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Lower-limb motor-performance asymmetries in English community-level female field hockey players: Implications for knee and ankle injury prevention.

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Highlights

- Clinically-significant asymmetries are not exposed by group-level statistics
- The majority had clinically-significant asymmetry for the eyes-closed-balance test
- Many players had clinically-significant asymmetry for the six-metre hop-for-time
- The unilaterality of hockey does not affect interpretation of absolute-asymmetries
- Clinically-significant asymmetry is widespread in a community-level adult hockey

ABSTRACT

Objectives: Side-to-side asymmetry of lower-limb motor-performance is associated with increased agility-sport noncontact injury-risk. Left leg preferential use (unilaterality) in hockey may influence lower-limb motor-performance asymmetry. Symmetry-analyses have not been reported for female hockey players. This study performed symmetry-analyses using the eyes-closed-balance test (ECB), anterior reach test (ART), triple-hop-for-distance (THD), and six-metre hop-for-time (6MHT).

Design: Cross-sectional.

Setting: Community-level club.

Participants: Thirty players (age 25.6±4.5yr; height 165.6±5.9cm; mass 64.8±5.5kg).

Main Outcome Measures: Right-left group-level (t-test with Bonferroni adjustment) and individual-level (absolute-asymmetry (%)) comparisons. A limb symmetry index (LSI) was computed for each player and a clinically-significant absolute-asymmetry defined >10% as per previous literature. Clinically-significant absolute-asymmetry prevalence (%) was calculated across tests. For unilaterality, prevalence of superior left-side performance was calculated.

Results: There were no right-left significant differences across tests. Findings for ECB, ART, THD, and 6MHT were: absolute-asymmetry, 28.7±26.9%, 3.5±2.8%, 3.5±3.4%, 6.1±4.7%; prevalence of clinically-significant absolute-asymmetries, 70.0%, 3.3%, 6.7%, 26.7%; prevalence of superior left-side performance, 46.7%, 53.0%, 50.0%, 47.0%.

Conclusions: Statistical tests fail to expose clinically-significant absolute-asymmetries. Many players demonstrated clinically-significant absolute-asymmetries for ECB and 6MHT tests. Clinical interpretation of LSIs and absolute-asymmetries need not consider unilaterality. Clinically-significant absolute-asymmetries previously linked to injury-risk are common in a community-level, adult female hockey players.

KEYWORDS

Field hockey, knee, ankle, asymmetry

INTRODUCTION

Field hockey ('hockey') is an Olympic sport played by men and women in 136 nations (1). In 2016 there were 92,700 male and female adult players in England (2). Community-level participation in England rapidly grew when hockey's popularity increased after the Great Britain women's team won the Olympic gold medal in 2016 (3) with 143,845 players by the end of 2017 (4). With increased sports participation comes an increase in injury frequency (5), and female hockey injuries have rates of 3.0 injuries/1,000 athlete-exposures (6) and 23.4-44.2 injuries/1,000 player-match-hours (7). Most hockey injuries occur to the lower-limb (6, 8-10) and are noncontact in nature (6, 8). Knee and ankle injuries account for the majority of injuries (6, 9, 11) and are of high severity defined by the amount of time-loss from participation (8, 12). Such injuries can result in physical and psychoemotional disability (13-15) and substantial socioeconomic healthcare burden (13, 16, 17). Because participation in hockey in England is increasing, and because of the personal and socioeconomic consequences of knee and ankle injuries, strategies are needed to mitigate injury for players, teams, and society, and prolong players' safe participation across the lifespan.

