 180° and 60° speeds and single-leg hop testing. These strength tests were repeated at four, six, and eight months postoperatively. At four months she was allowed to begin shooting baskets and light agility drills. At eight months postoperatively she was released to full participation (Table 3).

**OUTCOMES**

At four months postoperatively, the patient had symmetrical knee ROM including full equal hyperextension and full equal flexion. She had an equal active heel lift and was able to sit on her heels equally and comfortably. Isokinetic strength testing of the involved knee compared with the opposite normal knee revealed 79% strength at 180°/s speed and 66% strength at 60°/s speed. She rated her knee at 80%.

At one year postoperatively, the patient’s knee had symmetrical ROM including full equal hyperextension and full equal flexion. She had an equal active heel lift and

<table>
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<th>EVENT</th>
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<th>STRENGTH 180°</th>
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<td>05-25-04</td>
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<td></td>
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<tr>
<td>2 weeks</td>
<td>06-09-04</td>
<td>5-0-110°</td>
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<td>4 weeks</td>
<td>07-06-04</td>
<td>5-0-110°</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arthroscopic scar resection</td>
<td>07-19-04</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital Discharge</td>
<td>07-20-04</td>
<td>10-0-90°</td>
<td></td>
<td></td>
<td>Bed rest x 3 days</td>
</tr>
<tr>
<td>3 days PO</td>
<td>07-23-04</td>
<td>10-0-115°</td>
<td></td>
<td></td>
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<tr>
<td>10 days PO</td>
<td>08-03-04</td>
<td>10-0-125°</td>
<td></td>
<td></td>
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<tr>
<td>6 wks PO</td>
<td>08-31-04</td>
<td>10-0-143°</td>
<td></td>
<td></td>
<td>Low impact</td>
</tr>
<tr>
<td>2 mos PO</td>
<td>09-23-04</td>
<td>10-0-148°</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4 mos PO</td>
<td>11-16-04</td>
<td>10-0-150°</td>
<td>79%</td>
<td>66%</td>
<td>Shooting baskets</td>
</tr>
<tr>
<td>6 mos PO</td>
<td>01-12-05</td>
<td>10-0-150°</td>
<td>74%</td>
<td>75%</td>
<td>Agility drills</td>
</tr>
<tr>
<td>8 mos PO</td>
<td>03-09-05</td>
<td>10-0-150°</td>
<td>95%</td>
<td>83%</td>
<td>Return to basketball</td>
</tr>
<tr>
<td>1 yr PO</td>
<td>07-19-05</td>
<td>10-0-150°</td>
<td>89%</td>
<td>96%</td>
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PO = postoperatively
was able to sit on her heels equally and comfortably. Her quadriceps muscle strength was 89% of the opposite normal knee at 180°/s speed and 96% strength at 60°/s speed with isokinetic strength testing. She tested 101% on the single-leg-hop test. She rated her knee at 98% and her knee had a mild effusion. The patient’s IKDC score at one year postoperatively was 97/100, more than doubling the score she achieved on her initial visit. Additionally the patient returned to full athletic competition without pain or difficulty and was formally discharged from physical therapy at that time.

DISCUSSION

The treatment of arthrofibrosis is often a costly and time intensive treatment process. The focus of treatment in most published articles is in regards to surgical intervention with varying rehabilitation protocols. Authors of previously published papers state the importance of acquiring extension but no consensus exists on the best way to achieve this movement. Some authors have tried extension casts which require multiple visits to the clinic and can be very uncomfortable. In addition, a cast prevents the patient from being able to perform exercises in between visits. The use of the extension device used with the patient in this report allowed for a patient controlled intervention in increasing knee extension to include hyperextension.

Although most authors agree that restoration of normal knee ROM is a key tenant of treatment, disagreement exists as to what constitutes “normal” ROM. Other treatment programs to regain knee extension fail to take into account that most people have some degree of knee hyperextension. Many authors report they had achieved good ROM results by achieving zero degrees, however, these authors still did not have a good outcome. Achieving full hyperextension equal to the opposite normal knee was the focus of this rehabilitation utilizing the knee extension device. Previous attempts in physical therapy that utilized therapeutic exercises and manual therapy had failed. In this case report, full ROM equal to the opposite normal knee was achieved and it is the author’s opinion that this achievement of full extension was the most important factor in returning the patient to an active lifestyle, including competitive basketball.

Maximizing extension preoperatively may have helped in obtaining full extension postoperatively. Avoiding a hemarthrosis and subsequent quadriceps inhibition after surgery allowed for early quadriceps activation and the ability to maintain full terminal knee extension. Once the patient was able to maintain extension, flexion exercises were initiated followed by the rehabilitation program described earlier.

CONCLUSION

While prevention provides the best treatment for arthrofibrosis, a need exists for data on the best way to treat arthrofibrosis once it has occurred. This case is an example of a successful outcome in the treatment of Type 3 arthrofibrosis in which a knee extension device was utilized. The rehabilitation program described in this case study may assist physical therapists and physicians in the treatment of patients with arthrofibrosis.

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INVITED CLINICAL COMMENTARY

PRE-PARTICIPATION SCREENING: THE USE OF FUNDAMENTAL MOVEMENTS AS AN ASSESSMENT OF FUNCTION – part 2

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ABSTRACT

Part I of this two-part series (presented in the May issue of NAJSPT) provided the background, rationale, and a complete reference list for the use of fundamental movements as an assessment of function during pre-participation screening. In addition, Part I introduced one such evaluation tool that attempts to assess the fundamental movement patterns of an individual, the Functional Movement Screen (FMS™), and described three of the seven fundamental movement patterns that comprise the FMS™.

Part II of this series provides a brief review of the analysis of fundamental movement as an assessment of function. In addition, four additional fundamental tests of the FMS™, which complement those described in Part I, will be presented (to complete the total of seven fundamental tests): shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability. These four patterns are described in detail, a grading system from 0-III is defined for each pattern, and the clinical implications for receiving a grade less than a perfect III are proposed.

By reading Part I and Part II, it is hoped that the clinician will recognize the need for the assessment of fundamental movements, critique current and develop new methods of functional assessment, and begin to provide evidence related to the assessment of fundamental movements and the ability to predict and reduce injury. By using such a screening system, the void between pre-participation screening and performance tests will begin to close.

Key Words: pre-participation screening, performance tests, function

INTRODUCTION

The assessment of fundamental movements is an attempt to pinpoint deficient areas of mobility and stability that may be overlooked in the asymptomatic active population. The ability to predict injuries is equally as important as the ability to evaluate and treat injuries. The difficulty in preventing injury seems to be directly related to the inability to consistently determine those athletes who are predisposed to injuries. In many situations, no way exists for knowing if an individual will fall into the injury or non-injury category - no matter what the individual's risk factors are. Meeuwisse1 suggested that unless specific markers are identified for each individual, determining who is predisposed to injuries would be very difficult.

The inconsistencies surrounding the pre-participation physical and performance tests offer very little assistance in identifying individuals who are predisposed to injuries. These two evaluation methods do not offer predictable and functional tests that are individualized and may assist in identifying specific kinetic chain weaknesses. Numerous sports medicine professionals have suggested the need for specific assessment techniques that utilize a more functional approach in order to identify movement deficits.2-4

The Functional Movement System (FMS™) is an attempt to capture movement pattern quality with a primitive grading system that begins the process of functional movement pattern assessment in normal individuals. It is not intended to be used for diagnosis, but rather to demonstrate limitations or

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asymmetries with respect to human movement patterns and eventually correlate these limitations with outcomes, which may lead to an improved proactive approach to injury prevention.5

The FMS™ may be included in the pre-placement/pre-participation physical examination or be used as a stand-alone assessment technique to determine deficits that may be overlooked during the traditional medical and performance evaluations. In many cases, muscle flexibility and strength imbalances may not be identified during the traditional assessment methods. These problems, previously acknowledged as significant risk factors, can be identified using the FMS™. This movement-based assessment serves to pinpoint functional deficits (or biomarkers) related to proprioceptive, mobility and stability weaknesses.

Scoring the Functional Movement Screen™
The scoring for FMS™ was provided in detail in Part I. The exact same instructions for scoring each test are repeated here to allow the reader to score the additional tests presented in Part II without having to refer to Part I. The scores on the FMS™ range from zero to three; three being the best possible score. The four basic scores are quite simple in philosophy. An individual is given a score of zero if at any time during the testing he/she has pain anywhere in the body. If pain occurs, a score of zero is given and the painful area is noted. A score of one is given if the person is unable to complete the movement pattern or is unable to assume the position to perform the movement. A score of two is given if the person is able to complete the movement but must compensate in some way to perform the fundamental movement. A score of three is given if the person performs the movement correctly without any compensation. Specific comments should be noted defining why a score of three was not obtained.

The majority of the tests in the FMS™ test right and left sides respectively, and it is important that both sides are scored. The lower score of the two sides is recorded and is counted toward the total; however it is important to note imbalances that are present between right and left sides.

Three tests have additional clearing screens which are graded as positive or negative. These clearing movements only consider pain, if a person has pain then that portion of the test is scored positive and if there is no pain then it is scored negative. The clearing tests affect the total score for the particular tests in which they are used. If a person has a positive clearing screen test then the score will be zero.

All scores for the right and left sides, and those for the tests which are associated with the clearing screens, should be recorded. By documenting all the scores, even if they are zeros, the sports rehabilitation professional will have a better understanding of the impairments identified when performing an evaluation. It is important to note that only the lowest score is recorded and considered when tallying the total score. The best total score that can be attained on the FMS™ is twenty-one.

DESCRIPTION OF THE FMS™ TESTS
The following are descriptions of the final four specific tests used in the FMS™ and their scoring system. Each test is followed by tips for testing developed by the authors as well as clinical implications related to the findings of the test.

Shoulder Mobility
Purpose. The shoulder mobility screen assesses bilateral shoulder range of motion, combining internal rotation with adduction and external rotation with abduction. The test also requires normal scapular mobility and thoracic spine extension.

Description. The tester first determines the hand length by measuring the distance from the distal wrist crease to the tip of the third digit in inches. The individual is then instructed to make a fist with each hand, placing the thumb inside the fist. They are then asked to assume a maximally adducted, extended, and internally rotated position with one shoulder and a maximally abducted, flexed, and externally rotated position with the other. During the test the hands should remain in a fist and they should be placed on the back in one smooth motion. The tester then measures the distance between the two closest bony prominences. Perform the shoulder mobility test as many as three times bilaterally (Figures 1-3).

Tips for Testing:
• The flexed shoulder identifies the side being scored
• If the hand measurement is exactly the same as the distance between the two points then score the subject low
• The clearing test overrides the score on the rest of the test
• Make sure individual does not try to “walk” the hands toward each other
Clearing exam. A clearing exam should be performed at the end of the shoulder mobility test. This movement is not scored it is simply performed to observe a pain response. If pain is produced, a score of zero is given to the entire shoulder mobility test. This clearing exam is necessary because shoulder impingement can sometimes go undetected by shoulder mobility testing alone.

The individual places his/her hand on the opposite shoulder and then attempts to point the elbow upward (Figure 4). If there is pain associated with this movement, a score of zero is given. It is recommended that a thorough evaluation of the shoulder be done. This screen should be performed bilaterally.

Clinical Implications for Shoulder Mobility
The ability to perform the shoulder mobility test requires shoulder mobility in a combination of motions including abduction/external rotation, flexion/extension, and adduction/internal rotation. This test also requires scapular and thoracic spine mobility.

Poor performance during this test can be the result of several causes, one of which is the widely accepted explanation that increased external rotation is gained at the expense of internal rotation in overhead throwing athletes. In addition, excessive development and shortening of the pectoralis minor or latissimus dorsi muscles can cause postural alterations of forward or rounded shoulders. Finally, a scapulothoracic dysfunction may be present, resulting in decreased glenohumeral mobility secondary to poor scapulothoracic mobility or stability.

When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by using standard goniometric measurements of the joints as well as muscular flexibility tests such as Kendall’s test for pectoralis minor and latissimus dorsi tightness or Sahrmann’s tests for shoulder rotator tightness.

Previous testing has identified that when an athlete achieves a score of II, minor postural changes or shortening of isolated axio-humeral or scapulo-humeral muscles exist. When an athlete scores a I or less, a scapulothoracic dysfunction may exist.
Active Straight Leg Raise

Purpose. The active straight leg raise tests the ability to disassociate the lower extremity from the trunk while maintaining stability in the torso. The active straight leg raise test assesses active hamstring and gastrocnemius flexibility while maintaining a stable pelvis and active extension of the opposite leg.

Description. The individual first assumes the starting position by lying supine with the arms in an anatomical position and head flat on the floor. The tester then identifies mid-point between the anterior superior iliac spine (ASIS) and mid-point of the patella, a dowel is then placed at this position perpendicular to the ground. Next, the individual is instructed to lift the test leg with a dorsiflexed ankle and an extended knee. During the test the opposite knee should remain in contact with the ground, the toes should remain pointed upward, and the head remain flat on the floor. Once the end range position is achieved, and the malleolus is located past the dowel then the score is recorded per the established criteria (explained later). If the malleolus does not pass the dowel then the dowel is aligned along the medial malleolus of the test leg, perpendicular to the floor and scored per the established criteria. The active straight leg raise test should be performed as many as three times bilaterally (Figures 5-7).

Tips for Testing:
• The flexed hip identifies the side being scored
• Make sure leg on floor does not externally rotate at the hip
• Both knees remain extended and the knee on the extended hip remains touching the ground
• If the dowel resides at exactly the mid-point, score low

Clinical Implications for Active Straight Leg Raise
The ability to perform the active straight leg raise test requires functional hamstring flexibility, which is the flexibility that is available during training and competition. This is different from passive flexibility, which is more commonly assessed. The athlete is also required to demonstrate adequate hip mobility of the opposite leg as well as lower abdominal stability.

Poor performance during this test can be the result of several factors. First, the athlete may have poor functional hamstring flexibility. Second, the athlete may have inadequate mobility of the opposite hip, stemming from iliopsoas inflexibility associated with an anteriorly tilted pelvis. If this limitation is gross, true active hamstring flexibility will not be realized. A combination of these factors will demonstrate an athlete’s relative bilateral,
asymmetric hip mobility. Like the hurdle step test, the active straight leg raise test reveals relative hip mobility; however, this test is more specific to the limitations imposed by the muscles of the hamstrings and the iliopsoas.

When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by Kendall’s sit-and-reach test as well as the 90-90 straight leg raise test for hamstring flexibility. The Thomas test can be used to identify iliopsoas flexibility.6

Previous testing has identified that when an athlete achieves a score of II, minor asymmetric hip mobility limitations or moderate isolated, unilateral muscle tightness may exist. When an athlete scores a I or less, relative hip mobility limitations are gross.

**Trunk Stability Push-Up**

**Purpose.** The trunk stability push-up tests the ability to stabilize the spine in an anterior and posterior plane during a closed-chain upper body movement. The test assesses trunk stability in the sagittal plane while a symmetrical upper-extremity motion is performed.

**Description.** The individual assumes a prone position with the feet together. The hands are then placed shoulder width apart at the appropriate position per the criteria described later. The knees are then fully extended and the ankles are dorsiflexed. The individual is asked to perform one push-up in this position. The body should be lifted as a unit; no “lag” should occur in the lumbar spine when performing this push-up. If the individual cannot perform a push-up in this position, the hands are lowered to the appropriate position per the established criteria (Figures 8-10).

**Tips for Testing:**
- Tell them to lift the body as a unit
- Make sure original hand position is maintained and the hands do not slide down when they prepare to lift
- Make sure their chest and stomach come off the floor at the same instance
- When in doubt score it low
- The clearing test overrides the test score

**Figure 8. Trunk Stab Push Up III (male)**

III
- Males perform one repetition with thumbs aligned with the top of the forehead
- Females perform one repetition with thumbs aligned with chin

**Figure 9. Trunk Stab Push Up II (male)**

II
- Males perform one repetition with thumbs aligned with chin
- Females perform one repetition with thumbs aligned with clavicle

**Figure 10. Trunk Stab Push Up II (male)**

I
- Males are unable to perform one repetition with hands aligned with chin
- Females are unable to perform one repetition with thumbs aligned with clavicle
Clearing exam. A clearing exam is performed at the end of the trunk stability push-up test. This movement is not scored; the test is simply performed to observe a pain response. If pain is produced, a score of zero is given for the entire push-up test. This clearing exam is necessary because back pain can sometimes go undetected during movement screening.

Spinal extension can be cleared by performing a press-up in the push-up position (Figure 11). If pain is associated with this motion, a zero is given and a more thorough evaluation should be performed.

**Clinical Implications for Trunk Stability Push-up**
The ability to perform the trunk stability push-up requires symmetric trunk stability in the sagittal plane during a symmetric upper extremity movement. Many functional activities in sport require the trunk stabilizers to transfer force symmetrically from the upper extremities to the lower extremities and vice versa. Movements such as rebounding in basketball, overhead blocking in volleyball, or pass blocking in football are common examples of this type of energy transfer. If the trunk does not have adequate stability during these activities, kinetic energy will be dispersed and lead to poor functional performance, as well as increased potential for micro traumatic injury.

