RELIABILITY AND COMPARISON OF FORCE CHARACTERISTICS OF THE NODIC HAMSTRING EXERCISE

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The purpose of the current study was to ascertain the between-trial reliability of peak force (PF) and mean force (MF) during the Nordic hamstring exercise (NHE) performed on the Nordbord and determine bilateral differences in PF, MF and instantaneous force (IF). Nineteen strength-trained males performed three NHEs on the Nordbord. PF showed a trivial-small non-significant increase between trials (d = 0.15 – 0.29, p = 0.125 – 0.459), MF was significantly higher in the left limb in trial 3 compared to trial 1 (p = 0.021 d = 0.29). Reliability and variability of PF was moderate-excellent (95%CI ICC = 0.666 – 0.926) and acceptable (CV <10%), respectively, MF was poor-good (95%CI ICC = 0.413 – 0.835) and unacceptable (CV >10%) across trials. Reliability and variability of PF and MF, between trials 2 and 3 were moderate-excellent (95%CI ICC = 0.627 – 0.950,) and acceptable (CV <10%). No between limb-differences in PF were observed (p = 0.071; d = 0.16), however, significant-small differences (p = 0.005; d = 0.34) were evident in MF. IF was higher for the right limb between 10 and 89% of normalized time across trials 1-3 but was not significant across trials 2-3. There were no significant (p ≥0.05) between limb differences in PF, but significant-small between limb differences in MF (p = 0.005, d = 0.26-0.34). Reliability of Nordbord PF were moderate-excellent; however. Practitioners should use >3 repetitions of the NHE and disregard the first repetition, while including analysis of MF and IF.

KEY WORDS: Strength; Injury; Training; Hamstring Strain Injury Risk; Screening

INTRODUCTION: The Nordic hamstring exercise (NHE) is effective at increasing knee flexor eccentric strength,(Presland, Timmins, Bourne, Williams, & Opar, 2017) which can help to mitigate hamstring strain injury (HSI) occurrence.(Al Attar, Wesam Saleh A, Soomro, Sinclair, Pappas, & Sanders, 2017) The ‘Nordbord’ has been developed assess knee flexor strength during the NHE.(Opar, Piatkowski, Williams, & Shield, 2013) The test-retest reliability of both the between-trial peak force and between-trial mean PF during the NHE, as measured by an initial Nordbord prototype, was reported as acceptable (intraclass correlation coefficient [ICC] = 0.83-0.90; coefficient of variation percentage [CV%] = 5.8-11.0%),(Opar et al., 2013) but the prototype had a higher sample frequency than the current production version that is now widely used in sport (1000 vs 50 Hz, respectively). This an important factor as the force-time sample frequency of the Nordbord may influence the reliability of resultant force-time variables of the NHE. Thus, determining the reliability of NHE force-time variables calculated using the production version of the Nordbord is warranted.

Bilateral force asymmetries of ≥15% and ≥20% have been cited as risk factors for future HSI in rugby union players,(Bourne, Opar, Williams, & Shield, 2015). PF values alone describe just one force data point in a complete force-time series; thus they do not describe how force differs or changes between limbs throughout the full NHE. Comparing the relative force contribution from each limb *during* (i.e. instantaneous force [IF]) the full performance of the NHE between-trials may inform likely strength adaptations to be experienced by each limb after completing the NHE as part of a strength training program.

The purpose of this study was, (1) we aimed to ascertain the between-trial reliability of PF and MF during the NHE performed on the Nordbord. (2), to calculate bilateral differences in PF, MF and IF throughout the NHE. It was hypothesized that MF and PF would be lower during the first repetition than in subsequent repetitions and that significant differences in IF would be evident between limbs.

METHODS: Nineteen strength-trained male participants (age 30.6 ± 8.1 years, body mass 84.4 ± 5.9 kg, height 1.79 ± 0.06 m), volunteered to participate in this study. Subjects attended a single testing session (cross-sectional study design). Written informed consent was provided prior to testing and the study was pre-approved by the institutional ethics committee.