In injury prevention, single-leg balance (SLB) and hop (SLH) tests are used to make side-to-side comparisons of motor-performance and inform reasoning about knee and ankle injury predisposition and risk (18-20). Use of procedures to profile athletes and identify those predisposed to injury is good sports medicine practice (21-23) and decreased SLB, and SLH performance is associated with increased first-time agility-sport injury risk (18, 20, 24-27). When SLB and SLH tests are used to make side-to-side comparisons that inform reasoning about injury predisposition and risk, considerations include whether statistically or clinically significant side-to-side differences exist. Side-to-side comparison of the size of a variable represents a between-limb symmetry analysis (28), symmetry existing when the size of a variable is equal in both limbs and asymmetry existing when the size of a variable is unequal between limbs (28). For groups of athletes, symmetry analyses examine whether statistically significant side-to-side differences exist for measures of central tendency (28-33). A limitation of group-level analyses is that it masks clinically-significant asymmetries in individuals because group data is reduced to one central value that fails to highlight extreme values either side of that value and, therefore, presents a distorted picture of data distribution across all individuals (28-31, 34). For individual athletes, symmetry analyses examine whether clinically-significant side-to-side differences exist for an individual's mean or maximum values (28-31, 35). Procedures involve computing some form of 'limb symmetry index' (LSI) where one limb's value is divided by the other limb's value, the result multiplied by 100 to yield a percentage (28, 29, 35-37). The LSI is valuable because it identifies the size of a clinically-significant asymmetry in an individual, where 'clinically-significant' is historically defined as an absolute-asymmetry >10% (38-40). Recently, motor-performance asymmetries >10% have been prospectively associated with first-time lower-limb noncontact injury risk (24, 41). Because lower-limb motor-performance side-to-side comparisons and symmetry analyses are clinically valuable for injury predisposition and risk profiling (20, 24-26, 41) the use of SLB and SLH testing and symmetry analyses is a clinically diligent and prudent strategy in hockey.

When using SLB and SLH testing and symmetry analyses, reasoning should include the asymmetric and unilateral nature of hockey. The rules of hockey require all players to use a right-handed stick and strike the ball with its flat (left) side (42). Therefore, players commonly adopt stances involving semi-crouched positions with the left foot forward of the right and the left leg supporting most body-mass (9, 42, 43). When striking the ball, players frequently rotate the body from right-to-left to again have the left leg supporting most body-mass (42, 44, 45). Because the left leg is preferentially used, hockey has an "inbuilt asymmetry" (9) and is categorised as a unilateral sport (46). The inherent asymmetry/unilaterality of hockey is reflected by higher bone mineral density (BMD) and muscle mass in the left versus right leg (47, 48) and, therefore, SLB and SLH test symmetry analyses should be interpreted with the asymmetrical/unilateral nature of hockey in mind.

Several studies have employed lower-limb motor-performance tests with adult hockey players. Single-leg balance tests have been performed using force plates/electronic platforms (49-51), the Star Excursion Balance Test (52), and the Y-balance Test (53). Double-leg jump tests have been performed using the vertical jump (54-56) and broad jump (57-59). Three studies employed computers for SLB testing (49-51), none employed SLH testing, and one performed group-level symmetry analyses (53). There is, therefore, an absence of literature reporting use of 'field-based' tests to identify clinically-significant asymmetries and injury predisposition with any adult hockey player at any hockey club in any country. Reliable, low-cost, and portable lower-limb motor-performance tests able to provide data useful for injury predisposition and risk profiling are valuable for informing a community club's training strategies and changes in practice (28). Few studies have recruited players from local communities (50, 56, 57), and none focused on community-level adult players in England. Adult players in local communities comprise the greatest proportion of players in England (2), and profiling lower-limb motor-performance is important to provide data about the frequency of clinically-significant asymmetries and injury predisposition in such groups. Finally, no study has performed SLB or SLH testing with consideration for the asymmetrical/unilateral nature of hockey and, therefore, it is unknown whether this predisposes the left leg to enhanced motor-performance versus the right leg. Such knowledge is important for the clinical interpretation of hockey LSIs and absolute-asymmetries.

