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Original Research

Cross-sectional Study of EMG and EMG Rise During Fast and Slow Hamstring Exercises

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Background

Hamstring injuries remain a major burden in football while the effective prevention exercise the Nordic Hamstring is poorly adopted, despite the added positive effects on performance. Better understanding of hamstring function during Nordic Hamstring compared to other exercises may provide better insight to the physiological adaptations of different types of hamstring curls.

Purpose

This cross-sectional study therefore aimed to compare the Nordic Hamstring curl with a conventional prone Leg Curl at different loads, and novel high velocity Hamstring Catches; in terms of peak normalized electromyographical activity (nEMG) and rate of electromyographic rise (RER) of Biceps Femoris long head, and angular velocity of the knee.

Study design

Cross-sectional study.

Methods

Out of 28 participants enrolled, the final sample included 23 recreationally active male participants who attended a session for determining RM (repetition maximum) to establish loading (8 and 16RM for Hamstring Catches, and 8, 16 and 24RM for Leg Curl) and to familiarize themselves with the three different exercises (Nordic Hamstring, Leg Curl and Hamstring Catch), and a testing session >4 days after during which EMG data were collected during 3 repetitions of each exercise performed in a random order.

Results

The Nordic Hamstring evoked higher RER (1091.8 nEMG/s) than Hamstring Catches (mean difference: 421 nEMG/s, $p<0.0001$) and Leg Curl (mean difference: 705 nEMG/s, $p<0.001$), and at the earliest numerical timepoint from onset of muscle contraction (the Nordic Hamstring: 6 ms; Hamstring Catches: 36-41 ms; Leg Curl: 12-14 ms). Hamstring

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Catches displayed high peak angular velocity (mean: 471°/s). There was no difference in peak nEMG, irrespective of load for Leg Curl (8, 16 or 24RM) or Hamstring Catches (8- or 16RM).

Conclusion

The Nordic Hamstring displayed the highest level muscle activity and most explosive recruitment characteristics with early and high rate of electromyographic rise, compared to even high velocity exercises, thus providing a possible mechanism by which it may increase performance and reduce injuries.

Levels of evidence

3

What is known about the subject

Early phase force and muscle recruitment have been linked to both performance and hamstring-related inhibition and fatiguability. However, the potential for different hamstring exercises to elicit explosive recruitment is unknown.

What this study adds to existing knowledge

Early phase recruitment was higher and faster during the Nordic Hamstring exercise compared with conventional hamstring Leg Curl exercises with different loads and a high-velocity hamstring exercise.

Clinical Relevance

The surprisingly fast and explosive recruitment characteristics during the Nordic Hamstring exercise suggests the possibility that this exercise have the potential to improve the rate of force development and perhaps counter the effects of hamstring-related inhibition and fatigue.

