MOVEMENT VARIABILITY ASSOCIATED WITH HORIZONTAL ECCENTRIC TOWING

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The purpose of this study was to determine the movement variability associated with a novel custom built horizontal eccentric towing (HET) device. HET involves the athlete trying to move forwards whilst being pulled backwards. The variables of interest were the impulse, peak (PHEF), and mean (MHEF) horizontal eccentric force. Ten elite female field hockey players were tested on four occasions, each of which were separated by seven days. During each session, participants were required to perform three isokinetic maximal effort trials at 0.8 m/s over a distance of 10 m. The data from the three trials was averaged and the change in mean (CM), coefficient of variation (CV), and intraclass correlation coefficient (ICC) were quantified across the four testing occasions. There were large percent CMs for all three variables in initial testing (8.51% - 20.5%), this change reducing with latter testing (T4 - T3 = 1.41% - 8.47%), indicating a systematic learning effect. The between sessions CVs for all three variables ranged from 5.59% to 12.9%, the greatest variability associated with the first testing occasions (10.1% to 12.2%) and the least variability noted with the latter T4-T3 testing (5.59% to 8.49%). Only one ICC was less than 0.70 (T3-T2) and by the T4-T3 comparison all ICCs were greater than 0.85. This study concludes that two familiarisation sessions are required for the HET device in order to obtain reliable MHEF and impulse variables.

KEYWORDS: resistance, sled towing, consistency, isokinetic, sprinting, familiarisation, sports technology, load cell, motorised winch.

INTRODUCTION: Many different training methods and modalities are used in training the speed of athletes. One such method is the utilisation of resisted towing devices (Cronin et al. 2008; Kawamori et al. 2014). Typically, these devices concentrically overload the musculoskeletal system and are used by strength and conditioning coaches as an adjunct to gym based resisted training. However, it may be that eccentric (ECC) towing devices provide a better form of overload for the athlete given that: 1) a shift in fibre type towards fast twitch type IIb with fast ECC training can yield improvements in high speed concentric power (Paddon-Jones et al. 2001); 2) an increase in leg spring stiffness from ECC training can yield improvements in higher stride frequency due to a decreased ground contact time (Cronin and T Hansen 2006); and, 3) high frequency ECC leg press motion has been shown to improve both jump height and sprint time (Liu et al. 2013). However, typically the ECC overload is administered in the vertical plane, and to the knowledge of the authors no researchers have developed a device to eccentrically overload an athlete in the horizontal plane (Tinwala et al. 2016) e.g. an athlete trying to move forwards but is being pulled backwards. This concept has provided the impetus to design and construct such a device, aptly named a horizontal eccentric towing (HET) device. The device acts as a winch and uses an electric motor to tow the athlete at a set speed (follow this link to see a video of the device being used - https://goo.gl/yrkWKX). Prior to studying the acute and longitudinal adaptation associated with such a training device, it is important to understand the movement variability associated with the HET, hence the purpose of this study.

METHODS: Ten elite female field hockey players (mean ± SD: 22.2 ± 2.7 years, 168 ± 6.92 cm, 66.1 ± 6.49 kgs) participated in this study. All the athletes were undergoing resistance

training as per their regular training schedule. They had at least two years of resistance training experience and were injury free for the past six months.
Testing was conducted over four sessions that were separated by seven days. Each testing session was conducted on the same day of the week and at the same time of day. The athletes performed three maximal effort trials with two minutes rest during each session. The movement velocity of the HET was set at 0.8 m/s for a distance of 10 m for all testing sessions. The athletes were told to resist as hard as they could but at the same time provide constant resistance throughout the exercise. The HET device has a display which outputs metrics such as the peak force, mean force, and a real time force time curve. These metrics were calculated from the point at which the exercise started to when the athlete had travelled 10 metres.
The HET device is custom built and uses an electric servomotor and gearbox (SEW-Eurodrive, Germany). The motor is mounted to a cable drum and is controlled by a variable speed drive and programmable logic controller (SEW-Eurodrive, Germany). The device is operated with a touch screen monitor. In addition to the HET device, a load cell (Millennium Mechatronics, Auckland, New Zealand) was used to measure the tensile force between the athlete and the tether. The load cell was connected to a wireless data acquisition data module (National Instruments, Austin, Texas, USA). Data was sampled at 100 Hz.

