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Research article

The Effect of Ankle Position on Peak Eccentric Force during The Nordic Hamstring Exercise

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Abstract

Peak eccentric force during the Nordic hamstring exercise (NHE) is recognized as a predictive factor for hamstring strain injury (HSI). During the NHE, the knee flexor muscles are eccentrically contracting to resist the knee joint extension. Therefore, it is thought that the action of the gastrocnemius muscle, and thus the ankle position, influences peak eccentric force during the NHE. However, the effect of ankle position on peak eccentric force during the NHE remains unclear. Therefore, we investigated the effect of ankle position on peak eccentric force during the NHE in a cohort of 50 healthy young male rugby players (mean age, 18.7 ± 1.2 years; mean body mass, 81.7 ± 15.2 kg; height, 1.72 ± 0.06 m) with no history of HSI. Each participant performed NHE strength testing with the ankle dorsiflexed or plantarflexed position and was instructed to fall forward as far as possible within 3 s. Peak eccentric force, reported relative to body mass (N/kg), of both legs was recorded, and the mean values of both legs were compared in both ankle positions. The mean peak eccentric force was significantly greater with the ankle plantarflexed position than the dorsiflexed position (3.8 ± 1.1 vs. 3.5 ± 1.1 N/kg, respectively, $p = 0.049$). These results indicate that ankle position should be carefully considered when measuring peak eccentric force during the NHE and performing NHE training.

Key words: Eccentric exercise, hamstring strain injury, risk screening, injury prevention

Introduction

Hamstring strain injury (HSI) is among the most frequent sports injuries, as the hamstring is especially susceptible to strain injury during high-speed running due to eccentric contractions to absorb knee extension moment to decelerate lower limb momentum during the late swing phase of sprinting (Woods et al., 2004; Brooks et al., 2006; Chumanov et al., 2012; Schache et al., 2012). Therefore, eccentric hamstring strength is considered important to prevent HSI (van Dyk et al., 2016; Lee et al., 2018). Although many previous studies have investigated the mechanism, risk factors, and strategies for the prevention of HSI, the incidence has not changed over the past decade (Buckthorpe et al., 2019; Green et al., 2020).

Eccentric hamstring strength is commonly measured using an isokinetic dynamometer. However, a review article pointed out that the role of isokinetic strength assessment in detecting future risk of HSI is limited only in eccentric knee flexor torque at a lower angular velocity (60°/s), although this contribution is relatively small (effect size = 0.2) (Green et al., 2018). Thus, the authors suggest using alternative strength tests to assess eccentric hamstring force-generating capacity to predict the risk of HSI more accurately. The Nordic hamstring exercise (NHE) is a typical eccentric hamstring exercise to reduce HSI (Bourne et al., 2018; van Dyk et al., 2019). Recently, eccentric force during the NHE has been recognized as an indicator of eccentric hamstring strength. Previous studies have investigated the relationship between the peak eccentric force during the NHE and the risk of HSI (Opar et al., 2015; Timmins et al., 2016) and reported that athletes with peak eccentric force, reported relative to body mass (N/kg), of less than 4.35 N/kg were at a 2.5-fold greater risk of subsequent HSI than stronger players (Timmins et al., 2016). Thus, testing of eccentric force during the NHE has replaced isokinetic strength assessment as a predictive factor for HSI.

Hamstring strength may be affected by ankle position, as a previous study reported that isometric knee flexion torque was 14-22% greater with the ankle dorsiflexed position than the plantarflexed position (Ogborn et al., 2021; Marchetti et al., 2019). Similarly, concentric knee flexion torque (angular velocity of 60°/s) was 7-13% greater with the ankle dorsiflexed position than the plantarflexed position (Miller et al., 1996; Croce and Miller, 2000). However, a previous study found the ankle position had no impact on the electromyography activity of the hamstring and gastrocnemius, and suggested that by stretching the gastrocnemius due to ankle dorsiflexion, the gastrocnemius muscle length was extended to a sufficient position in the length-tension relationship, allowing more force to be produced during knee flexion (Croce et al., 2000). It is also generally believed that the ankle position affects knee flexion training and strength (Kim et al., 2016). Kim et al. (Kim et al., 2016) reported that the maximal concentric knee flexion torque (angular velocity of 60°/s) was 29-59% greater after four weeks of isokinetic knee flexion training with the ankle dorsiflexed position than training with the ankle plantarflexed position. These results suggest that performing NHE strength testing with the ankle dorsiflexed position could produce a greater eccentric force. Similar to the knee flexion testing, no difference was observed in electromyography activity of the hamstring and gastrocnemius during NHE between ankle dorsiflexed position and plantarflexed position (Comfort et

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al., 2017). However, no study has yet to investigate the relationship between peak eccentric force during the NHE and ankle position. Elucidation of the relationship between peak eccentric force during the NHE and ankle position could help to select the optimal ankle joint position for NHE strength testing and efficient NHE training.