There were three purposes for this study. First, to establish if there were statistically significant side-to-side differences for the single-leg eyes-closed balance (ECB), anterior reach test (ART), triple-hop-for-distance (THD), and six-metre hop-for-time (6MHT) in uninjured, adult, female players at one English community hockey club. It was hypothesised there would be statistically significant side-to-side differences across all tests. Tests were chosen because SLB and SLH tests are associated with first-time lower-limb injury in agility-sport athletes (18, 20, 24-27) and because they are portable, practically viable at many clubs, and are meaningful to players and coaches regarding athletic performance. Second, to determine the prevalence of clinically-significant asymmetries for the ECB, ART, THD, and 6MHT. It was hypothesised the majority of players would demonstrate clinically-significant asymmetries across tests. Third, to establish if the asymmetrical/unilateral nature of hockey results in side-to-side differences that favour the left leg. It was hypothesised the majority of players would demonstrate superior scores for the left versus right leg across tests. This study is original because no previous work has reported side-to-side comparisons and symmetry analyses for SLB and SLH field-tests in uninjured, adult, female players at one English community hockey club. This study's findings will be practically significant because they will highlight the extent to which clinically-significant lower-limb motor-performance asymmetries linked to injury predisposition and risk by previous authors exist at a single club and may require consideration for intervention.

MATERIALS AND METHODS

Study design, sample size calculation

This study was an in-season cross-sectional study which, relative to the first purpose of the study, included multiple (four) right-left comparisons of a measure of central tendency (one per test). Determination of sample size should balance both statistical needs relative to the study (e.g. study design, study hypothesis) and real-world feasibility and practicality (60-62). To balance statistical needs with real-world logistical considerations (e.g. limited number of players in the membership of one local community hockey club, limited club training sessions to collect data) we used an approach that: 1. estimated the smallest clinically-meaningful effect size for each test and then applied the resulting smallest effect size and largest sample size to all tests (60); 2. corrected for multiple comparisons with Bonferroni's adjustment (see Statistical Analyses section) (62). An *a priori* power analysis was performed using G*Power (63). To detect a side-to-side difference with medium effect size (ES) of 0.50, 85% power, and significance set at 0.05, 31 participants were required.

Ethical approval, participant recruitment, informed consent

Institution ethics approval was obtained. Participants were recruited from an English community hockey club using flyers on clubhouse noticeboards. Informed consent and physical activity readiness questionnaires were completed by all participants.

Participants

Inclusion criteria were: females aged ≥18 years, ≥4 years' hockey experience, and participating in ≥2 hours' training and one match per week. Exclusion criteria were: current lower-quadrant pain or time-loss injury in the previous two months (i.e. injury requiring withdrawal from one or more training/matches), any diagnosed hip/knee/ankle ligament deficiency or cartilage lesion, any history of lower-quadrant fracture or surgery, and any current condition affecting sensorimotor processing/balance. Thirty players volunteered (Table 1). The club competed in the Investec Women's Hockey League (Division One South and Conference East).

Table 1. Participant characteristics (n=30)

	Age (yr)	**Height** (cm)	**Mass** (kg)	**Leg-Length Right** (cm)	**Leg-Length Left** (cm)	**Length of Hockey Career** (yr)	**Hockey Training/ Playing** (hrs/wk)	**Other Exercise/ Sport** (hrs/wk)
Min	18.0	152.0	54.0	77.5	78.0	5.0	3.5	1.0
Max	34.0	176.0	74.0	92.6	93.7	26.0	8.0	14.0
Mean	25.6	165.6	64.8	87.0	87.0	15.5	4.7	4.5
SD	4.5	5.9	5.5	3.6	3.5	5.0	1.1	2.9

yr = years; cm = centimetres; kg = kilograms; hrs/wk = number of hours per week
Min = minimum; Max = maximum; SD = standard deviation

Procedures.

Data collection occurred at the club's indoor facility (artificial turf) in one session. Players were instructed to avoid fatiguing exercise/sports for 48 hours beforehand. Test order was: anthropometry (height, body-mass, leg-length), barefoot ECB, barefoot ART, shod (hockey shoes) THD, and shod 6MHT. For the ART, THD, and 6MHT, a fibreglass athletics tape-measure was secured to the ground perpendicular to a taped start-line. Limb order was randomised (coin-flip) with players alternating between limbs for each test. After anthropometric measures, players completed a standardised warm-up (jogging, dynamic stretching, running). Arm movement was permitted for SLH tests to assist balance (64, 65). Practice trials for all tests were followed by three measured trials. Trials were terminated if players reported any pain.