Poor performance during this test can be attributed simply to poor stability of the trunk stabilizers. When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by using test by Kendall or Richardson et al for upper and lower abdominal and trunk strength. However, the test by Kendall requires a concentric contraction while a push-up requires an isometric stabilizing reaction to avoid spinal hyperextension. A stabilizing contraction of the core musculature is more fundamental and appropriate than a simple strength test, which may isolate one or two key muscles. At this point, the muscular deficit should not necessarily be diagnosed. The screening exam simply implies poor trunk stability in the presence of a trunk extension force, and further examination at a later time is needed to formulate a diagnosis.

**Rotary Stability**

**Purpose** The rotary stability test is a complex movement requiring proper neuromuscular coordination and energy transfer from one segment of the body to another through the torso. The rotary stability test assesses multi-plane trunk stability during a combined upper and lower extremity motion.

**Description.** The individual assumes the starting position in quadruped with their shoulders and hips at 90 degrees relative to the torso. The knees are positioned at 90 degrees and the ankles should remain dorsiflexed. The individual then flexes the shoulder and extends the same side hip and knee. The leg and hand are only raised enough to clear the floor by approximately 6 inches. The same shoulder is then extended and the knee flexed enough for the elbow and knee to touch. This is performed bilaterally for up to three repetitions. If a III is not attained then the individual performs a diagonal pattern using the opposite shoulder and hip in the same manner as described (Figures 12-16).

**Tips for Testing:**
- Scoring is identified by the upper extremity movement on the score sheet, but even if someone gets a three, both diagonal patterns must be performed and scored. The information should be noted
- Make sure the elbow and knee touch during the flexion part of the movement
- Provide cueing to let the individual know that he/she does not need to raise the hip and arm above 6 inches off of the floor
- When in doubt, score the subject low
- Do not try to interpret the score when testing
Figure 12. Rotary Stab Start III

III
- Performs one correct unilateral repetition while keeping spine parallel to surface
- Knee and elbow touch

Figure 13. Rotary Stab Finish III

Figure 14. Rotary Stab Start II

II
- Performs one correct diagonal repetition while keeping spine parallel to surface
- Knee and elbow touch

Figure 15. Rotary Stab Finish II

Figure 16. Rotary Stab Start I

I
- Inability to perform diagonal repetitions
Clearing exam. A clearing exam is performed at the end of the rotary stability test. This movement is not scored; it is simply performed to observe a pain response. If pain is produced, a score of zero is given to the entire rotary stability test. This clearing exam is necessary because back pain can sometimes go undetected by movement screening.

Spinal flexion can be cleared by first assuming a quadruped position and then rocking back and touching the buttocks to the heels and the chest to the thighs (Figure 17). The hands should remain in front of the body reaching out as far as possible.

Figure 17. Spinal Flexion Clearing Test

Clinical Implications for Rotary Stability
The ability to perform the rotary stability test requires asymmetric trunk stability in both sagittal and transverse planes during asymmetric upper and lower extremity movement. Many functional activities in sport require the trunk stabilizers to transfer force asymmetrically from the lower extremities to the upper extremities and vice versa. Running and exploding out of a down stance in football and track are common examples of this type of energy transfer. If the trunk does not have adequate stability during these activities, kinetic energy will be dispersed, leading to poor performance and increased potential for injury.

Poor performance during this test can be attributed simply to poor asymmetric stability of the trunk stabilizers. When an athlete achieves a score less than III, the limiting factor must be identified. Clinical documentation of these limitations can be obtained by using Kendall’s test for upper and lower abdominal strength.6

SUMMARY
The research related to movement-based assessments is extremely limited, mainly because only a few movement-based quantitative assessment tests are being utilized. According to Battie et al,4 the ultimate test of any pre-employment or pre-placement screening technique is its effectiveness in identifying individuals at the highest risk of injury. If the FMS™, or any similarly developed test, can identify at risk individuals, then prevention strategies can be instituted based on their scores. A proactive, functional training approach that decreases injury through improved performance efficiency will enhance overall wellness and productivity in many active populations.

REFERENCES
ABSTRACT

Background. Abnormal scapular movement or malposition is related to shoulder pathology. The lateral scapular slide test (LSST) is used to determine scapular position with the arm abducted in three positions.

Objective. The purpose of this study was to test the reliability of the LSST using a scoliometer.

Methods. Thirty-three male subjects (18 to 34 years) participated in this study. Group one (n=15) had shoulder pathology; Group two (n=18) did not have pathology. A test-retest, repeated measures design, with three experienced raters and the three positions of the LSST, was used to test the reliability of the LSST. All measurements in each position were taken bilaterally.

Results. Pearson Correlations for Position 1 and 2 ranged from .78 to .92 whereas position 3 ranged from .62 to .81. The ICC (2,2) ranged from .87 to .95 for positions 1 and 2. ICC (2,2) ranged from .70 to .82 for positions 3. Overall ICC (2,3) ranged from .83 to .96. The coefficients of determination ranged from .38 to .89. The SEM ranged from 3.00 to 8.26 mm, with the largest error found in position 3.

Discussion and Conclusion. The LSST can be reliable in screening scapular position. Although a large range of error exists in measurements as indicated by the standard error of the measurement, the LSST provides more objective measures than pure observation.

Key Words: scapula, shoulder, measurement.

INTRODUCTION

Orthopedic clinicians frequently evaluate and provide therapeutic intervention for shoulder dysfunction. A very important link in shoulder function, the scapula merits special attention. The functional role of the scapula is often misunderstood by clinicians, and this lack of awareness can result in incomplete evaluation and diagnosis of impairment of the shoulder. Consequently, scapular rehabilitation is often ignored.

Most authors consider the assessment of scapular positioning on the thoracic cage to be part of a comprehensive evaluation of patients with suspected shoulder dysfunction. Restricted scapulohumeral motion may lead directly to rotator cuff impingement and an eventual partial or full-thickness tear of the rotator cuff tendons. Observing the scapulothoracic rhythm is necessary because disruption to this movement may lead to dysfunction.

Kibler described a test to clinically measure static scapular positions called the lateral scapular slide test (LSST). This test involves measuring the distance from the inferior angle of the scapula to the nearest vertebral spinous process using a tape measure or goniometer in three positions: shoulder in neutral, shoulder at 40-45 degrees of coronal plane abduction with hands resting on hips, and the shoulder at 90 degrees abduction with the arms in full internal rotation. Kibler contends that the injured or deficient side would exhibit a greater scapular distance than the uninjured or normal side and asserted that a bilateral difference of 1.5 cm (15 mm) should be the threshold for deciding whether scapular asymmetry is present. Kibler also suggested that the LSST may be used to monitor the scapular stabilizer muscles in any rehabilitative program that involves shoulder strengthening exercises. Inferences drawn by Kibler about scapular symmetry and shoulder...
pathology are based largely on unpublished work and most of his data collection is performed with overhead throwing athletes.

Several researchers determined that the LSST measurements may be too variable and, thus, unreliable to be useful. However, T’Jonck et al concluded that the LSST technique holds promise for further studies, has the advantage of measuring in three positions, and with some familiarization can be reliable.

The purpose of this study was to determine the reliability of the LSST and its error between raters using a scoliometer. A scoliometer similar to the one used in the present study has shown high reliability and moderate validity to detect scoliosis. Since the scoliometer has been shown to be a simple and reliable tool in detecting scoliosis, the present study extended its use to measure scapular position.

**METHODS**

**Subjects**

Thirty-three volunteer subjects were recruited from the Phoenix, Arizona metropolitan area. Subjects were males ranging in age from 18 to 34 years (mean = 25.5; SD = 5.69). Eighteen of the subjects reported no shoulder pain, injury, or history of dysfunction. Fifteen of the subjects reported diagnoses of unilateral or bilateral shoulder pathology or injury. Diagnoses included tendinitis/strain (6), impingement (3), acromioclavicular separation (3), clavicle fracture (2), and dislocation (1). Diagnoses of injury were made before inclusion of all subjects in the study. These diagnoses were self-reported by the subject following examination by a physician. Exclusion criteria included systemic disease that affects neuromuscular function, the inability to maintain at least 90 degrees of bilateral coronal plane shoulder abduction, existence of any observed postural or bony deformities regardless of physician’s diagnosis, or any existing medical diagnosis prohibiting the subject from participating in the study.

**Equipment**

A scoliometer (Dr. Sabia’s Scoliometer, Red Bank, NJ), marked in millimeters, was used in this study to measure the linear scapular distances. A scoliometer can be described as a caliper attached to two movable points as shown in Figure 1. Amendt et al found high intrarater and interrater reliability ($r = .86 - .97$) using the scoliometer in detecting scoliosis. Amendt et al also determined the validity of the scoliometer compared to x-ray and reported correlation coefficients between .32 and .46. Interrater reliability ranged from .81 - .82 in a different study by Murrell et al.

**Examiners**

Three physical therapists, employed within a separate private practice setting, administered the LSST to the subjects. The three therapists averaged 22.67 years of experience (SD = 2.52), predominantly in an orthopedic practice setting. All raters were experienced in using the LSST, but were not familiar with the scoliometer.

**Data Collection**

Prior to data collection, each evaluating therapist participated in a session to discuss the purpose of the study, as well as the inclusion and exclusion criteria of the subjects. Each therapist was then individually trained in the measurement procedure by the primary investigator, including written and verbal instructions for evaluating the subject, appropriate standing postures, and appropriate positioning of the shoulder in the three test positions. The evaluating therapist practiced the procedure until...
The subject was then instructed to assume the first test position of the LSST with the shoulders in neutral position (Figure 2). Using the scoliometer, each therapist measured the distance between the inferior angle of the scapula and the closest thoracic spinous process in the first test position. The therapist then locked the knobs of the scoliometer to assure that the caliper was fixed. The scoliometer was then handed to the primary investigator, who silently read and recorded the measures. The scoliometer was then reset to zero and the therapist repeated this procedure a second time. An average of the two readings was used for data analysis. This process was repeated on the right and left sides. The third test position required the subject to maintain a posture of approximately 90 degrees of shoulder abduction, full shoulder internal rotation, and full radioulnar supination (Figure 4). This movement was difficult for some subjects. Therefore, the subjects were allowed to return to the first test position after each evaluating therapist completed his series of measurements in the third test position. Before the subsequent evaluating therapist obtained their measures, the subject was instructed to return to the third test position. The subjects were not allowed to change their standing posture. Upon completion of the series of scoliometer measurements in each of the subsequent test positions by the evaluating therapist, the subject was then excused and the process was repeated with the next subject. The therapists were also unaware of any of their measurements, nor those of the other evaluators. All measurements were determined consecutively from position 1 to position 3 and bilaterally.

Data Analysis
Pearson correlation coefficients were calculated to determine the relationships between measures. When determining the relationship between the two sets of variables, Domholdt described terminology about the strength of the relationships. A correlation of .90 to 1.00 was described as a very high relationship; whereas a cor-
relation of .70 to .89 was described as a high relationship. A correlation of .50 to .69 was described as a moderate relationship and a correlation of .26 to .49 was described as a low relationship. However, a correlation of .00 to .25 was indicative of little, if any, relationship.

In addition, coefficients of determination were calculated to determine the shared variability between measures for the three therapists. This coefficient is an indication of the proportion or percentage of variance between two variables. A coefficient of determination of 50% or more is considered good.19

In addition, standard errors of the measurement (SEM) were calculated to determine the amount of error between the therapists. The SEM, as a measure of absolute reliability and the standard deviation of measurement error, can be an estimate of how much a score varies between raters for repeated measures.

Finally, to determine the agreement between the therapists, an intraclass correlation coefficient (ICC) was calculated, using models ICC (2,2) and ICC (2,3). All statistical calculations were performed using the Statview statistical package (SAS, Cary, NC).

RESULTS

In the group of subjects without pathology, a very high relationship existed between raters for test position 1 and test position 2 (Table 1). For test position 3, a moderate to high relationship existed. In the group of subjects with pathology, again, a very high relationship was found between raters for test position 1 and test position 2 (Table 2). For test position 3, a moderate relationship existed as the coefficients ranged between .62 and .72. Although a strong relationship occurred and less error (as indicated by the coefficient of determination) with test positions 1 and 2 in subjects with and without shoulder pathology, less relationship and shared variability was found in test position 3.

When comparing the SEM with the threshold of 15 mm proposed by Kibler,1 these coefficients were quite low, as found in Tables 1 and 2. For position 3 in both groups, the SEMs are less than the threshold of 15 mm, but are 50% of the threshold. This finding may be of some concern in that most of the measure to the threshold may be error.

Intraclass correlation coefficients (ICC), specifically an ICC (2,2) and ICC (2,3), were performed to determine the agreement between raters. Using an ICC (2,2), the agreement between raters for subjects without pathology and with pathology was considered good for position 1 and position 2. For position 3, the agreement was considered moderate to good for subjects without pathology and with pathology. The overall agreement between the three raters for subjects with and without pathology, using an ICC (2,3), was found to be good (Table 3). The ICC (2,3) for all the test positions of both involved and noninvolved shoulder groups had demonstrated a strong degree of agreement, thus, demonstrating high intrarater reliability.

DISCUSSION

Kibler1,21 proposed that assessment of scapular symmetry is based on biomechanics and believed that muscle deficiencies are associated with an unstable scapula. Although a thorough understanding of shoulder girdle mechanics is important, the reliability of the LSST remains in question. Results of previous reliability studies of scapular positioning, as well as those presented in this article, have demonstrated that measurements of linear distance related to the scapula can be reliable.12,22,23 The LSST has been used to assess scapular asymmetry, which may be indicative of shoulder dysfunction. Moreover, the LSST is a relatively simple procedure that is neither time intensive nor expensive. However, while some researchers have found the LSST to be reliable,14,25 many researchers concluded the LSST may be too variable and, thus, unreliable.7,13,14,26

<table>
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*All correlations were significant at an alpha level of .05
**SEM measured in mm
Using the ICC, good reliability appears to exist for using the LSST for test positions 1, 2, and 3 for subjects without pathology. For subjects with pathology, the reliability of test positions 1 and 2 would appear to be good; but for test position 3, the reliability would appear to be moderate to good. Test position 3 challenges scapular stability by abduction and internal rotation of the humerus at 90 degrees and closely approximating the humeral head against the coracoacromial hood. The scapular stabilizers, particularly the serratus anterior, are forced to contract and upwardly rotate the scapula to prevent impingement of suprascapular structures. Thus, test position 3 challenges the muscular force couple and, therefore, one may see more variability with scapular positioning. While maintaining position 3, impingement of pain sensitive structures may occur, thus, increasing the variability of the measures.

Kibler\textsuperscript{1,4} has asserted that a bilateral difference of 1.5 cm (or 15 mm) should be the threshold for deciding whether scapular asymmetry is present. As stated previously, the SEM for subjects without pathology ranged between 4.80 mm and 5.58 mm for position 1, between 4.38 mm and 7.16 mm for position 2, and between 6.22 mm and 8.26 mm for position 3. Portney and Watkins\textsuperscript{20} stated that the SEM can be used as an estimate of reliability, in that there is a 95% chance that the true mean score lies within a range of ± 2 SEM. For the SEM reported in this study, these ranges would be quite large. Therefore, while the relationships and agreement of the scores (as indicated with the Pearson Correlation Coefficients and ICCs) were quite high and would be indicative of high reliability, the true score for the LSST may be greater than the 1.5 cm asserted by Kibler.\textsuperscript{1} Therefore, the threshold of 1.5 cm to be considered shoulder asymmetry needs further scrutiny.

Odom et al\textsuperscript{13} found that comparing the LSST between the two scapulae was unreliable and, thus, deduced the LSST to be invalid and unreliable. They used a simple measurement procedure using a string to determine the linear measurement, whereas a scoliometer was used in this study. They acknowledged the differences in measurement technique and clinical experience among raters might partially account for their findings. Problems with the tensile properties of string may have existed, which was not taken into consideration in the Odom et al\textsuperscript{13} study and may have created significant intra and interrater variance.

A major difference in this study compared to Odom et al\textsuperscript{13} was the experience of the raters. Odom et al\textsuperscript{13} used six raters with an average of 5.8 years of experience. They felt this reflected the experience of a clinician in an outpatient orthopedic setting. The experience of the raters in this study averaged over 22 years. All of the raters in the study were familiar with the LSST, but were not familiar with the scoliometer. Using a scoliometer for measurement was an attempt to further provide objective measures. Perhaps by using a scoliometer, physical therapy students or novice physical therapists may be more reliable in measuring LSST.

Numerous investigators have been critical of 2-dimen-
sional methods for scapular assessment.\textsuperscript{2,15} Methods using 2-dimensional analysis do not assess the tipping or tilting of the scapula about an axis parallel to the scapular spine and winging of the scapula about a vertical axis.\textsuperscript{23,28} However, many clinicians are forced to assess shoulder and scapular motion with 2-dimensional methods. Furthermore, practical assessment using 3-dimensional methods remains conjecture at best, due to expense, time, and availability. It is not known if 3-dimensional methods would provide more information to the clinician in developing a plan of care for the patient or client.