Therefore, the aim of the present study was to examine the effect of ankle position during NHE strength testing on peak eccentric force. The hypothesis of this study is that peak eccentric force during the NHE is greater with the ankle dorsiflexed position than the planter flexion position.

Methods

Study approval

The study protocol was approved by the Ethics Committees of Fukuoka University (Fukuoka, Japan) and was conducted in accordance with the ethical principles for medical research involving human subjects described in the Declaration of Helsinki. The study procedures and potential risks were explained to all participants prior to providing written informed consent for study participation.

Participants

The study cohort consisted of 50 healthy young male rugby players with a mean ± standard deviation (range) age, body mass, and height of 18.7 ± 1.24 (16-20) years, 81.7 ± 15.2 (55.4-128.2) kg, and 1.72 ± 6 (1.6-1.88) m, respectively. Participants habitually performed resistance training, including knee flexors 2-3 times per week, and had experience with continuous NHE training. None of the participants had a history of HSI.

NHE strength testing

For evaluation of peak eccentric force during the NHE, each participant was in a kneeling position on a custom-made NHE device with each ankle secured above the lateral malleolus with an ankle brace that was attached to a load cell sensor (Figure 1). The force against the ankle brace in the vertical direction was quantified with the load cell sensor. Force data were synchronized and transferred at 1000 Hz from a PowerLab16/35 data acquisition and analysis system (AD Instruments, Bella Vista, NSW, Australia) to a personal computer (VersaPro; NEC Corporation, Tokyo, Japan). Each participant was instructed to gradually lean forward from the initial kneeling position at 90° knee flexion to a prone position within 3 s with the arms crossed at the chest and the hip joints fully extended. Before testing, the participants practiced the NHE strength testing 2-3 times. The NHE strength testing was conducted twice with the ankle dorsiflexed or plantarflexed position in random order. The ankle position was passively secured by the examiner. To standardize the velocity of the movement, the participants were instructed to lean forward at a constant angular velocity as indicated by a metronome. Peak eccentric force, reported relative to body mass (N/kg), of both legs was recorded, and the difference in the mean peak eccentric force between the right and left legs was used for further analyses.

Statistical analyses

The intraclass correlation coefficient (ICC), coefficient of variation (CV) and their 95% confident intervals (95% CIs) were calculated to assess relative reliability between the two trials. An ICC values were based on the lower bound 95% CI, and ICC of ≥ 0.9 was regarded as excellent, 0.75-0.9 as good,0.5-0.75 as moderate, and ≤ 0.5 as poor (Koo and Li, 2016), while a and CV of ≤ 10% was considered reliable (William, 2005) The Shapiro-Wilk test was used to assess the normality of the data. The Wilcoxon signed-rank test was used to compare the mean peak eccentric force of the right and left legs during NHE between the two ankle positions. Effect size (ES) describing the magnitude of the differences in peak eccentric force between ankle positions were examined by calculating r using the following equation: $r = Z/\sqrt{n}$ (Mizumoto and Takeuchi, 2008). Cohen et al.(Cohen, 1988) described r of 0.1-0.3 as representing a small, 0.3-0.5 as a moderate, and ≥ 0.5 as a large magnitude of change. In addition, Spearman's rank-order correlation was used to examine the relationship between the ankle position and the mean peak eccentric force, and 95% CIs of correlation coefficient was calculated. Thresholds of 0.1-0.3, 0.3-0.5, 0.5-0.7, 0.7-0.9, and ≥ 0.9 for small, moderate, large, very large, and extremely large correlation coefficients were used (Hopkins et al., 2009). A probability (p) value of < 0.05 was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics for Windows, version 27.0. (IBM Corporation, Armonk, NY, USA).

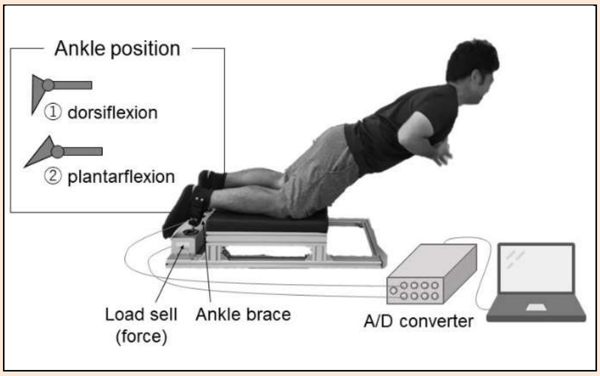

Figure 1. Setup for measurement of NH force.

