ASSESSMENT OF LOWER LIMB ASYMMETRY: DIFFERENCES DURING ISOMETRIC AND STRETCH-SHORTENING CYCLE TASKS

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Assessment of limb function asymmetry is of interest to practitioners due to its role in return to play guidelines and reported links to injury. Dynamometry is one of the most commonly used methods of assessing muscle function, but the mode of contraction used is different to the stretch-shortening cycles experienced during real-life activities. The aim of this study was to compare measures of limb function asymmetry during isometric and stretch-shortening cycle tasks and investigate agreement between the methods. Different between-limb effect sizes were observed between limbs dependent on test used, with different ranges of asymmetry observed. Agreement between methods was very poor. These results show the importance of assessing asymmetry in a condition that is as similar as possible to the task of interest.

KEYWORDS: limb preference, hopping, force sledge, muscle and tendon, force production

INTRODUCTION: The calf and ankle region is one of the most commonly injured parts of the lower limb in sport, second only to the knee (Fong *et al.*, 2007). Assessment of its function is important to practitioners in determining an athlete's ability to return to play. A common criteria used in return to play guidelines is the level of asymmetry between the injured and contralateral 'healthy' limb, with 15% asymmetry suggested to be the upper limit for healthy individuals (Knapik *et al.*, 1991). Despite this suggested limit however, there is a growing body of evidence showing much higher levels of asymmetry in kinematic and kinetic measures during movement even in healthy individuals (Exell *et al.*, 2012).
An important factor to consider in measurement of asymmetry is similarity of the assessment to the sporting task of interest. Assessments should be similar both in the mode of contraction and kinematics used during the task, which may explain why isokinetic dynamometry and countermovement jumps have been shown to be independent measures of assessing lower limb asymmetry (Menzel *et al.*, 2013). Isometric dynamometry is a highly controlled and relatively simple to conduct method of determining asymmetry but it does not effectively evaluate the stretch-shortening cycle (SSC) contractions evident in everyday activities such as hopping or running. Despite this, it has been used previously to assess muscle function asymmetry and determine rehabilitation progress in injured individuals (Frost *et al.*, 2006; Cichanowski *et al.*, 2007). Recent work has adapted a force sledge apparatus to isolate the plantarflexors during a SSC task which replicates the ankle kinematics observed during hopping and running, the contact times observed in running and the rate of loading on the plantarflexor muscle group during a locomotion task (Furlong & Harrison, 2013). This suggests this method may be better able to explain observed asymmetries in dynamic tasks.
The aim of this study was to identify differences in measures of peak plantarflexor force production in twenty healthy males and females using isometric dynamometry and the adapted force sledge, and to assess the level of agreement in measurement of asymmetry between methods. These results may guide practitioners in determining the most appropriate test to assess limb symmetry, establishing normative asymmetry values in healthy young adults and the interchangeability of methods.

METHODS: Participants: Following university ethical approval and written informed consent, twenty healthy participants (11 males, 9 females, age: 23.5 ±2.3 years, height: 1.73 ±0.08 m, mass: 74.2 ±11.3 kg) participated in this study. All were injury free for the preceding 3 months and did not have a history of lower limb surgery. Participants were advised to refrain from unaccustomed strenuous activity for the 24 hours preceding data collection. Due to the nature of the sledge testing, the preferred leg was defined as the preferred hopping leg.

Isometric dynamometry testing: All isometric tests were conducted using a Contrex dynamometer (CMV AG, Dübendorf, Switzerland). The test knee angles were determined by goniometry to be 135° and 180°, defined as the internal angle between the greater trochanter, estimated knee joint centre and the lateral malleolus. Joint and dynamometer axes were manually aligned with the joint maximally contracted and secured to avoid misalignment errors (Arampatzis *et al.*, 2007). Familiarisation consisted of a series of isometric plantarflexion contractions at 25%, 50%, 75% and 100% of maximum torque completed until the participants obtained 3 measures at the 100% loading within 10% of each other. Testing consisted of three maximal effort contractions against the plate for 3-4 s with 90 s recovery between each trial. Plantarflexor force during each knee angle condition was calculated from torque by measuring lever length from the joint axis of rotation to the point of application of the force during the isometric contraction. This point was considered to be the halfway point between the fifth metatarsophalangeal joint and the hallux, and was measured using a custom-made measuring board.