Height and body-mass were measured using standard methods (66). For leg-length (67), players were barefoot and supine-lying. Leg-length was measured from the anterior superior iliac spine to the tip of the medial malleolus to the nearest millimetre (mm) using a fibreglass anthropometric tape-measure. Reliability (intraclass correlation coefficient (ICC)=0.99) has been reported for this procedure (67).

For the ECB test (68), players stood on the test-leg, the opposite leg flexed with the heel level with but not touching the approximate mid-point of the test-leg’s calf, arms crossed and hands flat on the chest (Figure 1). Players were instructed to look forwards and acquire a steady posture before closing the eyes. Balance was measured to the nearest tenth of a second (s) using a digital stopwatch from the moment the eyes closed to the moment balance was lost (opening eyes, uncrossing arms, touching heel to the calf, shifting the test-leg foot, putting the non-test-leg’s foot to the floor). Reliability has been reported for the timed ECB test (ICC=0.83) (68).

Figure 1. Eyes-Closed-Balance Test

For the ART (26), players stood on the test-leg, the tip of the first toe aligned with the posterior edge of the start-line, hands on the iliac crests, and reached forward as far as possible with the opposite foot to touch the ground with the first toe (Figure 2). Loss of balance, taking hands off the iliac crests, lifting the stance-leg heel, transferring body-mass onto the reach-leg, and not returning to the starting position voided the trial. Reach distance was measured to the nearest 0.5cm from the posterior aspect of the start-line to the point where the reach-leg touched the ground. Reliability has been reported for the ART (ICC=0.91; standard error of measurement (SEM)=2.1cm) (69).

Figure 2. Anterior Reach Test

For the THD and 6MHT (70), players stood on the test-leg, the distal aspect of the foot aligned with the posterior edge of the start-line (Figure 3). For the THD, players hopped forwards on the same leg three times to stick the final landing. Hop distance was measured to the nearest 0.5cm from the posterior edge of the start-line to the distal aspect of the foot. For the 6MHT, players hopped forwards on the same leg to cover six metres in the shortest possible time. A “3, 2, 1, Go” countdown was given. Time was measured to the nearest tenth of a second (s) using a digital stopwatch from the “Go” to the moment the test-leg’s foot crossed the finish line determined by researcher observation. Reliability has been reported for the THD (ICC=0.97; SEM=11.2cm) (71) and 6MHT (ICC=0.92; SEM=0.06s) (71).

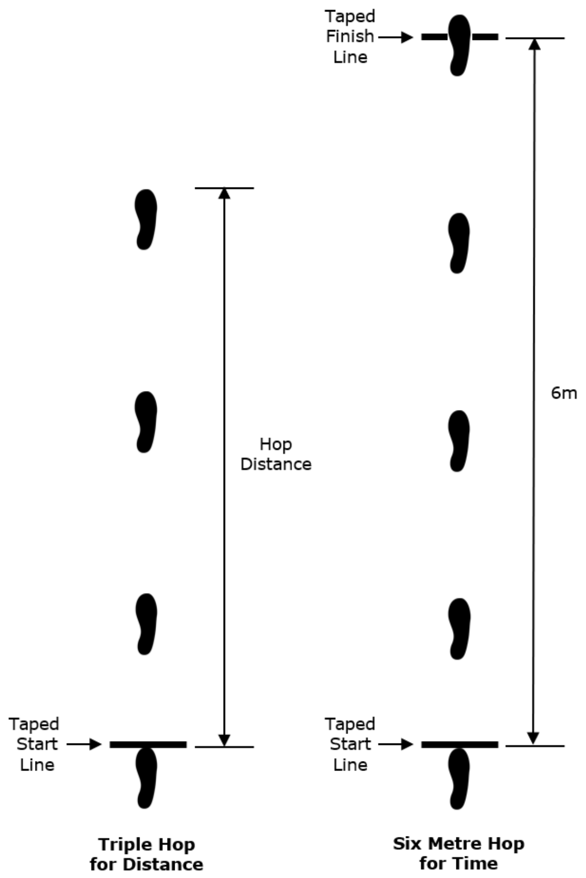

Figure 2. Triple-Hop-for-Distance and Six Metre Hop-for-Time

Statistical Analyses

For the ART and THD, data were normalised to leg-length (26, 72): percent leg-length (%LL) = (distance achieved (cm) ÷ leg-length (cm)) × 100. The mean non-normalised and normalised values for each leg were used for analyses. Summary statistics were calculated, including the absolute between-limb differences (right mean – left mean). The +/− sign was removed from the difference. There were no missing data.