Several limitations existed in this study. The investigator could not control the educational background of the rater/therapist. Although subjects with shoulder pathology were included in the sample, the investigator did not control the type of pathology the subject presented nor the functional range of motion presented by the subject. However, it should be noted that the validity of LSST is based on its face validity compared to clinical observation of scapular asymmetry. The raters in this study, due to their clinical experience, were assumed to use very accurate visualization, palpation, and measurement skills of the inferior angle of the scapula and the adjacent thoracic spinous process. Still, the raters in this study all reported greater difficulty evaluating mesomorphic males due to muscle mass and adipose tissue, which may obscure the identification of anatomical landmarks. Because the raters were unaware of either their own measurements or those of the other raters, the results are not likely to have been influenced by bias.

**CONCLUSIONS**

The results of our investigation were that measurements obtained with the lateral scapular slide test (LSST) and a scoliometer are reliable in assessing scapular positioning or symmetry. However, a large range of error in measurements was found as indicated by the SEM, when to the parameters proposed by Kibler.\textsuperscript{1} The parameter of 1.5 cm (15 mm) as an indicator of shoulder dysfunction should be further scrutinized. The authors believe the LSST provides more objective measures than pure observation and can be enhanced by using a scoliometer or caliper rather than a tape measure.

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ABSTRACT
Swimmer's shoulder is a musculoskeletal condition that results in symptoms in the area of the anterior lateral aspect of the shoulder, sometimes confined to the subacromial region. The onset of symptoms may be associated with impaired posture, glenohumeral joint mobility, neuromuscular control, or muscle performance. Additionally, training errors such as overuse, misuse, or abuse may also contribute to this condition. In extreme cases, patients with swimmer's shoulder may have soft tissue pathology of the rotator cuff, long head of the biceps, or glenoid labrum.

Physical therapists involved in the treatment of competitive swimmers should focus on prevention and early treatment, addressing the impairments associated with this condition, and analyzing training methods and stroke mechanics. The purpose of this clinical commentary is to provide an overview of the biomechanics of swimming, the etiology of the clinical entity referred to as swimmer's shoulder, and strategies for injury prevention and treatment.

Key words. Swimmer's shoulder, injury prevention, rotator cuff.

INTRODUCTION
The shoulder complex is designed to achieve the greatest range of motion (ROM) with the most degrees of freedom of any joint system in the body. The excessive mobility of the shoulder at the glenohumeral and scapulothoracic joints is balanced by the stability of the acromioclavicular (AC) and sternoclavicular joints. At the glenohumeral joint, a complex ligamentous system contributes to primary stability and an elaborate musculotendinous system serves as secondary stabilizers. This support mechanism allows the shoulder to withstand large external forces, while providing enough mobility for the upper extremity to accomplish complex movement patterns.

Perhaps the greatest illustration of the balance between shoulder mobility and stability occurs during sports that require overhead motions. Many overhead sports such as throwing, racket sports, and volleyball require two or three overhead movement patterns. Conversely, swimming requires several overhead movement patterns, involving continuous humeral circumduction in clockwise and counter-clockwise directions. A competitive swimmer usually exceeds 4000 strokes for one shoulder in a single workout, making this sport a common source of shoulder pathology. Shoulder pain is the most common musculoskeletal complaint in swimming with reports of incidence of disabling shoulder pain in competitive swimmers ranging from 27% to 87%. The purpose of this clinical commentary is to provide an overview of the biomechanics of swimming, the etiology of the clinical entity referred to as swimmer's shoulder, and strategies for injury prevention and treatment.

SWIMMING BIOMECHANICS
Swimming requires several different shoulder motions, most being performed during circumduction in clockwise and counter-clockwise directions with varying degrees of internal and external rotation and scapular protraction and retraction. Swimming is comprised of four different strokes of varying dis-
stances, including freestyle (sometimes referred to as the crawl), butterfly, backstroke, and breaststroke. Most strokes are divided into two primary phases referred to as the pull-through and recovery. The pull-through is where propulsion is achieved and is further divided into different phases consisting of the hand entry, the catch, mid-pull, and finish or end pull-through. This section will provide an overview of swimming mechanics for each stroke related to the shoulder. For more detailed analysis of swimming biomechanics, the reader is referred to other sources.13

**Freestyle** requires a combined motion of scapular retraction and elevation, with humeral abduction and external rotation during the recovery.2 During the pull-through phase, the scapula is protracted while the humerus is adducted, extended, and internally rotated. Stroke power is achieved through the shoulder adductors, extenders, and internal rotators with the serratus anterior and latissimus dorsi being the key propulsion muscles for swimmers.2 Because the trunk is rotated away from the side that is beginning to pull, the shoulder avoids a true impingement position of forward flexion with internal rotation and horizontal adduction.

The **butterfly** has a similar motion at the shoulder as freestyle, but the stresses are different because both arms are moved through the same motion simultaneously rather than alternating. For this reason, no trunk rotation occurs so the demand of the medial scapular stabilizers and retractors during recovery is greater with butterfly than freestyle.2 In addition, the humeral head moves into an impingement position of elevation, horizontal adduction, and internal rotation at hand entry. Much of the propulsion during the butterfly comes from the hips and trunk so inefficiency of these muscle groups can lead to increased stress on the shoulders.

The motion at the shoulder during the **backstroke** is opposite to the freestyle stroke with the shoulder in retraction, horizontal abduction, and external rotation at hand entry and the beginning of pull-through. This position places increased stress on the anterior capsule. The arm position during the recovery is different than freestyle because the elbow is extended (rather than flexed). Due to trunk rotation, the swimmer is rarely flat on the back during the movement, spending more time on the side.

Movement at the shoulder during **breaststroke** can vary, with more motion occurring below the surface of the water than any other stroke. Like the butterfly, the arms are moved simultaneously through a motion that starts in full flexion with internal rotation. However, the elbows remain flexed during the pull-through until the humerus is fully adducted and brought into horizontal adduction with forearms touching each other. Unlike the other strokes, the hands never move below the hips so the tensile forces on the rotator cuff that occurs during the other strokes at the end of pull-through does not occur during breaststroke.2

**ETIOLOGY OF SWIMMER’S SHOULDER**

Most musculoskeletal conditions can be divided into macrotrauma and microtrauma based on the onset.14 A condition with sudden onset that occurs due to one specific incident usually is referred to as macrotrauma.14 Macrotrauma results from external forces and patients usually present with tissue pathology that causes associated impairments such as loss of motion, strength, and proprioception. Swimmer’s shoulder is a condition with a gradual onset due to repetitive activity and can be classified as microtrauma. Unlike macrotrauma, the etiology of microtrauma is multifactorial and may be due to intrinsic factors or extrinsic factors.

**Intrinsic Factors**

Swimmer’s shoulder usually presents as subacromial impingement involving the rotator cuff tendon, bicipital tendon, or subacromial bursa.15 Primary subacromial impingement involves compression of these structures between the acromion and greater tuberosity.16 The cause of primary impingement is usually a tight posterior or capsule (causing the humeral head to migrate anteriorly) or abnormal acromial morphology. However, primary impingement syndrome is less common in competitive swimmers than secondary impingement.

The mechanism of secondary impingement occurs through a series of impairments, usually initiating in a swimmer with increased anterior glenohumeral laxity.10,15 Shoulder ROM in swimmers is similar to that of overhead athletes, with excessive external rotation and limited internal rotation. This shift in ROM towards increased external rotation is an adjustment to the demands on the glenohumeral joint which goes through approximately 4,000 strokes daily.15 The acquired anterior laxity permits excessive external rotation, but places greater demand on the rotator cuff and the long head of the biceps to reduce humeral head elevation and anterior translation.

Failure of the rotator cuff and the scapular stabilizers to maintain the humeral head in the glenoid fossa can lead to excessive humeral head migration and either increased
tensile stress on the tendons or compression of the tendons from abutment of the humeral head on the undersurface of the acromian. The proposed mechanism of failure initiates with muscle fatigue. For example, the serratus anterior in the healthy shoulder stabilizes the scapula in upward rotation and protraction, creating adequate subacromial space for the biceps tendon and rotator cuff and maintaining good approximation between the humeral head and the glenoid fossa. During the pulling motion of swimming, the serratus anterior effectively reverses origin and insertion to propel the body over the arm, while maintaining the subacromial space and glenohumeral joint congruency. When the serratus anterior becomes fatigued, the scapula fails to protract and upwardly rotate and the subacromial space may be compromised. Additionally, the space between the humeral head and glenoid increases, contributing to more laxity.

Symptoms that develop as a result of fatigue can also affect stroke mechanics. Research has documented changes in muscle activity that occurs in swimmers with painful shoulders compared to swimmers with healthy shoulders. Many swimmers will inherently adjust their stroke to avoid painful movement patterns. For example, during early pull-through, the hand usually enters the water close to the midline with the elbow above the surface of the water. The upper extremity then continues to “reach” forward below the surface of the water towards the midline of the body. In swimmers with painful shoulders, the hand enters further away from the midline with the elbow dropped closer to the surface of the water. This change is usually made to avoid an impingement position of full elevation with internal rotation and horizontal adduction. Another adjustment occurs at the end of the pull-through phase, when the hand should be close to the thigh with internal rotation of the shoulder. In swimmers with painful shoulders, the shoulder was externally rotated and the pull-through phase was shortened to avoid impingement.

Another proposed impingement mechanism involves the microvasculature of the rotator cuff. Studies indicate that when the shoulder is abducted, the vessels of the supraspinatus and long head of the biceps are filled. Conversely, when the arm is adducted and at the side, the vascular system to these tendons is compromised. This phenomenon is referred to as a “wringing out” of the tendon, causing a temporary avascular zone 1 cm proximal to the insertion on the humeral head. This response also occurs when the humerus is adducted and flexed, a position that occurs with faulty mechanics or muscle fatigue.

Extrinsic Factors
In addition to identifying the impairments that may have contributed to swimmer's shoulder, the clinician must determine if the microtrauma is due to overuse, misuse, abuse, or disuse. Overuse in sports is performing a task with a frequency that does not allow the tissues to recover and symptoms may be due to lack of muscle strength or endurance. An example of overuse would be a swimmer increasing her yardage in a swim workout from 5000 yards to 10,000 yards per day. Misuse is using improper form or equipment, which may put abnormal stress on the tissue structures. An example of misuse is a swimmer using faulty stroke mechanics. One common error is inadequate or excessive body roll during freestyle. A swimmer with excessive body roll may cross the midline of the body during the pull through phase and this increased horizontal adduction can lead to impingement. Lack of body roll will also cause the humerus to compensate by moving into further horizontal adduction for adequate propulsion. Abuse is having excessive force going though normal tissues. An example of abuse is a swimmer who trains excessively with hand paddles, increasing strain on the shoulder. Disuse occurs when a swimmer has taken a period of time off without training resulting in atrophy or altered neuromuscular control of the stabilizing shoulder girdle musculature. In all of these cases, the tissues cannot accommodate the repetitiveness, force, or stress that is encountered with a specific activity.

PRESEASON AND CLINICAL ASSESSMENT Overview
This section will discuss key points when assessing a swimmer during a preseason physical or during the season when symptoms are present. Some individuals may be predisposed to swimmer's shoulder if they have musculoskeletal impairments or engage in improper training methods. A preseason evaluation should screen for these impairments in a similar manner as a physical evaluation used for a swimmer with symptoms. In both cases, the goal is to determine if impairments exist that could lead or have led to swimmer's shoulder. The reader is referred to other sources for a comprehensive orthopedic shoulder assessment.

During a clinical examination, information is collected in the subjective and objective assessment to determine a
potential cause and effect relationship between the tissue pathology and presenting impairments. This information may be used to set up a preventative training program or guide treatment. The exact impairments that may predispose a swimmer to symptoms or tissue pathology are not fully understood as no research has studied impairments in asymptomatic swimmers to determine which impairments were most likely to lead to swimmer’s shoulder. Most of the preventative programs are based on addressing impairments that occur as a result of developing swimmer’s shoulder.

In swimmers who have already developed symptoms, the primary complaint is usually pain in the subacromial region. These symptoms may be associated with an inflammatory condition such as tendonitis, bursitis, capsulitis, or arthritis and may be labeled as impingement syndrome. While diagnosis of these symptoms and tissue pathology may guide medical treatment of either pharmacological intervention with oral medication or injections, this treatment may not address the causative factors. Physical therapists should focus on the impairments that are associated with the onset of symptoms including glenohumeral hypermobility or instability, impaired posture, impaired rotator cuff strength, altered scapulohumeral rhythm or poor neuromuscular control, or a tight posterior capsule. Like most microtraumatic conditions, swimmers can usually not single out a specific event so the physical therapist has to discern which of these impairments or training errors may have contributed to the condition or injury. The subjective assessment may help identify the contributing impairments while the physical examination can focus on specific tests and measures to confirm this information.

**Subjective Assessment**

The subjective examination also provides information about the area, symptom description, and behavior of the symptoms in patients with swimmer’s shoulder. This information may help the clinician identify potential sources of the symptoms. For example, a patient who points with one finger to the anterior lateral aspect of the shoulder and describes a sharp pain with overhead movements may have involvement of the subacromial region or AC joint. The physical examination would need to focus on these areas. Conversely, a patient who presents with diffuse pain throughout the shoulder and upper extremity and describes burning, shooting pains may need to have a detailed evaluation of the cervical spine to rule out spinal pathology.

Other subjective information may help the physical therapist determine the appropriate amount of testing performed during the physical examination. The clinician should determine the level of irritability of a condition during the subjective examination. Irritability is characterized by three parameters: pain level, what it takes to provoke the symptoms, and the latency or time it takes the symptoms to resolve after provocation. A highly irritable condition is determined by all three factors. For example, a patient who reports symptoms with a 7/10 pain level that are brought on with lifting the arm above 90 degrees without a load and the symptoms last for several hours, has a highly irritable condition. Conversely, a patient who reports symptoms with a 5/10 pain level that comes on with lifting 200 lbs on a bench press, and last only for a few seconds has low irritability.

In swimmers, low-level shoulder pain that only occurs after heavy training and resolves quickly is low irritability. A swimmer who has high-level shoulder pain during swimming and following training for the remainder of the day has high irritability. The rehabilitation specialist must be cautious during the physical examination of a patient with high irritability because once the symptoms are provoked, results from the remaining tests and measures may be unclear.

One key element in the history is assessing the training program and methods of the swimmer. The physical therapist should determine the number of yards or meters performed in each workout, the number of workouts per week, the dry-land program, and any recent changes in training.

**Common Findings on Physical Examination**

A preseason physical or clinical examination of a swimmer with shoulder symptoms will screen for several impairments. Initial observation may reveal common postural impairments related to the shoulder girdle. A common postural deviation observed with swimmers is a forward head, rounded shoulder posture. This posture is a combination of upper quarter impairments including increased thoracic kyphosis, decreased cervical lordosis, protracted scapulae, and internally rotated/anterior humeral head. Soft tissue findings associated with this posture include restricted anterior shoulder musculature, lengthened and weak medial scapular stabilizers, tight glenohumeral posterior capsule, and weak anterior cervical flexors.
Physical examination of swimmer's shoulder will usually reveal alterations in active ROM of the shoulder, particularly at the midrange or end range of elevation. Swimmers with impingement may have a painful arc from 60-120 degrees if the head of the humerus is not maintained in the glenohumeral joint. Altered scapulohumeral rhythm may be observed with excessive elevation or upward rotation of the scapula. Kibler has presented an assessment technique to measure lateral scapular slide, by measuring the distance between the medial border of the scapula and the spine during elevation. Assessment of passive ROM will usually show excessive external rotation and horizontal abduction due to hypermobility of the anterior glenohumeral joint capsule. These swimmers will usually have a sulcus sign, a positive load and shift, a positive relocation test, and may have a positive apprehension sign. However, hypermobility determined by these tests may be the result of ligamentous laxity. Hypermobility is not instability unless the secondary stabilizers do not function adequately and symptoms occur. In swimmers with instability, weakness of the rotator cuff and scapular stabilizers will be noted. If these structures are inflamed, impingement tests will be positive and resisted tests may be painful.

If these provocation tests are positive, the clinician must rule out sources of primary impingement such as abnormal acromial morphology (through x-ray) or a tight posterior capsule. In addition, if tissue pathology is suspected by the physical therapist based on the findings in the physical examination, the swimmer may need to be referred back to the physician for additional tests. Chronic swimmer's shoulder can result in pathology of the rotator cuff, glenoid labrum, and long head of the biceps.

Address Impairments
The first step in treating swimmer's shoulder is to address any related impairments. Because the clinical presentation usually involves pain related to inflammation, initial treatments may use modalities and manual techniques, such as grade I or II mobilizations, to address pain. As pain resolves, the physical therapist should prioritize the problem list related to the symptoms. Potential common impairments that need to be addressed include postural deviations, tight anterior chest musculature, hypomobility of the thoracic spine, loss of joint mobility or excessive joint mobility, tight posterior capsule, and impaired strength and endurance of the rotator cuff and scapular stabilizers.

