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Prevalence and magnitude of preseason clinically-significant single-leg balance and hop test asymmetries in an English adult netball club

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Prevalence and Magnitude of Preseason Clinically-Significant Single-Leg Balance and Hop Test Asymmetries in an English Adult Netball Club

ABSTRACT

Objectives: Side-to-side asymmetry of lower-limb motor-performance is associated with increased noncontact injury risk in agility-sports. Side-to-side symmetry-analyses using single-leg balance and hop tests has not been reported for community-level adult netball players. The purpose of this study was to perform preseason side-to-side symmetry-analyses using eyes-closed-balance (ECB), triple-hop-for-distance (THD), single-hop-for-distance (SHD), and vertical-hop (VH) tests.

Design: Cross-sectional

Setting: Community-level adult netball club.

Participants: Twenty-three female players (age 28.7±6.2yr; height 171.6±7.0cm; mass 68.2±9.8kg).

Main Outcome Measures: Right-left group-level comparisons (paired t-test) and individual-level comparisons (absolute-asymmetry (%)). A limb symmetry index was calculated for each test and a clinically-significant absolute-asymmetry defined as >10%. Clinically-significant absolute-asymmetry prevalence (%) was computed for each test.

Results: There were no right-left significant differences for any test. Maximum absolute-asymmetries for the ECB, THD, SHD, and VH were 93.3%, 15.2%, 16.7%, and 60.3%, respectively. The prevalence of clinically-significant absolute-asymmetries for the ECB, THD, SHD, and VH was 91.3%, 8.7%, 8.7%, and 52.2%, respectively.

Conclusions: Group-level comparisons with statistical tests fail to expose the extent of clinically-significant absolute-asymmetries. Most players demonstrated preseason clinically-significant absolute-asymmetries for the ECB and VH tests. Preseason clinically-significant absolute-asymmetries that may predispose increased lower-limb noncontact injury risk are widespread in a community-level adult netball club.

KEYWORDS

Netball, balance test, hop test, limb symmetry index

INTRODUCTION

Netball is a predominantly female team sport with millions of players across more than 113 countries (1). In England in 2015, there were 2,945 netball clubs and 104,000 players (2) which increased to 180,200 players in 2017 (3). Since then, community-level netball participation in England has grown further with an increase in netball's popularity after the women's national team won the Commonwealth Games gold medal in 2018 (4). With an increase in sports participation comes an increase in the number of injuries (5). Netball injuries have reported rates of 9.49 injuries/1,000 players (6) and 500.7 injuries/1,000 playing hours (7). Of all injuries, 57.2-85.3% occur to the lower-limb (6, 8) with knee and ankle injuries being most frequent (7-10) and knee trauma representing almost one-third of netball-related hospitalisations (8). Such injuries result in profound consequences including disability (6, 11, 12), socioeconomic burden (6, 11, 13), and premature retirement from netball (14). Because netball participation in England is increasing, and because of the potential consequences of knee and ankle injury, strategies are needed to mitigate the effects of injury for players, teams, and society, and prolong players' safe participation across the lifespan.

In epidemiology, 'injury control' refers to preventing or reducing the severity of injury (15) and includes prevention, acute care, and rehabilitation phases of intervention (16). In the injury prevention phase, single-leg balance (SLB) and hop (SLH) tests are used to make side-to-side comparisons of motor-performance and inform judgements about lower-limb injury predisposition and risk (17-19). Single-leg balance and SLH tests are popular in clinical environments because they are quick-and-easy to perform and reliable and valid measures of lower-limb functional joint stability (20-23). The administration of assessments to profile athletes and identify those predisposed to injury is good clinical practice (24-26) and lower SLB and SLH performance is associated with higher lower-limb injury risk in agility-sport athletes (18, 27-30). When making SLB and SLH side-to-side comparisons that inform clinical reasoning about first-time injury predisposition, consideration is for whether statistically or clinically significant side-to-side differences exist. Making a side-to-side comparison of the quantity of a variable represents a between-limb symmetry analysis. Symmetry occurs when the variable is equal in magnitude in both limbs. Asymmetry occurs when the variable is unequal in magnitude in both limbs.

At group-level, symmetry analysis involves procedures to determine if statistically significant side-to-side differences exist for measures of central tendency (e.g. mean, median) (31-35). A disadvantage of group-level analysis is that it masks clinically-significant asymmetries in some individuals in the group (31-33). Measures of central tendency can mask clinical significance because they reduce group data to a single central value that does not identify extreme values either side of that value, presenting an incomplete picture of data distribution across all individuals in the group (36). Consequently, measures of central tendency lose clinical meaningfulness because individuals who demonstrate extreme values and resulting clinical concerns are missed. At individual-level, symmetry analysis involves procedures to determine if clinically-significant side-to-side differences exist for individuals' mean or maximum values (31, 32, 37). Procedures involve the calculation of some form of 'limb symmetry index' (LSI) (31-33, 38). Calculation of an LSI involves one limb's value divided by the other limb's value and the result multiplied by 100 to yield a percentage (20, 33, 38); 100% represents symmetry, and the size of any difference below/above 100% represents the size of the absolute-asymmetry (e.g. LSIs of 85% and 115% both indicate an absolute-asymmetry of 15%) (29, 31, 32). The LSI is valuable because it identifies the size of a clinically-significant asymmetry in the individual (31, 32) where 'clinically-significant' is historically defined as an absolute-asymmetry >10% (39-41). Recently, SLH test asymmetries >10% have been prospectively associated with higher first-time lower-limb noncontact injury risk (29, 30). Because lower-limb motor-performance side-to-side comparisons and asymmetry-analyses are clinically valuable for preseason screening and injury predisposition and risk profiling (18, 27, 29, 42, 43) the use of preseason SLB and SLH testing and symmetry analyses is a clinically diligent and sensible strategy in netball.