Results

The relative reliability of the mean peak eccentric force of the right and left legs was good to excellent with the ankle dorsiflexed position (ICC = 0.88; 95% CI 0.81 to 0.93, CV = 7.8%; 95% CI 2.6 to 14.1) and ankle plantarflexed position (ICC = 0.91; 95% CI 0.85 to 0.95, CV = 6.8%; 95% CI 3.3 to 10.1). As shown in Figure 2, the mean peak eccentric force of the right and left legs was significantly greater with the ankle plantarflexed position than the dorsiflexed position ($p = 0.049$). Effect size (r) was small ($r = 0.28$). Significant correlations in the mean peak eccentric force of the right and left legs were evident with the ankle dorsiflexed and plantarflexed positions ($r = 0.72$; 95% CI 0.55 to 0.83, $p < 0.01$) (Figure 3).

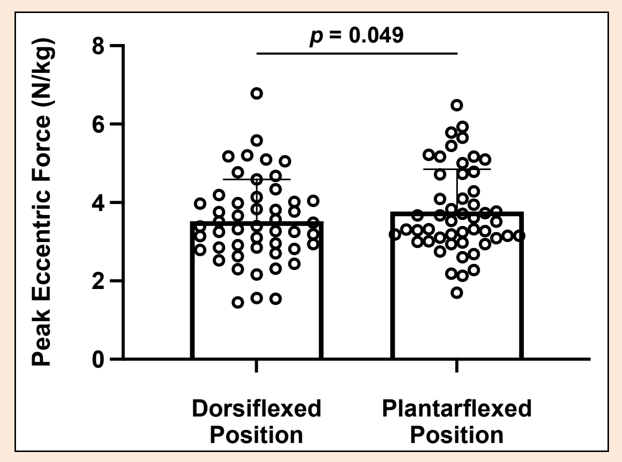

Figure 2. **Comparison of the mean peak eccentric force values of the right and left legs with the ankle plantarflexed and dorsiflexed positions.**

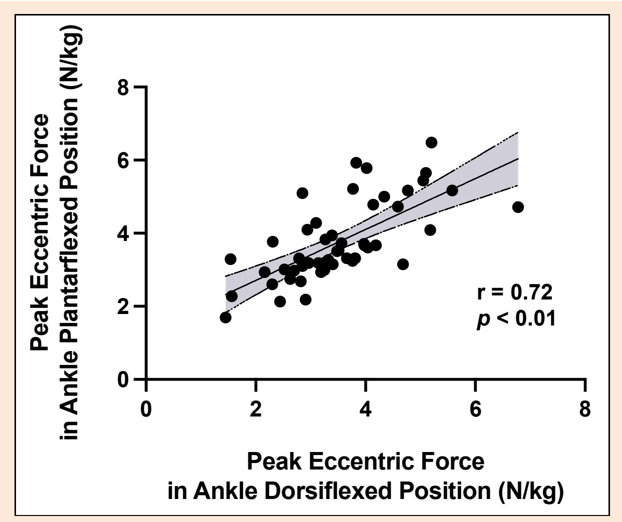

Figure 3. **Correlations between the mean peak eccentric force values of the right and left legs with the ankle plantarflexed and dorsiflexed positions.**

Discussion

The present study investigated the effect of ankle position during NHE on peak eccentric force in well-trained young rugby players. The most important finding was that the mean peak eccentric force during the NHE of the right and left legs was significantly greater with the ankle plantarflexed position than the dorsiflexed position. However, this result did not support the hypothesis that peak eccentric force during the NHE is greater with the ankle dorsiflexed position than the planterflexed position.

Previous studies have reported that isometric and concentric knee flexion torque was significantly greater with the ankle dorsiflexed position than the plantarflexed position (Ogborn et al., 2021; Marchetti et al., 2019; Miller et al., 1996; Croce et al., 2000). Since the gastrocnemius is a biarticular muscle, it is thought that ankle dorsiflexion stretches the gastrocnemius and brings it closer to its optimal length, which contributes to knee flexion strength and knee joint stability, thereby enabling greater muscle force (Miller et al., 1996; Croce et al., 2000) In NHE strength testing, it was thought that the ankle dorsiflexed position was suitable for exerting greater peak eccentric force than the plantarflexed position; but, our results differed from the hypothesis. Ankle plantarflexion slackens the gastrocnemius, possibly resulting in decreased activity of the hamstring as well as the gastrocnemius. However, Comfort et al. (2017) reported that ankle position did not influence the activity of the hamstring and gastrocnemius during NHE. In addition, recent studies have shown that peak eccentric force during the NHE was not related to isometric and isokinetic knee flexion strength (Moreno-Pérez et al., 2020; van Dyk et al., 2018) These results suggest that differences in ankle position might influence peak eccentric force during the NHE by affecting factors other than knee flexion torque and muscle activity acting on knee flexion. Notably, NHE was performed without securing the hip joint and trunk; thus, the hip and trunk muscles were likely to be used during the NHE strength testing. In fact, Sarabon et al. (2019) reported that during NHE, the torque exerted by the hip joint was about half of that of the knee joint (150 vs. 300 Nm, respectively). Moreover, Narouei et al. (Narouei et al., 2018) reported that muscle activity of the internal and external obliques or erector spine was observed during NHE. Accordingly, in the present study, changes to the hip and trunk muscle activities with the ankle plantarflexed position might exert a larger peak eccentric force during the NHE. It appears that further studies are required to clarify the effects of ankle position on the mechanical properties of hip and trunk muscles during NHE.