Posture
Postural impairments are managed through joint/soft tissue mobilization, flexibility, and strengthening/stabilization exercises of the scapular retractors and deep cervical flexors. Tight anterior shoulder musculature including the pectoralis minor can be self stretched or manually stretched. Care must be taken to avoid overstretched the anterior capsule. One method that allows the anterior chest to be stretched without overstressing the anterior capsule is to apply a low load on the anterior aspects of the shoulder using cuff weights while the patient lies supine over a bolster (Figure 1). This position allows the scapulae to retract over the bolster so the stretch is concentrated on the anterior chest musculature.

Joint Mobility
In swimmer's shoulder, posterior capsule tightness may accompany anterior shoulder laxity and should be addressed by the physi-
ophysical therapist. Posterior capsule mobilizations can be performed with the patient in supine and the shoulder blade supported in the scapular plane using a mobilization wedge or folded towel. The clinician holds the arm in mid range abduction, applies a gentle glenohumeral distraction while providing a posterior glide to the proximal humerus (Figure 2). A self stretch to the posterior capsule can also be applied by lying on the involved side with the shoulder flexed to 90 degrees. The patient applies a self stretch by applying a downward force to the distal forearm towards the plinth (Figure 3).

Scapular Stabilization
Scapular stability and proper scapulohumoral rhythm is an essential element of shoulder rehabilitation and prevention. Scapular position directly affects humeral head position and determines the length tension relationship for the rotator cuff as these muscles originate on the scapula. An unstable scapula or faulty movement patterns can change the demands on the rotator cuff muscles, potentially leading to microtrauma injuries. The physical therapist should assess the muscles essential to scapular stability such as the middle and lower trapezius, serratus anterior, and rhomboids. Scapular position and improper movement patterns are treated with a combination of soft tissue release and neuromuscular re-education to inhibit overactive, dominant muscles and facilitate weak, inhibited muscles.

Rehabilitation and prevention of swimmer’s shoulder should incorporate neuromuscular re-education and strengthening of the scapular stabilizers. Research has documented the effectiveness of different prone exercises for recruiting the scapular stabilizers. Prone scapular stability exercises are assessed by the ability to recruit targeted muscles is positions that simulate swimming. For prone exercises, the clinician should instruct the patient to maintain the scapula in retraction/depression while palpating the upper trapezius to ensure no compensation is occurring.

Figures 4-11 illustrate some common prone table exercises used for shoulder strengthening and scapular stabilization. The rowing motion is accomplished with humeral extension with elbow flexion (Figure 4). For prone extension, the patient extends the shoulder with the elbow extended and thumb facing away from the body (Figure 5). For prone horizontal abduction, the patient horizontally abducts the arm with the elbow extended and either neutral rotation or external humeral rotation (Figure 6). During these exercises, the clinician should instruct the patient to retract the scapula prior to and during the humeral motion. The patient should also know not to advance the humerus beyond the plane of the body, particularly if an injury or postoperative condition warrants protection of the anterior capsule. Figure 7 is an example of an exercise used in our clinic to recruit the lower trapezius. The patient lies prone with the humerus abducted to 150 degrees and the elbow is flexed to 90 degrees. The patient is instructed to lift the hand off the table by externally rotating the shoulder.
Figure 7. Recruitment of the lower trapezius. Lift the hand off the table by externally rotating the shoulder.

Figure 8. “Superman.”

Figure 9. “TYI Exercises.” T: Prone on mat. Retract scapulae with arms abducted to 90 degrees and humerus in horizontal abduction.

Figure 10. “TYI Exercises.” Y: Shoulders externally rotate with elbow flexed to 90 degrees.

Figure 11. “TYI Exercises.” I: Shoulders in full bilateral elevation with elbow extension.

Figure 12. Protraction of scapula.

Figure 13. Prone, supported on elbows.

Figure 14. Quadruped position.

Figure 15. Push up position.

Figure 16. Push up position; legs elevated in chair.
Figures 8 through 11 represent bilateral scapular stabilization exercises. “Supermans” are performed in prone with the elbows in full extension and the shoulders externally rotated at the sides of the body (Figure 8). The patient is instructed to retract the scapulae and lift the hands and arms off the table. Figure 9 is the first in a progressive sequence of three exercises that we refer to as TYI exercises because of the patterns formed. The patient retracts the scapulae with the arms abducted to 90 degrees and moves the humerus into horizontal abduction forming a “T”. As the patient advances, the shoulders are externally rotated with the elbows flexed to 90 degrees, forming a “Y” (Figure 10). The final exercise requires the patient to move into a position of full bilateral elevation with elbow extension, forming an “I” (Figure 11).

Scapular protraction and stabilization in the protracted position are trained through a series of exercises, starting with a supine punch. The patient is positioned supine with the arm held in 90 degrees flexion with full elbow extension and maintained in the scapular plane. During the movement, the patient is told to move the hand towards the ceiling, by protracting the scapula. Manual resistance or weights can be added to this motion as the patient advances (Figure 12). These exercises may also be used in conjunction with weight bearing exercises.

Weight bearing exercises for scapular stabilization are illustrated in figures 13-19. Exercises are advanced from prone on elbows (Figure 13) to quadruped (Figure 14) to a push up position (Figure 15). As the patient improves, the lower extremities can be elevated to increase resistance (Figure 16). A dynamic component can be added to higher level athletes who demonstrate good control with the preceding exercises. These patients can perform these exercises with the upper extremities on a wobble board (Figure 17), “walk-outs” with their upper extremities with the lower quarter on a gym ball (Figure 18), or “step-overs” using the upper extremities to “walk” up and down over a foot stool (Figure 19). A slide board is also an excellent device to use for dynamic upper extremity stabilization. Patients can be progressed from performing horizontal abduction and adduction on their knees and eventually on their toes. For these exercises, patients are instructed to maintain scapular protraction during the activity to strengthen the serratus anterior.

**Rotator Cuff Strength**

Strengthening exercises for the rotator cuff are progressed based on the presenting condition and the ability of the patient. The range of rotator cuff strengthening exercises may include isometric, concentric, eccentric, and plyometric activities. As healing allows, shoulder strengthening is initiated with isometric exercises including rhythmic stabilization drills, which are exercises to challenge a patient to maintain the upper extremity in a variety of positions while the rehabilitation specialist challenges the position with manual resistance. The exercise selection should be based on positions that do not overstress the healing tissues. This activity helps restore proprioceptive feedback to the central nervous system through mechanoreceptors of the shoulder girdle and prepares the shoulder for isotonic strengthening.

Isotonic strengthening of the rotator cuff can be accomplished with different types of resistance in different positions. Resistance can be applied manually, with resistive bands, or with weights. The advantage of using manual resistance is that the therapist can vary the resistance to accommodate the output from the patient. The advantage of using resistive bands is that the patient can perform functional movement patterns against resistance. However, these forms of resistance do not allow a clinician to quantify the amount of resistance, which is the advantage of using weights. When choosing a position for rotator cuff strengthening, the rehabilitation specialist should have a goal for the exercise. If the goal is to stabilize the scapula, exercising in supine may
be the best position because the scapula is fixed against the table. Patients can be progressed to a sidelying position to work against gravity or in standing position to simulate functional movement patterns. Patients should be encouraged to exercise in the scapular plane and the position of humeral abduction can advance to reproduce the position the arm is in during a specific sport.

Rotator cuff exercises are performed and advanced based on the available ROM. Due to the importance of the eccentric component of the rotator cuff in overhead sports, this mode of exercise should be integrated into the rehabilitation program, particularly for external rotation. The infraspinatus and teres minor contract to stabilize the humeral head by maintaining a posterior pull to counter any anterior translatory forces.

Address Training Errors
Overuse is a classic training error that occurs in swimming as athletes typically train 10-12 hours per week in the water in addition to dry-land training. Swimmers can average 10,000 yards per day of training. The high level of repetitions, estimated at 4,000 strokes per side, that occur during training sessions can cause fatigue, leading to the conditions discussed earlier. Modification of swim yardage may need to be emphasized if the swimmer wants to prevent progression of an injury.

Abuse is another training error that can occur in swimming, causing increased external stress on the shoulder. The use of hand paddles increases stress on the upper extremity by increasing surface area and resistance to movement. Kickboards put the arm in position of full elevation and internal rotation, leading to subacromial joint compression. Use of these devices should be omitted or limited for a swimmer returning from a shoulder injury.

Misuse in swimming occurs if an individual has faulty stroke mechanics. An example of improper technique is when the hand crosses the mid-line during the pull-through phases of the freestyle stroke. This motion is common in swimmers who have excessive body roll and can predispose them to impingement. Optimal body roll allows the arm to stay close to the plane of the scapula, thus reducing the stress of soft tissue structures in the anterior shoulder region. Optimal body roll also allows greater lengthening of the abdominal oblique muscles, shoulder adductors/medial rotators, and scapular retractors so that at the beginning of the pull-through these muscles have a mechanical advantage. Conversely, a lack of adequate body roll forces the recovering arm into a greater range of shoulder extension, horizontal abduction, and medial rotation in order to clear the hand from the water, causing encroachment of the subacromial space.

An important issue to consider when working with swimmers is their reluctance to stay out of the water. Although swimmers are involved in dry-land training, no suitable substitute exists for swimming. Modification of training schedules and techniques allow the patient to continue swimming, enabling the physical therapist to establish or maintain credibility with the swimmer. In extreme cases, the swimmer may need a short dry-land period to allow for adequate soft tissue healing. In these cases, the rehabilitation specialist should educate the swimmer so that the reason for the lay-off is understood. Time spent out of the water should be kept as short as possible, even if the swimmer is doing primarily kicking activities. Although returning to the water may not be ideal for rehabilitation, keeping a swimmer out of the water for a lengthy period may result in a rehabilitation program that is ignored. Activity modification in swimming may consist of the following tasks:

- Temporarily reduce training distance and frequency.
- Alter training patterns so that different strokes are used more frequently throughout the practice. This alteration will reduce the repetitive pattern at the glenohumeral and allow the muscles to function differently.
- Avoid the use of hand paddles, kickboards, and surgical tubing.
- Use swim fins to enhance the propulsion from the legs and reduce the stress on the shoulder.

SUMMARY
Swimmers shoulder is a condition that may be prevented with adequate preseason screening that can identify impairments and training errors that may lead to symptoms. If a swimmer does become symptomatic during the season, the physical therapist should identify the most likely impairments or training errors and rule out any significant tissue pathology that would warrant a referral to an orthopedic surgeon. A comprehensive rehabilitation program usually includes strengthening of the rotator cuff and scapular stabilizers, stretching anterior chest musculature that may be shortened, and implementing activity modification so the athlete can...
still participate in the sport. Future research should focus on determining if addressing specific impairments prior to the season can reduce the incidence of swimmer’s shoulder and assessing which impairments are the greatest risk factors.

REFERENCES


ABSTRACT
Preparticipation examinations are often performed based on the assumption that the exam contributes to the identification of risk factors for injury and, therefore, lead to the implementation of appropriate injury prevention strategies for athletes. Research evidence supporting the components, benefits, and limitations of the preparticipation examination performed by a physiotherapist is the focus of this paper. Evidence exists that some specific preparticipation examination components will identify known risk factors which may be addressed in the context of injury prevention strategies for that athlete. Examinations should use existing evidence-based practice to identify valid and appropriate tests examining known risk factors. Physiotherapists are encouraged to continue development, implementation, and evaluation of appropriate training techniques for the athletes to minimize their risk of injury. Physiotherapists need to be aware of athlete confidentiality issues as well as the importance of cost effectiveness of preparticipation examinations. The future of physiotherapist delivered preparticipation examinations may lie in the utilization of an evidence-based approach to risk factor identification, development and evaluation of prevention strategies, and development and evaluation of performance enhancement strategies for the athlete.

Key words. Preparticipation exam, screening, prevention.

INTRODUCTION
A preparticipation examination, also called a pre-season examination or a screening examination was original described in 1978. The intent of this examination was that it would (i) fulfill the athlete’s institution legal and insurance requirements, (ii) assure the coaches that team members would start the season with some common level of health and fitness, (iii) provide the medical team with the opportunity to discover treatable conditions that might interfere with or be worsened by athletic participation, (iv) potentially aid in predicting/preventing future injuries, and (v) be appropriate for all sports. A musculoskeletal version of the original preparticipation examination is often performed annually by physiotherapists working with athletic teams to anticipate and preclude physiological and biomechanical problems for athletes prior to the commencement of a sport season. As such, the ultimate goal of such a preparticipation examination is injury prevention. Additional and parallel objectives to injury prevention include assurance of optimal musculoskeletal health, to optimize performance (physiological and biomechanical), to develop a professional relationship with the athlete and to educate the athlete. Ideally, a preparticipation examination should also make it possible to identify the factors common to athletes with great performances which would facilitate the identification of such factors in other athletes.

Research evidence supporting the preparticipation examination performed by a physiotherapist is the focus of this paper. This paper will not discuss the medical screening or preparticipation evaluation of athletes that is often performed by physicians to ensure optimal medical health for sport participation despite underlying medical conditions (i.e. asthma, diabetes, menstrual dysfunction, depression...
sion), to review medications and vaccinations, and to prevent sudden death of the athlete.12

Definition and Role of the Preparticipation Examination
Preparticipation examinations are performed based on the assumption that they can enhance performance of the athlete and identify potentially modifiable risk factors for injury. Modifiable risk factors are those that can potentially reduce injury rates through the implementation of injury prevention strategies.11,13 Evidence exists that modifiable risks, such as, decreased levels of sport specific training in the off season, endurance, strength, and balance do increase the risk of injury in sport.14-22 Non-modifiable risk factors are those factors that can not be altered to reduce injury rates through the implementation of injury prevention strategies.11,13 Examples of a non-modifiable risk factor would be age, gender, and previous injury. An ideal preparticipation examination system applicable to all sports does not exist, although there are examples of sport-specific preparticipation examinations. A comprehensive examination should identify the sport-specific biomechanical and physiological requirements for training and competition, as well as when these requirements exceed the athlete's ability to perform.2-4,10,11 Additionally, the examination should be capable of detecting possible biomechanical and physiological deficits that might be a precursor to injury.2,4,10,11 Upon recognition of potentially modifiable risk factors by the physiotherapist, sport-specific injury prevention strategies can be implemented to reduce such risks.2,4,10,11

Identifying Risk Factors for Injury
The injury prevention model developed by vanMechelen et al23,24 suggests that the incidence and severity of sport injury need to be established prior to identifying risk factors for injury. Sport injury prevention strategies may be developed and evaluated if a good understanding exists of injury rates, the participant population at risk, and the risk factors associated with injury for this population.11,10,13

Sport injury risk factors are defined as those entities which contribute to the occurrence of athletic injury.11,13 Both intrinsic (i.e. decreased strength, previous injury) and extrinsic factors (i.e. shoes, equipment) that may increase susceptibility to injury should be identified prior to the occurrence of an injury-inciting event.13 Further, Bahr and Krosshaug26 identified the importance of recognizing that one or more factors (i.e. biomechanics, playing situation, player/opponent behaviour) may generate an injury-inciting event. An understanding of sport-specific mechanisms of injury will facilitate the identification of potential risk factors during the preparticipation examination and subsequent delivery of appropriate and sport-specific injury prevention strategies.

The use of validated sport-specific injury surveillance will assist the therapist in identifying risk factors and their component biomechanical and physiological aspects contributing to injury in that sport.27 Given the limited evidence that exists identifying sport-specific risk factors for injury using adequate sport-specific injury surveillance, the support for injury prevention strategies is often based on anecdotal evidence.24 In a systematic review of the literature regarding prevention strategies for injury in sport at any age, MacKay et al25 concluded that very few well designed prospective studies exist. In order for the physiotherapist to provide the most appropriate, evidence-based preparticipation examination, they must stay current with the research identifying sport-specific risk factors and injury prevention strategies pertinent to their athletes. Desirable features of the preparticipation examination include valid and reliable measurement of these risk factors in order to assess the athlete's risk of injury as well as to compare the athlete's test results within a sport in a given year, across years, and with other sports.

Who is Using Preparticipation Examinations?
Judging from informal discussions with coaches, athletes, and support personnel (in various sports communities around the world) as well as reports in the literature, it would appear that most elite teams and many university and high school based teams are using some form of preparticipation examination.12,10,13 Examples of the use of physiotherapist delivered preparticipation examinations include football and triathlon teams in the United Kingdom.3 In these examples, teams had a complete physiotherapy assessment of every player that included flexibility, range of motion, balance, and core stability tests. These tests provided a baseline measurement of the musculoskeletal status of the athletes and enabled the physiotherapist to plan specific training and injury prevention programs tailored for individual players. In addition, a preparticipation evaluation by a physician is critical but beyond the scope of this paper.12

Components of the Preparticipation Examination
Although no standard examination has been identified across sports, certain consistencies exist among these examinations. Based on the literature and informal discussions with health care professionals monitoring other
sport teams, preparticipation examinations consistently include athlete questionnaires, standard neuro-musculoskeletal examinations, and some form of functional testing. A good preparticipation examination should be accurate, practical in order to apply to a large number of subjects, and testing procedures must be safe and acceptable to most individuals. A preparticipation examination should be performed in a 45 minute time frame, similar to the time allotted for a physiotherapy assessment in the sport medicine setting. An example of a format used for preparticipation assessment for elite athletes can be found in Appendix A.

