Assessing Eccentric Hamstring Strength using the Nordbord: Between-Session Reliability and Inter-limb Asymmetries in Professional Soccer Players

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Abstract

The aims of the current study were to: 1) determine between-session reliability of peak force during the Nordic hamstring exercise (NHE) in professional soccer players during the pre-season, and 2) determine the subsequent magnitude and direction of peak force asymmetry from the NHE between all test sessions. The NHE was used as a weekly monitoring tool in 14 professional soccer players, throughout a 6-week pre-season period to record peak force from the Nordbord device (in Newtons – N) across an average of six repetitions for the dominant and non-dominant limbs. The first two weeks were used as familiarization sessions, with four data collection sessions thereafter. When considering relative reliability, intraclass correlation coefficients (ICC) showed moderate levels of between-session reliability across the 4-weeks on both limbs (dominant = 0.54-0.73; non-dominant = 0.68-0.73) and for the sum total (0.69-0.73). For absolute reliability, both limbs showed coefficient of variation (CV) values < 10% across all 4-weeks, with the exception of the dominant limb between sessions 1-2 (10.06%). When determining systematic bias, no meaningful changes were evident in peak force on either limb (g = -0.59 to 0.40) or for the magnitude of asymmetry (g = -0.24 to 0.35). However, when assessing consistency in the direction of asymmetry, levels of agreement ranged from 43-57% across the data collection period, indicating substantial variation in the superior performing limb from session to session. The findings from this study indicate that two familiarization sessions is enough to elicit reliable peak force data during the NHE in professional soccer players during pre-season, despite a very small learning effect across the testing period.

Key Words: Knee flexors; between-limb difference; team sport.

Introduction

Hamstring injuries have been the single most common injury in professional soccer for many years (28), and the sport is renowned for having high re-injury rates as well (30). Hamstring injuries alone represent 37% of all muscle injuries within soccer players, with an average of 5-6 hamstring strain injuries per season expected within elite male teams (19). For those players who do experience such injuries, an average of 18 days and 3 matches per injury are typically missed (38). When considering how these injuries occur, 57% of hamstring injuries have been suggested to occur during running or sprinting (38). A more in-depth analysis of running suggests that hamstring injuries occur during the end of the swing phase, when a powerful eccentric muscle action of the hamstring muscles are required to decelerate the shank in preparation for foot strike (12). This rapid transition from eccentric to concentric contractions during the swing phase, is likely to be when the muscle is most vulnerable to injury due to the elongation placed on the hamstrings (2,21). Thus, the evidence indicates that hamstring strain injuries are a prominent and serious problem in professional soccer, with a recent editorial suggesting that the incidence and recurrence of these injuries are continuing to rise within the professional game (28).

Assessing strength qualities is paramount in soccer (3), and this is particularly important for a muscle group so susceptible to injuries, such as the hamstrings. Currently, the gold standard measure for the assessment of eccentric hamstring strength is the isokinetic dynamometer (13). However, this device is limited due to its high cost, time it takes to complete testing, and its lack of portability (20). Handheld dynamometers have become popular as a field-based alternative; however, they require the operator to have skill and strength for the data collected to be reliable and valid (37). Consequently, the Nordbord has become a readily available piece of equipment which is designed to complete the Nordic hamstring exercise (NHE) whilst getting real-time feedback for peak and mean force in both limbs. The NHE is commonly adopted as an injury prevention strategy and has been shown as a valid and effective means of developing eccentric hamstring strength, reducing the incidence and severity of hamstring injuries in soccer (1,2,31,34). The Nordbord device has been shown to be a reliable (ICC = 0.85-0.89, CV = 5.8-8.5%) method to measure bilateral and unilateral eccentric knee flexor strength (29). Furthermore, elite soccer players with low eccentric hamstring strength measured using the NordBord, have been reported to be at a greater risk of a future hamstring injuries (32). Finally, a moderate association (r = 0.65) between peak eccentric force measured during the NHE and isokinetic eccentric hamstring peak torque have been previously reported (27). Thus, given the strength of this relationship with isokinetic dynamometry and the strong reliability previously reported, it stands to reason that the Nordbord can be adopted in practice, noting it has the advantage of giving real-time feedback during testing.