Several studies have employed lower-limb motor-performance tests with female netball players. Single-leg balance tests have been performed using sophisticated computer equipment with elite players in South Africa (44) and high-grade club players in New Zealand (45). Single-leg balance tests have also been performed using the Star Excursion Balance Test (SEBT) with Superleague players in England (46), using a modified SEBT with university players also in England (47), and using eyes-closed-balance (ECB) for time with school players in New Zealand (48). Single-leg hop tests have been performed using a force-plate and a vertical/forward/lateral task with national-level players in New Zealand (37) and a vertical-hop (VH) with club-level players in Australia (49). Single-leg hop tests have also been performed using the single-hop-for-distance (SHD) and triple-hop-for-distance (THD) with regional academy players in England (50). Of the studies cited, only three engaged in preseason assessments (44, 48, 50) with two focusing on players aged <19 years (yr) (44, 48). There is, therefore, an absence of literature reporting preseason lower-limb motor-performance in adult players. Adult players in local communities represent the largest proportion of players in England (2), and so characterising preseason lower-limb motor-performance is important to provide data about the frequency of clinically-significant asymmetries and injury predisposition in this population. Also of the studies cited, three required sophisticated computer equipment (37, 44, 45) and only one performed symmetry analyses (37). There is, subsequently, also an absence of literature regarding the use of ‘field-based’ lower-limb motor-performance tests with widely available equipment to identify clinically-significant asymmetries and injury predisposition with any adult netball player at any netball club in any country. A battery of low-cost, portable, and reliable lower-limb motor-performance tests capable of providing data useful for injury predisposition and risk profiling is a valuable tool for informing a community club’s preseason planning and rational changes in practice.

There were two purposes for this study: 1. to determine if there were statistically significant side-to-side differences for the preseason single-leg ECB, THD, SHD, and VH in uninjured, adult, female netball players at one English community netball club; 2. to determine the prevalence of clinically-significant preseason asymmetries for the ECB, THD, SHD, and VH tests. Tests were chosen because they are associated with first-time lower limb injury risk in agility-sport athletes (18, 27-30) and because they are portable, practically viable at many clubs, and are meaningful to players and coaches regarding athletic performance. It was hypothesised: 1. there would be statistically significant side-to-side differences for the ECB, THD, SHD, and VH tests; 2. the majority of players would demonstrate clinically-significant asymmetries for the ECB, THD, SHD, and VH tests. This study is original because no previous work has reported side-to-side comparisons and asymmetry analyses for a battery of SLB and SLH field-tests in uninjured, adult, female netball players at one English community netball club. This study's findings will be practically significant because they will highlight the extent to which clinically-significant preseason lower-limb motor-performance asymmetries linked to injury predisposition and risk exist at a single club and require subsequent consideration for intervention.

METHODS

Study design

Cross-sectional.

Sample size calculation

An *a priori* power analysis was performed using G*Power (51). To detect a side-to-side difference with a medium effect size (ES) of 0.50, 80% power, and significance set at 0.05, 27 participants were required.

Ethical approval, participant recruitment, informed consent

University ethics approval was obtained. Participants were recruited from an English community netball club using an email invitation distributed by the Club Secretary to all adult players. Informed consent and a physical activity readiness questionnaire were completed by all participants.

Participants

Inclusion criteria were: females aged 18-55yr participating in one or more netball training/matches per week and registered for unrestricted preseason training. Exclusion criteria were: current lower-quadrant pain, any time-loss lower-quadrant injury in the previous two months (i.e. injury requiring withdrawal from one or more training/matches), any history of lumbar spine/hip/knee/ankle fracture or surgery, and any current neurological condition that could affect sensorimotor processing at any level of the nervous system (e.g. concussion). Twenty-three players volunteered and reported being uninjured and available for selection (mean±standard deviation: age 28.7±6.2yr; height 171.6±7.0 centimetres (cm); mass 68.2±9.8 kilograms (kg)). The club competed in the London and South East Regional League and the Surrey County League.

Instrumentation.

Height was measured with a SECA 213 stadiometer (HaB Direct, Warwickshire, UK). Mass was measured with SECA 760 weighing scales (HaB Direct, Warwickshire, UK). Leg-length was measured with a fibreglass anthropometric measuring tape (HaB Direct, Warwickshire, UK). The ECB test was measured with a Junso JS510 digital stopwatch (Sports Warehouse, Edinburgh, UK). The THD and SHD were measured with a fibreglass athletics measuring tape (Sports Warehouse, Edinburgh, UK). The VH was recorded with a Panasonic HC-V720 high-definition Camcorder (Panasonic UK Ltd, Berkshire, UK) and analysed using Kinovea freeware (52).

Procedures.

Data collection occurred at the club's outdoor training site (concrete netball court) in one session. Players were instructed to avoid fatiguing exercise/sports for 48 hours beforehand. Test/limb order considered skill demands (high-to-low), cumulative muscle fatigue, and time-efficiency. Data collection occurred in station order format: anthropometry (height, mass, leg-length), barefoot ECB, shod THD, shod SHD, and shod VH. Limb order was right then left, players alternated between limbs for each test. After the anthropometry and ECB stations, players completed a standardised warm-up (toe-walking, heel-walking, parallel squats, forward lunge-walk, right lateral-lunge walk, left lateral lunge-walk, high-knee lifts, butt-kicks, right and left single-leg squats). Arm movement was permitted for all SLH tests to assist balance (21, 53, 54). Practice trials for all tests were followed by three measured trials for each limb. Trials were terminated if players reported any pain.

For anthropometry, standing height and mass were measured using routine procedures (55). For leg-length (56), players were barefoot and supine-lying on a portable treatment table. Leg-length was measured once from the anterior superior iliac spine to the tip of the medial malleolus using the anthropometric tape measure to the nearest millimetre (mm). Reliability (intraclass correlation coefficient (ICC)=0.99) has been reported for this procedure (56).