Despite the limited consistency among preparticipation examinations, the importance of musculoskeletal screening is evident in the fact that athletes frequently resume full athletic participation following a significant injury with considerable deficits in strength, range of movement and proprioception. Consistent evidence exists that one of the most likely predictors of injury is a previous injury. Therefore, any post injury deficits should be fully assessed with a goal of designing a rehabilitation program to restore full function. Such an assessment should include an athlete questionnaire that identifies the nature and date of any previous injury; lists any residual problems; describes the nature, date, and symptoms of any current injury; as well as any past or current treatment received for these injuries. For example, identification of previous injury (i.e. ankle sprain) and providing appropriate prevention strategies (i.e. wobble board training) will reduce the risk of recurrent injury.

There is evidence that muscle strength ratios are an individual risk factor for a particular injury in athletes. The standard neuro-musculoskeletal examination which tests for strength in the form of isometric, concentric, or eccentric testing contribute to the identification of such strength ratios. The standard neuro-musculoskeletal examination should also include a neurological examination, active and passive range of motion testing, articular testing in the form of joint glides, muscle recruitment testing (especially around the torso and pelvis), static and dynamic postural and balance investigations, and appropriate functional tests. For example, Gabbe et al. provide evidence that Australian Football players with increased quadriceps flexibility (as measured by the modified Thomas test) were less likely to sustain a hamstring injury. Evidence also exists to support investigation of torso and core strength with regard to lower quadrant injury prevention as well as injury reoccurrence. Improving balance has been shown to be important in injury prevention in sports such as soccer. Additionally, Trojan et al. demonstrated the ability to predict ankle sprain injury with a positive single leg balance test in high school and varsity athletes. Validated testing methods for the preparticipation examination should always be used. For torso strength, for example, two validated testing methods exist: a) modified double straight leg lowering test and b) flexor endurance test. It is strongly suggested that neuro-musculoskeletal screening assessments be particular to the sport the athletes are involved in. For example, sports with high risk of specific joint or muscle injuries (i.e. swimmers’ shoulders, pitchers’ elbows) should have specific assessments performed on these areas. Many validated orthopaedic tests for various regions of the body can be found in medical and physiotherapy textbooks and should be used for the preparticipation examination (i.e. Patrick’s test for examining hip range of motion).

Many functional performance tests exist and are commonly recommended for inclusion in a preparticipation examination (i.e. sit-ups, push-ups, endurance runs, sprints, and agility activities). For example, Hewitt et al. demonstrate the identification of high-risk landing force profiles in youth athletes using a functional box drop vertical jump test. It is suggested that not only the clinical test outcome be scored (i.e. sit-up repetitions) but also the form and efficiency of the underlying functional movement involved in the test. For example, taking note of the weight that an athlete can hold during a lunge test and how the athlete’s body was aligned during the test. Scoring such function can be challenging as few validated systems exist. The examiner is advised to develop scoring methodologies and submit this scoring method to future research scrutiny.

Additional Benefits of the Preparticipation Examination
In addition to potential injury prevention and performance enhancement, the preparticipation examination allows the physiotherapist additional opportunities. This examination provides an opportunity for the physiotherapist to commence their professional relationship with the athlete. This relationship allows the physiotherapist to educate the athlete on issues such as injury prevention (i.e. importance of core strength, stretching, warm-up), immediate injury management (i.e. RICE management for acute inflammation), and appropriate equipment use (i.e. helmets, mouth guards, shin pads). The examination enables the physiotherapist to become fully aware of the athlete’s past history and gives them insight into the
athlete’s physical, mental, and emotional state. Additionally, the athletes are typically given the opportunity to discuss any pertinent issues with the physiotherapist.

**Limitations with the Preparticipation Examination**

Many limitations exist with the current state of the physiotherapist delivered preparticipation examination. As with any preparticipation examination performed by health care professionals, often no uniformity of protocols is used. As a result, concrete recommendations concerning the findings from a preparticipation examination are lacking and are often attributed to (i) the lack of consensus regarding the threshold for abnormality, (ii) the unavailability of data indicating the predictive value of specific physical ‘abnormalities’ for injury, and (iii) the lack of definitive proof that corrective interventions alter outcome. Extensive examinations are often performed with various resultant recommendations, but frequently no follow-up occurs. Literature and clinical experience suggest follow up at 6 weeks to ensure that the recommended actions have been taken.

The extent of the examination is limited by financial and time constraints. The examinations are time consuming for both the athlete and the examiner leading to potential compliance issues from the athlete. The time consuming nature of the preparticipation examination can potentially interfere with the time available to treat athletes. As such, the physiotherapist may have to prioritize the most essential components of the examination based on the sport-specific requirements for each athlete. Overall, if the process is to be cost-effective then it has been suggested that it needs to be regularly audited and evaluated.

Reliability issues are of primary concern with multiple examinations performed by health care professionals from different disciplines (i.e. athletic therapist, physiotherapist, chiropractor, medical doctor) or other support team members (i.e. strength trainer, physiologist) on the same athlete or by different examiners on different athletes within a team. Smith and Laskowski recognize that in order to integrate the history and physical examination components of a preparticipation examination, one requires a substantially higher level of knowledge and skill on the part of the examiner. Therefore, the task may be impractical, especially at the high school and youth sports levels that are utilizing non-medical trained personal.

Confidentiality is a very important issue to consider. Individuals within the specific sport organization (i.e. athlete, coach, physician) and outside the sport organization (i.e. National Olympic Committee) who have access to the data from the preparticipation examination must be clearly identified. Some health care professionals suggest that the traveling athlete should have a medical passport (i.e. hard copy or electronic record) containing all relevant information to ensure complete communication of the athlete’s medical information to all involved in their care.

**CONCLUSION**

Preparticipation examinations are often performed based on the assumption that they contribute to the identification of risk factors for injury, and therefore, lead to the implementation of appropriate injury prevention strategies for athletes. However, despite evidence identifying some specific risk factors for injury that may be identified in a preparticipation examination, little global evidence exists supporting the use of preparticipation examinations to reduce injury rates among athletes. Identification of previous injury (such as ankle sprains) and providing appropriate prevention strategies (such as balance training) has been shown to reduce the risk of recurrent injury. There is also evidence that some specific preparticipation examination components will identify known risk factors (i.e. specific strength, flexibility, balance tests) which may be addressed in the context of injury prevention strategies for that athlete. However, much needed research to further validate specific components of the preparticipation exam and provide further evidence for identification of sport-specific risk factors is needed. Currently, physiotherapists rely on the examples supported in the literature for injury prevention in conjunction with their clinical expertise and judgment within their own team practices. The future of physiotherapist delivered preparticipation examinations may lie in the utilization of an evidence-based approach to risk factor identification, development and evaluation of prevention strategies, and development and evaluation of performance enhancement strategies for the athlete.
REFERENCES


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APPENDIX A
PRE-PARTICIPATION PHYSIOTHERAPY ASSESSMENT

Athlete to please fill out the following: Date: _____________
Name: __________________________ Address: _______________________
Phone No: __________ Age: _______ Physician: ____________________________ Physician Phone No: __________
Sport: ___________________________ Level of Completion: ___________________________
Distance: _________________________ Number of Years Completing: ___________________________
Coach(s) Name: ___________________________ Coach(s) Phone No: __________

Past Medical History: (list injury, date and percentage of recovery)
Fractures: ____________________________________________________________
Surgery(s): __________________________________________________________
Sprains/Strains: ______________________________________________________
Car Accidents: _______________________________________________________
Illness / Hospitalization: ______________________________________________
Other: _______________________________________________________________

Past Treatment: (list injury, date treated, name of practitioner & also indicate if treatment ongoing)
Physiotherapy: _______________________________________________________
Chiropractor: _______________________________________________________
Acupuncture: _______________________________________________________
Athletic Therapy: ____________________________________________________
Massage: ___________________________________________________________
Other (medical tests such as blood work, x-rays, ect): _______________________

Present Injury(s) & Present Treatment:
________________________________________________________
________________________________________________________
________________________________________________________
________________________________________________________

Medications / Supplements:
________________________________________________________
________________________________________________________

Braces / Orthotics / Splints Usage:
_________________________________________________________________

Map of Symptoms (grade pain 0-10/10)

PT Initial: _____
**Physical Examination**

**Posture:**

<table>
<thead>
<tr>
<th>Functional Tests:</th>
<th>Palpation Findings:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sit-stand-sit:</td>
<td>Tender ○</td>
</tr>
<tr>
<td>Heel raise:</td>
<td>Painful ●</td>
</tr>
<tr>
<td>Vertical jumping:</td>
<td>Stiff X</td>
</tr>
<tr>
<td>Tuck jumping:</td>
<td>Spasm 🎃</td>
</tr>
<tr>
<td>Lunge: right fwd</td>
<td>Tightness III</td>
</tr>
</tbody>
</table>

**Range of Motion**

**TMJ**

PPM:

PAM:

Compression:

Stress Tests:

- Anterior:
- Inferior:
- Other:

**Ribs**

AROM:

CTJ Stress Tests:

- Anterior:
- Inferior:
- Other:

**SIJ**

Gillet's:

- Stance leg:
- Nonstance leg:

- Hip Ext: Standing: Prone:
- Fwd / Bwd Bend:

- ASLR:
  - Form closure:
  - Force Closure — TA
  - Mult
  - Lat
  - Glut

- MRecurit:
  - Crookly hip flex:
  - Prone hip exten:
  - Sidehip hip exten:

- MRecruit:
  - Scapular Control:
  - Other:

**Lsp**

PPIVM:

PAIVM:

Stress Tests:

- Passive / Dynamic
  - Ant:
  - Post:
  - Lat:
  - Rot:
  - Comp:
  - Traction:

- Alar:

- VA tests:

- MRecruit: (rep's/qual/dur/measurement)

- DNF Supine:

- Other:

**Neuro Conductivity:**

**Upper / Lower Quadrant**

Dermatomes:

- Light Touch
- Sharp / Dull
- Temperature:

- Myotomes:

- LMN Reflexes:

- Clonus:
- Babinski:
- Cranial Nerves:

**Pulses:**

**PT Initial:** _____
# Peripheral Joints

<table>
<thead>
<tr>
<th>Shoulder:</th>
<th>Elbow:</th>
<th>Name:</th>
</tr>
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<tbody>
<tr>
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</tr>
<tr>
<td>PROM:</td>
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<td>Sup:</td>
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<tr>
<td>IR: 0°</td>
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</tr>
<tr>
<td>ER: 0°</td>
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<tr>
<td>90°</td>
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<tr>
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<td>Combined:</td>
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<tr>
<td>Quadrants:</td>
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<td>HBH:</td>
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<tr>
<td>Horz Add:</td>
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</tr>
</tbody>
</table>

**Observation and Palpation:**

**Stress Tests:**

**PAM:**

**Special Tests:**

**Muscle Recruitment:**

(reps’/quality/duration/measurement)

**Muscle Recruitment:**

(reps’/quality/duration/measurement)

# Elbow:

## Hand 

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Description</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pron</td>
<td>Pronation</td>
<td></td>
</tr>
<tr>
<td>Sup</td>
<td>Supination</td>
<td></td>
</tr>
<tr>
<td>Combined</td>
<td>Quadrants</td>
<td></td>
</tr>
</tbody>
</table>

**Observation and Palpation:**

**Stress Tests:**

**PAM:**

**Special Tests:**

**Muscle Recruitment:**

(reps’/quality/duration/measurement)

**Thomas Test:**

**Ham’s Tripod:**

---

**PT Initial:** ___
Digital and Video Analysis / Comments:

Name: __________________________
Date: __________________________

Clinical Impression / Key Points Identified: __________________________

Suggestions for Coach / Strength Trainer: __________________________

Contraindications to treatment:

Rationale for possible pathology given to patient
Rationale for treatment given to patient
Patient gave consent for assessment, future assessment and treatment

Treatment Given:

Treatment Plan:

Consent for sharing information with coaches, trainers, team medical personnel on file: Yes___ No___

Therapist____________________________
physical therapists regarding their practices with athletes. For the purposes of this article, the sport of ice hockey is used to illustrate the subject matter and highlight some of the behaviors in sport that carry CV risk.

**EPIDEMIOLOGY OF CARDIOVASCULAR RISK IN ATHLETES**

A competitive athlete has been defined as “one who participates in an organized team or individual sport that requires competition against others as a central component, places a high premium on excellence and achievement, and requires some form of systematic training.” Given this definition, the primary negative CV events precipitated by exertion reported in the literature are acute myocardial infarction (AMI) and sudden cardiac death (SCD). Thompson and his colleagues reported in 1982 that SCD was seven times more likely during jogging than at rest with one death annually for every 15,240 healthy joggers. Similarly, in 1984 Siscovick et al documented one cardiac arrest each year for every 18,000 healthy men and that the risk was greatest for the habitually least active subjects. In 1993, Mittleman et al and Willich et al provided supporting evidence of the increased risk of AMI with vigorous exercise and that the risk was greatest for the least active individuals. Finally, Van Camp et al, in 1995, estimated the risk of SCD among young athletes as one in every 133,000 males and 770,000 females annually. They cited the US National Center for Catastrophic Sports Injury Research which reported 160 nontraumatic athlete deaths in high school and college organized sports between July 1983 and June 1993, of which 88% were of cardiac etiology. The estimated incidence of sudden death in this group was 7.47:1,000,000 per year in males and 1.33:1,000,000 in females. In athletes over 35, McGrew summarizes estimates of the frequency of SCD as 1:15,000 to 1:50,000 annually. Of note is

**ABSTRACT**

Although acute myocardial infarction and sudden cardiac death are relatively rare occurrences in athletics, cardiovascular accidents do occur. This manuscript presents information on the cardiovascular risks in athletics. In addition, information is provided on screening for cardiovascular risk – including history taking, chart review, physical examination – and the appropriate guidelines on the treatment of athletes found to be at risk. For the purpose of this article, the sport of ice hockey is used to illustrate the subject matter and highlight the behaviors in sport that carry cardiovascular risk. Physical therapists have ethical and legal responsibility to undertake the necessary screening procedures to recognize and respond to any signs of cardiovascular risk in their clients.

**BACKGROUND**

The debate regarding the cardiovascular (CV) risks and benefits of vigorous exercise and physical competition has appeared in the literature since ancient times. The benefits of exercise in decreasing all-cause morbidity and mortality in adolescents and older adults hypothesized centuries ago are now well known and well documented. The questions for the physical therapist (PT) are: ‘What are the CV risks in athletes?’, ‘Can those risks be mitigated?’, and ‘Should those risks be mitigated?’ As with all clinical research, the need exists for more prospective, large, randomized control trials to solidify the answers to these questions. The current state of the literature and the consensus of leading researchers, clinicians, and organizations across the world is sufficient to provide strong answers and to make sound recommendations to
that these data are likely underestimates of the true prevalence of sports-related AMI and SCD because many of the retrospective studies have relied on institutionally reported rates. Unlike the relative risk these authors have reported, the absolute risk that an acute CV event will occur during vigorous exercise in a healthy population has been estimated to be between 1 in 500,000 and 1 in 2,600,000 hours of exercise.\textsuperscript{8,11}

**PATHOGENESIS OF EXERTION-RELATED CV EVENTS**

The cause of exertion-related cardiovascular complications correlates with the athlete's age, with coronary atherosclerosis being the most frequent finding in individuals over the age of 35 to 40 after SCD.\textsuperscript{8} Conversely, inherited structural CV abnormalities are the major cause of SCD during exercise in younger athletes.\textsuperscript{1,7,10-17} These silent CV diseases predominantly consist of cardiomyopathies, premature coronary artery disease, and congenital coronary anomalies including anomalous coronary artery anatomy, arrhythmogenic right ventricular cardiomyopathy, myocarditis, conduction system abnormalities, and Marfan Syndrome.\textsuperscript{16} In the majority of United States reports, hypertrophic cardiomyopathy is documented as being the primary congenital or inherited CV disease linked to SCD in sporting activities accounting for more than one third of deaths.\textsuperscript{17} It is not the CV abnormality that causes the event but the combination of the physiological changes occurring during exercise and the abnormality. Although the mechanisms of exercise-related AMI and SCD are beyond the scope of this paper, suggested sequelae of these physiological alterations are decreased coronary perfusion, increased myocardial irritability, and altered myocardial conduction.\textsuperscript{8}

**CARDIOVASCULAR RESPONSES IN ICE HOCKEY**

**Game Characteristics of Ice Hockey**

Hockey originated in Ireland as a field game using a ball and stick called Hurley. In Canada, when the winter arrived, the game moved to the ice and the ball was replaced by the puck. The word “hockey” is probably derived from the French hoquet (“shepherd's crook”), referring to the shape of the stick.\textsuperscript{18} Hockey is now Canada's national game and played seriously, at recreational and elite levels, in 20 countries. The game involves five active skaters on each team covering a 200' by 85' ice rink surface. Most elite competitive games are played in climate controlled arenas whereas, recreational games may be indoors or, alternatively, on outdoor rinks in a wide variety of weather conditions. For protection, players in all venues wear substantial gear with full body coverage. Game play is for 3 periods of 20 minutes each. The nature of the game of hockey is to have the players take 1.5-3 minute shifts of high intensity skating on the ice and 2.0-5.0 minutes off the ice throughout the 60 minutes of play. Each period is also separated from the next with a 15 minute break in play. These bouts of intermittent exercise followed by stationary rest periods have been studied specifically in ice hockey by a handful of published researchers to determine the physiological and morphological myocardial adaptations as well as the demands on the CV systems of the athletes.\textsuperscript{19,24}

**The Elite Hockey Player**

Elite ice hockey players present with an increase in left ventricular (LV) cavity size, wall thickness, and mass, as well as a reduction in resting heart rate (HR) and blood pressure (BP). These findings are typical of a combination of sports requiring predominantly sprint work (wall thickness) and endurance work (cavity size).\textsuperscript{19,25} Physiologically, using the Fick Equation \[ \text{VO}_2 \text{max} = \frac{Q \times \Delta \text{vO}_2}{\text{min}} \], where endurance capacity (\text{VO}_2 \text{max}) is the result of cardiac output (CO = Q) and the ability to extract oxygen (\Delta \text{vO}_2) and where CO is the result of left ventricular stroke volume (SV) times heart rate, in the hockey player it appears that an increase in SV is the method for increasing CO for play. Conversely, in control groups of healthy age matched peers, the increased CO is primarily derived from an increase in HR.\textsuperscript{19} In both groups an increase in \text{aVO}_2 \text{difference} occurs but the increase is greater in the elite hockey players.\textsuperscript{19} In addition, ice hockey is often described as an anaerobic sport, a fact supported by Bossone et al\textsuperscript{16} in their study of elite college ice hockey players who noted their requirement to tolerate anaerobic debt.