Participants performed three maximal NHE trials, interspersed by one minute, on a Nordbord (Vald Performance, Newstead, Australia), sampling force data at 50 Hz. In Microsoft Excel, the mean force plus five times the standard deviation (±) was calculated from the initial second of data which corresponded to when participants were knelt upright before they commenced the NHE. This calculation created a ‘force threshold’, with the onset of movement defined as the instant at which force exceeded this value. The PF was defined as the highest force after the onset of movement. The MF was calculated as the average force between the onset of movement and PF.

Relative reliability was determined using ICC (3,1) and associated 95% confidence intervals (CI) and were interpreted based on the lower bound CI.(Koo & Li, 2016) Absolute variability was calculated using CV%, with ≤10% considered acceptable. Likely limb differences in IF (between onset of movement and PF) were determined by plotting the time normalized (200 samples) ensemble average curves for each limb with upper and lower 95% confidence intervals and identifying non-overlapping areas. Mean differences (α = 0.05) in PF and MF between trials were identified using a repeated-measures ANOVA with Bonferroni post-hoc analysis. Within trial differences between the left and right limbs were compared using dependent t-tests.

RESULTS: PF increased subtly across trials (Figure 1a), with trivial-small but non-significant differences noted between trial 1 and trials 2-3 (d = 0.15-0.29; p = 0.125 – 0.459,) but only trivial differences noted between trials 2 and 3 (d = 0.10-0.13; p = 0.958 - 1.00). MF increased across trials with trivial-small differences noted between trial 1 and trials 2-3 (d = 0.004 - 0.44; p = 0.038 – 0.271). Post-hoc analysis showed that MF was higher in trial 3 than trial 1 in the left limb (d = *0.29;* p = 0.021). Reliability and variability of PF between trials 1, 2 and 3 was moderate to excellent and acceptable, respectively (ICC = 0.823-0.834 95% CI = 0.666 – 0.926, CV = 9.0-9.1%) but this was not evident for MF (ICC = 0.651-0.690, 95% CI = 0.413 – 0.835, CV = 12.6-13.8%). Reliability and variability of both PF and MF, between trials 2 and

3, however, were moderate to excellent and acceptable (ICC = 0.835-0.875, 95% CI = 0.627 – 0.950, CV = 7.0-9.9%), respectively.

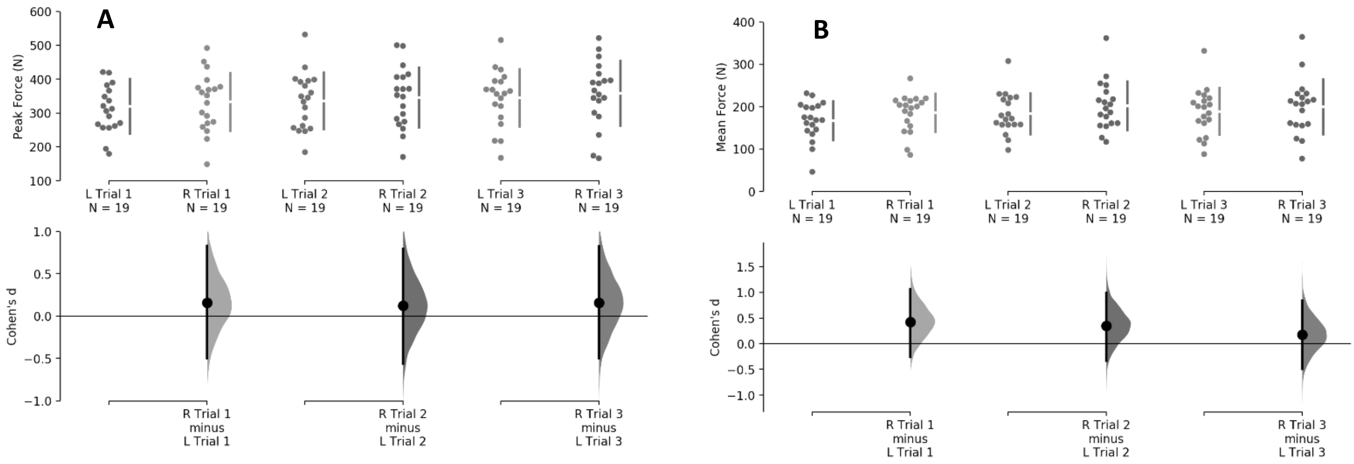

Figure 1 Cohen's *d* comparisons of peak force (A) and mean force (B) in a Cumming plot. Raw data from both limbs across each trial are presented on the upper axes; each mean difference is plotted on the lower axes as a bootstrap sampling distribution. Mean differences are depicted as dots; 95% confidence intervals are indicted by the ends of the vertical error bars.