For statistical analyses (group-level), normality of data was assessed with histogram inspection and Shapiro-Wilk tests. Alpha was set *a priori* at 0.05. Paired t-tests were used to compare within-test right and left values. Bonferroni-corrected alpha was set *a priori* at 0.01. Also, 95%

confidence intervals (CI) were estimated for both sides (73). Cohen's *d* was calculated for within-test right-left ES with 0.20, 0.50, and 0.80 considered small, medium, and large, respectively (62).

For clinical analyses (individual-level), an LSI (%) was calculated: (right mean ÷ left mean) × 100 (31, 38, 74). For the ECB, ART, and THD, larger numerator and denominator values represent better performance; an LSI of 100% representing side-to-side symmetry, <100% lower right-side/higher left-side performance, >100% lower left-side/higher right-side performance. For the 6MHT, smaller numerator and denominator values represent better performance; an LSI of 100% representing side-to-side symmetry, <100% better right-side performance, >100% better left-side performance. The LSI, therefore, indicated both the magnitude (size) and direction (side) of asymmetry (28). Because the size of asymmetry is the principal matter of clinical interest (36), absolute-asymmetry was quantified: 100% − player's LSI. The +/− sign was removed from the difference. Because a clinically-significant absolute-asymmetry is defined as >10% (38-40) and asymmetries >10% have been prospectively associated with first-time noncontact lower-limb injury risk (24, 41), absolute-asymmetries >10% were used to define a 'clinically-significant' threshold across tests. Counts were made of players with absolute-asymmetries >10% and overall-prevalence (%) computed: (number of players with absolute-asymmetry >10% ÷ total number of players) × 100 (75). For players with absolute-asymmetry >10%, side-prevalence (%) was calculated for those with right-side better performance: (number of players with right-side better performance ÷ number of players with absolute-asymmetry >10%) × 100. The remaining proportion represented those with left-side better performance. Because an ART side-to-side difference ≥4cm has been prospectively identified as a risk factor for first-time noncontact lower-limb injury (26), counts were also made of players with asymmetries ≥4cm and overall-prevalence (%) computed: (number of players with an asymmetry ≥4cm ÷ total number of players) × 100 (75). For players with a side-to-side difference ≥4cm, side-prevalence (%) was calculated for those with right-side better performance (number of players with right-side better performance ÷

number of players with a side-to-side difference ≥4cm) × 100. The remaining proportion represented those with left-side better performance.

For the asymmetrical/unilateral nature of hockey, counts were made of players with better left-side mean values for each test and proportions (%) calculated: (number of players with better left-side mean values ÷ total number of players) × 100. The remaining proportion represented those with better right-side mean values.

RESULTS

Thirty players volunteered to participate from a club with 100 female players. No player experienced pain or adverse event during testing. Summary statistics are presented in Table 2 and 3.

Table 2. Summary statistics and effect sizes for all tests (n=30)

	Eyes Closed Balance (s)			Anterior Reach (cm)			Triple Hop (cm)			Six Metre Hop (s)		
	R	L	Absolute Difference	R	L	Absolute Difference	R	L	Absolute Difference	R	L	Absolute Difference
Min	9.5	13.8	0.5	46.4	47.2	0.1	341.3	358.7	0.3	1.6	1.6	0.0
Max	90.0	76.4	33.9	75.6	79.9	7.5	558.3	541.7	44.7	2.4	2.4	0.3
95% CI	34.1, 48.7	35.3, 48.4	6.8, 12.9	59.8, 65.0	59.6, 65.2	1.3, 2.6	447.1, 481.8	445.1, 482.8	10.2, 20.3	1.8, 2.0	1.8, 2.0	0.1, 0.2
Mean	41.4	41.8	9.9	62.4	62.4	2.0	464.4	464.0	15.2	1.9	1.9	0.1
SD	19.5	17.6	8.2	7.0	7.4	1.7	46.5	46.5	13.6	0.2	0.2	0.1
ES	0.02			0.00			0.01			0.00		

s = seconds; cm = centimetres; R = right; L= left; Absolute Difference = right − left (+/− sign removed)
Min = minimum; Max = maximum; 95% CI = 95% confidence interval (lower bound, upper bound); SD = standard deviation; ES = effect size