To the best of our knowledge, this is the first study to examine the relationship between ankle position and peak eccentric force during the NHE. Previous studies revealed that a greater peak eccentric force during the NHE decreases future risks of HSI (Opar et al., 2015; Timmins et al., 2016) and that a peak eccentric force, reported relative to body mass (N/kg), of less than 4.35 N/kg was associated with a 2.5-fold greater risk of a subsequent HSI (Timmins et al., 2016). The results of the present study showed that peak eccentric force during the NHE was significantly greater with the ankle plantarflexed position than the dorsiflexed position, suggesting the importance of considering ankle position for measurement of peak eccentric force during the NHE. However, no previous studies that examined the relationship between peak eccentric force during the NHE and the incidence of HSI took into account the position of the ankle during NHE. Hence, further studies are needed to confirm the optimal ankle position for prediction of the risk of HSI by peak eccentric force during the NHE. On the other hand, it has been reported that NHE training improves peak eccentric force during the NHE and several variables related to HSI, such as sprint performance and hamstring fascicle length (Bourne et al., 2017; Bautista et al., 2021). The effect of ankle position on the efficacy of NHE training is an interesting matter from the viewpoint of HSI prevention.

Of note, a very large positive correlation (r = 0.72) was observed in the present study between peak eccentric force during the NHE with the ankle in both the plantarflexed and dorsiflexed positions. This result indicates that athletes who exerted greater peak eccentric force on the ankle plantarflexed position also exerted a larger peak eccentric force on the ankle dorsiflexed position, suggesting that there is no net difference in peak eccentric force during the NHE on the ankle planterflexed position vs. the dorsiflexed position. On the other hand, the eccentric force was significantly greater with the ankle plantarflexed position than the dorsiflexed position, but the effect size (*r*) was small (*r* = 0.28) in the present study. In addition, fifteen participants exerted a peak eccentric force during the NHE greater than 4.35 N/kg, which is a critical cut off value of the future risk of HSI(Timmins et al., 2016); however, peak eccentric force was less than 4.35 N/kg with the ankle plantarflexed position for several participants (n = 2), whereas the peak eccentric force with the ankle dorsiflexed positions was greater than 4.35 N. These results suggest that the ankle plantarflexed position is not necessarily suitable for global evaluation of peak eccentric force during the NHE. During the late swing to contact phase of sprinting, which is considered to be a high risk for HSI, ankle dorsiflexion movement and preactivation of ankle dorsiflexor and plantarflexor will increase the stiffness of those muscle-tendon units to tolerate and absorb high impact loads at the beginning of the ground contact (Kyröläinen et al., 1999; Kuitunen et al., 2002). The importance of peak eccentric force during the NHE evaluation with the ankle dorsiflexed position can be seen from the mechanical characteristics in this phase, during which HSI is more likely to occur. Therefore, the choice of the ankle position during NHE should be carefully considered for each participant.

It should be noted that NHE was performed within 3 s in the present study, a longer duration of NHE (e.g., 5 or 6 s) was provided in previous studies (Blandford et al., 2018; Hegyi et al., 2019). Moreover, the duration of NHE was controlled by metronome in this study, but the exact duration was not measured. Duration of NHE may affect the difference of ankle position in eccentric force during NHE; therefore, future study should be required to examine the difference of ankle position in eccentric force during NHE within the variable duration.

Conclusion

The results of the present study revealed that peak eccentric force during the NHE was significantly greater with the ankle plantarflexed position than the dorsiflexed position. The position of the ankle should be carefully considered when measuring peak eccentric force during the NHE.

Acknowledgements

The experiments comply with the current laws of the country in which they were performed. The authors have no conflict of interest to declare. The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author who was an organizer of the study.

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Key points

- We examine the relationship between ankle position and peak eccentric force during the Nordic hamstring exercise.
- Peak eccentric force was significantly greater with the ankle plantarflexed position than the dorsiflexed position
- Significant positive correlation was observed between peak eccentric force with the ankle in both the plantarflexed and dorsiflexed positions.
- These results suggest that the position of the ankle should be carefully considered when measuring peak eccentric force during the Nordic hamstring exercise.

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