In addition to monitoring eccentric hamstring strength, there has been a plethora of research in recent years relating to inter-limb asymmetries in soccer players (4,5,8,17,26). It has been previously proposed that between-limb imbalances > 15% in eccentric strength may significantly increase an athlete's risk of a hamstring injury (16,25). However, the notion of using any single asymmetry threshold to predict injury or reductions in performance has been recently questioned (9). When considering the assessment of asymmetry from the NHE specifically, much less information currently exists. Cuthbert *et al*. (17) undertook a test-retest design of peak force asymmetry from the NHE in elite female soccer players. Mean asymmetries were 3.94 ± 7.41% in session one, and 1.49 ± 7.80% in session two. Despite the mean values being small, both sessions exhibited large standard deviations (SD) relative to the mean, indicating a large amount of within-group variability in asymmetry scores. This was further supported by the Kappa coefficient values (which assessed the direction of asymmetry – i.e., consistency in limb dominance between sessions), which was 0.62, indicating that the limb which produced the greatest peak force, sometimes "swapped sides" between test sessions. This may be a typical compensatory strategy that asymmetry shows during bilateral tasks, noting that when two limbs interact together, the chances of this are greater compared to unilateral tasks (4,14). Consequently, failure to take into consideration the direction of asymmetry when assessing eccentric hamstring strength may result in practitioners missing key information relating to whether one limb is consistently under-performing and requires improvements in capacity, or whether such imbalances are merely fluctuations in performance variability.

To the authors' knowledge, test-retest design asymmetry studies have only been undertaken using two test sessions (6,10,11,17). Given the previously reported variable nature of asymmetry (4,8,11,17), and the high risk of injury that the hamstrings seem predisposed to in soccer (19,38), additional test sessions which determine reliability of data and the consistency in asymmetry seems warranted. Such information will provide practitioners with evidence of the usability of such data in their day-to-day practice. Furthermore, if such methods are employed as part of the weekly monitoring process during pre-season (i.e., before any cumulative fatigue effects of competition during the season), this too would provide practitioners with a more accurate measurement of baseline data for eccentric hamstring strength. Therefore, the aims of the present study were twofold: 1) to determine between-session reliability of peak force during the NHE exercise in professional soccer players during the pre-season, and 2) to determine the subsequent magnitude and direction of peak force asymmetry from the NHE between all test sessions.

Methods

Experimental Approach to the Problem

The present study employed a test-retest design using professional soccer players from the first team of a professional soccer club in the UK. Weekly monitoring of eccentric hamstring strength was conducted during a six-week pre-season period in June and July, in preparation for the 2020-2021 soccer season. The first two test sessions (conducted over two consecutive weeks) were treated as test familiarization protocols for the players, with data collection used for the following four test sessions (conducted over four consecutive weeks). All tests were conducted on the same day each week (Tuesday) and at the same time of day throughout the testing period (14.00-15.00). This time was chosen as the time where sufficient rest was given to all players from previous training or matches, which would minimize any interference in test scores. An example micro-cycle during the six-week period is provided in Table 1.

*** Insert Table 1 about here ***

Subjects

Fourteen male professional soccer players volunteered to participate in this study (age = 27.50 ± 4.40 years; mass = 81.34 ± 8.57 kg; height = 1.82 ± 0.05 m). Sample size estimation was done based on the work of Walter *et al.* (36), which estimates the *n* required for reliability studies. In the present study, which used a test-retest design over four sessions, a sample of 9 was required for the minimal acceptable ICC value to be 0.5 (23) and the estimated ICC to be 0.8. Players participated professionally in the English football league for the previous two seasons, on average trained six times a week (two of which were designated for strength and conditioning), and competed in one match per week (Table 1). Players were also required to be free from injury at the time of testing and in the preceding six-weeks. Written informed consent was given prior to participating in this study and ethical approval was granted from the *** deleted for peer review *** research and ethics committee at *** deleted for peer review *** University.