An analysis of the CV demands involved in playing ice hockey, and similar intermittent exercise sports, is performed by measuring the intensity of the CV workload at any given time during play, rest, and into recovery. Exercise at moderate intensities of 50 to 70% of oxygen uptake reserve (\text{VO}_2 \text{max} - \text{VO}_2 \text{rest}), 60 to 80% heart rate reserve (HRR= HR\text{max} - HR\text{rest}) or 70 to 85% of age-predicted maximum HR (HR\text{max}) have been widely demonstrated to be safe and beneficial.\textsuperscript{20,26} The American College of Sports Medicine (ACSM) estimates maximum predicted HR in a healthy population as HR\text{max} = 220 - age in years in beats per minute(bpm).\textsuperscript{26} The ACSM and Canadian Association of Sports Sciences both advocate target heart rate zones for training that do not exceed 85%
of predicted $\text{HR}_{\text{max}}$ in healthy populations. Yet, authors report that these hockey players frequently exceed 85% of both measured and predicted $\text{HR}_{\text{max}}$ during bouts of play on the ice for between 10-30% of on-ice time, with their HRs returning to below 60% $\text{HR}_{\text{max}}$ during rest. Perhaps as interesting, a finding in a study of elite women hockey players by Spiering et al indicated that these players experienced significantly greater CV load during game play than during practice (mean working HR during the game 90 +/- 2%, during practice 76 +/- 3%; mean percent session time >90% $\text{HR}_{\text{max}}$ during the game 10.5% +/- 4%, during practice 5.6 +/- 3.5%). Further, Paterson’s literature search suggested a reduced efficiency of the thermoregulatory system in intermittent exercise, placing added demand on the CV system.

**Adult Recreational Hockey**

The most widely cited study of adult recreational ice hockey is the 2002 *Hockey Heart Study* conducted as a descriptive, cross-sectional study of male players in Sydney, Nova Scotia (n=113; average age 42.7 +/- 6.9). All subjects were over 35 years of age and were without known CV diseases or abnormalities. Atwal et al assessed participant symptoms, HR, heart rhythm, and electrocardiogram (ECG) changes. In 100% of subjects, $\text{HR}_{\text{max}}$ during play was greater than target exercise HR, calculated as 55-85% age-predicted $\text{HR}_{\text{max}}$(mean 184 +/- 11). The mean duration of these elevated HRs was 30 +/- 13 SD minutes. In addition, for 70.1% of data sets, HR recovery was poor, dropping as little as 4 bpm in the first minute of recovery when a drop of >12 bpm is correlated with lower CV risk. Also of concern were the recordings of non-sustained ventricular tachycardia from two monitoring sessions and ST-segment depression indicating myocardial ischaemia in data from 15 sessions. Symptoms reported while playing hockey included one report each of shortness of breath, palpitations, and chest pain or heaviness. No incidents of AMI or SCD were reported. Another finding of these particular recreational hockey players was that, although the authors reported a few risk factors present in adult recreational hockey players, no association existed with ischaemic heart disease and sudden death. In his published commentary of the study and recreational hockey, Mittleman stated that the participants had not received adequate primary prevention. Yet, despite elevated cholesterol levels (52.8%) and strong family histories of CV disease (41%), over 60% of the participants did exercise ≥3 times per week (excluding hockey) and were not considered sedentary. This exercise history appeared to have a substantial protective effect considering the risk of an AMI or SCD triggered by vigorous exertion is approximately 50 times higher among sedentary people.

**RATIONAL FOR CLIENT PRE-SCREENING FOR CARDIOVASCULAR RISK**

**Cardiovascular Risk Levels**

Ice hockey is a sport requiring high intensity CV workloads for short bouts of intermittent exercise with maximum HRs exceeding current guidelines of ≤85% of $\text{HR}_{\text{max}}$ for a large percentage of the time spent on-ice. This intensity translates into an elevated relative risk level of 2-2.5 fold. In absolute terms, though, the risk is extremely low. Despite this fact, clinicians must recognize that one CV event or one death is a result that must be avoided if at all possible. The risk in individuals under the age of 35 correlates with undiagnosed cardiovascular abnormalities such as hypertrophic cardiomyopathy or premature atherosclerosis. In individuals over the age of 35 the strongest correlations with risk are the incidence and degree of CV risk factors such as hypertension, smoking, dyslipidemias, sedentary lifestyle, diabetes, central obesity, and elevated body mass index (BMI).

**Physical Therapist’s Legal And Ethical Liability**

Physical therapists across North America are now primary care practitioners in many jurisdictions giving the public direct access to our services. With this right comes an ethical and legal responsibility to screen for any risks associated with the initiation of, or return to, sport. This responsibility becomes especially true when the possible outcome is as extreme as a CV event or death. Further, the principle of beneficence held by the PT as a primary ethical foundation suggests that the access to athletes and the knowledge base and scope of practice allow the PT to determine their CV risk and take that information to mitigate that risk through education, training and rehabilitation.

**CARDIOVASCULAR EVENT PREVENTION Screening for Cardiovascular Risk**

Recognizing and mitigating CV risk by physical therapists takes two forms: (1) the assessment and (2) training...
regimes, including coaching and athlete education. A screening process should have target outcomes that have a significant impact on morbidity and mortality and should be accurate, practical to apply, and relatively low in cost. A PT history taking and physical assessment of athletes of every level can meet all of these goals (Figure 1).

Physical Therapy Assessment: History Taking and Chart Review
The components of a PT history taking that are key to documenting increased CV risk related to both (i) discovering the non-modifiable and modifiable known CV risk factors (Table 1) and (ii) getting an accurate symptom and event history. The modifiable CV risk factors include: hypertension, smoking, dyslipidemias {low high density lipoprotein (HDL) levels or elevated cholesterol, total cholesterol/HDL ratio, triglycerides, and low density lipoprotein (LDL) levels}, sedentary lifestyle, diabetes mellitus (DM), depression, central obesity, and elevated body mass index (BMI). Although international guidelines may vary somewhat in target values of some of the risk factors, strong consensus exists on healthy ranges. Of note is that individuals of a lower socioeconomic bracket are

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**Figure 1:** Physical Therapy Assessment and Intervention Algorithm for Ice Hockey Athletes

[Diagram showing the algorithm for assessment and intervention for ice hockey athletes.]

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also known to have a greater incidence of atherosclerosis, CV, and cerebrovascular events. If any single modifiable risk factor is borderline or exceeds recommended levels, the PT should communicate the findings to the client's family physician. The PT may also make direct referrals to clinicians whose scope of practice addresses any one or more key risk factor.

<table>
<thead>
<tr>
<th>CV Risk Factors for the Development of Atherosclerosis (Target Definitions)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-modifiable:</strong></td>
</tr>
<tr>
<td>1. advancing age (VO₂max decreases ~ 10% per decade)</td>
</tr>
<tr>
<td>2. male sex</td>
</tr>
<tr>
<td>3. ethnicity (Canadian First Nations, South Asian, African American, African Caribbean, Mexican American)³²,³⁴,³⁵</td>
</tr>
<tr>
<td>4. family history (premature deaths, vascular disease in surviving relatives)</td>
</tr>
<tr>
<td>5. genetic factors</td>
</tr>
<tr>
<td><strong>Modifiable:</strong></td>
</tr>
<tr>
<td>1. tobacco smoking (any exposure)</td>
</tr>
<tr>
<td>2. physical inactivity (&lt; 30 to 60 minutes moderate exertion most days of the week;²⁶ &lt; 1.5 kcal/kg body weight/day⁴⁵)</td>
</tr>
<tr>
<td>3. over-weight (&gt; 25 BMI); obesity (&gt;30 BMI)*</td>
</tr>
<tr>
<td>4. increased waist circumference- central obesity ( &gt; 90 cm; &gt; 100 cm)*</td>
</tr>
<tr>
<td>5. excessive alcohol consumption (&lt; 2/day; _&lt;9/week, _&lt;14/week)</td>
</tr>
<tr>
<td>6. hypertension (&lt;140/90 mmHg in the absence of co-morbidities)*</td>
</tr>
<tr>
<td>7. dyslipidemia (total cholesterol &gt; 5.0 mmol/L; LDL &gt;2.5 mmol/L; HDL _&lt; 1.3 mmol/L, _&lt; 1.0 mmol/L); total cholesterol HDL ratio &lt; 4.0; triglycerides &lt; 1.7 mmol/L)*</td>
</tr>
<tr>
<td>8. diabetes mellitus (fasting blood glucose 6.0 mmol/L; 2-hour post-prandial &lt; 7.8 mmol/L)*</td>
</tr>
<tr>
<td>9. depression</td>
</tr>
<tr>
<td>* Metabolic Syndrome is a cluster of three or more specific risk factors that increases overall CV risk</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Emerging Risk Factors / Markers of Vascular Disease:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. C-reactive protein (high sensitivity) – inflammatory marker (&gt;1.0 mg/L)</td>
</tr>
<tr>
<td>2. lipoprotein(a) – lipid related factor</td>
</tr>
<tr>
<td>3. fibrinogen – haemostosis thrombosis marker</td>
</tr>
<tr>
<td>4. homocysteine - other</td>
</tr>
<tr>
<td>5. erectile dysfunction</td>
</tr>
</tbody>
</table>

The symptoms (Table 2) most closely related to atherosclerosis are angina (chest discomfort or heaviness; aching in the chest, neck or jaw; radiation into the shoulder or arm), shortness of breath, palpitations or irregular heart beat, dizziness, nausea, lightheadedness, and diaphoresis (heavy perspiration). Individuals may not initially report these symptoms but when they reveal that they are not as active as they were five years earlier, the clinician may be able to probe more specifically to determine if the reason is the avoidance of one or more of these symptoms. The clinician should also note if the client has a history of calf discomfort with exertion that resolves with rest possibly suggesting peripheral arterial disease or claudication.
Primary Symptoms of Myocardial Ischaemia

1. chest discomfort or heaviness (angina)
2. aching in the neck or jaw, radiation into the shoulder or arm
3. shortness of breath (dyspnea)
4. irregular heart beat (palpitations)
5. dizziness, lightheadedness
6. nausea
7. diaphoresis (heavy perspiration)

Table 2: The symptoms most closely linked to a decreased myocardial oxygen supply due to atherosclerosis.

Mitigation of Risk

Several components exist for minimizing CV risk when undertaking any sport, but this reduction in risk is especially true of sports, such as ice hockey, involving high intensity bouts of intermittent exercise, including the following:

Training. Training regimes must include aerobic training at moderate to high intensities 3 to 5 times per week to optimize VO2max. In addition, practices must incorporate periods of high intensity exercise of similar duration to those encountered in game play. Athletes should be charged with self-monitoring shifts on and off the ice. Athletes should also spend 2-3 sessions on resistance training for the primary muscles used on the ice.

Pre-game preparation. Athletes should take a dietician’s advice on nutritional needs for play but should recognize the risk of any significant intake of solid foods within one hour of a practice or game due to the high oxygen cost of digestion. To decrease cardiac workload from vascular resistance through vasodilation and to promote increased CO, athletes should warm-up by performing continuous aerobic exercise for 8 to 20 minutes prior to play. Pre-game hydration is also important in preparation for myocardial and skeletal muscle cell elevated metabolism during play. Dehydration can cause a significant increase in workload on the heart causing elevated heart rates and body temperature, lowered BP, and up to a 50% loss in performance. To avoid over-heating, players must consider their clothing and gear from the perspective of the temperature of the arena on the day of play.

During the practice or game. Players must avoid an abrupt drop in HR and BP when coming off the ice to avoid situations where myocardial oxygen supply does not meet demand, as well as to ensure they are ready for the next bout on-ice. To do this the player can remain standing and perform intermittent static or dynamic muscle contractions of the large muscle groups of the body. Hydration remains vital. Any signs or symptoms of CV deficit must be noted and reported. Players must also recognize any signs of over-heating and take action to cool themselves down (cold applied to the neck or wrists, removing gloves).

Immediately following the game. Players need to allow 12 to 20 minutes to let their HR and BP to decrease gradually, ensuring again that oxygen supply continues to meet the elevated metabolic rate anticipated for an extended period after exercise. This “cool down” is very difficult given
current practices of heading immediately for the locker room to debrief and change. Marching on the spot, walking, or any type of movement during this period can help to pace the drop in CO.

Education
Players and coaches in sports involving high intensity bouts of intermittent exercise should be approached and informed of the CV risks and how to mitigate those risks. Training should be laid out for the athletes and, in the case of recreational athletes, monitored for sufficient frequency, duration, and intensity. Although elite ice hockey is unlikely to change its format of play, recreational hockey groups can revise warm-up and cool-down routines to optimize CV health.

CONCLUSIONS
The benefits of recreational or elite ice hockey participation well outweigh the risks of AMI and SCD during play. As Mittleman27 describes it, the risk of AMI in an hour of vigorous exertion is doubled compared to rest but their risk of CV events in the other 23 hours of the day is 50% lower than a sedentary individual.

The risks of ice hockey are sufficient to warrant pre-screening and targeted interventions to mitigate that risk. Physical therapists have an ethical and legal imperative to recognize and respond to any signs or findings of elevated CV risk in their clients. The basic parameters for assessing and mitigating CV risk for ice hockey players should apply equally to other sports with bouts of high intensity intermittent exercise.

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27. Mittileman MA. The double-edged blade of recreational hockey. CMAJ. 2002;166:331-332.


ABSTRACT

Background. Coaches play an important role in the prevention of female athlete triad, but their current knowledge level, perceptions, and practice behaviors are not known.

Objectives. The purpose of this study was to describe the knowledge, perceptions, and behaviors college coaches have about the female athlete triad. This study’s purpose was to describe the relationships between these variables, and to compare coaches having high levels of general knowledge about the triad with coaches having low levels of knowledge with their perceptions, behaviors, and more specific knowledge about the triad.

Methods. A questionnaire was sent to 300 Division I collegiate coaches in the United States. Descriptive statistics, the Pearson product-moment correlation, and independent t-tests were used to describe the participants, relationships between variables, and compare groups of coaches with high and low levels of knowledge about the triad.

Results. Forty-three percent of the 91 college coaches responding to the survey (30% return rate) were able to correctly list the specific components of the disorder. Coaches with high levels of general knowledge about the triad had statistically significant differences in their perceptions, behaviors, and more specific knowledge of the triad than coaches with low levels of general knowledge about the triad.

Conclusion. The best intervention for the female athlete triad is prevention. Future education about the triad should focus on treatment and prevention as well as specific factors related to the syndrome, such as nutritional requirements, methods of assessing menstrual irregularities, and screening techniques.