Table 3. Summary statistics and effect sizes for normalised anterior reach and triple hop values (n=30)

	Anterior Reach (%LL)			Triple Hop (%LL)		
	R	L	Absolute Difference	R	L	Absolute Difference
Min	56.9	58.7	0.2	440.4	422.7	0.3
Max	82.6	85.3	9.0	634.4	629.7	53.3
95% CI	69.1, 74.3	70.0, 74.2	1.7, 3.2	516.7, 550.5	513.6, 551.9	11.9, 24.0
Mean	71.7	71.6	2.0	533.6	532.7	17.9
SD	6.9	7.0	1.9	45.3	51.3	16.2
ES	0.01			0.01		

%LL = percentage of leg-length; R = right; L= left; Absolute Difference = right − left (+/− sign removed)
Min = minimum; Max = maximum; 95% CI = 95% confidence interval (lower bound, upper bound)
SD = standard deviation; ES = effect size

All data were normally distributed. There were no significant side-to-side differences for the non-normalised ECB (*P*=0.84), ART (*P*=0.96), THD (*P*=0.90), or 6MHT (*P*=0.45), or the normalised ART (*P*=0.90) and THD (*P*=0.84) (Table 2-3). For both normalised and non-normalised variables, 95% CIs had highly similar upper and lower boundaries, and all within-test right-left ESs were negligible (Table 2-3).

Summary statistics for LSIs and absolute-asymmetries are presented in Table 4. The minimum and maximum LSIs for the ECB test extended far below and above 100% indicating some players had large absolute-asymmetries (Table 4). The overall-prevalence of an absolute-asymmetry >10% for the ECB test indicated the vast majority of players had clinically-significant asymmetries (Table 4). The overall-prevalence of an absolute-asymmetry >10% for the 6MHT indicated over one-quarter of players had clinically-significant asymmetries. For side-prevalence, almost half to half of the players had right-side better performance for the ECB test and 6MHT, respectively (Table 4). For the ART threshold of ≥4cm, 10% of players had a clinically-significant absolute-asymmetry, of which 33% had right-side better performance. Two players had an absolute-asymmetry of 3.9cm.

Table 4. Summary statistics for limb symmetry indices and absolute-asymmetries (n=30)

	Eyes Closed Balance		**Anterior Reach***		**Triple Hop***		**Six Metre Hop**	
	LSI (%)	Absolute Asymmetry (%)	LSI (%)	Absolute Asymmetry (%)	LSI (%)	Absolute Asymmetry (%)	LSI (%)	Absolute Asymmetry (%)
Min	31.4	0.9	92.9	0.3	92.0	0.0	85.8	0.0
Max	197.3	97.3	113.3	13.3	112.6	12.6	114.0	14.2
95% CI	89.5, 118.9	18.6, 38.7	98.5, 101.9	2.4, 4.5	98.6, 102.2	2.3, 4.8	96.3, 102.0	4.3, 7.8
Mean	104.2	28.7	100.2	3.5	100.4	3.5	99.2	6.1
SD	39.5	26.9	4.5	2.8	4.9	3.4	7.7	4.7
O-Prevalence (%)	70.0		3.3		6.7		26.7	
S-Prevalence (%)	47.6		100.0		100.0		50.0	

* = calculated using normalised values (percent leg-length values); LSI = limb symmetry index (see text for equation)
Absolute Asymmetry = absolute difference (+/− sign removed) between an LSI of 100% and an actual LSI
Min = minimum; Max = maximum; 95% CI = 95% confidence interval (lower bound, upper bound); SD = standard deviation
O-Prevalence = overall-prevalence for an absolute-asymmetry >10% (see text for defintion and equation)
S-Prevalence = side-prevalence for an absolute-asymmetry >10% (see text for defintion and equation)

For the asymmetrical/unilateral nature of hockey, 46.7%, 53.0%, 50.0%, and 47.0% of players had better left-side mean values for the ECB, ART, THD, and 6MHT, respectively. The remaining proportions of players had better right-side mean values.