Procedures

The assessment of eccentric hamstring strength was assessed using the NordBord device (Vald Performance, Newstead, Australia), sampling at a frequency of 50 Hz. The protocol for the NHE was conducted in accordance with previous research (18). Specifically, each player’s knees were placed on the padded board of the NordBord device, with their ankles fixed by individual hooks secured immediately superior to the lateral malleolus by individual ankle braces which were attached to custom made uniaxial load cells with wireless data acquisition capabilities. The ankle braces and load cells were secured to a pivot which allows the force generated by the knee flexors to be indirectly measured through the long axis of the load cells. For a warm-up, players completed 5-minutes on a stationary bike at a perceived RPE of 5 out of 10, followed by 1 x 10 repetitions of the following dynamic stretches: multi-planar lunges, multi-planar leg swings, bodyweight squats and the 'world's greatest stretch'. This final mobility exercise begins in a push-up position, with one foot then brought forward to the outside of the hands. Thoracic rotation is then performed by rotating the arm towards the sky in the direction of the planted foot, before coming back down and finishing with the elbow aiming to meet the medial malleolus of the ankle. Prior to the completion of the NHE, players received the following specific test instructions: "Gradually lean forward, maintaining the slowest possible speed resisting through both lower limbs with the trunk and hips in a neutral position throughout, and with hands held across your chest". Subsequently, a warm-up set of six bilateral NHE repetitions were completed where no data was collected, followed by a 3-minute rest period. Then, a single set of six bilateral NHE repetitions was performed and used for data collection, in line with the club's injury prevention exercise protocols. The order of subjects was randomised throughout testing weeks and test scores were exported as the maximum force in Newtons (N) obtained for each limb, and then averaged for each limb across all six repetitions.

Statistical Analyses

All data were initially presented as means ± SD. Normality of the data was confirmed ($p > 0.05$) using the Shapiro-Wilk test. Between-session reliability was computed using the coefficient of variation (CV) calculated as the (SD/mean)*100 and a two-way random ICC with absolute agreement and 95% confidence intervals (CI). CV values < 10% were considered acceptable (15) and ICC values were interpreted in line with suggestions by Koo and Li, (23) where: > 0.90 = excellent, 0.75-0.90 = good, 0.50-0.74 = moderate, and < 0.50 = poor). A one-way analysis of variance (ANOVA) was used to evaluate systematic bias between test sessions, with statistical significance set at $p < 0.05$. Practical differences were assessed using Hedges *g* effect size (ES) data, with 95% confidence intervals, and were interpreted in line with suggestions by Hopkins *et al.* (22) where: 0.00-0.19 = trivial; 0.20-0.59 = small; 0.60-1.19 = moderate; 1.20-1.99 = large; ≥ 2.00 = very large. The magnitude of asymmetry was calculated using the formula: (dominant/non-dominant)/total*100, as per suggestions by Bishop *et al.* (7) when using bilateral tests, with the dominant limb being defined as the preferred kicking limb for each player. Previous research on this topic has used the Kappa coefficient to determine the direction of asymmetry between test sessions (4,5,6,17); however, this statistic is sensitive to large alterations in the outcome if sample sizes are small (35). Thus, levels of agreement for the direction of asymmetry were reported as a percentage of the total sample between each subsequent test session.

Results

Table 2 shows mean ± SD peak force data for both dominant and non-dominant limbs, and the subsequent mean inter-limb asymmetry values, across all test sessions. Hedges *g* ES data with 95% CI is also presented for each variable and showed no significant differences ($p > 0.05$) between all test sessions for the dominant limb (*g* range = -0.41 to 0.14), non-dominant limb (*g* range = -0.59 to 0.40) or asymmetry (*g* range = -0.24 to 0.35).

Table 3 shows between-session reliability data using the CV and ICC. For absolute reliability, all CV values were < 10%, with the exception of the dominant limb between sessions 1-2, which showed a slightly elevated CV of 10.06%. For relative reliability, all ICC values were found to be moderate (ICC range = 0.54-0.73) between test sessions.

Owing to the variable nature of asymmetry (as shown by the large SD values relative to the mean), individual asymmetry data has been presented for each player in Figure 1. Levels of agreement expressed as a percentage were as follows: sessions 1-2 = 57%, sessions 2-3 = 50%, and session 3-4 = 43%.