For the ECB test (57), players stood on the test-leg on a thin mat, the opposite leg flexed with the heel level with but not touching the approximate mid-point of the standing leg's calf, the arms crossed with the hands flat on the chest (Figure 1). Players were instructed to assume the test position, look forwards, and acquire a steady posture before closing their eyes. Balance was measured using the digital stopwatch in seconds (s) from the moment the eyes closed to the moment balance was lost (opening eyes, uncrossing arms, touching heel to the calf, shifting the stance leg foot, putting the non-stance leg foot to the floor). Reliability has been reported for the timed ECB test (ICC=0.83) (57).

Figure 1. Eyes-Closed-Balance Test

For the THD (58) and SHD (33), players stood on the test-leg, the distal aspect of the foot aligned with the posterior edge of a start-line (Figure 2). For the THD, players rapidly hopped forwards on the same leg three times to stick the final landing (Figure 2). For the SHD, players countermovement hopped forwards on the same leg once to stick the landing (Figure 2). For both tests, loss of balance and placing the opposite foot on the floor voided the trial and resulted in another attempt. Hop distance was measured from the posterior edge of the start-line to the distal aspect of the foot to the nearest 0.5cm. Reliability has been reported for the THD (ICC=0.95) (59) and SHD (ICC=0.96) (59).

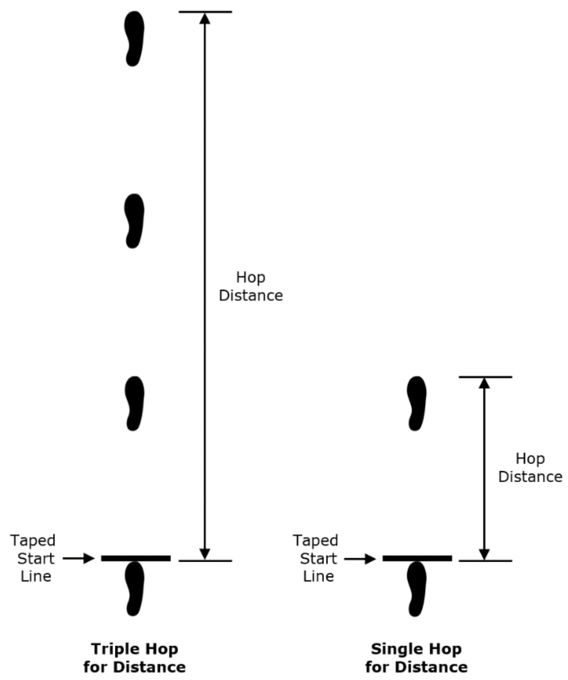

Figure 2. Triple-Hop-for-Distance and Single-Hop-for-Distance Tests

The VH was modified from previous work (38, 60). Players stood on the test-leg with the video camera flat on the floor, the front of the camera 30cm from the lateral border of the foot and perpendicular to the mid-point of the foot's long axis. Players countermovement hopped upwards once as far as possible, straightening the leg (Figure 3), and then sticking the final landing. If the test-leg failed to straighten or opposite foot touched down first the trial was voided and another attempt performed. Players were given a "3, 2, 1, Go" countdown with camera recording started before the "Go" and stopped after the player had both feet on the ground. The camera was not moved during filming; players faced one direction for one leg and then turned to face the opposite direction for the other leg. Hop distance was calculated from flight-time. Reliability for the calculation of distance from flight-time has been reported (ICC=1.00) (60).

Figure 3. Vertical-Hop Test

Data Reduction

For the VH, video footage was transferred to a laptop computer with Kinovea freeware (52). Test-leg take-off and landing were defined as the first frame in which the foot was fully off the ground and any part of the foot was touching the ground, respectively (60). The freeware's timer was used to calculate flight-time (s), and VH height was then calculated using the formula $h = (t^2 \times 1.22625)$ where h is the height in meters and t is the flight-time in seconds (60). Hop height in meters was converted to centimetres. Normalisation of data to leg-length was performed for all SLH test trials (61): percent leg-length (%) = (distance hopped (cm) ÷ leg-length (cm)) × 100. The mean normalised values for each leg within all SLH tests were used for all analyses.

Data 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-side mean values (20, 33). Bonferroni-corrected alpha was set *a priori* at 0.01 (62, 63). In addition, 95% confidence intervals (CI) were calculated for within-test right- and left-side values (63-65) and Cohen's *d* was estimated for within-test right-left ES (62). Effect sizes of 0.20, 0.50, and 0.80 were considered small, medium, and large, respectively (62).

For clinical analyses (individual-level), an LSI (%) was calculated for each player: (right mean ÷ left mean) × 100 (32, 39, 66). An LSI of 100% represented side-to-side symmetry, <100% lower ride-side/higher left-side performance, >100% lower left-side/higher right-side performance; the LSI, therefore, indicated both the magnitude (size) and direction (side) of asymmetry. Because the size of asymmetry is the principal matter of clinical interest (20), absolute-asymmetry was calculated: 100% − player's LSI. The +/− sign was removed from the difference. Because a clinically-significant absolute-asymmetry is historically defined as an asymmetry >10% (39-41) and an asymmetry >10% has been reported as prospectively associated with first-time noncontact lower limb injury risk (29, 30), an absolute-asymmetry >10% was used in this study to define 'clinically-significant' and players 'at-risk' of injury (30). Counts were made of players with absolute-asymmetries >10% and overall-prevalence (%) computed for each test: (number of players with an absolute-asymmetry >10% ÷ total number of players) × 100 (67, 68). For the players with an absolute-asymmetry >10%, side-prevalence was calculated for those with right-side lower performance (% = number of players with right-side lower performance ÷ number of players with absolute-asymmetry >10%); the remaining proportion represented those with left-side lower performance.