INTRODUCTION

Hamstring injuries remain a continuing burden in football (soccer).[1,2] A growing body of evidence has established implementation of the Nordic Hamstring (NH) exercise as an effective preventive measure.[3] Although the NH is simple to perform and implement at team level,[3] evidence suggests uptake of NH is poor.[4] Data from clinicians and researchers indicate that this is likely due to concerns about the specificity of NH and other conventional slow strength training exercises for the hamstrings (e.g. Leg Curl) to high-speed running; the most common injury mechanism.[2,5–8] High-speed running is characterized by explosive rate of force development (RFD),[9] high knee angular velocity,[10] eccentric peak muscle activity at long muscle lengths of the knee flexors,[8,11] and multi-joint movement,[9] which may lead to injuries without proper conditioning of the muscle-tendon complex.[3,8,12] Conversely, the NH is an isolated knee-flexion exercise performed slowly at short muscle lengths. The 'Hamstring Catches' (HC) exercise is performed with rapid eccentric contractions at moderate muscle lengths.[12] A variation of the exercise was recently devised with the goal of achieving higher angular velocity and controlled external loading by using the suspension force of an elastic band; however, no evidence supports its use presently (Supplementary video 1, Hamstring Catches). In contrast, NH and the conventional prone Leg Curl is performed with movement only over the knee joint at primarily short muscle lengths and low velocity.[13] Despite the theoretical concerns with characteristics of NH, data from on-field research has repeatedly shown implementation of the NH exercise decreases new and recurrent hamstring injuries,[3,6,8] improves sprint and jump performance;[14–16] as well as eccentric knee flexor strength and muscle architecture of the hamstring muscles associated with decreased risk of hamstring injury.[6,8,11,13] However, it could be that other exercises involving eccentric loads at longer muscle lengths and rapid decelerations would display more specific explosive characteristics, such as high angular velocity, or rate of electromyographic rise (RER) which is closely related to RFD.[17,18] Such exercises would better fit the concept of exercise specificity[5,19] and potentially offer a more acceptable alternative or supplement to the NH exercise and conventional slow strength training exercises at different loads in strength and conditioning programmes aimed at reducing injuries and maintaining or improving performance. Previous work on hamstring muscle activity has shown that most conventional hamstring exercises evoke more medial than lateral peak muscle activity,[6] and therefore the distribution of muscle activity between semitendinosus (ST) and the long head of biceps femoris (BFlh) during high velocity exercises and RER extraction is also of interest. In line with this, measuring RER provides the advantage of estimating neural function of specific muscles opposed to joint- or whole-body kinetics, by allowing investigations directly of the most commonly injured long head of biceps femoris (BFlh)[2,6] rather than the entirety of the knee flexors.

The purpose of this exploratory study was therefore to compare the Nordic Hamstring curl with a conventional prone Leg Curl at different loads, and the novel high velocity Hamstring Catches; in terms of peak normalized electromyographical activity (nEMG) and rate of electromyographic rise (RER) of Biceps Femoris long head, as well as angular velocity of the knee.

METHODS

The study used a cross-sectional design in which twenty-eight healthy sports-active males were enrolled through convenience sampling at Hvidovre Hospital, Denmark. A familiarization session was performed at least four days prior to the testing session to familiarize the participants with the experimental procedures and to determine the exercise load. The study was not pre-registered, as it took place before trial-registration was as prevalent as today; however, as this was an exploratory study there were no pre-specified hypotheses or outcomes selected, and the aim was formulated before data collection began. The study was approved by the Danish National Committee on Health Research Ethics *(H-3-2011-145)* and all participants gave written informed consent according to the Helsinki Declaration. The reporting of the study follows the STROBE guidelines, using the checklist for cross-sectional studies.[20]

PARTICIPANTS

Participants was eligible for inclusion if aged 18-40 years and also participated systematically in sports more than two and a half hours weekly. Reasons for exclusion included having suffered from any hamstring strain injuries or other serious lower limb injuries in the preceding six months (e.g. ligament tear, fracture, muscle ruptures, major trauma), hamstring pain the week prior to testing or any current delayed onset muscle soreness, or serious pathology or infections near the area of electrode-placement. History of previous hamstring injuries besides during the preceding six months was not captured.

EXERCISES

Slow conventional prone Leg Curl at 8, 16 and 24 RM was performed prone on an examination bed with ankles clear of the bed. An elastic band was fixed around the ankle of the participant at a 45° angle from the floor. The knee was flexed to 90° at a repetition tempo of 3 s concentric phase, 2 s isometric hold, 3 s eccentric phase and a 2 s pause to a pre-recorded instruction.

Slow eccentric training: The *Nordic Hamstring (NH) exercise* is a partner-assisted exercise where the subject attempts to resist a forward-falling motion using his knee flexors to maximize loading in the eccentric phase, while the partner holds the ankles in place. The participants were asked to keep their hips fixed in a slightly flexed position throughout the whole range of motion, to brake the forward fall for as long as possible using their knee flexors eccentrically, and to try keeping maximum tension in these muscles even after they could no longer control their descent. Subjects were asked to use their arms and hands to buffer the fall, let the chest touch the surface, and then use their arms to get back to the starting position.[13]

