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Title: The influence of maturation on the reliability of the Nordic hamstring exercise in male youth footballers

Running head: Maturation and NHE reliability

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Abstract

This study sought to establish the reliability of the Nordic hamstring exercise (NHE) in male youth football players. Sixty-four youth football players completed two x three repetitions of the NHE, separated by one week. Eccentric hamstring strength was during the NHE using the NordBord. Participants were categorised via maturity offset (based on peak height velocity [PHV]) and age. For all dependent variables and groups, the typical error (TE) was greater than the smallest worthwhile change. Reliability for left, right, bilateral and relative peak force for the U11s (TE=0.26 to 11.1N, coefficient of variation (CV) = 5.9 to 7.4%), U13s (TE=0.28 to 17.9N, CVs=5.6 to 7.8%) and U16s (TE=0.28 to 24.3, CVs=6.6 to 8.7%) was favourable and demonstrated no clear pattern between groups. According to PHV, those less mature provided smaller TEs (0.22 to 9.3N) and CVs (4.8 to 5.7%) compared to their more mature counterparts (TE=0.30 to 22.5N, CVs=7.2 to 8.5%). For all age and maturation groups, imbalances yielded poor reliability (TE=7.1 to 10.8N, CVs=33.1 to 38.3%). Eccentric left and right limb, bilateral and relative hamstring peak force can reliably be measured during the NHE across maturation stages. Applied practitioners should exercise caution when assessing muscular imbalances using the NHE.

Key words

Peak force; imbalance; reproducibility; relative force; eccentric; eccentric force

Introduction

Strength refers to the maximal force or torque that the skeletal muscles can exert [1] and is dependent on the muscle contraction type (e.g. concentric, isometric or eccentric) and velocity. For example, when compared to eccentric contractions, concentric and isometric contractions exhibit lower peak forces [2]. Furthermore, for the youth athlete, strength is an important part of sporting performance [3]. That is, strength is moderately and strongly correlated with sprint (r = > -0.60) and jump performance (r = > -0.76), respectively [4] and is integral for the performance of fundamental movement skills [3].

Strength increases naturally throughout maturation [5] and is underpinned by neural and muscular alterations [6–9]. For those who want to maximise a youth's strength gain, resistance training is a potent method for enhancing strength [10]. However, the magnitude of strength adaptations to resistance training can be dependent on maturation status, amongst other factors [10]. For example, strength adaptations are greater in boys during, and after, peak height velocity (PHV) than before PHV [11]. When resistance training (e.g. traditional high intensity training, Olympic lifting) youths in the pre-, mid- and post-PHV stages can expect enhancements in strength that range from 3.5 to 36% [12,13], 1.1 to 44.4% [14,15] and 8.7 to 44.5% [16,17], respectively.

Despite the well-documented strength increases with resistance training in youths, eccentric muscle actions have received little attention in the literature. Although speculative, this might be owing to coach perceptions of eccentric contractions. That is, the high force and lengthening nature of eccentric actions might cause damage to the muscle. However, it has consistently been reported that bouts of eccentric exercise in youths results in similar, and often attenuated, symptoms of exercise induced muscle damage, as compared to adults [18–20]. When used longitudinally, eccentrically-biased training can provide a range of benefits including enhanced concentric and eccentric strength [21], change of direction ability [22,23], sprint and jump performance [23,24] and decreased injury incidence [24]. Moreover, a recent meta-analysis concluded that the Nordic hamstring exercise (NHE) can induce positive changes in muscle architecture and strength [25]. Notwithstanding the performance related benefits, the NHE has the ability to reduce hamstring injuries by up to 51% in a sample of 8459 athletes [26] and is advocated within youth soccer injury prevention programmes [27] This is particularly important when considering that hamstring strains account for 12% of injuries among 17 top fight European soccer teams [28] and is considered the most important injury risk factor [29]. Though these injury rates are lower in youths compared to adults, injury prevention is still an important issue in youths as its occurrence negatively affects participation in sport and can have medical implications[30]. Before the efficacy of such a training study can be investigated, the reliability of the test must first be determined. Consequently, accurate assessment of eccentric hamstring strength via a field-based measure such as the NHE is warranted. Whilst the reliability of the NHE has been determined in adults [31], there is no available data in youths. Previous work has established that isokinetic eccentric [32] and isometric hamstring [33] muscle actions can be reproduced within acceptable limits in males youth (~13 and 17 years, respectively). However, these authors did not ascertain if maturation altered the reliability of these exercises. This is a concern in testing the youth athlete as disrupted motor coordination can occur around the interval of maximal growth [34]. Thus, it is plausible that the reliability of a test could change as it is used across the maturational spectrum [35]. A study that determines the reliability of measures of eccentric hamstring strength across maturation stages would help applied practitioners monitor strength adaptations with confidence. Whether for athlete support or inclusion in research, the importance of exercise test reliability is well established [36,37]. Moreover, by establishing the reliability of an exercise test, a practitioner/research can identify if a change has occurred due to a training intervention rather than biological variation or maturation [37]. Consequently, the aim of this study is to establish the reliability of the NHE in male youths using a field-based device (NordBord). A further aim was to establish if maturation stage, determined by both chronological age and maturity offset, influences the reliability of the NHE.