RESULTS

Although the power analysis required 27 players, only 23 volunteered to participate from a potential pool of 50 players. No player experienced pain during testing, and there were no adverse events. Summary statistics are presented in Table 1 and 2.

Table 1. Summary statistics for right and left leg-length and non-normalised hop test values (n=23)

	Leg-Length (cm)			Triple Hop (cm)			Single Hop (cm)			Vertical Hop (cm)		
	R	L	Absolute Difference	R	L	Absolute Difference	R	L	Absolute Difference	R	L	Absolute Difference
Min	79.3	80	0.0	347.0	389.7	1.0	119.3	122.3	0.0	9.6	13.1	0.5
Max	104.5	104.9	1.5	592.0	541.0	65.3	202.3	191.0	25.0	26.7	27.5	6.0
95% CI	88.8, 94.3	88.7, 94.0	0.6, 0.9	440.1, 486.1	447.9, 481.3	12.8, 27.3	159.2, 174.8	159.6, 173.2	3.3, 8.6	18.4, 21.6	18.2, 20.9	1.6, 2.8
Mean	91.5	91.4	0.7	463.1	463.6	20.0	167.0	166.4	6.0	20.0	19.5	2.2
SD	6.3	6.2	0.4	53.2	38.7	16.8	18.0	15.7	6.1	3.7	3.1	1.3

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

Table 2. Summary statistics and effect sizes for right and left balance and normalised hop test values (n=23)

	Eyes Closed Balance (s)			Triple Hop (%LL)			Single Hop (%LL)			Vertical Hop (%LL)		
	R	L	Absolute Difference	R	L	Absolute Difference	R	L	Absolute Difference	R	L	Absolute Difference
Min	3.0	7.2	0.8	383.4	427.6	1.3	131.9	133.0	0.6	8.5	6.5	0.6
Max	57.9	60.0	27.7	686.8	632.0	68.7	234.7	223.1	26.4	28.4	28.9	8.7
95% CI	15.6, 29.3	22.9, 36.3	8.3, 15.9	477.5, 539.5	486.4, 535.4	12.2, 28.6	172.7, 194.0	173.7, 192.4	4.2, 9.8	19.0, 23.5	18.4. 22.3	1.7, 3.3
Mean	22.5	29.6	12.1	508.5	510.9	20.4	183.4	183.0	7.0	21.3	20.6	2.5
SD	15.8	15.5	8.8	71.8	56.7	19.0	24.6	21.5	6.4	5.2	5.0	1.8
ES	0.50			0.04			0.01			0.18		

s = seconds; %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 (P>0.05). There were no significant side-to-side differences for the ECB (P=0.02), THD (P=0.69), SHD (P=0.87), or VH (P=0.31) tests. The ECB test right and left mean values and 95% CI were, however, quite different (Table 2). The right and left mean values and 95% CI for the THD, SHD, and VH were similar (Table 2). The ECB test demonstrated a medium ES, all other ES were small (Table 2).

Summary statistics for LSIs and absolute-asymmetries are presented in Table 3. The minimum and maximum LSIs for the ECB and VH tests extended below and above 100% indicating some players had large absolute-asymmetries where the lower performance was demonstrated by the right or left side, respectively (Table 3). Very large absolute-asymmetries were evidenced by the maximum absolute-asymmetries for the ECB and VH tests (Table 3). The overall-prevalence of absolute-asymmetries >10% was high for the ECB test indicating the vast majority of players demonstrated clinically-significant asymmetries (Table 3). The overall-prevalence of absolute-asymmetries >10% for the VH indicated that more than half of the players demonstrated clinically-significant asymmetries (Table 3). The overall-prevalence of clinically-significant absolute-asymmetries was low for the THD and SHD (Table 3). For side-prevalence, the majority of players had right-side lower performance for the ECB test whereas for the VH test the majority of players had left-side lower performance (Table 3).

Table 3. Summary statistics for limb symmetry indices and absolute-asymmetries (n=23)

	Eyes Closed Balance		Triple Hop		Single Hop		Vertical Hop	
	LSI (%)	Absolute Asymmetry (%)	LSI (%)	Absolute Asymmetry (%)	LSI (%)	Absolute Asymmetry (%)	LSI (%)	Absolute Asymmetry (%)
Min	17.5	1.3	84.8	0.2	83.3	0.3	72.2	2.8
Max	193.3	93.3	112.1	15.2	116.4	16.7	160.3	60.3
95% CI	59.6, 99.5	33.3, 54.0	96.8, 101.9	2.4, 5.9	97.6, 102.7	2.2, 5.9	96.8, 112.7	8.3, 19.4
Mean	79.6	43.7	99.3	4.2	100.2	4.1	104.7	13.1
SD	46.2	24.0	5.8	4	6.0	4.3	18.4	12.8
O-Prevalence (%)	91.3		8.7		8.7		52.2	
S-Prevalence (%)	76.2		50.0		50.0		41.7	

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 (see text for definition and equation)
S-Prevalence = side-prevalence (see text for definition and equation)

DISCUSSION

Netball participation in England is rapidly increasing at community-level versus elite-/professional-level (3, 4) and, therefore, netball injury prevention efforts at community-level are critical to maximise positive impacts on the largest numbers of players and help mitigate the socioeconomic burden of netball lower-limb injury. The first purpose of this study was to determine if there were statistically significant side-to-side differences for the preseason single-leg ECB, THD, SHD, and VH tests in uninjured, adult, female netball players at one English community netball club. It was hypothesised there would be statistically significant side-to-side differences for all tests. Findings demonstrate there were no statistically significant side-to-side differences for any test. The second purpose of this study was to determine the prevalence of clinically-significant preseason asymmetries for the ECB, THD, SHD, and VH tests. It was hypothesised the majority of players would demonstrate clinically-significant asymmetries for all tests. Findings demonstrate the majority of players had clinically-significant asymmetries for the ECB and VH tests only.