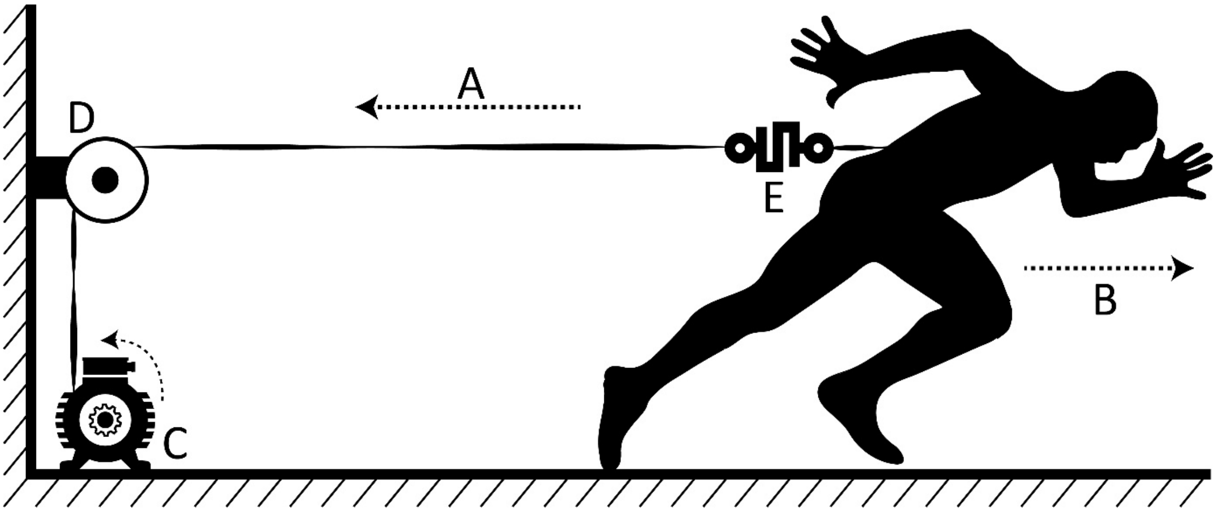

Figure 1: Conceptual drawing of the winch towing system. A=The direction the athlete moves due to the winding in of the motor, B=The direction of the force the athlete produces and tries to resist the motion, C=The motor winding in the tether/cable, D=A pulley that guides the tether/cable, E=S-beam load cell.

During each trial the peak horizontal eccentric force (PHEF), mean horizontal eccentric force (MHEF), and impulse was calculated. The initiation of the exercise was defined at the point of a sharp decrease in force following a steady increase in force indicating the slack in the cable was taken up and the first step was taken. The end of the exercise was defined at the point of the last sharp decrease in force indicating the penultimate step. The raw data was used for all the analysis without the need of a filter.
The body weight normalised mean and standard deviation was calculated for the three trials within a session for each athlete. Change in the mean (CM), typical error of measurement expressed as a coefficient of variation (CV), intraclass correlation coefficients (ICC), and 90% confidence limits were used to determine the variability of the PHEF, MHEF, and impulse. The CV was used to quantify the absolute variability or within-athlete variation of the different variables (Kayo and Koizumi 1998). All measures were computed using a customised Microsoft Excel spreadsheet (Hopkins 2015).

RESULTS: The means and standard deviations for the three variables of interest can be can be observed in Table 1. There is a systematic increase in all variables over the four testing occasions, the largest change in the mean between sessions T2-T1 (8.51% to 20.5%), which is reduced over subsequent sessions (1.41% to 8.47%). The greatest change in the means was noted for impulse whereas the least was PHEF.

The between sessions CVs for all three variables across the four testing occasions ranged from 5.59% to 12.9%, the greatest variability associated with the first testing occasions (10.1% to 12.2%) and the least variability noted with the latter T4-T3 testing (5.59% to 8.49%). PHEF had the greatest average variability across all testing occasions (CV = 9.53%), whereas MHEF and impulse were less variable and the variation very similar in magnitude (CV = ~8.6%).

The ICC is a measure of relative consistency and of the nine comparisons only one ICC was less than 0.70 (T3-T2) and by the T4-T3 comparison all ICCs were greater than 0.85. Were it not for the ICC=0.32, the rank order between testing occasions would seem very consistent and trending upwards.

Table 1: Mean, SD and reliability of the HET variables

Variables	**Mean ± Standard Deviation**				**% Change in Mean CM (90% CI)**		
	T1	T2	T3	T4	T2-T1	T3-T2	T4-T3
PHEF (N/kg)	12.7±2.83	13.6±2.15	13.7±1.70	13.9±2.36	8.51 (0.25 - 17.5)	1.41 (-8.19 - 12.0)	1.94 (-2.8 - 6.92)
MHEF (N/kg)	4.22±1.11	4.97±0.93	5.20±1.04	5.48±1.10	19.8 (9.04 - 31.6)	4.35 (-0.97 - 9.94)	7.84 (1.46 - 14.6)
Impulse (N.s/kg)	56.8±15.1	67.4±13.2	70.1±14.9	74.4±15.2	20.5 (10.5 - 31.5)	3.79 (-1.15 - 8.98)	8.47 (1.00 - 16.5)