DISCUSSION

The first purpose of this study was to establish if there were statistically significant side-to-side differences for the ECB, ART, THD, and 6MHT in uninjured, adult, female players at one English community hockey club. It was hypothesised there would be statistically significant side-to-side differences across tests. Findings demonstrate there were no statistically significant side-to-side differences for any test. The second purpose was to establish the prevalence of clinically-significant asymmetries for the ECB, ART, THD, and 6MHT. It was hypothesised the majority of players would demonstrate clinically-significant asymmetries across tests. Findings demonstrate the majority of players had clinically-significant asymmetries for the ECB test and more than one-quarter of players had clinically-significant asymmetries for the 6MHT. The third purpose was to determine if the asymmetrical/unilateral nature of hockey results in side-to-side differences that favour the left leg. It was hypothesised the majority of players would demonstrate superior scores for the left versus right leg across tests. Findings demonstrate that approximately half of the players had better left-side mean values across tests, and the other half of the players had better right-side mean values across tests.

Comparison of the present data (Table 2-3) to previous literature is not possible because no other work has reported such data for such participants. The alternative is to compare the present data (Table 2-3) to values reported for other adult female athletes and mixed-sex adult groups. The mean ECB values in this study are higher than those reported for netball players (22.5-29.6s) (28) and a mixed-sex group of adults (27.8-28.8s) (76). The present mean normalised ART test values are also higher than those reported for collegiate hockey players (62.8-63.1%LL) (53) and lower than those reported for mixed-sport collegiate athletes (73.4%LL) (77). The current mean non-normalised THD values are equal to those reported for netball players (463.1-464.6cm) (28) and lower than those reported for mixed-sport collegiate athletes (470.0cm) (78). The mean 6MHT values in this study are shorter (better) than those reported for mixed-sport collegiate athletes (2.1s) (78) and fitness enthusiasts (2.4-2.5s) (79). The present mean test values are comparable with some previous literature. The present data, therefore, can serve as reference data for uninjured, adult, female community-level hockey players and may be used within clinical decision-making processes.

This study found no statistically significant side-to-side difference in group mean values for any test. Such findings are consistent with ECB and ART right-left comparisons in physically active females (28, 53, 76). Such findings are inconsistent with other research that reported statistically significant differences for THD right-left comparisons in female basketball players (80). The authors have been unable to locate any study that performs right-left statistical comparisons for the 6MHT. For both normalised and non-normalised variables (Table 2-3), 95% CIs had highly similar upper and lower boundaries and all within-test right-left ESs were negligible, supporting trivial right-left differences for group-level analyses across all tests. However, group-level analyses by statistical significance tests and ES are limited because they mask individual-level clinically-significant asymmetries; this is due to the inherent need to first reduce all individuals' data to a single central value that does not indicate the true extent of data distribution (29-31, 34). Consequently, group-level analyses are not useful in injury prevention because they fail to identify individuals who possess clinically-significant side-to-side differences and asymmetries (28-30).

