Physical Therapy in Sport 40 (2019) 44–52

Contents lists available at ScienceDirect

Physical Therapy in Sport

journal homepage: www.elsevier.com/ptsp

Original Research

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

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ARTICLE INFO

Article history:
Received 19 June 2019
Received in revised form
22 August 2019
Accepted 22 August 2019

Keywords:
Netball
Balance test
Hop test
Limb symmetry index

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 ± 7.0 cm; mass 68.2 ± 9.8 kg).
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.

1. Introduction

Netball is a predominantly female team sport with millions of players across more than 113 countries (International Netball Federation, 2017). In England in 2015, there were 2945 netball clubs and 104,000 players (England Netball, 2017) which increased to 180,200 players in 2017 (England Netball, 2018a, 2018a). 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 (England Netball, 2018b). With an increase in sports participation comes an increase in the number of injuries (Parkkari et al., 2004). Netball injuries have reported rates of 9.49 injuries/1000 players (Otago & Peake, 2007) and 500.7 injuries/1000 playing hours (Langeveld, Holtzhausen, & Coetzee, 2012). Of all injuries, 57.2–85.3% occur to the lower-limb (Flood & Harrison, 2009; Otago & Peake, 2007) with knee and ankle injuries being most frequent (Attenborough et al., 2017; Flood & Harrison, 2009; Langeveld et al., 2012; Smith, Damodaran, Swaminathan, Campbell, & Barnsley, 2005) and knee trauma representing almost one-third of netball-related hospitalisations (Flood & Harrison, 2009). Such injuries result in profound consequences including disability (Finch &

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https://doi.org/10.1016/j.ptsp.2019.08.008
1466-853X/

Cassell, 2006; Genoese, Baez, & Hoch, 2018; Otago & Peake, 2007), socioeconomic burden (Finch & Cassell, 2006; Janssen, Orchard, Driscoll, & van Mechelen, 2012; Otago & Peake, 2007), and premature retirement from netball (England Netball, 2016). 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 (Avery, 1995) and includes prevention, acute care, and rehabilitation phases of intervention (Rivara, 2003). 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 (Brumitt et al., 2017; Hewit, Cronin, & Hume, 2012; Stiffler et al., 2017). 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 (Clark, 2001; Clark, Gumbrell, Rana, Traole, & Morrissey, 2002; Eechaute, Vaes, & Duquet, 2009; Kivlan & Martin, 2012). The administration of assessments to profile athletes and identify those predisposed to injury is good clinical practice (Meeuwisse, Tyreman, Hagel, & Emery, 2007; Roe et al., 2017; Verhagen, van Dyk, Clark, & Shrier, 2018) and lower SLB and SLH performance is associated with higher lower-limb injury risk in agility-sport athletes (Brumitt et al., 2013, 2017, 2019a; McGuine, Greene, Best, & Leverson, 2000; Watson, 1999). 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) (Barber, Noyes, Mangine, & Hartman, 1990; Clark, Davies, & Reilly, 2018; Parr et al., 2015; Paterno & Greenberger, 1996; Sell et al., 2014). A disadvantage of group-level analysis is that it masks clinically-significant asymmetries in some individuals in the group (Barber et al., 1990; Clark et al., 2018; Parr et al., 2015). 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 (Manikandan, 2011). 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 (Clark et al., 2018; Hewit et al., 2012b; Parr et al., 2015). Procedures involve the calculation of some form of 'limb symmetry index' (LSI) (Barber et al., 1990; Clark et al., 2018; Parr et al., 2015; Risberg, Holm, & Ekeland, 1995). 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 (Barber et al., 1990; Clark, 2001; Risberg et al., 1995); 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%) (Brumitt et al., 2013; Clark et al., 2018; Parr et al., 2015). The LSI is valuable because it identifies the size of a clinically-significant asymmetry in the individual (Clark et al., 2018; Parr et al., 2015) where 'clinically-significant' is historically defined as an absolute-asymmetry >10% (Grace, Sweetser, Nelson, Ydens, & Skipper, 1984; Juris et al., 1997; Sapega, 1990). Recently, SLH test asymmetries >10% have been prospectively associated with higher first-time lower-limb noncontact injury risk (Brumitt et al., 2013, 2019a). Because lower-limb motor-performance side-to-side comparisons and asymmetry-analyses are clinically valuable for preseason screening and injury predisposition and risk profiling (Brumitt et al., 2013, 2017, 2019b; Devan, Pescatello, Faghri, & Anderson, 2004; McGuine et al., 2000) 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 (Ferreira & Spamer, 2010) and high-grade club players in New Zealand (Waterman, Sole, & Hale, 2004). Single-leg balance tests have also been performed using the Star Excursion Balance Test (SEBT) with Superleague players in England (Soper, Simmonds, Kaz, & Ninis, 2015), using a modified SEBT with university players also in England (Armstrong & Greig, 2018), and using eyes-closed-balance (ECB) for time with school players in New Zealand (Taylor & Lander, 2018). Single-leg hop tests have been performed using a force-plate and a vertical/forward/lateral task with national-level players in New Zealand (Hewit et al., 2012b) and a vertical-hop (VH) with club-level players in Australia (Pruyn, Watsford, & Murphy, 2016). 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 (Thomas, Ismail, Comfort, Jones, & Dos'Santos, 2016). Of the studies cited, only three engaged in preseason assessments (Ferreira & Spamer, 2010; Taylor & Lander, 2018; Thomas et al., 2016) with two focusing on players aged <19 years (yr) (Ferreira & Spamer, 2010; Taylor & Lander, 2018). 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 (England Netball, 2017), 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 (Ferreira & Spamer, 2010; Hewit et al., 2012b; Waterman et al., 2004) and only one performed symmetry analyses (Hewit et al., 2012b). 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 (Brumitt et al., 2013, 2017, 2019a; McGuine et al., 2000; Watson, 1999) 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.