*** Insert Tables 2-3 about here ***

*** Insert Figure 1 about here ***

Discussion

The aims of the present study were twofold: 1) to determine between-session reliability of peak force during the NHE exercise in professional soccer players during pre-season, and 2) to determine the subsequent magnitude and direction of peak force asymmetry from the NHE between all test sessions. For absolute reliability, all CV values were < 10% between test sessions, with only the dominant limb exhibiting a slightly elevated value of 10.06% between sessions 1-2. For relative reliability, ICC values were moderate between all test sessions (ICC = 0.54-0.73). Trivial to small changes in peak force were evident between test sessions (g = -0.59 to 0.40, $p > 0.05$) and asymmetry (g = -0.24 to 0.35, $p > 0.05$). When assessing consistency in the direction of asymmetry, levels of agreement ranged from 43-57% across test sessions.

When considering our first aim, the NHE exhibits moderate reliability between test sessions, as represented by ICC values of 0.54-0.73, which is notably lower than the values reported by Opar *et al.* (29) of 0.85-0.89. It is worth acknowledging though, the ICC statistic is a measure of 'relative reliability' and determines rank order consistency between test sessions. In this instance, when players score similar peak force values in a given test session, they may be prone to small changes in 'rank order' during the subsequent test session. Such changes in rank order will have an impact on the ICC outcome, which may explain why the values were moderate throughout. When considering absolute reliability however, all CV values were < 10% between test sessions – noting just a slightly elevated value between sessions 1-2 of 10.06%. Given 10% is commonly used as a threshold to determine acceptable levels of absolute reliability during testing (4,5,8,15), it seems that there may have been a very small learning effect across data collection sessions, as CV values improved throughout the weeks. However, practitioners should be mindful that this elevated CV value of 10.06% between sessions 1-2 was only slightly over the accepted 10% threshold, with this value dropping below 10% between sessions 2-3. Therefore, we suggest that two familiarization sessions are enough to elicit reliable NHE peak force data on the Nordbord. Practitioners should also consider that absolute reliability (CV) is perhaps more appropriate than relative reliability (ICC), as it enables a variance (or reliability) score for each individual; something which is of critical importance when working with large squads of athletes and setting target scores (33).

In support of our reliability data, we also determined systematic bias between test sessions, which showed no significant changes across test sessions for either peak force or asymmetry. Given the present study was test-retest in design over a period of continuous weeks, it seems logical to assume that no meaningful changes were evident. This is also supported by virtue of our analysis being 'week-to-week' for monitoring purposes throughout pre-season (as opposed to monitoring changes from week 1 to week 4), noting that this is unlikely to be long enough to elicit any major adaptations in strength (24). It is worth noting however, that reductions in peak force were close to being statistically significant on the non-dominant limb (*g* = -0.59; *p* = 0.06) and were greater than those reductions on the dominant limb (*g* = -0.41). Although anecdotal, these reductions (on both limbs) are likely to be a response to the increasing volumes of training loads throughout the pre-season period, which were largely reversed when collecting the players' data during week 3. For asymmetry, practitioners should be mindful of the very large SD relative to the mean score in comparison to peak force (Table 2). Specifically, in test session 1, the SD for peak force represented 18-21% of the mean values across both limbs. However, the subsequent SD for asymmetry represented 81% of the mean. The relevance here, is that such large within-group variability often precludes any significant differences from being found between test sessions. Thus, and based off previous recommendations for asymmetry (4,9,10,11,17), individual data analysis is paramount.

This leads on to an important discussion point relating to the direction of asymmetry. Figure 1 shows individual peak force asymmetry data for each test session and supports the need to assess and monitor such data on an individual basis. A good example of this is athlete 6 who initially exhibits an asymmetry of 6.13% in week 1, followed by an asymmetry of 5.09% in week 2. If asymmetry was only being monitored as an absolute value (i.e., with all values as positive numbers), practitioners would note a small reduction in the imbalance which intuitively may be considered beneficial. However, this ~1% reduction is likely to be far less important than the resultant ~11% shift in asymmetry, but this only becomes evident if limb dominance (i.e., the direction of asymmetry) is concurrently monitored. This individual case is a good example of how the data is also manifested for the group, where levels of agreement ranged from 43-57% across the data collection period. Simply put, with levels of agreement so far from 100%, it highlights the fluctuating nature of limb dominance for many players, which further reinforces the need to assess each athlete's magnitude and direction of asymmetry individually, as has been previously suggested (4,9,10,11,17). Furthermore, previous research from Cohen *et al.* (14) has indicated that bilateral tests may offer a greater amount of compensation strategies when considered against comparable unilateral tasks (e.g., bilateral vs. unilateral jumping), which may be a better measure of true limb capacity. Thus, the fluctuating nature of limb dominance seen in this study may simply be a product of the test measure (NHE) being a bilateral task.