Methods

Subjects

Sixty-four male youth football players aged between 10 and 16 years took part in the study (Table 1). All participants were free from lower-limb musculoskeletal injuries, physically active and participated regularly in association football training. None of the participants were involved in any formalised strength and conditioning programmes and had no prior experience of performing the NHE. Parental informed consent was obtained for the study which was approved by the host institutions ethics committee.

[Insert Table 1 about here]

Study design

This study employed a repeated measures design in which participants performed the NHE on six separate occasions. Before each performance participants complete a standardised warm up consisting low-intensity jogging, change of direction, jumping tasks and dynamic lower-limb stretching. In the first four sessions, participants were familiarised to the NHE. Participants were deemed 'familiarised' when they could perform multiple repetitions with the correct technique (see below). These familiarisation trials were not used for analysis. For the testing trials participants attended on two occasions , separated by seven days. During each testing trial, participants completed three repetitions of the NHE. Participants did not report any symptoms of exercise-induced muscle damage (e.g. reduced muscle function or elevated muscle soreness).

Methodology

Anthropometry

Age, stature and body mass were obtained prior to testing. Participants' standing and seated height were measured using a stadiometer (Seca Model 213, Birmingham, England). Body mass was measured using a calibrated electronic scale (Seca Model 813, Birmingham, England). Maturity offset was calculated using age, body mass, standing and seated height [38]. This method provides a practical, non-invasive and accurate measure of maturation status [38]. Pre-PHV and mid-post PHV participants were categorized as exceeding -2 years and between -1 to +2.5 years, respectively, from PHV. In addition, participants were categorised chronologically by age (i.e. under 11, 13 and 16 years).

Eccentric hamstring strength

Eccentric hamstring strength was determined using the NHE on the NordBord (Nordbord, Vald Performance, Australia). The NHE is deemed a reliable marker of peak eccentric hamstring force in adult males athletes (coefficient of variation (CV) % = 5.8 to 8.5%) [31]. Participants were instructed to kneel on the padded part of the NordBord and were positioned with their ankles secured with padded hooks, which were attached to load cells. Participants were positioned so that their ankles were perpendicular to the lower limb and the hooks superior to the lateral malleolus. Participants were instructed to gradually lower their upper-body whilst trying to resistance the movement by contracting the hamstrings. With trunk and hips in a neutral position, participants were encouraged to maintain an upright posture. Coaching cues (i.e. "stay as tall as you can", "slowly fall like a tree") were provided. During the movement, participants arms were flexed at the elbow so that their palms were pronated at shoulder level. In the final stages of the movement participants were allowed to use their hands to buffer their fall. The researchers assisted in returning the participants back to the starting position. Participants performed three repetitions with a self-selected rest that ranged from 10 to 15s. The NordBord provides peak forces for each limb thus bilateral peak force was determined by averaging the three scores from each limb. Bilateral peak force was divided by body mass to established relative peak force. The imbalance in peak force between limbs was calculated as the absolute difference between left and right limbs.

Statistical analysis

The average value of peak force (N) across the three repetitions was used for analysis. Data was found to be normally distributed according to the Shapiro-Wilk statistic ($P > 0.05$). A paired samples t-test was used to determine the differences in peak force metrics between trials 1 and 2. The reliability of the NHE was quantified via the typical error (TE; standard deviation of the differences divided by √ 2) and CV (TE divided by the grand mean test-retest score, multiplied by 100) statistics [39]. The smallest worthwhile change (SWC; 0.2 multiplied by the shared standard deviation) was calculated to provide a practical interpretation of the findings. The dependent variables were considered capable of detecting small changes if the TE was less than the SWC [40].

