EFFECT OF THE NORDIC HAMSTRING EXERCISE ABILITY ON IN-VIVO FASCICLE DYNAMICS DURING VARIATIONS OF THE NORDIC HAMSTRING EXERCISE

Nicholas Ripley[1], Paul Comfort[1,2] and John J. McMahon[1]

Human Performance Laboratory, Directorate of Psychology and Sport, University of Salford, Salford, United Kingdom[1]
Centre for Exercise and Sport Science Research, Edith Cowan University, Joondalup, Australia[2]

The purpose of this study was to determine if the ability to perform the Nordic hamstring exercise (NHE) impacts upon the fascicle dynamics of the bicep femoris long head during the NHE performed flat, decline and incline angles. 10 physically active individuals (8 males and 2 females, age 24.1±3.9 years, body mass 81.8±8.9kg, height 178.8±7.7cm) with a history of performing the NHE for training, were separated into two equal groups of high and low performers of the NHE via break-point angle assessed using 3D motion capture. Dynamic ultrasound (US) videos were collected using a 10cm probe, while semi-automatic software was used to analysed the fascicle changes. Fascicle lengthening during the NHE is dependent on NHE performance ability, with likely differences (non- overlapping control limits) between high and low performers. While absolute fascicle change was greater in the incline NHE for low performers, greater FL change was observed in the flat NHE for high performers. This could be as a result of the high performers possessing greater resting fascicle length and eccentric hamstring strength.

KEYWORDS: Hamstrings, dynamic ultrasound, bicep femoris, fascicle length tracking.

INTRODUCTION: The plasticity of the hamstring muscles’ fascicle length (FL), in response to different training stimuli, is extremely important in the reduction of HSI risk (Bourne et al., 2018). Supramaximal eccentric exercises, i.e. Nordic hamstring exercise (NHE), have been shown to increase bicep femoris (BF) FL due to the addition of sarcomeres in-series (Bourne et al., 2018). Fascicle dynamics of eccentric hamstring exercises, utilising dynamic ultrasound (US), has only been reported in one study (Cataneo, 2018). However, the examined exercises were submaximal, performed at a low load and with minimal to no negative work. Despite this, the greatest fascicle lengthening occurred within the glider, followed by the diver and extender exercises (Cataneo, 2018). Unfortunately, due to poor video quality the authors could only observe differences in FL between images captured at the beginning and end of each exercise, thus the results should be interpreted with caution, as they do not represent fascicle behavior throughout entire repetitions.
The NHE is generally prescribed on a flat horizontal surface, where the eccentric portion is performed with a controlled descent until a break point is reached. However, increases in eccentric hamstring strength have been shown to be related to an increased break point angle (Delahunt, McGroarty, De Vito, & Ditroilo, 2016), therefore, once athletes are able to perform most of the movement with control, there should be a progressive application of external load (Bourne et al., 2018). However, performing the NHE at an incline or decline allows for manipulation of the lever arm through which the centre of mass (with respect to the knee) is acting, thereby increasing or decreasing the amount of force required to control the descent of the centre of mass for any given knee angular displacement. A decline position would result in a greater load at a shorter muscle length, whereas an incline position would reduce the load and potentially result in a longer muscle length at any given angular displacement. However, to date, no research has attempted to quantify the BF FL changes during the NHE. Therefore, the aim of this study was to quantify BF FL changes during the NHE and determine if the ability to perform the NHE, defined by NHE break point angle, impacts FL changes. This information may aid researchers and practitioners in explaining why preferential adaptations (i.e. increased BF FL), may occur when utilising the NHE.

METHODS: Ten physically active individuals (8 males and 2 females, age 24.1 ± 3.9 years, body mass 81.8 ± 8.9 kg, height 178.8 ± 7.7 cm) with no history of lower-limb injury participated. All participants reported being physically active having a training history of performing the NHE. The study was approved by the institutional Ethics committee and conformed to the principles of the Declaration of Helsinki (1983). Prior to performing the NHE, a standardised warm up was performed consisting of two sets of ten repetitions of body weight squats, lunges and leg swings. To perform the NHE, participants were knelt on a padded bench (Power lift, Jefferson, IA, USA), with the ankles secured immediately superior to the lateral malleolus by ankle pads. Participants performed three repetitions of the NHE at each position (Nordic hamstring bench angle flat (0°), incline 20° and decline -20°), in a random order, with one-minute rest provided between each repetition and 2-3 minutes between each position.