Keywords: female athlete, disordered eating, menstrual dysfunction, osteoporosis

INTRODUCTION

Greater participation of women in sports has increased competition among female athletes. The desire to succeed in athletics, combined with the pressure to maintain a lean appearance may cause female athletes to intentionally or inadvertently restrict their dietary intake and train excessively. This desire may be particularly true for athletes who participate in sports having a competitive or aesthetic value on maintaining a lean appearance (cross-country, gymnastics, figure skating, and ballet). Female athletes may engage in disordered eating patterns to achieve a low body weight believing that it will improve their sports performance. The internal desire to achieve an “ideal appearance” may be intensified by external stresses, such as societal pressure to be thin and demands placed upon the athlete by coaches or parents to excel in their sport. Women who chose disordered eating patterns to attain a desired body weight and athletic performance may be at risk for developing a condition known as the female athlete triad. The female athlete triad includes three interrelated components that are often expressed on a continuum: disordered eating, menstrual dysfunction, and osteoporosis.

Disordered eating is a continuum of abnormal patterns of eating ranging from mild or occasional abnormal eating behaviors (restriction of high fat foods or episodic fasting) to the more extreme conditions of anorexia (voluntary starvation) and...
Nutritional deficiencies resulting from caloric restriction or over-exercising may cause an irregularity or disruption of the menstrual cycle, known as oligomenorrhea (less than 8 menstrual cycles per year) or amenorrhea (a complete cessation of the menstrual cycle). Eventually, this condition can lead to osteoporosis (a loss of bone mineral density that is 2.5 standard deviation or more below the average bone mineral density (BMD) of young adult women) or osteopenia (a loss of BMD that is between 1.0 and 2.5 standard deviation below the average BMD of a young adult women) at an early age. The premature onset of osteoporosis in the young female athlete occurs at a time when peak bone mass is normally reached. In time, if not treated appropriately, the effects of this syndrome may be irreversible and eventually detrimental to the health of the athlete later in life.

The athlete who engages in inappropriate eating patterns or excessive behaviors to improve athletic performance may become nutritionally deficient if their energy intake (the amount of calories taken in) is less than the energy they have expended through intense training and exercise. A lack of energy or nutritional availability can have an effect on hormones responsible for the normal function of the menstrual cycle. Normal concentrations of the lutenizing hormone (LH) in the blood can become disrupted, limiting the secretion of estrogen by the ovaries. Lutenizing hormone is secreted from the pituitary gland when triggered by the release of the gonadotropin-releasing hormone (Gn-RH) from the hypothalamus. Suppression of the Gn-RH, thought to be initiated by a deficiency in energy availability or caloric restriction, can inhibit the release of LH. Low serum LH levels can result in oligomenorrhea or amenorrhea, the second condition of the triad. A subsequent loss of estrogen, combined with calcium and vitamin deficiencies, can lead to osteoporosis (a loss of bone mineral density), or osteopenia, a more common, less severe form of osteoporosis. Recent findings indicate, however, that the disruption in LH secretion resulting in amenorrhea can be prevented by proper nutrition.

In children, bone mass increases until it generally reaches peak by about age 20. Nutritional and hormonal deficiencies can impede this process and result in low bone mineral density. Although not entirely understood, failure to reach peak bone mass is thought to occur when the amount of bone reabsorbed by the body exceeds new bone formation. Low bone mineral density has been associated with the presence of stress fractures in the female athlete and may be one of the first clinical signs of an irreversible osteoporotic state. Failure for young women to reach peak bone mass at the appropriate time could result in accelerated rates of bone loss with aging and a greater risk of osteoporotic fracture in adulthood. To date, it is not known if large bone density losses can be reversed even when a woman's menstrual cycle returns when nutrition is improved. Preliminary evidence suggests that opportunity may exist for skeletal development to "catch-up" in bone mineral density, when interrupted in adolescence, even into the third decade of life. But this evidence was based on a single case study about an elite female athlete and other studies are needed to support this conclusion. One way of ensuring that peak bone mass is achieved during teen-age years is to make sure that the female athlete is receiving adequate nutrition per day. For example, a diet that includes an adequate amount of total calories, as well as a sufficient amount of micronutrients (such as calcium), is needed to meet the needs of the athlete's training program. Adequate nutrition is imperative for the prevention of osteoporosis, the final and most deleterious condition of the female athlete triad.

Coaches play an important role in the prevention of the female athlete triad. They have the ability to positively impact the female athlete by educating and encouraging them to adopt healthy patterns of behavior. Proper nutritional advice, training programs, screening tools, and referral to appropriate sources are essential to the prevention and treatment of the female athlete triad, but knowledge and understanding of the condition is required. The extent to which coaches know how to recognize, treat, and prevent the female athlete triad is not known. Determining where gaps in knowledge exist gives direction as to where education about the female athlete triad should be focused. Determining specific strategies that are effective is important in the treatment and prevention of the syndrome so that other coaches, health professionals, and parents involved in the care of the athlete can adopt these methods, as well.

The purpose of this study was to: 1) describe levels of knowledge, perceptions (attitude), and skills (behavior) collegiate coaches have about the female athlete triad; 2) describe the relationships between coach's knowledge of the female athlete triad and demographic/general practice information; 3) compare coach's general knowledge of the components of the female athlete triad with their perceptions (attitude), skills (behavior), and more specific knowledge of the syndrome; and 4) describe current
strategies used by college coaches for the prevention and treatment of the female athlete triad.

METHODS
A questionnaire was developed to gather data for this study consisting of a 5-page questionnaire divided into two parts. The first two pages of the survey were to be completed by all respondents. This first part consisted of 31 questions, including demographic and general practice information about the survey participants and an assessment of the coach's knowledge and perceptions about the female athlete triad. The coach's response to this first part of the survey was converted into scales that were used for subsequent data analysis. For example, one question asked was: “Do you ask your female athletes about their menstrual cycle?” The response of the question ranged from the highest score of 5 (yes, 100% of the time) to the lowest score of 1 (no, never).

The second part of the survey (the remaining two pages of the questionnaire) was to be completed only by those participants who had in the last 24 months coached female athletes suspected of having the female athlete triad (for example, through observation or discussion with other health care professionals) or athletes who were medically diagnosed with the condition. Coaches who did not fit the criteria for continuation of the survey were finished with the survey and thanked for their participation in the study.

This second portion of the survey was designed to assess current strategies for treatment and prevention of the female athlete triad. Coaches were asked to describe the likelihood they would use particular intervention strategies using 10-point Likert scales (0 indicating a behavior they were not likely to do at all and 10 indicating a behavior they were extremely likely to do (Figure 1). Finally, coaches were also asked if they currently screen or employ prevention strategies for the female athlete triad and were given an opportunity to describe in narrative form the specific strategies that they were using.

A prototype questionnaire was sent to a panel of 20 experts (90% response rate) who reviewed the survey for construct and content validity. Revisions were made to the survey based on recommendations made by the expert panel by consensus. The resulting 5-page survey consisted of a total of 36 questions, containing two parts.

The survey was sent to a systematic random sample of 300 Division I collegiate coaches involved in women's sports in the United States (U.S.), following approval by the Institutional Review Board at Drexel University. In the systematic random sampling process, subjects were selected from a database of coaches (a random selection of coaches in the U.S.) in a systematic fashion in that every third coach in the database was chosen for participation in the study. A cover letter and a self-addressed stamped envelope accompanied the survey. To increase the survey response rate, coaches who did not respond to the survey after one month of the first mailing were sent a letter of reminder and a second survey to complete. Survey questionnaires were returned anonymously. Completion of the questionnaire indicated informed consent to participate in the study.
Data analysis
Descriptive statistics were used to summarize demographic and general practice information supplied by the survey respondents. Participant responses to survey questions regarding general and specific knowledge about the female athlete triad were described as percentages. The Pearson product-moment correlation was used to describe the relationships between the coach’s knowledge of the female athlete triad and demographic/general practice information (age, gender, years of practice, and the percentage of female athletes coached).

To allow the statistical comparison of general knowledge about the triad with perceptions (attitude) and behavior (skill) and more specific knowledge about the triad, coaches were divided into two groups: those who were “high” in their general knowledge of the components of the female athlete triad and those who were “low” in their general knowledge about the triad. The classification of groups was based on the responses made to the question which asked coaches to “list the 3 conditions of the female athlete triad”. Respondents who were able to correctly identify all three components of the triad: disordered eating, menstrual dysfunction (amenorrhea, oligomenorrhea, or menstrual irregularity) and osteoporosis (osteopenia) scored the highest score of “3” for their responses. Participants who could not identify any of the components of the triad received a score of “0”.

Two-tailed independent sample t-tests were used to compare coaches who were “high” or “low” in their general knowledge of the components of the female athlete triad with their perceptions (attitude), behavior (skill), and more specific knowledge level about the prevention and treatment of the disorder. A correction for multiple comparisons using t-tests was made by adjusting the alpha level to \( p < .002 ( .05/25 = .002 ) \). Qualitative information about current strategies for treatment and prevention was analyzed, divided into themes, and summarized in narrative form.

RESULTS
Ninety-one U.S. collegiate coaches responded to the mailed survey (30% return rate). Demographic and general practice information about the survey respondents are summarized in Table 1 and Figure 2. The largest percentage of survey respondents were female (54.9%), between 25-35 years old (38.5%), and had 16 or more years of experience as a coach (45%). The primary sports that survey participants reportedly coached were basketball, track and field, gymnastics, cross-country, swimming, crew, rowing and diving. The sports coached by the respondents included many of the sports in which the female athlete triad is considered to be most prevalent.

Fifty-eight (64%) of the responding coaches reported having “heard of the female athlete triad” (Table 2). Forty-four of the 91 survey participants (48%) responded “yes” when asked if they could identify the three distinct conditions of the female athlete triad, and approximately 39 coaches (43%) were able to correctly list the specific components of the triad (Table 2). A description of the coach’s responses to questions reflecting specific knowledge, perceptions (attitudes), and behaviors (skills) about each of the three components of the triad are listed in Table 3.

A very low correlation was found between knowledge of the female athlete triad and gender of the coach \( ( r = .07, p = .52 ) \). A coach’s knowledge of the female athlete triad was also not related to the age of the coach \( ( r = -.035, p = .74 ) \), years of experience as a coach \( ( r = -.06, p = .59 ) \), and the number of female athletes coached \( ( r = -.13, p = .20 ) \), respectively.
College coaches with a high level of general knowledge about the components of the female athlete triad (n = 52) had statistically significant differences in their perceptions (attitudes), behaviors (skills), and more specific knowledge of factors related to the female athlete triad than college coaches with low levels of general knowledge about the triad (n = 39). The results of these are detailed in Table 4 (a 3-point ordinal scale), Table 5 (a 5-point ordinal scale), and Table 6 (a 10-point ordinal scale). Specific strategies that coaches reported using for the treatment and prevention of the female athlete triad are described in Table 7.

DISCUSSION
The intent of this study was to determine the extent to which collegiate coaches in the U.S. know about the female athlete triad, the perceptions (attitudes) they have about the syndrome, and the behaviors (skills) that are currently being practiced. Understanding what coaches know about the female athlete triad and where information may be lacking helps direct where education needs to be focused. Based on the sample of collegiate coaches that responded to the survey, this study found that gaps in knowledge and misconceptions about the triad continue to exist. Although approximately 64% of the coaches participating in this study reported having heard of the female athlete triad, less than half (48%) thought they could identify its components, and only 43% were actually able to correctly list all of the three components of the triad (Table 3). This finding suggests that although the majority of the survey respondents were familiar with the term “female athlete triad”, many did not know what the specific components of the triad were and may have overestimated their knowledge level.

It was interesting to note that for the group of collegiate coaches studied, no relationship existed between knowledge of the female athlete triad and gender, years of experience as a coach, and the number of female
TABLE 3. Coach's responses to survey questions about the three components of the female athlete triad, reflecting specific knowledge, perceptions and skills used (n = 91).

<table>
<thead>
<tr>
<th>Survey Question</th>
<th>Survey Response</th>
<th>Percentage (%) of Response</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DISORDERED EATING</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“When coaching female athletes, have you noticed any disordered eating behaviors?”</td>
<td>Yes</td>
<td>87.9</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>12.1</td>
</tr>
<tr>
<td>“Do you ask female athletes questions to try to expose any type of abnormal eating pattern?”</td>
<td>Yes, &gt; 50% of the time</td>
<td>38.5</td>
</tr>
<tr>
<td></td>
<td>Yes, 25-49% of the time</td>
<td>7.7</td>
</tr>
<tr>
<td></td>
<td>Yes, &lt; 25% of the time</td>
<td>35.2</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td>Missing</td>
<td>1.0</td>
</tr>
<tr>
<td>“Are you comfortable discussing disordered eating with female athletes?”</td>
<td>Yes</td>
<td>86.8</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>13.2</td>
</tr>
<tr>
<td>“Do you think emotions affect how a female athlete may eat or exercise?”</td>
<td>Yes</td>
<td>99.0</td>
</tr>
<tr>
<td></td>
<td>I don’t know</td>
<td>1.0</td>
</tr>
<tr>
<td>“Do you assess or have body fat assessed on your athletes?”</td>
<td>Yes</td>
<td>27.5</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>57.1</td>
</tr>
<tr>
<td></td>
<td>Sometimes</td>
<td>15.4</td>
</tr>
<tr>
<td><strong>MENSTRUAL DYSFUNCTION</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Do you believe that irregular menstruation or absent menstruation is a normal consequence of exercise in female athletes?”</td>
<td>Yes</td>
<td>24.2</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>71.4</td>
</tr>
<tr>
<td></td>
<td>Not sure</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Do not know</td>
<td>1.1</td>
</tr>
<tr>
<td>“Do you ask your female athletes about their menstrual cycle?”</td>
<td>Yes, 100% of the time</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>Yes, @ 50-99% of the time</td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td>Yes, @ 25-49% of the time</td>
<td>8.6</td>
</tr>
<tr>
<td></td>
<td>Yes, &lt; 25% of the time</td>
<td>28.6</td>
</tr>
<tr>
<td></td>
<td>No, never</td>
<td>36.3</td>
</tr>
<tr>
<td>“Do you assess menstrual history in your female athletes if you are suspicious of irregular menstruation?”</td>
<td>Yes, 100% of the time</td>
<td>34.5</td>
</tr>
<tr>
<td></td>
<td>Yes, @ 50-99% of the time</td>
<td>13.8</td>
</tr>
<tr>
<td></td>
<td>Yes, @ 25-49% of the time</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>Yes, &lt; 25% of the time</td>
<td>24.1</td>
</tr>
<tr>
<td></td>
<td>No, never</td>
<td>22.4</td>
</tr>
<tr>
<td>“Are you comfortable discussing menstrual irregularity with female athletes?”</td>
<td>Yes</td>
<td>81.3</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>18.7</td>
</tr>
<tr>
<td>“A loss or irregularity of the menstrual cycle may result in the following (mark all that apply):” *</td>
<td>Improved bone growth</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Improved athletic performance</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td>Hot flashes</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td>Stress fractures</td>
<td>69.3</td>
</tr>
<tr>
<td></td>
<td>Do not know</td>
<td>28.4</td>
</tr>
<tr>
<td><strong>OSTEOPOROSIS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“What is the suggested intake of calcium for females, ages 11-24 years according to the NIH?”</td>
<td>401-800 mg</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>801-1200mg</td>
<td>13.2</td>
</tr>
<tr>
<td></td>
<td>1201-1500 mg</td>
<td>15.4</td>
</tr>
<tr>
<td></td>
<td>Not sure</td>
<td>28.6</td>
</tr>
<tr>
<td></td>
<td>Do not know</td>
<td>34.1</td>
</tr>
<tr>
<td>“Please indicate the age range in which peak bone mineral density in women is reached.”</td>
<td>11-14 years</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>15-18 years</td>
<td>26.4</td>
</tr>
<tr>
<td></td>
<td>19-22 years</td>
<td>33.0</td>
</tr>
<tr>
<td></td>
<td>Not sure</td>
<td>20.9</td>
</tr>
<tr>
<td></td>
<td>Do not know</td>
<td>16.5</td>
</tr>
<tr>
<td>“How often have you encountered or treated a female athlete with a stress fracture?”</td>
<td>Never</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td>1-5 times</td>
<td>52.7</td>
</tr>
<tr>
<td></td>
<td>6-10 times</td>
<td>19.8</td>
</tr>
<tr>
<td></td>
<td>11 or more times</td>
<td>16.5</td>
</tr>
<tr>
<td>“Do you believe that bone mineral density needs to be measured in female athletes when they have abnormal or absent menstruation?”</td>
<td>Yes</td>
<td>72.5</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>Not sure</td>
<td>27.5</td>
</tr>
<tr>
<td>“Indicate when it might be appropriate for women to be screened for osteopenia or osteoporosis if they had a history of the female athlete triad in high school?”</td>
<td>Immediately when diagnosed</td>
<td>52.7</td>
</tr>
<tr>
<td></td>
<td>Within 1 year</td>
<td>11.0</td>
</tr>
<tr>
<td></td>
<td>Not sure</td>
<td>18.7</td>
</tr>
<tr>
<td></td>
<td>Do not know</td>
<td>17.6</td>
</tr>
<tr>
<td></td>
<td>Never</td>
<td>0.0</td>
</tr>
</tbody>
</table>

*Percent values represent those responding “yes” to each of the answers provided.
athletes coached. One might have predicted that since the triad occurs in female athletes; female coaches, coaches more exposed to female athletes, and those with more coaching experience may have been more knowledgeable about the syndrome, but this was not the case. The results suggest that knowledge about the female athlete triad is neither gender specific or based on the amount or type of coaching experience. The fact that knowledge about the triad was not influenced by certain demographics may be useful information to consider when educating coaches about the condition. It is the author's opinion that all coaches, regardless of sex, years of experience and proportion of females athletes coached, should have an awareness and understanding about the female athlete triad.