Fast eccentric training: *Hamstring Catch*es with external load of 8 and 16 RM derived from Leg Curl, started with the participants in the same setup and position as during the prone Leg Curl. With the participant instructed to relax the hamstrings, the investigator pulled the restrained foot to 90° knee flexion with one hand while palpating the hamstring muscle belly for noticeable muscle activity with the other. Participants was then instructed to stop or ‘catch’ the lower leg in the range of 45-0° knee flexion once the therapist let go of the ankle at an unknown time within the following 10 s. Once the extension of the knee was halted, participants then relaxed to full extension (Supplementary Video 1)

TEST SESSIONS

Participants attended a familiarization session and an experimental session with a minimum four-day interval to avoid delayed onset of muscle soreness. No exercise was allowed on the day of any of the sessions or the day before. At the familiarization session a 10-min, standardized warm-up of running drills and mobility exercises was performed (light running, while hip-in, hip-out, backwards running, side shuffles, high knees, butt-kicks, skipping, accelerations, and front-back and side-side leg swings), followed by familiarization with the exercises and determination of absolute loads of 8, 16 and 24 repetition maximum (RM) for Leg Curl in a randomized order. This was done with the starting load (comprised of type and length of elastic band) being estimated by the participant in the first set and subsequently adjusted until repetition failure was reached corresponding to the relevant RM-zone (e.g. load resulting in failure on repetition 7 to 9 was used for 8 RM). External load established for 8 and 16 RM Leg Curl was also used for Hamstring Catches. During the experimental session, the participants performed a similar warm-up followed by isometric maximum voluntary contraction (MVC) tests of the knee flexors which were used for normalization of the EMG signal (nEMG). Finally, participants performed three repetitions of each exercise in a random order to avoid the confounding of fatigue. Data from a mean of these three repetitions were used for analyses. Perceived exertion was identified on the Borg CR10 scale[21] by participants immediately after exercises and is reported as a descriptive variable.

ELECTROMYOGRAPHY

Rectangular 20 x 30 mm non-disposable differential surface-electrodes (DE-2.1, Delsys, Boston, MA, USA) were unilaterally applied following standard procedures of skin-preparation and according to SEINAM placement procedures. Electrodes were placed with electrode gel and medical grade adhesive parallel with presumed muscle fiber direction to collect electromyographic data from BFlh and semitendinosus on one leg defined as the preferred kicking leg. Verification of EMG signal quality, that is the presence of artifacts or noise, was conducted by visual inspection of the raw EMG after initial electrode placement and again after the warm-up routine. The electrodes were connected to small built-in preamplifiers and further to a main amplifier unit (Bagnoli-16, Delsys, Boston, USA) with a band-pass of 15–450 Hz and a common-mode rejection ratio of 92 dB. The signals were sampled at 1 kHz using a 16-bit A/D converter (6036E, National Instruments, Austin, TX, USA). Data were obtained and stored on a personal computer (EMGworks acquisition 3.1, Delsys, Boston, USA). A mean was calculated for muscle activity during Hamstring

Catches for up to 0.5 s prior to change in knee flexion angle to post hoc verify the extent of relaxation of the participants hamstrings, which was found to be <6% nEMG for BFlh and ST. Two isometric MVCs were performed with participants laying prone on an examination bed with 25° knee flexion and pulled against a fixed belt attached just proximal to the ankle for 5 s with at least 30 s rest between repetitions. All raw EMG signals were filtered using a Butterworth filter (10 Hz cut-off frequency) and subsequently smoothed by a moving root mean square (RMS; 500 ms and 50 ms time constant) filter. Peak nEMG of each muscle within each contraction was identified as the maximum value of the smoothed 500 ms RMS EMG signal and normalized to the maximal 500 ms RMS EMG obtained during MVCs. Fifty ms RMS EMG was used to identify RER, that is, the maximal slope of the rectified smoothed EMG-time curve (ΔnEMG/Δt) defined as exceeding 5% of peak nEMG. Slopes are commonly extracted and presented in the epochs from onset to 30 ms, 50 ms, 100 ms and 200 ms.[17]

ANGULAR VELOCITY

Angular velocity of knee flexion was recorded with a digital goniometer (Delsys, Boston, USA) and extracted using a 50 ms RMS filter. Calibration was done with a manual goniometer for each participant with 90° knee flexion as the reference value during visual inspection.