Three-dimensional lower limb motion data were acquired for the NHE variations via infrared Oqus cameras (Qualisys, Partille, Sweden) and Qualisys C-motion software (version 3.90.21, Gothenburg, Sweden). Passive retro-reflective markers were placed upon the lateral malleoli, lateral femoral epicondyles, greater trochanter and acromion process. Motion data were captured for 15 seconds, sampling at 250Hz. A linear array probe (10cm, 44Hz, Mylab 70 XVision, Genoa, Italy) collected dynamic US video clips from the participants' self-identified dominant leg. A custom designed cast was used to attach the probe to the posterior thigh ensuring adequate pressure. The probe was applied in orientation to the BF fascicles following the line of the muscle to enable optimal imaging through the entire movement. An external synch pulse was applied to both the US scanner along with an open analogue channel into the Qualisys software (error <0.002s). This synch pulse provided a matched time whereby the US images could be synchronised to the 3D motion for appropriate analysis and interpretation. Instantaneous hip and knee angles and knee angular velocity were calculated. Raw data was subsequently exported into a custom designed Excel spreadsheet, where movement onset was identified when participants moved >5° from a knee angle taken from the first two-seconds of data collection. To identify the instance where participants could no longer control the decent (i.e. break-point), a knee angular velocity threshold of $20°.s^{-1}$ was applied (Delahunt et al., 2016). Dynamic US videos were analysed using a semi-automated tracking algorithm (Ultratrack, MATLAB, Math-works) (Farris & Lichtwark, 2016). Video files were initially cropped corresponding to the points between movement onset and break point. Following this, a muscle region of interest and fascicle end points were defined. The muscle region of interest was defined as the area between the superficial and deep aponeuroses of the BF. A muscle fascicle of interest was defined as the straight-line distance between the superficial and deep aponeuroses. A fascicle was chosen based on it being visible across the entire task for all participants.

Data are presented as mean ± SD. Normality was assessed by Shapiro-Wilk's statistic. Absolute and relative between-trial reliability were assessed by coefficient of variation (CV) percentages and a two-way random effect model intraclass correlation coefficient (ICC) with 95% CIs. Between trial reliability of time-series data from the US was assessed using a coefficient of multiple correlation (CMC) with 95% CIs. Minimum acceptable reliability was confirmed using an CV <10%. The ICC and CMC values will be interpreted based on the lower bound CI as (<0.50) poor, (0.5-0.74) moderate, (0.75-0.90) good and (>0.90) excellent (Koo & Li, 2016). Mean time-series data of high and low NHE performers change in FL was plotted along with the corresponding upper and lower 95% confidence intervals to create upper and lower control limits, where a likely difference is determined by non-overlapping shaded areas. The NHE performance was determined by break-point angle, with high (n=5) and low performers (n=5).

RESULTS: All data was normally distributed (p >0.05). Break point angle demonstrated high absolute and relative reliability (Table 1). The high performing group reached break point angles of 141 ± 4°, 129 ± 6° and 108 ± 11° for incline, flat and decline, respectively. In contrast however, the low performing group reached break point angles of 122 ± 13°, 103 ± 7° and 82± 13° for incline, flat and decline, respectively.

Table 1. Absolute and relative between-trial reliability for kinematic and dynamic ultrasound measures			
	Break point angle		
	Incline	**Flat**	**Decline**
ICC (95%CI)	0.877 (0.626 - 0.975)	0.965 (0.877 - 0.993)	0.943 (0.809 - 0.989)
CV%	0.67	1.44	1.64
	Dynamic Fascicle change		
ICC (95% CI)	0.977 (0.965 - 0.989)	0.917 (0.816 - 1.000)	0.979 (0.963 - 0.995)
CMC (95% CI)	0.969 (0.958 - 0.981)	0.901 (0.802 - 1.000)	0.972 (0.958 - 0.985)

The performance groupings were identical across each position. Between trial time-series data for FL changes demonstrated nearly perfect relative reliability for all positions (Table1). The higher performing groups (i.e. those who achieved a greater break-point angle) displayed greater FLs across all positions (Figure 1-3). The incline angle displayed likely differences across the entire normalised time-series (Figure 1), whereas both flat and decline variations displayed overlapping control limits; indicating non-likely differences within the time-series (Figures 2 & 3).