**Behavior (skill)**
Although knowledge and awareness about the female athlete triad is essential in the treatment and prevention of the condition, certain skills or behaviors need to be implemented to make this happen. The results of this survey indicate that the likelihood of asking female athletes about their menstrual cycle, assessing menstrual history with their female athletes, and encountering female athletes with stress fractures was significantly higher in coaches that had more knowledge about the triad than

<table>
<thead>
<tr>
<th>TABLE 4: t-test results showing the items that were statistically significant when comparing coach's “knowledge score” (ability to correctly list each of the three components of the female athlete triad) with perceptions, behaviors, and more specific knowledge factors related to components of the triad, by the survey respondents. The responses to the questions in this table were rated on a 3-point ordinal scale (p &lt; .05) (n=91).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Values</td>
</tr>
<tr>
<td><strong>ATTITUDE, BEHAVIORS &amp; SPECIFIC KNOWLEDGE</strong></td>
</tr>
<tr>
<td>General Knowledge Level</td>
</tr>
<tr>
<td>“LOW”</td>
</tr>
<tr>
<td>Knows none of components of the triad.</td>
</tr>
<tr>
<td>(n=39)</td>
</tr>
<tr>
<td>“HIGH”</td>
</tr>
<tr>
<td>Knows all three components of the triad.</td>
</tr>
<tr>
<td>(n=52)</td>
</tr>
<tr>
<td>Specific Knowledge</td>
</tr>
<tr>
<td>When comparing more specific knowledge items on the survey, coaches who had a high level of knowledge of the components of the triad, compared to those with low levels of knowledge, were more likely to recognize the signs and symptoms of the triad, understand that absent or irregular menstruation could lead to stress fractures, and knew when it was most appropriate for women, with a history of the female athlete triad in high school to be screened for osteoporosis (Table 5). The findings suggest that coaches with a more general understanding of the components of the triad had better awareness of specific information related to the female athlete triad.</td>
</tr>
</tbody>
</table>
**TABLE 5**: t-test results showing the items that were statistically significant when comparing coach’s “knowledge score” (ability to correctly list each of the three components of the female athlete triad) with behaviors by the survey respondents, related to questions asked of female athletes about their menstrual cycle. The responses to the questions in this table were rated on a 5-point ordinal scale (p < .05) (n=91).

<table>
<thead>
<tr>
<th>Mean Values</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Knowledge Level</td>
<td>“LOW” Knows none of components of the triad. (n = 39)</td>
<td>“HIGH” Knows all three components of the triad. (n = 52)</td>
</tr>
<tr>
<td>ATITUDE, BEHAVIORS &amp; SPECIFIC KNOWLEDGE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do you ask female athletes about their menstrual cycle?</td>
<td>3.27</td>
<td>4.18</td>
</tr>
<tr>
<td>Do you assess menstrual history in your female athletes if you are suspicious of irregular menstruation?</td>
<td>2.05</td>
<td>3.13</td>
</tr>
</tbody>
</table>

**TABLE 6**: t-test results showing the items that were statistically significant when comparing coach’s “knowledge score” (ability to correctly list each of the three components of the female athlete triad) with current strategies used by survey respondents for intervention. The responses to the questions in this table were rated on a 10-point ordinal scale (p < .05) (n=91).

<table>
<thead>
<tr>
<th>Mean Values</th>
<th>t-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Knowledge Level</td>
<td>“LOW” Knows none of components of the triad. (n = 39)</td>
<td>“HIGH” Knows all three components of the triad. (n = 52)</td>
</tr>
<tr>
<td>If you encounter a female athlete suspected of having the triad describe your current strategy for intervention:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talk with athlete</td>
<td>1.17</td>
<td>5.10</td>
</tr>
<tr>
<td>Talk with athlete’s parents, if a minor.</td>
<td>.68</td>
<td>3.28</td>
</tr>
<tr>
<td>Contact team or athlete’s physician</td>
<td>1.36</td>
<td>5.05</td>
</tr>
<tr>
<td>If you encounter a female athlete suspected of having the triad describe your likelihood in coordinating multi-disciplinary involvement with a:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutritionist</td>
<td>1.26</td>
<td>4.72</td>
</tr>
<tr>
<td>Athletic trainer</td>
<td>1.30</td>
<td>4.58</td>
</tr>
<tr>
<td>Physical therapist</td>
<td>.76</td>
<td>1.34</td>
</tr>
<tr>
<td>Mental/Behavioral health practitioner</td>
<td>1.06</td>
<td>4.35</td>
</tr>
</tbody>
</table>

This item was not statistically significant, but was included in this report to illustrate all the health professionals that coaches were asked to rate in this question.
those who had less knowledge about the triad (Table 5). Collegiate coaches who were more knowledgeable about the triad appeared to be more likely to apply skills that exposed components of the triad and were coaches who had more exposure to athletes with stress fractures. These findings suggest that knowledge influenced the coach’s actions in discussing the menstrual cycle with female athletes. In addition, experience in dealing with an athlete with a stress fracture may have influenced the coach’s knowledge of the triad.

Perceptions (attitudes)

One of the more interesting findings of this study was the fact that some coaches (24%) believe that irregular or absent menstruation is a “normal” consequence of exercise. Another 4% of the responding coaches stated they were “not sure” or “did not know” if this fact was true (Table 4). Some female athletes, as well as coaches, may erroneously believe that absent menstruation is a normal response in exercising women. The coaches may recognize amenorrhea as a sign of a dedicated, hard-working athlete who trains intensively, rather than as a warning sign that the athlete may be nutritionally deficient. Increasing knowledge and recognition of the female athlete triad among college coaches requires proper education about the syndrome, so that certain myths such as these can be discarded.

Treatment/Intervention

Coaches with higher levels of knowledge about the female athlete triad were more likely to know how to treat a female athlete with the signs and symptoms of the triad, employ preventative strategies, and screen for the triad during sports pre-participation physical evaluations than those with lower levels of knowledge (Table 5). The findings were not surprising given that the ability to treat and use preventative strategies and screening tools would be factors that knowledge would impact.

Because of the complex nature of the syndrome, intervention strategies are most likely to be successful when they include a multidisciplinary team approach. Coaches need to encourage and communicate healthy nutrition and training but must call on the support of other health care professionals when appropriate and necessary. Collegiate coaches having a high level of knowledge of the components of the triad, who encountered a female suspected of having the triad, were more likely to talk with the athlete about it, talk with the athlete’s parents, if a minor, and contact a team or personal physician about the athlete’s condition, (Table 5) than those with a low knowledge level. Coaches with higher levels of knowledge about the triad were also more likely to coordinate a multidisciplinary assessment with a nutritionist, an athletic trainer, and a mental health practitioner, but not a physical therapist (Table 5). It was encouraging to note that coaches who had knowledge about the triad were employing a team approach that addressed important, but differing issues of the triad: dietary/nutritional, psychological, physical training, and general medical concerns. The methods in which coaches applied this approach are useful in that they can serve as a model for those who are not currently utilizing a specific plan for intervention.

It was interesting to note that physical therapists were not included in this multi-disciplinary team. This finding may be explained by the fact that coaches may work more closely with an athletic trainer than a physical therapist, and that the athletic trainer may fulfill the coach’s need for advice about physical training and conditioning. It is also quite possible that coaches may not perceive physical therapists as having a role in the treatment of the female athlete triad. Perhaps this opinion is due to the limited extent that physical therapists may have in nutritional education or due to the thought that physical therapists may not become involved in the care of an athlete until an injury, such as a stress fracture, occurs. This time might be when the athlete may undergo a more formal rehabilitation program that is provided by a physical therapist before returning to sports participation. It is important for coaches to understand that physical therapists may also play a role in the treatment and prevention of this disorder, particularly when an athletic trainer may not be available. The physical therapist can give suggestions for maximizing bone health in young females, educate athletes in preventing future stress fractures by alternating impact training with weight training, and participate in school activities and educational programs for the athlete and the athlete's parents.14

Lastly, collegiate coaches using prevention strategies for the female athlete triad were given an opportunity to describe the methods they currently use in narrative form. These suggestions were compiled in Table 6. Strategies included educating individual and team members on healthy living and healthy eating, open communication between the coach and athlete, and referring to other health care professionals when necessary. More specific strategies included those that emphasized a
degree of accountability for the athletes’ actions, such as keeping a food journal, a menstrual cycle journal, and devising behavioral contracts that enforced exclusion from sports practice or participation if the contract was not kept. Information provided by the responding coaches included roles that other health professionals play in the treatment of the disorder and the support that they receive within their individual programs. This information provides a glimpse of what collegiate coaches are currently doing for the prevention and treatment of the female athlete triad and is a valuable resource for others to draw from. For example, this information may educate other coaches and health care professionals on how to initiate a prevention and treatment program if they were previously unsure about how to proceed.

<table>
<thead>
<tr>
<th>Specific Strategies Used by a Sample of Coaches in the U.S. for the Prevention of the Female Athlete Triad</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. Direct Intervention by Coaches</strong></td>
</tr>
<tr>
<td><strong>With athlete:</strong></td>
</tr>
<tr>
<td>• Educate individual athlete and team on healthy living and healthy eating.</td>
</tr>
<tr>
<td>• Have open communication between the athlete and coach.</td>
</tr>
<tr>
<td>• Provide handouts on recent literature.</td>
</tr>
<tr>
<td>• Engage individual/team in preseason discussions about triad.</td>
</tr>
<tr>
<td>• Immediately address the emotional needs of the athlete.</td>
</tr>
<tr>
<td>• May need to determine if athlete is in appropriate weight class for the sport and restrict supervised weigh-ins to lightweight rowing only.</td>
</tr>
<tr>
<td>• Avoid “undersizing” uniforms; they encourage the athlete to lose weight.</td>
</tr>
<tr>
<td>• A food journal or a menstrual cycle journal are required.</td>
</tr>
<tr>
<td>• All athletes, men and women, are educated on the importance of nutrition. We provide packets of suggested meals and snacks that are easy to prepare on a college budget and talk openly about drug and alcohol abuse.</td>
</tr>
<tr>
<td>• Eliminate athlete from competition, if diagnosed as anorexic or bulimic.</td>
</tr>
<tr>
<td>• Weight lifting, impact sports are encouraged to increase bone mass.</td>
</tr>
<tr>
<td><strong>With other health care professionals:</strong></td>
</tr>
<tr>
<td>• Nutritionists consult athlete on a regular basis to discuss calcium, vitamin D, and nutritional needs.</td>
</tr>
<tr>
<td>• Coaches, team physicians, athletic trainers, and nutritionists work together to discuss warning signs or symptoms that may be observed in the athlete and devise a comprehensive nutritional plan and training program for the athlete.</td>
</tr>
<tr>
<td>• Mandatory meetings are held with nutritionists and sports psychologists who specialize in eating disorders.</td>
</tr>
<tr>
<td>• Team physician monitors for the presence of amenorrhea during physicals.</td>
</tr>
<tr>
<td>• Intervention starts with the team physician. As coaches, we never try to solve the problem ourselves; we involve a multidisciplinary team of medical professionals.</td>
</tr>
<tr>
<td>• A comprehensive screening, assessment and educational program in place, which is supported by college staff and resources.</td>
</tr>
<tr>
<td>• Behavioral contracts are used to assure that the athlete is compliant in behavioral changes, for example, if athletes do not keep appointments with health professionals, they cannot practice or compete.</td>
</tr>
<tr>
<td><strong>Referrals sources most frequently used and rationale:</strong></td>
</tr>
<tr>
<td>Nutritionist/Dietitian</td>
</tr>
<tr>
<td>• Educate individuals/team on healthy eating strategies</td>
</tr>
<tr>
<td>• Educate about the components of the triad</td>
</tr>
<tr>
<td>• Set realistic body image/goals for athlete</td>
</tr>
</tbody>
</table>
Clinical Relevance and Future Direction

Since the American College of Sports Medicine (ACSM) published its first position paper about the female athlete triad in 1992, an extensive amount of information about the female athlete triad has been published and made available to the general public. Despite efforts to increase exposure about the devastating effects that the female athlete triad may have on women, the condition may often go unnoticed. This lack of understanding can be attributed to the complexity of each of the conditions or due to the fact that each of the components is expressed on a continuum rather than as separate or discrete disorders. The different types of disordered eating patterns or the underlying psychological reasons an athlete may decide to practice inappropriate eating patterns may not be easily recognized or understood. Recognition and prevention of the female athlete triad by coaches and other health care professionals requires knowledge and close attention to the athlete's nutrition and training habits. Preventative measures can begin by screening athletes for the disorder and educating or guiding athletes to adopt healthy nutritional and training habits. Coaches should know when it is appropriate to refer the athlete to another health professional for treatment. When recognized early, treatment can avoid progression of the stages and the most severe effect, the development of osteoporosis.15-18

Coaches are involved first-hand in the care of the female athlete and may be the first ones to notice abnormal or inappropriate eating or training behaviors. It is therefore important that the coaches understand the female athlete triad and its complexities. This study was relevant in that it provided a base-line understanding of knowledge collegiate coaches had about the female athlete triad. This study was also important to describe how levels of knowledge influenced the coach's perceptions and behaviors about the triad. While significant differences in attitude and behavior were found between groups of coaches with high levels of knowledge and those with low levels of knowledge about the triad, it is important to mention that 40% (21/52) of coaches who had a high level of knowledge did not report incorporating strategies for intervention. As evidenced by the low mean values for the high knowledge group when current strategies for intervention were assessed (Table 5). Using a scale of 0-10 (Table 1) the highest mean values for current strategies for intervention were “talking with the athlete” (5.1) and “contacting the team or athlete's physician” (5.05). This finding indicates that recognizing what the three components of the triad are does not necessarily mean there is an understanding of how the condition should be treated or prevented. Given the results of this study, it is likely that educating collegiate coaches about the female athlete triad needs to be focused towards how the triad should be treated and prevented, as well as to increase specific knowledge about the condition.

Educating college coaches about the specifics of the condition should include nutritional requirements for the female athlete, recognizing behaviors or conditions that may signal a “red-flag” for medical intervention, recognizing individual coach's comfort levels with addressing the conditions of the triad with the athlete, and determining when medical screening and intervention is necessary. Future directions could include assessing levels of knowledge about the female athlete triad in high school coaches and educating them about prevention and treatment of the syndrome as necessary. High school coaches can instill and promote healthy habits in female athletes early on, so that by the time the athlete competes on a collegiate level, positive behaviors are already well established.
The information that collegiate coaches in the U.S. provided as to specific strategies for prevention and treatment of the female athlete triad was interesting and insightful. The suggestions provided can help others formulate decisions as to how they might implement these strategies in their athletic programs. While this study focused on collegiate coaches and collegiate female athletes, it is important to be aware that the conditions of the triad are also present in normal active females, who are not necessarily involved in college sports. Education and preventative measures regarding disordered eating, menstrual dysfunction, and the development of osteoporosis should then extend to include all physically active girls and young women.15

Lastly, a limitation of this study was the small sample of coaches that responded to the mailed questionnaire (30%). It is possible that the responses from the participating coaches did not accurately represent levels of knowledge, perceptions, and behaviors practiced by the majority of population of collegiate coaches in the U.S. Non-respondents to the survey may have had differing levels of knowledge, perceptions, and behaviors that may have not been reflected in the observed results. Another limitation of this study was the possibility that survey respondents may have consulted different resources to find answers to the survey questions prior to returning the survey, which may have inflated the reported results on knowledge about the female athlete triad. In addition, by classifying survey respondents into “high” and “low” knowledge levels by their ability to correctly list the components of the triad may not have necessarily tested their depth of understanding of the syndrome, including their ability to treat and prevent the condition.

CONCLUSION
Women’s participation in sports will likely continue to increase, as might their risk of developing the female athlete triad, unless preventative strategies are put into practice. Coaches play an important role in the prevention of the female athlete triad by encouraging healthy patterns of behavior and recognizing when warning signs are present, but adequate knowledge of the condition is necessary. This study suggests that educating collegiate coaches about the female athlete triad should focus more on specific factors related to the syndrome, such as nutritional requirements, methods of assessing menstrual irregularities, and proper screening techniques. Prevention may include the use of comprehensive sports pre-participation examinations and carrying out some of the methods of intervention suggested by the participating collegiate coaches surveyed in this study.

REFERENCES


**CORRESPONDENCE**

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