STATISTICAL METHODS

A repeated measures linear mixed model (Proc Mixed, SAS) was used for the evaluation of RER and peak nEMG (dependent variables) for each muscle with exercise as independent variable. Per-protocol analyses was chosen, and no imputation of data points were performed. This decision was made before running any analyses of the data. All nEMG values are reported as least square mean with confidence intervals and level of significance was set at $p < 0.05$. All data were normally distributed. No statistical inferences were thought needed *a priori* for evaluating the differences in angular velocity. For evaluation of the ordinal data from perceived exertion, the Wilcoxon Signed-Rank test with a significance level of $p < 0.05$ was used. As inferential statistics are performed in spite of an exploratory design, caution is warranted when making inferences. No power-calculation was performed to inform the sample size needed prior to the study.

RESULTS

PARTICIPANTS

Of 28 participants enrolled in the study, 23 (25.5±4.6 years, 181.5±3.4 cm, 80±9 kg, 7.5±7.3 weekly training hours) were included for final data analyses. Three participants experienced pain during the familiarization session or suffered from a recent acute trauma; data from one participant was incomplete; and another reported back pain during testing session and therefore data from all five participants were excluded from analysis.

ANGULAR VELOCITY

The angular velocity of Hamstring Catches 16 RM peaked at 490.1°/s [95%CI: 416-564] and 8 RM at 451.9°/s [95%CI: 429-475] (Table 1). Peak velocity of NH was 100.3°/s [95%CI: 90-111] and the set-tempo Leg Curl exercises peak velocities ranged from 90 to 137°/s.

PERCEIVED EXERTION OF THE THREE DIFFERENCE EXERCISE TYPES

Nordic Hamstring (median 5, mean 6.2) and Leg Curl 8 RM (median 5, mean 5.7) reached exertion levels above “hard” (>5), as rated by participants on the Borg CR10 scale. Leg Curl at 16 and 24 RM, and Hamstring Catches at 8 and 16 RM (median range: 3-4, mean range: 3.3-4.1) were perceived as less strenuous with levels between “moderate” and “hard” (3-5). Nordic Hamstring and Leg Curl 8 RM did not differ in levels of percieved exertion (p=0.373), but were perceived to be more strenuous than all other exercises (p=0.037-0.012), which in turn were not statistically different from each other (p=0.571).

PEAK NEMG

Peak BFlh nEMG did not differ between intensities (8, 16 and 24 RM) during Leg Curl Leg Curl (range: 65-68% nEMG, p=0.6599-0.9386) nor during Hamstring Catches (range: 53-49% nEMG, p=0.6700) (table 1). Nordic Hamstring and Leg Curl 8 RM and 16 RM generated higher peak BFlh activity (range: 65-82% nEMG) than any other exercises (mean difference: 16%, p=0.0429-0.0003), but were not different from each other (p=0.0514-0.1125). With the exception of the Leg Curl 8 RM (ST: 86% nEMG [95%CI: 67-105] versus BFlh: 68% nEMG [95%CI: 56-76], p=0.0432) no statistically significant differences in nEMG between ST and BFlh were observed (p=0.1047-0.8244), however a numerically higher activity for ST compared to BFlh was observed throughout all exercises (Table 1).

RATE OF EMG RISE

Peak rate of EMG rise was significantly higher during NH (1091.8 nEMG/s [95%CI: 849-1334]) than during any other exercise (p=0.0002-0.0001) (figure 1). Hamstring Catches at 8 RM (631.6 nEMG/s [95%CI: 500-763]) and at 16 RM (709.2 nEMG/s [95%CI: 510-908]) were not different from each other (p=0.4169) and both were higher than Leg Curl at 8, 16 and 24 RM (range: 352-406 nEMG/s, p=0.0343-0.0006), between which there were no difference (p=0.9872-0.5870). All exercises reached peak RER within 50 ms after onset of muscle activity (figure 2), with NH after 5.8 ms [95%CI: 4-8]; Hamstring Catches 8 RM after 36 ms [95%CI: 25-47] and 16 RM after 40.9 ms [95%CI: 24-58]; Leg Curl 8 RM after 23.8 ms [95%CI: 6-41], 16 RM after 12.4 ms [95%CI: 5-19] and 24 RM after 13.7 ms [95%CI: 8-19]. With the exception of the Hamstring Catches 8 RM (ST: 632.2 nEMG/s [95%CI: 497-767] versus BFlh: 359.7 nEMG/s [95%CI: 224-495], p=0.0046) no statistically significant differences in RER between ST and BFlh were observed (p=0.3693-0.9191), however a numerical higher RER for ST compared to BFlh was observed throughout all exercises (12-67% difference).