Results

The descriptive characteristics for the NHE across groups and for the entire sample is presented in table 2. A paired samples t-test revealed a significant bias from trial 1 to trial 2 for 25 of the 30 comparisons ($P < 0.05$). For all dependent variables and for all comparisons, the TE was greater than the SWC (Table 3). Across the age groups, the CVs for left (CV% = 5.6 to 7.4), right (CV% = 5.9 to 8.7), bilateral (CV% = 6.1 to 7.4) relative peak force (CV% = 6.3 to 6.6) were generally favourable and revealed no clear trend in agreement. The peak force imbalance between left and right limbs demonstrate poor agreement between trials (CV% = 33.1 to 38.3) across the age groups. Reliability for those pre-PHV was better than those mid-post-PHV for left (CV% = 5.7 vs 6.9, respectively), right (CV% = 4.8 vs 8.5, respectively), bilateral (CV% = 4.9 vs 7.3, respectively), relative peak force (CV% = 5.0 vs 7.2, respectively) and the imbalance (CV% = 35.3 vs 36.1, respectively).

[Insert Tables 2 and 3 about here]

Discussion

We sought to establish the reliability of the Nordic hamstring exercise using a field-based device in male youth soccer players. We report that certain measures of peak force (i.e. individual limits, bilateral and relative force) can be reproduced within acceptable limits for this population. A secondary aim was to investigate if maturation affected the reliability of the NHE. Whilst reliability was not different across chronological age groups, those classified as pre-PHV demonstrated better agreement between trials than those in the mid-post-PHV group.

Atkinson and Nevill [36] propose that the reliability of a measure/test is dependent on the setting that it is applied in. For youths who resistance train, lower-body strength (maximal force, torque or kilograms) can increase by up to 44.5% [12–17] depending on maturation stage. As such a variation of 10% (i.e. a CV of 10%) would allow such improvements to be detected. Importantly, the TE and SWC can be incorporated to facilitate the analysis [37].

The reliability for the whole sample, for left, right, bilateral and relative peak force was generally favourable (CV% = 6.3 to 8.3), albeit none of the TEs were able to detect the SWC. Previous work has also reported good reliability for eccentric hamstring exercise in circumpubertal males (r = 0.71 to 0.85) [32] and isometric hamstring dynamometry in male youths (minimal detectable change = 11.8 to 15.9%) [33]. Similarly, during the NHE (in adult males) Opar and colleagues [31] reported low CVs for peak force (5.8 to 8.5%). However, our study adds to the current body of literature by demonstrating poor reliability of lower-limb strength asymmetry during the NHE (TE and CV of 9.1N and 36.9%, respectively). It is unclear why such poor reliability was observed, especially given the good agreement observed for left and right limbs individually. Irrespective of the mechanism, this data indicates that when assessing muscular imbalances during the NHE across a range of ages, applied practitioners should be cautious.

When categorising the participants by chronological age, reliability was similar across U11 (CV% = 5.9 to 7.4%), U13 (CV% = 5.6 to 7.8) and U16 (CV% = 6.6 to 8.7) groups, although none of the TE were lower than the SWC. Conversely, when categorised by maturity offset those in pre-PHV group demonstrated better reliability (TE = 0.22 to 9.3N, CV% = 4.8 to 35.5) than the mid-post-PHV group (TE = 0.30 to 22.5, CV% = 6.9 to 36.1). The reliability observed for these maturity groups can comfortably detect the increases in strength that occur in those pre- (~36%) [13] and mid-post-PHV (~44.5%) [15]. However, practitioners should adopt caution when establishing muscular imbalances using the NHE across maturation stages given the large random errors (TE = > 8.1 N and CVs > 35.5%). That we observed better reliability in those pre-PHV than their more mature counterparts, might be due to the well-established disruptions in motor performance that occur during maturation [34]. Moreover, these data reinforce the importance of catergorising youths by maturation rather than chronological age [11,41]. Nonetheless, the reliability of left and right limb, bilateral and relative peak force for the mid-post-PHV group was still acceptable and thus typical changes in strength can still be detected.

In the present study, we observed a systematic bias for several of the dependent variables. While the reasons for this are not entirely clear, the larger values in trial 2, than trial 1, might be indicative of short-term adaptation to the exercise. That participants were given four familiarisation attempts before the testing trials and could competently perform the exercise might support this. Nonetheless, applied practitioners should consider these short-term changes when assessing peak force variables using the NHE.

Conclusion

To our knowledge, this is the first study to provide a comprehensive assessment of Nordic hamstring exercise reliability in male youth soccer players. We report that, despite not being able to detect the small changes, the reliability of the exercise in generally favourable. Notably, the reliability in less mature (i.e. pre-PHV) participants was generally better than their mid-post-PHV counterparts. Nonetheless, applied practitioners can be confident in assessing changes in eccentric hamstring strength using the NHE. However, when assessing muscular imbalances using the NHE, applied practitioners should exercise caution given the large random errors.