Sledge testing: A 9.5 mm retro-reflective marker was placed on the sledge plate edge for tracking by a three camera 3D motion analysis system (500 Hz, MAC Eagle, Motion Analysis Corporation Inc., Santa Rosa, CA., USA). Participants were supine at the base of the sledge and the thigh was secured using Velcro straps so maximum knee angle during impact was between 140 and 160°. Familiarisation consisted of 25-30 impacts where participants rhythmically struck the plate and where the plate was dropped from 30 cm above the foot, until the researcher was satisfied the plate was being struck as instructed i.e. as rhythmically as possible minimising plate contact time and using only the ankle joint. The same instructions were used for the test protocol. A loading of 70% of an 11 repetition maximum was used for the test trial for both limbs (Furlong & Harrison, 2013). Marker position data was filtered using a fourth order, zero lag, low-pass Butterworth filter with a cut-off frequency of 12 Hz. Plate acceleration was calculated as the second derivative of plate position with respect to time. Force was calculated using Newton's second law with a correction for the component of weight acting down the sledge rails as the sledge was angled at 30°. Contact time (CT) and flight time (FT) were identified using acceleration traces, with CT defined as the period when plate marker acceleration was greater than zero and FT defined as the period when it was zero or less. Peak force (F_P) was defined as the peak concentric force exerted during each CT. The average of impacts five to seven were used for analysis.

Data analysis: Statistical analysis was completed in SPSS Statistics 20 (IBM, Armonk, NY, USA). As data was not normally distributed, between-limb differences were assessed using Wilcoxon signed rank test and effect sizes derived using Cohen's d_z (Cohen, 1977). The scale for classification of effect size was 0.2 to 0.59 = small, 0.50 to 1.19 = medium, 1.20 and above = large (Hopkins, 2006). The level of significance for all tests was set at $\alpha < 0.05$. Limb asymmetry was calculated using the absolute symmetry index (ASI) of Karamanidis *et al.* (2003). To assess agreement between methods, Bland Altman's Limits of Agreement (LoA) were calculated in Microsoft Excel and two-way random effects intra-class correlation coefficients (ICC) with absolute agreement and consistency were obtained for measures of ASI for all five methods in SPSS.

RESULTS: Observed between-limb differences varied with test condition. While no significant differences were observed in any test, a higher effect size was observed in the measure of plantarflexor force production during the stretch-shortening cycle task. A greater range of asymmetry was observed during the 180° test condition than the 135° or sledge protocols. The range of asymmetry observed was also higher than the 15% upper limit previously reported for healthy individuals.

The level of agreement between methods was very poor. The LoA between conditions were -8 to 6% between torque and force measures from the dynamometer for the same knee angle, and between -37 and 43% when comparing isometric conditions with different knee angles. LoA comparing the isometric condition to the SSC condition were between -43 and

48%. ICC scores were very low for both absolute agreement (single: 0.181, average: 0.525) and consistency (single: 0.178, average: 0.520).

Table 1. Between-limb differences using the five different methods to assess strength asymmetry

	Preferred	Non-preferred	Effect size	Absolute symmetry index (%)
Dynamic (N)	529 ±191	485 ±132	0.41	16 ±10.5
Isometric 135° (N.m)	80 ±32	81 ±35	0.02	17 ±15.0
Isometric 135° (N)	457 ±164	453 ±182	0.03	18 ±16.1
Isometric 180° (N.m)	101 ±43	95 ±41	0.21	21 ±16.2
Isometric 180° (N)	569 ±221	536 ±217	0.24	22 ±15.7

DISCUSSION: The aim of this study was to identify between-limb differences in measures of peak plantarflexor force in healthy males and females using isometric dynamometry and an adapted force sledge, and to assess the level of agreement between methods. No statistically significant between-limb differences were observed using any method. However, the magnitude of effect size and average and range of ASI differed with method. No effect of preference was observed in the 135° test condition, but a small effect was observed in the 180° condition and a small tending towards moderate effect was observed in the SSC task. The range of asymmetry also greatly varied with scores ranging from 5.5 to 26% in the dynamic task and from 1.9 to 37.7% in isometric conditions. This suggests observed asymmetry is dependent on the form of assessment used which has implications for the practitioner using this measure as a return to play criterion. Variation between methods is most likely because different factors influence performance in each of these conditions. During isometric tasks, torque is primarily dependent on muscle mass and physiological cross-sectional area. Knee angle affects force output due to the change in gastrocnemius force producing abilities with angle (Cresswell *et al.*, 1995). Performance in the SSC task is also dependent on the tendon mechanical properties (Anderson, 1996) and motor control.