Table 1: Absolute values of variables collected during six hamstring exercises, Mean and 95% confidence intervals

	Leg curl 8 RM	Leg curl 16 RM	Leg curl 24 RM	Nordic Hamstring	Hamstring Catches 8 RM	Hamstring Catches 16 RM
Peak knee angular velocity* *(°/s)*	117.9[72-164]	136.9[52-222]	90.5[85-96]	100.3[90-111]	451.9[429-475]	490.1[416-564]
Knee angle at peak nEMG of BFlh† *(°)*	76.2[71-81]	74.9[71-79]	75.1[69-81]	59.6[51-68]	47.1[43-51]	44.3[40-49]
Time of peak RER for BFlh *(ms)*	23.8[6-41]†	12.4[5-19]†	13.7[8-19]†	5.8[4-8]†	36[25-47]‡	40.9[24-58]‡
Peak RER for BFlh *(% nEMG/s)*	403[309-498]‡	406[304-508]‡	352[279-424]‡	1092[849-1334]†	633[500-763]§	709[510-908]§
Peak muscle activity of BFlh *(% nEMG)*	68[60-76]†,‡	64.8[57-73]†,‡,§	64[56-72]‡,§	82[71-93]†	53.2[43-63]‡,§	49.4[40-59]§
Peak muscle activity of ST *(% nEMG)*	85.9[67-105]†	79.1[62-97]†	76.7[60-94]†	91.7[80-104]†	56.7[49-65]‡	51.4[45-58]‡

* = variables not tested for significance; † = variables not different from each other ($p<0.05$); ‡ = variables not different from each other ($p<0.05$); § = variables not different from each other ($p<0.05$); RM = repetition maximum; nEMG = normalized electromyography; RER = rate of EMG rise; BFlh = Biceps Femoris long head; ST = Semitendinosus

DISCUSSION

The purpose of this study was to quantify the extent of peak and explosive muscle activity to characterize and compare the slow eccentric NH exercise, slow conventional prone Leg Curl, and fast eccentric Hamstring Catches with each other. The Nordic Hamstring exercise evoked the highest peak muscle activity whereas Hamstring Catches evoked the lowest. Besides RER data on Hamstring Catches 8RM, all exercises in the present study displayed numerically higher nEMG (6-26% nEMG difference) and RER (12-76% nEMG/s difference) in ST than BFlh, in line with previous data showing ST being more active during most hamstring exercises.[6] Surprisingly, the NH exercise showed the highest rate of EMG rise at a very early time point in muscle contraction, even compared to the high velocity Hamstring Catches.

The levels and relationships of peak muscle activity between muscles and exercises found in this study, are consistent with other findings during hamstring exercises.[6] Only NH and Leg Curl exercises, which were also the exercises perceived to be most strenuous, evoked BFlh nEMG of >60%, a minimum intensity level recommended to promote longitudinal strength gains.[19] The most surprising finding was the peak rate of EMG rise during NH after just 6 ms at a rate of 1092 nEMG/s compared to the high velocity Hamstring Catches (8 RM: 632 nEMG/s at 36 ms; 16 RM: 709 nEMG/s at 41 ms), indicating a fast and explosive pattern of muscle activity. This could be due to the very sudden onset of force exertion during the NH, in which the hamstrings need to instantly control and decelerate a long and heavy lever (from knee joint and up with high proportion of the total body mass). In contrast, during Hamstring Catches, the hamstrings were allowed delayed force exertion until reaching the 45-0° knee flexion range of motion, perhaps thereby slowing the rate of muscle activation. Nevertheless, this seems to characterize NH as a heavy low velocity eccentric exercise with explosive recruitment characteristics. The rate of EMG rise values attained during the slow conventional prone Leg Curl (range: 350-406 nEMG/s) is comparable with previous data obtained from soccer players during isokinetic testing.[22] The slightly higher values from the current data could be due to the more unstable nature and slightly inconsistent rate of loading of the elastic bands utilized compared to isokinetic testing, possibly requiring faster muscle activation to confidently adhere to the tempo and withstand the backwards force of the band. As for the nEMG levels, peak RER, and time of peak RER obtained for ST were similar to BFlh in the present study.