An absolute-asymmetry >10% was used to define clinically-significant asymmetry because a motor-performance absolute-asymmetry >10% is prospectively related to first-time noncontact lower-limb injury risk (24, 41). The majority of players demonstrated a clinically-significant absolute-asymmetry for the ECB test (Table 4). Such findings are aligned with previous work in agility-sport athletes (28, 30). Two players for the THD and more than one-quarter of players for the 6MHT demonstrated a clinically-significant absolute-asymmetry (Table 4). For the ART, an absolute-asymmetry ≥4cm was also used to define clinically-significant asymmetry because it is specifically related to increased risk of first-time noncontact lower-limb injury (26). Two players demonstrated a side-to-side difference of 3.9cm and 10% of players demonstrated a clinically-significant absolute-asymmetry using the ≥4cm threshold. There were, therefore, individual players within the larger group with absolute-asymmetries that may predispose an increased risk of first-time noncontact knee and ankle injury. Based on such findings, correction of clinically-significant absolute-asymmetries using targeted interventions for selected players may need to be considered by clinical and coaching personnel (28). Effective interventions can be implemented using generic whole-team exercise programmes (81-83) or individualised exercise programmes (84-86). Because some players had better performance for the right-side and others for the left-side (Table 4), individualised interventions designed according to each player's asymmetry profile may be preferable for optimal outcomes (23, 28, 87). Clinical personnel in collaboration with coaching staff will need to determine which intervention strategy is best according to their team's logistical needs and the time-of-season. Based on the present data, because clinically-significant absolute-asymmetries were evident for large proportions of players (Table 4), screening for clinically-significant absolute-asymmetries is a clinically diligent and prudent strategy in English community-level adult female hockey. Individualised and targeted correction of clinically-significant absolute-asymmetries may then contribute to the prevention of knee and ankle injuries. An alternative consideration is that because the players in this study were uninjured and apparently healthy and available for full training and competition, it may not actually be unusual to observe several players in a single sample with relatively large absolute-asymmetries. As such, because similar observations have been reported in other studies (28, 30), clinicians should conscientiously reason whether a definitive need for intervention exists.

Preferential use of the left leg in hockey reflects higher BMD and muscle mass in the left versus right leg with hockey classed as a unilateral sport (46-48). Based on this study, morphological adaptations that favour the left leg are not paralleled by better left-side motor-performance as evidenced by approximately half of the players having better left-side mean values and the other half having better right-side mean values. Further support for lack of left-sided superior motor-performance comes from an absence of statistically significant side-to-side differences across tests (Table 2-3). Therefore, the clinical interpretation of LSIs and absolute-asymmetries in hockey need not consider preferential use of the left leg.

Potential limitations include not performing dominant-to-nondominant side-to-side comparisons (19, 29). Such comparisons were not performed because dominance/preference changes according to task demands (e.g. skill, load-bearing) (46, 50, 88) and because in real-world practice the size of an absolute-asymmetry is the factor that first draws practitioners' attention, after which the side with inferior performance is identified (28). Potential limitations also include using a simple LSI equation compared to other complex equations using right-left designators within multiple mathematical operations (89). Such equations were not employed because the equation used in this study requires few mathematical operations, is quicker to complete, and yields clinically meaningful values. Potential limitations further include not sub-grouping players into different team positions (58). Sub-grouping was not performed because individual-level analysis and intervention-customisation are of primary clinical importance when considering injury control interventions (23). This study is only generalisable to similar samples of hockey players. Future research should replicate this study to determine the consistency of findings. Future research should also replicate this study with community-level adult males and child/adolescent females and males to compare the prevalence of clinically-significant absolute-asymmetries across sexes and growth/development. Future research should further employ the motor-performance tests used here within prospective studies to determine the association between absolute-asymmetries of different magnitudes and injury risk as well as the effect of individualised corrective interventions on actual knee and ankle injury incidence. All contexts of suggested future research will provide valuable information for the community-level hockey-specific injury control process.

CONCLUSION

The tests used in this study were safely employed with a community-level hockey club. There were no statistically significant side-to-side differences for the ECB test, ART, THD, or 6MHT. Group-level asymmetry analyses using statistical significance tests masked the extent to which individuals possessed clinically-significant absolute-asymmetries. The majority of players demonstrated clinically-significant asymmetries for the ECB test, and more than one-quarter of players demonstrated clinically-significant asymmetries for the 6MHT. Researchers should use individual-level as well as group-level data analysis methods when performing asymmetry analyses with groups of players. The ECB test and 6MHT may be particularly useful for identifying clinically-significant absolute-asymmetries, although the ART and THD should also be employed because they are also capable of identifying players with clinically-significant absolute-asymmetries. The unilateral nature of hockey does not predispose the left leg to enhanced lower-limb motor-performance versus the right leg and, therefore, need not be considered when interpreting LSIs and absolute-asymmetries. This study highlights that clinically-significant lower-limb motor-performance asymmetries linked to injury predisposition and risk exist at a single hockey club and require consideration for intervention.

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