There are a couple of key limitations that should be acknowledged in the present study. Firstly, the sample size is small, but this is also not unexpected given data was collected from the first team of a single professional soccer club. Consequently, practitioners are advised to determine their own reliability data with their own cohort of athletes and use the results from this study as a guide to compare back to. Secondly, this study provided no reliability data in-season, which is arguably needed in order to determine the usability of the NHE when peak force data may be impacted by training and competition loads. Thus, this second limitation should be considered as a potential future research directive, to help determine the efficacy of the NHE as a monitoring tool all-year round.

Practical Applications

The findings from this study have a number of important implications for coaches. Firstly, our results provide further evidence that the NHE can reliably assess eccentric hamstring strength in professional soccer players. Secondly, coaches should note that only two familiarization sessions are required to obtain reliable NHE data for this population. Thirdly, the peak force values presented here contributes further descriptive data to the existing literature that coaches can compare professional soccer players' eccentric hamstring strength to. Fourthly, this study has highlighted the importance of monitoring the direction of asymmetry during the NHE; arguably more so than the magnitude value. If practitioners are able to identify consistent limb deficits (as opposed to natural fluctuations in performance variability) in their cohort of athletes, this will enable them to provide more targeted training interventions for the weaker limb, which in turn, may help to reduce the risk of such imbalances contributing to hamstring injuries over time.

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Table 1. Example micro-cycle during the 6-week pre-season period.

Time of Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
AM	Technical training	On-pitch training	11 vs. 11	Rest day	Small sided games	Match	Rest
PM		Weight room	Weight room		Rest		

Table 2. Mean ± standard deviation peak force data for dominant and non-dominant limbs, inter-limb asymmetry values and Hedges *g* effect size data between test sessions. N.B: all values are presented as an average of six NHE repetitions.

Test Session	**Force in Newtons (N)**		***Asymmetry %***
	Dominant	*Non-Dominant*	
Session 1	432.71 ± 90.33	408.71 ± 73.25	6.88 ± 5.59
Session 2	396.57 ± 78.51	362.64 ± 77.31	9.15 ± 6.98
Session 3	406.79 ± 57.15	392.07 ± 63.91	7.49 ± 6.29
Session 4	410.79 ± 78.64	387.50 ± 69.39	9.21 ± 5.98
Hedges *g* (95% confidence intervals)			
Session 1-2	-0.41 (-1.04, 0.21)	-0.59 (-1.23, 0.04)	0.35 (-0.28, 0.97)
Session 2-3	0.14 (-0.48, 0.77)	0.40 (-0.22, 1.03)	-0.24 (-0.87, 0.38)
Session 3-4	0.06 (-0.57, 0.68)	-0.07 (-0.69, 0.55)	0.27 (-0.35, 0.90)

Table 3. Between-session reliability data using the coefficient of variation (CV) and intraclass correlation coefficient (ICC) with 95% confidence intervals (CI).

Test Measure	**Session 1-2**		**Session 2-3**		**Session 3-4**	
	CV (%)	*ICC (95% CI)*	*CV (%)*	*ICC (95% CI)*	*CV (%)*	*ICC (95% CI)*
Dominant	10.06	0.73 (0.29, 0.91)	9.74	0.56 (0.06, 0.84)	8.67	0.54 (0.09, 0.83)
Non-Dominant	9.93	0.72 (0.05, 0.92)	9.38	0.68 (0.26, 0.88)	7.24	0.73 (0.33, 0.90)
Total	9.52	0.73 (0.17, 0.92)	8.23	0.69 (0.30, 0.89)	6.49	0.70 (0.28, 0.90)