The highest documented and quantified angular velocity using a controlled external load during concentric hamstring exercises is 450°/s isokinetically[23] which is comparable to our recordings during Hamstring Catches (8 RM: 452°/s; 16 RM: 490°/s). Although >180°/s is usually defined as high velocity exercise in the literature, the angular velocity of knee extension during sprinting has been documented at more than 1000°/s,[10] making Hamstring Catches a high velocity exercise, but still lacking some velocity in terms of specificity to high-speed running. The explosive recruitment characteristics combined with the eccentric contraction mode during NH could partly explain the positive longitudinal effects of NH on sprinting and jumping ability.[14–16] Eccentric hamstring training is known to be essential for sprint and change of direction abilities,[8,24,25] and produce increased eccentric and concentric RFD which is predominantly determined by early phase neural adaptations.[17,25] In line with this, eccentric training has been reported to preferentially activate high threshold motor units[26] and lower neural inhibition.[17,25,27] Training with ballistic or high velocity muscle actions can also increase RFD and lead to velocity specific strength gains, by improving neural drive in early phase muscle contraction.[5,25,28–30] In accordance with this, unpublished data from our group have shown a six week intervention of NH was superior to the ballistic exercise Kettlebell Swing in improving early-phase isometric hamstring RFD (*Ishøi et. al. unpublished*), while other data from elite footballers show associations between early phase RFD and sprint performance.[31] Combined, the observations of explosive and eccentric nature of muscle activity during NH seen in the early phase of muscle contraction, might explain some of the effects seen in high-velocity characteristics skills, such as RFD ability, high velocity strength gains,[32] and sprint and jumping performance; despite it being performed at slow angular velocity. In terms of injury reduction perspectives of the current data, the early and high eccentric RER during NH could be characteristics that target BFlh-specific neural inhibition seen in either previously injured athletes[33] or acutely at-risk athletes displaying inhibition in a state of fatigue.[22,34]

The NH exercise has previously been reported to increase eccentric hamstring strength at higher velocities than those at which the exercise is performed[32] while other data show adaptations following eccentric training is velocity specific.[28,29] Even though NH seems to provide numerous positive physiological and performance adaptations in spite of the low velocity contractions at short to moderate muscle lengths, data suggest contractions at long muscle lengths and high velocity can also make positive changes to morphology and performance[5,19,23,25,28,29] which would better fit the concept of exercise specificity. [5,19] Therefore, eccentric Hamstring Catches performed at high velocity and longer muscle lengths, showing greater RER than conventional resistance training exercises, could be a useful supplement in either rehabilitation or injury prevention programs.

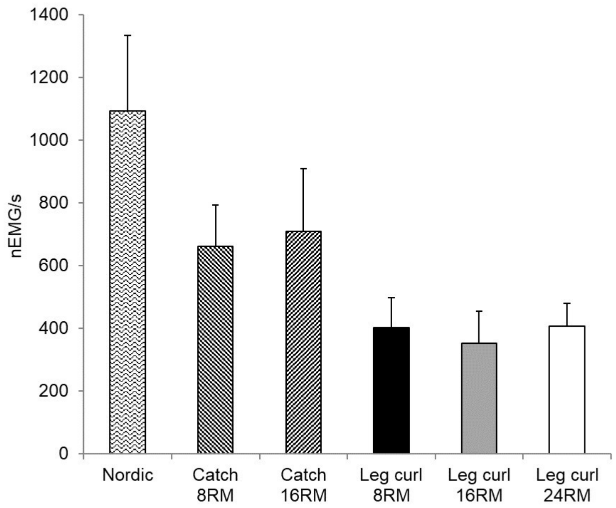

Figure 1: Peak rate of EMG rise in Biceps Femoris

BFlh = Biceps Femoris long head; nEMG/s = percentage of normalized electromyography change per second. * = variables not different from each other (p<0.05); † = variables not different from each other (p<0.05). Error bars represent the upper limits of 95% confidence intervals