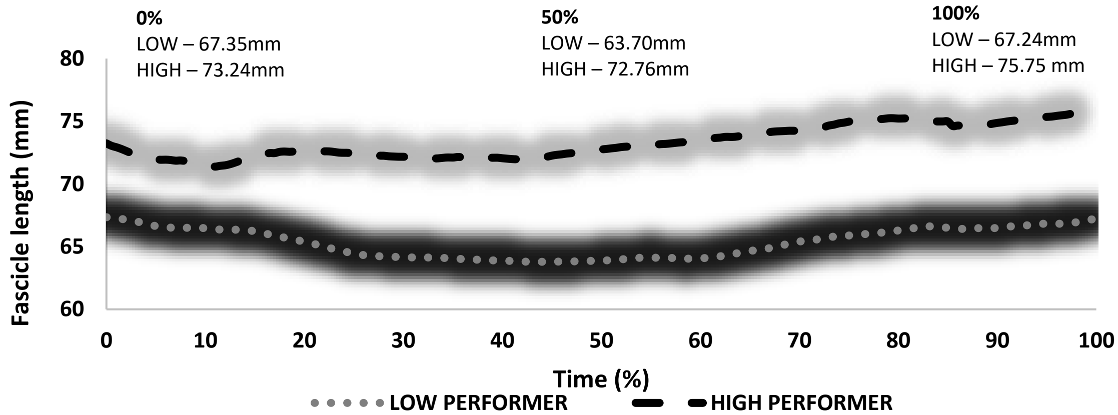

Figure 1. Dynamic BF FL changes during the incline NHE for high and low performers with 95% CIs.

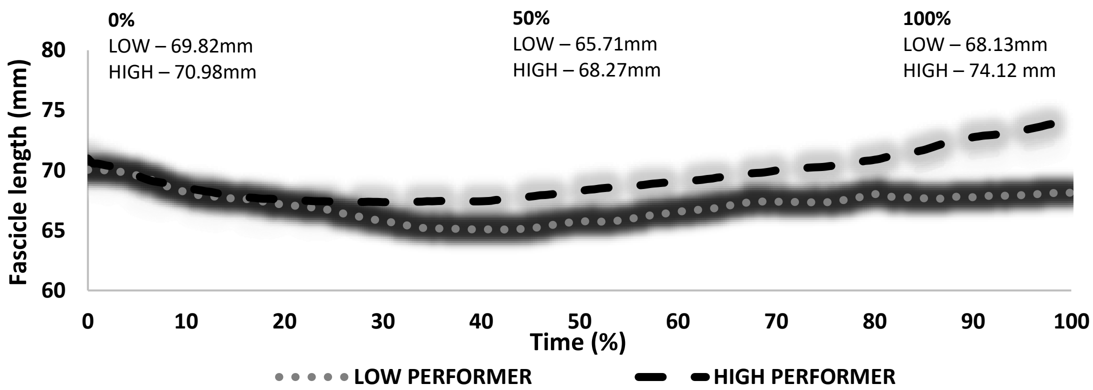

Figure 2. Dynamic BF FL changes during the flat NHE for high and low performers with 95% CIs

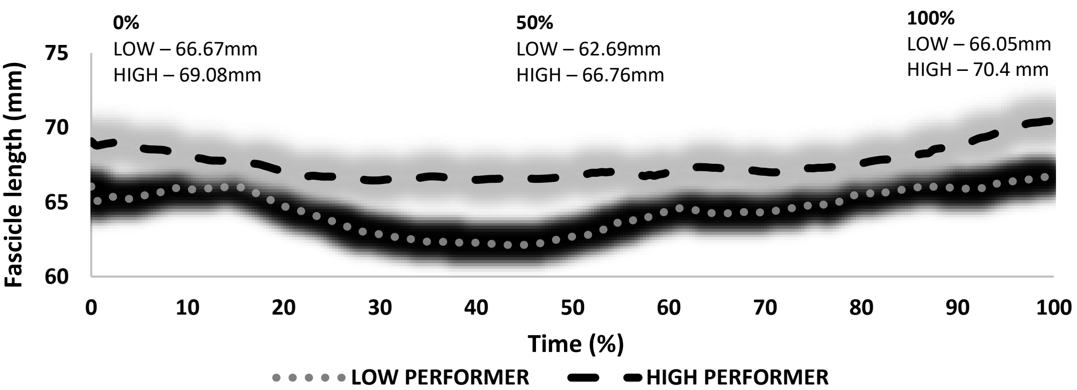

Figure 3. Dynamic BF FL changes during the decline NHE for high and low performers with 95% CIs.