Between limb measures of PF were trivial, non-significant ((*d* = 0.16); *p* = 0.071) (left = 333.1 ± 78.5 N; right = 345.9 ± 84.7 N) but there was a small, significant (*d* = 0.34); *p* = 0.005) small difference in MF (left = 179.6 ± 45.0 N; right = 195.8 ± 49.5 N) between limbs. Additionally, IF was higher for the right limb between 10 and 89% of normalized time (Figure 2).

When only considering trials 2 and 3, between limb measures of PF were trivial, non-significant (*d* = 0.14; *p* = 0.47) trivial (left 339.8 ± 84.1 N; right 352.4 ± 92.1 N) but there was a small significant (*d* = 0.26; *p* = 0.005) difference in MF (left 186.2 ± 51.7 N; right 200.8 ± 61.2 N). There were no significant within trial differences in MF or PF between limbs (Figures 1a-b).

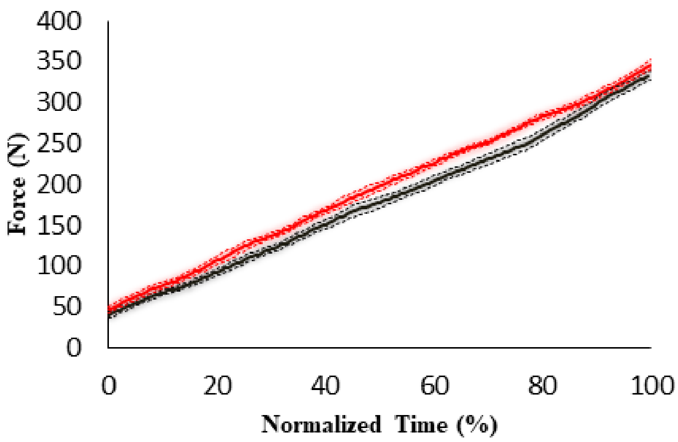

Figure 2 Mean force-time curves normalized to 100% the NHE. Solid lines represent the mean with shaded areas representing 95% CI. Statistically significant differences between the right (red) and left (black) limbs are represented by the areas at which the 95% do not overlap.

DISCUSSION: The purpose of the current study was to establish between-trial reliability of PF and MF scores obtained on the commercially available version of the Nordbord, at a sample frequency of 50 Hz. Additionally, we aimed to calculate bilateral differences in PF, MF and IF during the NHE. Minimal learning effects were observed between the three trials of the NHE (subtle trial-trial increase in PF and small-significant significant-small increase MF)., and both reliability and variability were improved, when the final two trials alone were compared.

A further observation made within the present study, is that regardless of whether all trials, or only trials 2-3 were considered, MF was statistically higher in the right limb, albeit small in magnitude. The between-limb difference in MF seems to highlight the importance of practitioners including MF in the athlete assessment, given that the NHE is often used as a rehabilitative or injury prevention technique for HSI. Should one limb produce greater MF over normalized time, it would be expected that the stronger limb would experience greater strength training adaptations due greater training load over normalized time. This may reduce the effectiveness of the NHE for reducing HSI risk in the weaker limb, as it undergoes a reduced training impulse.

The results of this study indicate that monitoring PF asymmetries alone during the NHE masks the magnitude and nature of knee flexor force asymmetries before PF is achieved. This can be evidenced by the non-significant trivial between limb differences in PF reported here, while significant-small differences were evident in MF and higher IF in the right limb between 10 and 89% of normalized time. It may be prudent, therefore, for researchers and practitioners who use the Nordbord to analyze MF and IF, alongside PF, for each limb when determining bilateral asymmetries during the NHE, particularly in those athlete groups that may already be at risk of between-limb strength asymmetries due to the nature of their sport (e.g. sports with a particularly dominant limb).

CONCLUSION: Peak force scores obtained on the Nordbord, at a sample frequency of 50 Hz have good reliability, with acceptable CVs. Measures of PF alone only provide one single force measure across an entire force-time series, therefore IF should be used to identify force asymmetry across the force-time series.

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