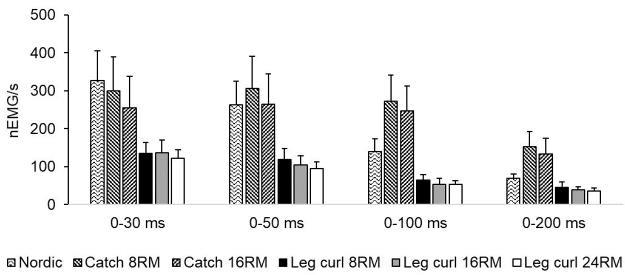

Figure 2: Mean rates of EMG rise in intervals of early phase contraction in Biceps Femoris

BFlh = Biceps Femoris long head; nEMG/s = percentage of normalized electromyography change per second. Error bars represent the upper limits of 95% confidence intervals

METHODOLOGICAL LIMITATIONS

Any potential future studies including Hamstring Catches should aim to include previously injured players, either at some stage in rehabilitation or after they return to play, and preferably in a prospective study design. The same limitations and pitfalls inherent to measuring surface EMG would also apply to the RER measures. The peak velocity during the slow fixed tempo prone Leg Curl were in the range 91-136°/s, in contrast to what was observed during experimental sessions when athletes followed a voice-recording dictating a tempo of three seconds eccentric and concentric phases which would correspond to 30°/s. This could be attributed to the small perturbations from athletes constantly trying to stabilize the elastic band which the high sampling frequency would have detected as valid data points.

PRACTICAL APPLICATIONS

The surprisingly fast and explosive recruitment characteristics during the NH exercise suggests the possibility that this exercise have the potential to improve the rate of force development and perhaps counter the effects of hamstring-related inhibition and fatigue.

Data from Hamstring Catches highlight a potential for the exercise when there is a need for eccentric exercises more specific to high-speed running in regards to high angular velocity (range: 452-490°/s vs. >1000°/s during sprinting) and eccentric contractions at longer muscle lengths with increased acceleration of muscle activity at moderate intensity levels. The exercise could potentially be implemented before commencing high-speed running drills and decelerations in rehabilitation. Another benefit of Hamstring Catches is that they can be performed with an elastic band on an examination table or training bench, opposed to requiring heavy, immobile, or costly equipment. To further adjust the muscle lengths, angular velocity or load when applying the exercise in the clinic, a wedge could be inserted under the hip, the suspension force of the band could be increased, or the athlete could be asked to catch their lower leg at different target angles.

CONCLUSION

The NH displayed not only the highest muscle activity, but also most explosive recruitment characteristics with early and high electromyographic activity rise compared to even high velocity exercises. This could be a contributory mechanism by which the NH reduces inhibition, and thereby increases performance and reduces injuries. The devised Hamstring Catches were performed at high velocity and displayed more explosive muscle activity than conventional prone Leg Curl and may provide a useful exercise-based supplement in late phase rehabilitation with higher transfer of training potential in relation to high-speed running.

CONFLICTS OF INTEREST AND SOURCE OF FUNDING

The study received no specific funding. Anthony J. Shield is a co-inventor of a device employed to assess eccentric knee flexor strength (PCT/AU2012/001041.2012) and is also a shareholder in a company responsible for commercialising the device; he was not involved in data collection or analysis in the present study. Besides this, the authors declare no conflict of interest.

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SUPPLEMENTARY MATERIALS

Video 1

Download: https://ijspt.scholasticahq.com/article/25364-cross-sectional-study-of-emg-and-emg-rise-during-fast-and-slow-hamstring-exercises/attachment/64507.mp4?auth_token=msF1cPCn4Z2cr42jrUCg