DISCUSSION: The results of the present study demonstrate that an individual's NHE performance could alter the FL dynamics within the BF, as the higher performers possessed greater FLs and went through a greater degree of FL change throughout each of the NHE variations. In contrast, low performers who underwent similar initial shortening, only lengthened to their initial starting lengths up to the break point (100%) of the NHE. This finding could be explained by potential relationships between NHE break point angle, eccentric hamstring strength and BF FL. The high performers, who possessed the greater FLs, would also be expected to possess greater eccentric strength and capability to actively, control, lengthening prior to reaching a break point. The FLs observed within the present study are shorter than those previously reported for resting and 25% MVIC lengths (Bourne et al., 2018), however this is not surprising given the changes in anatomical position. The observed FLs are similar to those presented by Kellis (2018), who observed FL at different anatomical positions, during passive stretching.

This is the first study to investigate the effect of the performance angle on the NHE. For both groups, break-point angle was found to be greatest in the incline variations indicating that this variation could be of a lower intensity, permitting the participants to train at longer muscle lengths, a common complaint made by coaches about the NHE. Furthermore, during the incline variation the low performing group went through the greatest fascicle lengthening, albeit to return to the initial length. This finding is crucial, as controlled, lengthening is what is required for the desired adaptive response (increased FL and eccentric strength (Bourne et al., 2018)). Therefore, an incline variation that permits greater fascicle lengthening, under control could be more effective exercise for training, especially for lower performing individuals.

Dynamic ultrasound imaging is not a novel concept; however, this is the first study to analyse dynamic ultrasound videos of the BF during exercise, whereas previous attempts have only analysed single images (Cataneo, 2018). A number of methodological difficulties have been reported previously such as plane, depth, image quality and the fact that the FL often exceeds many ultrasound probes, requiring extrapolation increasing the potential sources of error. One explanation as to why this study succeeded with high levels of reliability, is that a 10 cm field of view which was utilised, was able to image the entire fascicle without the need for estimation equations, providing optimal image quality for the automatic processes.

CONCLUSION: Dynamic FL changes during the NHE could be dependent on NHE performance ability. Furthermore, alterations made to the position of the NHE can also impact upon FL changes, with the incline and flat variations permitting the greatest absolute FL change for the low and high performing groups, respectively. This of interest to practitioners as the desired adaptations, from the controlled lengthening action, could be optimised by altering the performance angle of the NHE, with an appropriate regression of intensity within the NHE being an incline for lower ability individuals.

REFERENCES

Bourne, M. N., Timmins, R. G., Opar, D. A., Pizzari, T., Ruddy, J. D., Sims, C., Shield, A. J. (2018). An Evidence-Based Framework for Strengthening Exercises to Prevent Hamstring Injury. *Sports Medicine, 48*(2), 251-267.

Cataneo, M. (2018). Hamstring dynamics during three different eccentric exercises.

Delahunt, E., McGroarty, M., De Vito, G., & Ditroilo, M. (2016). Nordic hamstring exercise training alters knee joint kinematics and hamstring activation patterns in young men. *European Journal of Applied Physiology, 116*(4), 663-672.

Farris, D. J., & Lichtwark, G. A. (2016). UltraTrack: Software for semi-automated tracking of muscle fascicles in sequences of B-mode ultrasound images. *Computer methods and programs in biomedicine, 128*, 111-118.

Kellis, E. (2018). Biceps femoris fascicle length during passive stretching. *Journal of Electromyography and Kinesiology, 38*, 119-125.

Koo, T. K., & Li, M. Y. (2016). A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *Journal of Chiropractic Medicine, 15*, 166-169.