Comparison of the ECB and normalised SLH test values for this study (Table 2) to previous literature is not possible because no other work has reported such data for uninjured, adult, female netball players at one English community netball club. The alternative is to compare the ECB and non-normalised hop test values for this study (Table 1) to data reported for uninjured female netball players of different age and other similar adults. For the ECB test, mean values of 15.8-20.8s for female netball players aged 15-17yr (48) and 28.8s for a mixed-sex group aged 20-29yr (69) have been reported. For the THD, mean values of 586.0-590.0cm for female regional academy netball players aged 17-19yr (50) and 519.4-532.4cm for female elite basketball players with mean age 20.5yr (70) are recorded. For the SHD, mean values of 153.8-154.6cm for female elite basketball players with mean age 20.5yr (70) and 187.0-188.0cm for female regional academy netball players aged 17-19yr (50) have been reported. For the VH, mean values of 16.9-17.6cm for female recreational agility-sport athletes (33) and 29.0-30.0cm for female elite tennis players aged over 16yr (71) are recorded. Based on the studies cited here, mean test values for the present work appear comparable with some literature. Until more literature examining preseason single-leg motor-performance in uninjured, adult, female community-level netball players become available, the present data serve as reference data for such players.

This study found no statistically significant side-to-side difference in group mean values for any test (Table 2). Such findings are consistent with ECB and SHD right-left comparisons in uninjured adults (69, 72). However, such findings are inconsistent with other work that identified statistically significant differences for THD right-left comparisons in uninjured female elite basketball players (70) (right-left ES=0.20). Use of ES alongside *P*-values is advocated because *P*-values alone do not give an indication of the magnitude of difference between two central tendency values for the same variable (63, 64). Use of the 95% CI is advocated because ES themselves can distort study findings and be misleading (65). Although the ECB test demonstrated a non-significant side-to-side difference, the right-left ES was medium and the right and left 95% CI were quite different (Table 2) suggesting there were, in fact, real performance differences between the right and left sides. Such findings are aligned with ECB data for adolescent female netball players (48) (right-left ES=0.46). In contrast, for the THD, SHD, and VH, right-left ES were small (trivial) and right and left CI were very similar (Table 2). Such findings are also aligned with THD and SHD data for regional-level netball players (50) (right-left ES=0.09-0.10). Regardless of the advocated use of ES alongside *P*-values, and regardless of the trivial right-left ES for the THD, SHD, and VH in this study (Table 2), ES analysis still represents group-level analysis which employs a variable's mean and/or standard deviation value for its calculation (65). Such procedures, therefore, do not account for individuals with extreme values either side of the central value and for whom there may be individual clinical concerns. Consequently, although group-level right-left comparisons may demonstrate trivial side-to-side ES, such comparisons are not useful in injury prevention because they fail to identify individuals within the group who possess clinically-significant side-to-side differences and asymmetries (31-33, 37).

An absolute-asymmetry >10% was used in this study to define clinically-significant asymmetry because an absolute-asymmetry >10% is prospectively associated with first-time noncontact lower-limb injury risk (29, 30). The majority of players demonstrated a clinically-significant absolute-asymmetry for the ECB and VH tests (Table 3). Such findings are consistent with previous work in uninjured agility-sport athletes (31). Because the majority of players in this study demonstrated a clinically-significant absolute-asymmetry for either the ECB test or VH (Table 3), this could indicate the majority of players were predisposed to and at-risk of first-time noncontact lower-limb injury at that point-in-time. As such, preseason correction of clinically-significant absolute-asymmetries using appropriate interventions should be considered by team coaches and clinical personnel. Generic injury prevention interventions (i.e. standardised whole-team exercise programmes) are known to be effective for reducing knee and ankle injury incidence in agility-sport athletes (73-75). Alternatively, specific and targeted injury prevention interventions (i.e. individualised exercise programmes) are also advocated for beneficially modifying injury risk factors in agility-sport athletes (76-78). Because some players had right-side lower performances and other players had left-side lower performances for different tests (Table 3), individualised interventions may need to be prioritised over generic whole-team training sessions (26, 79). Coaches and clinical personnel will need to decide which intervention method best suits their team's logistical needs. Based on the present data, because clinically-significant preseason absolute-asymmetries were highly prevalent, preseason screening for clinically-significant absolute-asymmetries is a clinically diligent and overall sensible strategy in English community-level adult netball. Correction of preseason clinically-significant absolute-asymmetries may then contribute to the prevention of in-season knee and ankle injuries.

Potential limitations include not performing dominant-to-nondominant side-to-side comparisons (33, 37, 72). Such comparisons were not performed because dominance changes according to task demands (e.g. skill versus load-bearing) (80, 81) and because the size of an absolute-asymmetry is the principal factor that first draws clinical attention after which the side with the lower task performance is identified. Potential limitations also include using a simple LSI formula compared to other more complex equations employing right and left designators within several mathematical operations (82). Such equations were not used because the LSI formula used in this study is indeed simple with few mathematical operations, is quick to complete, and ultimately yields a clinically meaningful value. Potential limitations further include not sub-grouping players into different team positions because different positions have distinct physiological/technical demands (83). Sub-grouping was not performed in this study because individual-level analysis and intervention-customisation are of most clinical importance when considering injury control interventions (26). Future research should replicate this study's design with other similar player samples to corroborate its findings. Future research should also replicate this study's design with community-level child/adolescent samples to establish the prevalence of clinically-significant absolute-asymmetries in the growing player. Both contexts of suggested future research will provide valuable information for the community-level netball-specific lower-limb injury control process.