Asymmetry was observed in all participants, with average asymmetry indices ranging from 16 to 22%. Of note, however, the asymmetry observed here was greater than the 15% upper limit previously recommended for healthy individuals (Knapik *et al.*, 1991). None of the participants proceeded to develop any overuse injuries in the subsequent 12 months following data collection. Therefore this upper limit, beyond which the risk of overuse injury is proposed to increase, may need further investigation. Since no participant had an absolute symmetry index of 0, it appears that a certain level of asymmetry is normal in healthy individuals. The range of asymmetry observed here is closer to that observed in sprinting by Exell *et al.* (2012).

There was very poor agreement between the five methods with low ICC and high LoA observed, even though each method measured force production asymmetry of the plantarflexors. This is most likely because each test assesses different underlying muscular behaviours. Some participants also demonstrated larger asymmetry in the isometric task than the SSC task and vice versa, which greatly influences indices of agreement. The LoA between torque and force for a given knee angle in the isometric condition of -8 to 6% suggest that lever length further influences asymmetry which does not appear to have been considered in most previous work. LoA were much larger between isometric and dynamic test conditions, which has significant implications for muscle function asymmetry assessment.

CONCLUSIONS: Assessment of muscle function in a valid test condition is essential for the accurate determination of a player's ability to return to play. The results of this study support Menzel *et al.* (2013) in relation to the importance of test validity for the task of interest to ensure accurate assessment of asymmetry, as different between-limb effect sizes and ranges of asymmetry were observed in the five methods. There is very poor agreement between the methods, so results from one method cannot be used if asymmetry in a different type of task is of interest. While isometric conditions are often used in clinical settings to assess torque and force, this does not reflect ASI during a SSC task. Practitioners are hence advised to choose tests of asymmetry with maximum test validity to the task of interest.

REFERENCES:

Anderson, T. (1996). Biomechanics and running economy. *Sports Medicine,* 22, 76-89.

Arampatzis, Adamantios, De Monte, Gianpiero, & Morey-Klapsing, Gaspar. (2007). Effect of contraction form and contraction velocity on the differences between resultant and measured ankle joint moments. *Journal of Biomechanics,* 40(7), 1622-1628.

Cichanowski, HR, Schmitt, JS, Johnson, RJ, & Niemuth, PE. (2007). Hip strength in collegiate female athletes with patellofemoral pain. *Medicine and Science in Sports and Exercise,* 39(8), 1227-1232.

Cohen, J. (1977). *Statistical power analysis for the behavioral sciences*. (Revised ed.). New York: Academic Press Inc.

Cresswell, AG, Loscher, WN, & Thorstensson, A. (1995). Influence of gastrocnemius muscle length on triceps surae torque development and electromyographic activity in man. *Experimental Brain Research* 105, 283-290.

Exell, TA, Gittoes, MJR, Irwin, G, & Kerwin, DG. (2012). Gait asymmetry: Composite scores for mechanical analyses of sprint running. *Journal of Biomechanics,* 45, 1108-1111.

Fong, D. T. P., Hong, Y. L., Chan, L. K., Yung, P. S. H., & Chan, K. M. (2007). A systematic review on ankle injury and ankle sprain in sports. *Sports Medicine,* 37(1), 73-94.

Frost, KL, Bertocci, GE, Wassinger, CA, Munin, MC, Burdett, RG, & Fitzgerald, SG. (2006). Isometric performance following total hip arthroplasty and rehabilitation. *Journal of Rehabilitation Research and Development,* 43(4), 435-444.

Furlong, LAM, & Harrison, AJ. (2013). Reliability and consistency of plantarflexor stretch-shortening cycle function using an adapted force sledge apparatus. *Physiological Measurement,* 34(4), 437-448.

Hopkins, WG. (2006). A new view of statistics: A scale of magnitudes for effect sizes. Retrieved January 9, 2014

Karamanidis, K., Arampatzis, A., & Bruggemann, G. P. (2003). Symmetry and reproducibility of kinematic parameters during various running techniques. *Medicine and Science in Sports and Exercise,* 35(6), 1009-1016.

Knapik, J, Bauman, C, Jones, B, Harris, J, & Vaughan, L. (1991). Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *American Journal of Sports Medicine,* 19, 76-81.

Menzel, H.-J., Chagas, MH, Szmuchrowski, LA, Araujo, SRS, Andrade, AGP de, & de Jesus-Moraleida, FR. (2013). Analysis of lower limb asymmetries by isokinetic and vertical jump tests in soccer players. *Journal of Strength and Conditioning Research,* 27(5), 1370-1377.

Acknowledgement

The authors would like to thank the Irish Research Council for funding this research under the Embark Initiative.