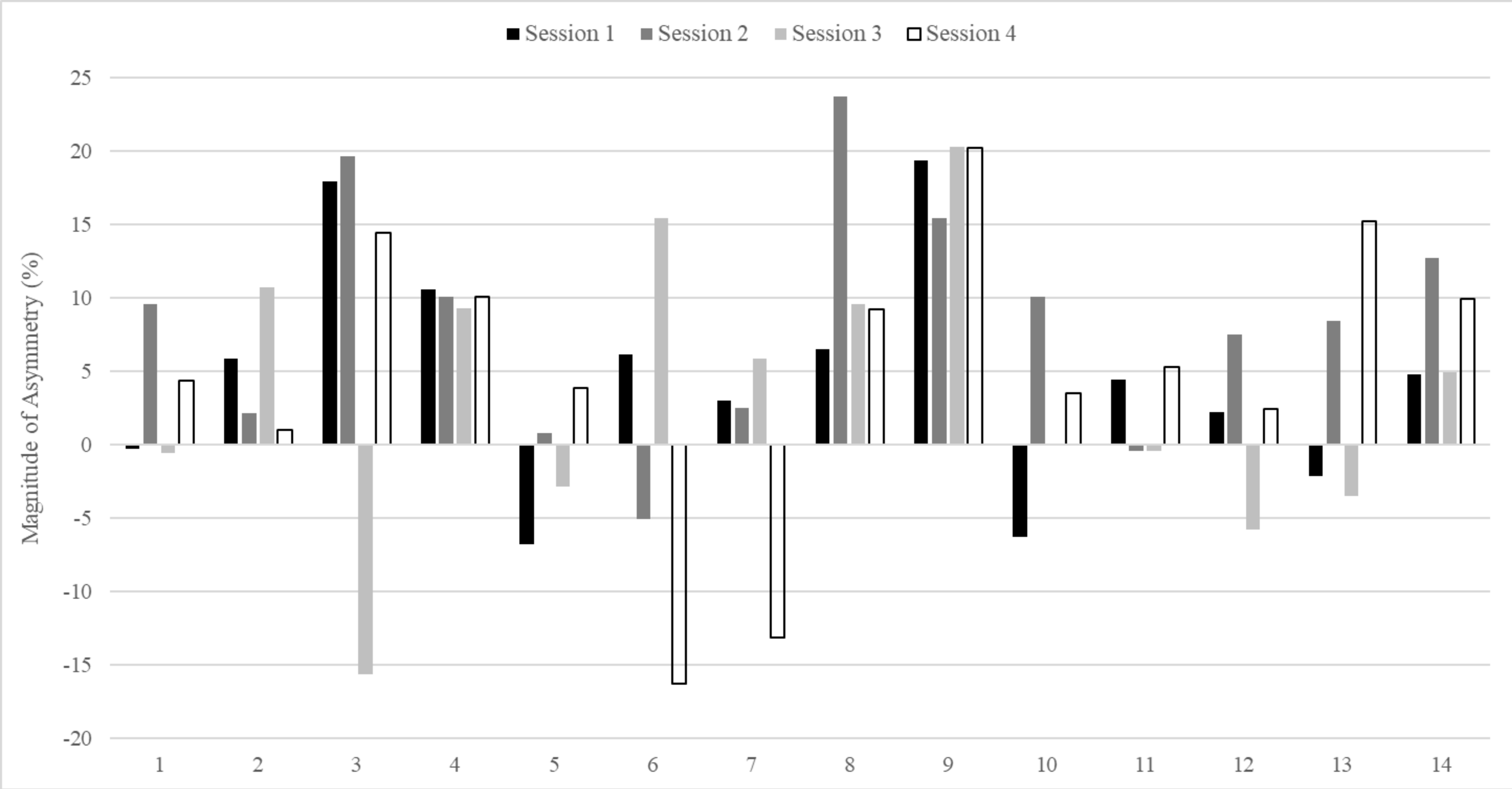

Figure 1. Individual asymmetry data for all participants across all test sessions, when defined as dominant vs. non-dominant. N.B: above 0 indicates direction of asymmetry favours the dominant limb and below 0 favours the non-dominant limb.