CONCLUSION

The test battery used in this study was safely employed with a community-level netball club. Uninjured, adult, female netball players did not demonstrate preseason statistically significant side-to-side differences in ECB, THD, SHD, or VH performance. Group-level asymmetry analyses using statistical significance tests, however, masked the extent to which individual players possessed clinically-significant absolute-asymmetries that may require corrective intervention. Researchers should use individual-level as well as group-level data analysis methods when reporting asymmetry analyses with groups of athletes. The ECB and VH tests may be particularly useful for identifying preseason clinically-significant asymmetries, although the THD and SHD should also be employed for thoroughness because they are also capable of identifying players with clinically-significant absolute-asymmetries. This study highlights the widespread existence of preseason clinically-significant lower-limb motor-performance absolute-asymmetries linked to injury predisposition and risk in a single English adult netball club. This study also highlights a battery of low-cost and portable field-tests that are capable of contributing to diligent and sensible netball club preseason screening.

REFERENCES

1. Federation IN. Netball on the rise 2017 [Available from: https://netball.sport/archives/7279.

2. Netball E. England Netball Membership Statistics. Hertfordshire; 2017.

3. Netball E. England Netball Annual Report 2016-2017. Leicestershire; 2018.

4. Netball E. Six months on: Commonwealth Games impact report 2018 [Available from: https://www.englandnetball.co.uk/commonwealthgamesimpactreport/.

5. Parkkari J, Kannus P, Natri A, Lapinleimu I, Palvanen M, Heiskanen M, et al. Active living and injury risk. International Journal of Sports Medicine. 2004;25(3):209-16.

6. Otago L, Peake J. The role of insurance data in setting priorities for netball injury prevention strategies. Journal of Science and Medicine in Sport. 2007;10(2):105-9.

7. Langeveld E, Holtzhausen LJ, Coetzee FF. Epidemiology of injuries in elite South African netball players. South African Journal for Research in Sport, Physical Education and Recreation. 2012;34(2):83-93.

8. Flood L, Harrison JE. Epidemiology of basketball and netball injuries that resulted in hospital admission in Australia, 2000–2004. Medical Journal of Australia. 2009;190(2):87-90.

9. Attenborough A, Sinclair P, Sharp T, Greene A, Stuelcken M, Smith R, et al. The identification of risk factors for ankle sprains sustained during netball participation. Physical Therapy in Sport 2017;23:31-6.

10. Smith R, Damodaran A, Swaminathan S, Campbell R, Barnsley L. Hypermobility and sports injuries in junior netball players. British Journal of Sports Medicine. 2005;39(9):628-31.

11. Finch C, Cassell E. The public health impact of injury during sport and active recreation. Journal of Science and Medicine in Sport. 2006;9(6):490-7.

12. Genoese F, Baez S, Hoch JM. The association of fear-avoidance beliefs and self-reported knee function in patients with a knee injury: A critically appraised topic. International Journal of Athletic Therapy and Training. 2018;23(5):187-91.

13. Janssen K, Orchard J, Driscoll T, van Mechelen W. High incidence and costs for anterior cruciate ligament reconstructions performed in Australia from 2003–2004 to 2007–2008: time for an anterior cruciate ligament register by Scandinavian model? Scandinavian Journal of Medicine and Science in Sports. 2012;4(22):495-501.

14. Netball E. Top 10 on the 10th – Injury Prevention 2016 [Available from: https://www.englandnetball.co.uk/coachblog/top-10-10th-injury-prevention/.

15. Avery J. Accident prevention-injury control-injury prevention-or whatever? Injury prevention. 1995;1(1):10.

16. Rivara F. Introduction: the scientific basis for injury control. Epidemiol Rev. 2003;25:20-3.

17. Hewit J, Cronin J, Hume P. Multidirectional leg asymmetry assessment in sport. Strength & Conditioning Journal. 2012;34(1):82-6.

18. Brumitt J, Heiderscheit B, Manske R, Niemuth PE, Mattocks A, Rauh MJ. Preseason functional test scores are associated with future sports injury in female collegiate athletes. Journal of Strength and Conditioning Research. 2017;32(6):1692-701.

19. Stiffler MR, Bell DR, Sanfilippo JL, Hetzel SJ, Pickett KA, Heiderscheit BC. Star excursion balance test anterior asymmetry is associated with injury status in division I collegiate athletes. Journal of Orthopaedic and Sports Physical Therapy. 2017;47(5):339-46.

20. Clark NC. Functional performance testing following knee ligament injury. Physical Therapy in Sport. 2001;2(2):91-105.

21. Clark NC, Gumbrell CJ, Rana S, Traole CM, Morrissey MC. Intratester reliability and measurement error of the adapted crossover hop for distance. Physical Therapy in Sport. 2002;3(3):143-51.

22. Eechaute C, Vaes P, Duquet W. The dynamic postural control is impaired in patients with chronic ankle instability: reliability and validity of the multiple hop test. Clinical Journal of Sport Medicine. 2009;19(2):107-14.

23. Kivlan B, Martin R. Functional performance testing of the hip in athletes: a systematic review for reliability and validity. International Journal of Sports Physical Therapy. 2012;7(4):402-12.

24. Meeuwisse WH, Tyreman H, Hagel B, Emery C. A dynamic model of etiology in sport injury: the recursive nature of risk and causation. Clinical Journal of Sport Medicine. 2007;17(3):215-9.

25. Roe M, Malone S, Blake C, Collins K, Gissane C, Büttner F, et al. A six stage operational framework for individualising injury risk management in sport. Injury Epidemiology. 2017;4(1):26-.