Variables	**Coefficient of Variation CV (90% CI)**			**Intraclass Correlation Coefficient ICC (90% CI)**		
	T2-T1	T3-T2	T4-T3	T2-T1	T3-T2	T4-T3
PHEF (N/kg)	10.1 (7.30 - 17.2)	12.9 (9.24 - 22.1)	5.59 (3.98 - 9.76)	0.81 (0.50 - 0.94)	0.32 (-0.24 - 0.72)	0.90 (0.69 - 0.97)
MHEF (N/kg)	12.2 (8.73 - 20.8)	6.58 (4.76 - 11.1)	7.21 (5.13 - 12.7)	0.79 (0.47 - 0.93)	0.91 (0.74 - 0.97)	0.90 (0.71 - 0.97)
Impulse (N.s/kg)	11.2 (8.08 - 19.2)	6.13 (4.44 - 10.3)	8.49 (6.03 – 15.0)	0.83 (0.54 - 0.94)	0.93 (0.79 - 0.98)	0.87 (0.63 - 0.96)

DISCUSSION: It is important to understand the reproducibility of movement associated with any new training device, this contention providing the purpose of this paper. HET is a novel movement pattern and certainly was performed on a novel custom built device and therefore a high degree of movement variability was expected. In summary, for the most part the reliability statistics improved over the trials suggesting a learning effect and more time is needed to be spent in familiarisation. By the fourth testing occasion the reliability statistics were more than acceptable, with percentage change in the means and CVs less than 10% and ICCs greater than 0.85.

Large CMs were observed for all three variables between T2-T1, which can likely be explained as a learning effect. This learning effect is a systematic change in performance and these changes are probably due to the exposure and experience of the previous trials (Kayo and Koizumi 1998). A similar learning effect was also shown when Brughelli and Van Leemputte (2013) studied the variability associated with a novel ECC sprint cycling task. They reported significant increases in mean and peak power (% or ES) on their second testing occasion. It would seem that at least 1-2 familiarisation sessions are needed to reduce the movement variability associated with HET.

In terms of absolute consistency, the greatest CVs were associated with the first testing occasions (10.1% to 12.2%) and the least variability noted with the latter T4-T3 testing (5.59% to 8.49%). The within-athlete variation or CV consists of technological variation (variation arising from measurement equipment) and biological variation (variation arising from athlete-related factors) (Kayo and Koizumi 1998). It can be assumed that technological variation would be minimal over the testing sessions as the equipment and testing conditions were constant, hence the reduction in variation is more likely associated in a reduction in biological variation. Attempting to resist (ECC) being towed backwards was a novel and therefore challenging movement task for most athletes. The athletes were instructed to find a balance between resisting as hard as they could and holding that resistance throughout the exercise. This was important because, athletes can generate very high forces during initial ground strike but cannot hold this force with muscle shortening in between steps (follow link to see slow motion footage of this phenomenon - https://goo.gl/1qh65N). So initially backward motion was typified by a high degree of 'jerkiness'. As the athletes familiarised themselves with the technique in subsequent sessions, a more constant force was applied and hence the reduction in the CV, particularly evident in the MHEF and impulse variables.

The movement variability of this study was similar to the study done by Stock and Luera (2014) who reported CVs of 10.6% and 9.6% for peak and mean ECC force respectively, as measured on a novel isokinetic ECC squat machine. Although, the squat exercise was not novel, the device being used to administer the exercise was. Brughelli and Van Leemputte (2013) found large CVs between T2-T1 (10.9% to 37.9%) and showed decreases in CVs in T4-T3 (4.7% to 16.2%). The findings of both these studies quantifying the variability associated with novel ECC training devices were similar to the trends of this study. Finally, PHEF had the greatest average variability across all testing occasions. This is most likely explained by the peak relating to one point in the force time curve, whereas the MHEF and impulse variables are an average or integral of the complete signal. This inherently causes the PHEF to have greater variation compared to MHEF and impulse variables.

ICCs are used as a measure of relative consistency and relate to the reproducibility of the rank order of athletes on the retest. Of the nine comparisons only one ICC was less than 0.70 (T3-T2) and by the T4-T3 comparison all ICCs were greater than 0.85. Were it not for the one outlier (ICC=0.32) which is difficult to explain, the rank order between testing occasions would seem very consistent and trending upwards. Brughelli and Van Leemputte (2013) also found similar improving ICCs by T4-T3 (0.82 to 0.96).

CONCLUSION: There are many ECC training devices available, but none overload the musculoskeletal system eccentrically in the horizontal plane in a gait-specific modality (Tinwala et al. 2016). This novel stimulus and training tool could have potential impacts on sprinting-specific performance given the benefits of ECC training as described earlier. The results of this study suggest that MHEF and impulse can be reliably measured after two familiarisation sessions. This allows for further research into the training adaptions of the HET device to be conducted.

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