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Table 1. Anthropometric characteristics of the participants

	All (n=64)	U11 (n=17)	U13 (n=29)	U16 (n=18)	Pre-PHV (n=29)	Mid-post-PHV (n=35)
Age (y)	13.2 ± 1.7	10.8 ± 0.3	12.1 ± 0.7	15.4 ± 0.4	11.6 ± 0.9	14.5 ± 0.9
Mass (kg)	52.3 ± 12.8	42.0 ± 3.7	39.6 ± 2.5	63.7 ± 6.6	40.0 ± 3.8	62.3 ± 7.2
Stature (cm)	161.9 ± 13.4	148.6 ± 2.8	149.2 ± 4.7	173.9 ± 6.7	148.4 ± 5.1	172.4 ± 6.7

Table 2. Mean ± standard deviations values for left, right and bilateral peak flexor force, relative peak force and peak force imbalances during the Nordic hamstring exercise

	Left limb (N)		Right limb (N)		Bilateral force (N)		Relative force (N・kg)		Imbalance (N)	
	Trial 1	*Trial 2*	*Trial 1*	*Trial 2*	*Trial 1*	*Trial 2*	*Trial 1*	*Trial 2*	*Trial 1*	*Trial 2*
U11	141.7 ± 42.8	159.1 ± 44.7*	165.2 ± 41.8	176.1 ± 40.2*	153.5 ± 40.3	167.6 ± 41.7*	3.9 ± 0.9	4.2 ± 1.0*	29.5 ± 17.7	20.5 ± 10.3
U13	211.8 ± 51.7	221.3 ± 55.7	220.0 ± 52.1	240.4 ± 63.2*	215.9 ± 51.1	230.9 ± 58.6*	4.3 ± 0.7	4.5 ± 0.7*	18.8 ± 15.6	24.3 ± 14.7*
U16	244.5 ± 65.3	264.7 ± 54.6*	260.4 ± 55.5	296.1 ± 59.8*	252.5 ± 58.9	280.4 ± 56.0*	4.0 ± 1.1	4.4 ± 1.1*	25.5 ± 18.9	32.4 ± 22.7
Pre-PHV	157.8 ± 41.8	168.4 ± 37.5*	175.7 ± 39.5	183.5 ± 36.4*	166.7 ± 38.7	176.0 ± 35.9*	4.2 ± 0.9	4.4 ± 0.9*	25.4 ± 17.0	20.3 ± 11.0
Mid-post-PHV	234.9 ± 64.8	252.4 ± 61.5*	247.5 ± 57.8	280.2 ± 66.0*	241.2 ± 60.0	266.3 ± 62.8*	4.0 ± 0.9	4.4 ± 0.9*	22.8 ± 18.3	29.9 ± 19.3*
All	202.4 ± 66.2	217.0 ± 65.0*	216.8 ± 61.2	239.0 ± 71.8*	209.6 ± 62.5	228.0 ± 67.7*	4.1 ± 0.9	4.4 ± 0.9*	23.5 ± 17.5	25.6 ± 16.8

*denotes significantly different between trials 1 and 2 ($P < 0.05$).

Table 3. Reliability statistics for left, right and bilateral peak flexor force, relative peak force and strength imbalances during the Nordic hamstring exercise

		Left limb	**Right limb**	**Bilateral force**	**Relative force**	**Imbalance**
All	*TE (N)*	14.0	18.9	15.4	0.27	9.1
	SWC (N)	4.0	5.3	4.4	0.08	2.6
	CV (%)	6.7	8.3	7.0	6.3	36.9
U11	*TE (N)*	11.1	10.0	9.8	0.26	9.6
	SWC (N)	3.1	2.8	2.8	0.07	2.7
	CV (%)	7.4	5.9	6.1	6.3	38.3
U13	*TE (N)*	12.1	17.9	14.1	0.28	7.1
	SWC (N)	3.4	5.1	4.0	0.08	2.0
	CV (%)	5.6	7.8	6.3	6.3	33.1
U16	*TE (N)*	18.3	24.3	19.8	0.28	10.8
	SWC (N)	5.2	6.9	5.6	0.08	3.1
	CV (%)	7.2	8.7	7.4	6.6	37.3
Pre-PHV	*TE (N)*	9.3	8.7	8.4	0.22	8.1
	SWC (N)	2.6	2.5	2.4	0.06	2.3
	CV (%)	5.7	4.8	4.9	5.0	35.5
Mid-post-PHV	*TE (N)*	16.7	22.5	18.4	0.30	9.5
	SWC (N)	4.7	6.4	5.2	0.09	2.7
	CV (%)	6.9	8.5	7.3	7.2	36.1