26. Verhagen E, van Dyk N, Clark N, Shrier I. Do not throw the baby out with the bathwater; screening can identify meaningful risk factors for sports injuries. British Journal of Sports Medicine. 2018;52(19):1223-4.
27. McGuine T, Greene J, Best T, Leverson G. Balance as a predictor of ankle injuries in high school basketball players. Clinical Journal of Sport Medicine. 2000;10(4):239-44.
28. Watson AWS. Ankle sprains in players of the field-games Gaelic football and hurling. Journal of Sports Medicine and Physical Fitness. 1999;39(1):66-70.
29. Brumitt J, Heiderscheit BC, Manske RC, Niemuth PE, Rauh MJ. Lower extremity functional tests and risk of injury in Division III collegiate athletes. International Journal of Sports Physical Therapy. 2013;8(3):216-27.
30. Brumitt J, Mattocks A, Loew J, Lentz P. Preseason functional performance test measures are associated with injury in female collegiate volleyball players. Journal of Sport Rehabilitation. 2019;24:1-20.
31. Clark NC, Davies S, Reilly L. Single-leg hop test side-to-side asymmetry and statistical versus clinical significance data analysis in knee injury control research. Knee Surgery, Sports Traumatology, Arthroscopy. 2018;26:S166.
32. Parr JJ, Clark NC, Abt JP, Kresta JY, Keenan KA, Kane SF, et al. Residual impact of previous injury on musculoskeletal characteristics in Special Forces Operators. Orthopaedic Journal of Sports Medicine. 2015;3(11):2325967115616581.
33. Barber SD, Noyes FR, Mangine RE, Hartman W. Quantitative assessment of functional limitations in normal and anterior cruciate ligament-deficient knees. Clinical Orthopaedics and Related Research. 1990;255:204-14.
34. Paterno MV, Greenberger HB. The test-retest reliability of a one legged hop for distance in young adults with and without ACL reconstruction. Isokinetics and Exercise Science. 1996;6(1):1-6.
35. Sell TC, Clark NC, Wood D, Abt JP, Lovalekar M, Lephart SM. Single-leg balance impairments persist in fully operational military special forces operators with a previous history of low back pain. Orthopaedic Journal of Sports Medicine. 2014;2(5):2325967114532780.
36. Manikandan S. Measures of central tendency: The mean. Journal of Pharmacology and Pharmacotherapeutics. 2011;2(2):140-.
37. Hewit JK, Cronin JB, Hume PA. Asymmetry in multi-directional jumping tasks. Physical Therapy in Sport. 2012;13:238-42.
38. Risberg M, Holm I, Ekeland A. Reliability of functional knee tests in normal athletes. Scandinavian Journal of Medicine and Science in Sports. 1995;5(1):24-8.
39. Grace T, Sweetser E, Nelson M, Ydens L, Skipper B. Isokinetic muscle imbalance and knee-joint injuries. A prospective blind study. Journal of Bone and Joint Surgery America. 1984;66(5):734-40.
40. Juris PM, Phillips EM, Dalpe C, Edwards C, Gotlin RS, Kane DJ. A dynamic test of lower extremity function following anterior cruciate ligament reconstruction and rehabilitation. Journal of Orthopaedic and Sports Physical Therapy. 1997;26(4):184-91.
41. Sapega A. Muscle performance evaluation in orthopaedic practice. Journal of Bone and Joint Surgery America. 1990;72(10):1562-74.
42. Brumitt J, Mattocks A, Loew J, Lentz P. Preseason functional performance test measures are associated with injury in female collegiate volleyball players. Journal of Sport Rehabilitation. 2019(In press).
43. Devan MR, Pescatello LS, Faghri P, Anderson J. A prospective study of overuse knee injuries among female athletes with muscle imbalances and structural abnormalities. Journal of Athletic Training. 2004;39(3):263-7.
44. Ferreira MA, Spamer EJ. Biomechanical, anthropometrical and physical profile of elite university netball players and the relationship to musculoskeletal injuries. South African Journal for Research in Sport, Physical Education and Recreation. 2010;32(1):57-67.
45. Waterman N, Sole G, Hale L. The effect of a netball game on parameters of balance. Physical Therapy in Sport. 2004;4(5):200-7.
46. Soper K, Simmonds JV, Kaz HK, Ninis N. The influence of joint hypermobility on functional movement control in an elite netball population: A preliminary cohort study. Physical Therapy in Sport. 2015;2(16):127-34.
47. Armstrong R, Greig M. The Functional Movement Screen and modified Star Excursion Balance Test as predictors of T-test agility performance in university rugby union and netball players. Physical Therapy in Sport. 2018;31:15-21.

48. Taylor L, Lander P. Adolescent netball players normative data and physical performance profiles. New Zealand Physical Educator. 2018;51(1):20-4.

49. Pruyn E, Watsford M, Murphy A. Validity and reliability of three methods of stiffness assessment. Journal of Sport and Health Science. 2016;5(4):476-83.

50. Thomas C, Ismail KT, Comfort P, Jones PA, Dos'Santos T. Physical profiles of regional academy netball players. Journal of Trainology. 2016;5(2):30-7.

51. Buchner A, Erdfelder E, Faul F, Lang A. G*Power: Statistical power analyses for Windows and Mac 2019 [Available from: http://www.gpower.hhu.de/.

52. Charmant J. Kinovea 2019 [Available from: https://www.kinovea.org/.

53. Kramer JF, Nusca D, Fowler P, Webster-Bogaert S. Test-retest reliability of the one-leg hop test following ACL reconstruction. Clinical Journal of Sport Medicine. 1992;2:240-3.

54. Ageberg E, Zätterström R, Fridén T, Moritz U. Individual factors affecting stabilometry and one-leg hop test in 75 healthy subjects, aged 15–44 years. Scandinavian Journal of Medicine and Science in Sports. 2001;11(1):47-53.

55. Lohman T, Roche A, Martorell R. Anthropometric Standardization Reference Manual. Abridged ed. Illinois: Human Kinetics; 1991.

56. Gogia PP, Braatz JH. Validity and reliability of leg length measurements. Journal of Orthopaedic and Sports Physical Therapy. 1986;8(4):185-8.

57. Springer BA, Marin R, Cyhan T, Roberts H, Gill NW. Normative values for the unipedal stance test with eyes open and closed. Journal of Geriatric Physical Therapy. 2007;30(1):8-15.

58. Noyes F, Barber S, Mangine R. Abnormal lower limb symmetry determined by function hop tests after anterior cruciate ligament rupture. American Journal of Sports Medicine. 1991;19(5):513-8.

59. Bolgla LA, Keskula DR. Reliability of lower extremity functional performance tests. Journal of Orthopaedic and Sports Physical Therapy. 1997;26(3):138-42.

60. Balsalobre-Fernández C, Tejero-González CM, del Campo-Vecino J, Bavaresco N. The concurrent validity and reliability of a low-cost, high-speed camera-based method for measuring the flight time of vertical jumps. Journal of Strength and Conditioning Research. 2014;28(2):528-33.

61. Pincivero D, Lephart S, Karunakara R. Relation between open and closed kinematic chain assessment of knee strength and functional performance. Clinical Journal of Sport Medicine. 1997;7(1):11-6.

62. Portney L, Watkins M. Foundations of Clinical Research: Applications to Practice. 3rd ed. New Jersey: Pearson/Prentice Hall; 2009.

63. Stovitz SD, Verhagen E, Shrier I. Misinterpretations of the'p value': a brief primer for academic sports medicine. British Journal of Sports Medicine. 2017;51(16):1176-7.

64. Gardner M, Altman D. Confidence intervals rather than P values: estimation rather than hypothesis testing. British Medical Journal. 1986;292(6522):746-50.

65. Dankel SJ, Mouser JG, Mattocks KT, Counts BR, Jessee MB, Buckner SL, et al. The widespread misuse of effect sizes. Journal of Science and Medicine in Sport. 2017;5(20):446-50.

66. Barber-Westin S, Hermeto A, Noyes F. A six-week neuromuscular training program for competitive junior tennis players. Journal of Strength and Conditioning Research 2010;24(9):2372-82.

67. Rivara F, Cummings P, Koepsell T, Grossman D, Maier R. Injury Control. A Guide to Research and Program Evaluation. Cambridge: Cambridge University Press; 2001.

68. Augustsson J, Thomee R, Karlsson J. A test battery for evaluating hop performance in patients with an ACL injury and patients who have undergone ACL reconstruction. Knee Surgery, Sports Traumatology, Arthroscopy. 2006;14:778-88.

69. Bohannon RW, Larkin PA, Cook AC, Gear J, Singer J. Decrease in timed balance test scores with aging. Physical Therapy. 1984;64(7):1067-70.

70. Berdejo-del-Fresno D, Lara-Sánchez AJ, González-Ravé JM. Fitness level and body composition of elite female players in England basketball league Division I. International Journal of Sport and Exercise Science. 2012;4(2):15-24.

71. Reid M, Sibte N, Clark S, Whiteside D. Tennis Players. In: Tanner R, Gore C, editors. Physiological Tests for Elite Athletes. 2nd ed. Illinois: Human Kinetics; 2013. p. 449-62.

72. Östenberg A, Roos E, Ekdahl C, Roos H. Isokinetic knee extensor strength and functional performance in healthy female soccer players. Scandinavian Journal of Medicine and Science in Sports. 1998;8(5):257-64.

73. Hewett T, Lindenfeld T, Riccobene J, Noyes F. The effect of neuromuscular training on the incidence of knee injury in female athletes. A prospective study. American Journal of Sports Medicine. 1999;27(6):699-706.

74. Steffen K, Emery CA, Romiti M, Kang J, Bizzini M, Dvorak J, et al. High adherence to a neuromuscular injury prevention programme (FIFA 11+) improves functional balance and reduces injury risk in Canadian youth female football players: a cluster randomised trial. British Journal of Sports Medicine. 2013;47(12):794-802.
75. Olsen O-E, Myklebust G, Engebretsen L, Holme I, Bahr R. Exercises to prevent lower limb injuries in youth sports: cluster randomised controlled trial. British Medical Journal. 2005;330(7489):449.
76. Augustsson SR, Augustsson J, Thomeé R, Karlsson J, Eriksson BI, Svantesson U. Performance enhancement following a strength and injury prevention program: A 26-week individualized and supervised intervention in adolescent female volleyball players. International Journal of Sports Science & Coaching. 2011;6(3):399-417.
77. Shrier I, Gossal K. Myths and truths of stretching: individualized recommendations for healthy muscles. The Physician and Sports Medicine. 2000;28(8):57-63.
78. Śliwowski R, Jadczak Ł, Hejna R, Wieczorek A. The effects of individualized resistance strength programs on knee muscular imbalances in junior elite soccer players. PloS One. 2015;10(12):e0144021.
79. Steffen K, Engebretsen L. More data needed on injury risk among young elite athletes. British Journal of Sports Medicine. 2010;44(7):485-9.
80. McGrath T, Waddington G, Scarvell J, Ball N, Creer R, Woods K, et al. The effect of limb dominance on lower limb functional performance - A systematic review. Journal of Sports Sciences. 2016;34(4):289-302.
81. Spry S, Zebas C, Visser M, editors. What is leg dominance? International Symposium on Biomechanics in Sports; 1993; Massachusetts: ISBS Conference Proceedings Archive.
82. Bell DR, Sanfilippo JL, Binkley N, Heiderscheit BC. Lean mass asymmetry influences force and power asymmetry during jumping in collegiate athletes. Journal of Strength and Conditioning Research 2014;28(4):884-91.
83. Davidson A, Trewartha G. Understanding the physiological demands of netball: A time-motion investigation. International Journal of Performance Analysis in Sport. 2008;8(3):1-17.

Highlights

- Group-level statistics fail to expose preseason clinically-significant asymmetries
- Most players had clinically-significant asymmetry for the eyes-closed-balance test
- Most players had clinically-significant asymmetry for the vertical-hop test
- Clinically-significant asymmetry is widespread in a community-level adult netball

Conflicts of Interest

None declared.

Ethical statement

This study received institutional ethics approval and all participants gave informed consent to participate.

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