2. Methods

2.1. Study design

Cross-sectional.

2.2. Sample size calculation

An *a priori* power analysis was performed using G*Power (Buchner, Erdfelder, Faul, & Lang, 2019). 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.

2.3. 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.

2.4. 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.

2.5. 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 (Charmant, 2019).

2.6. 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 (Ageberg, Zätterström, Fridén, & Moritz, 2001; Clark et al., 2002; Kramer, Nusca, Fowler, & Webster-Bogaert, 1992). 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 (Lohman, Roche, & Martorell, 1991). For leg-length (Gogia & Braatz, 1986), 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 (Gogia & Braatz, 1986).

For the ECB test (Springer, Marin, Cyhan, Roberts, & Gill, 2007), 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 (Fig. 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) (Springer et al., 2007).

For the THD (Noyes, Barber, & Mangine, 1991) and SHD (Barber et al., 1990), players stood on the test-leg, the distal aspect of the foot aligned with the posterior edge of a start-line (Fig. 2). For the THD, players rapidly hopped forwards on the same leg three times to stick the final landing (Fig. 2). For the SHD, players countermovement hopped forwards on the same leg once to stick the landing (Fig. 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 0.5 cm. Reliability has been reported for the THD (ICC = 0.95) (Bolgla & Keskula, 1997) and SHD (ICC = 0.96) (Bolgla & Keskula, 1997).

The VH was modified from previous work (Risberg et al., 1995; Balsalobre-Fernández, Tejero-González, del Campo-Vecino, & Bavaresco, 2014). Players stood on the test-leg with the video camera flat on the floor, the front of the camera 30 cm 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 (Fig. 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) (Balsalobre-Fernández

Fig. 1. Eyes-closed-balance test.

et al., 2014).

2.7. Data reduction

For the VH, video footage was transferred to a laptop computer with Kinovea freeware (Charmant, 2019). 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 (Balsalobre-Fernández et al., 2014). 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 (Balsalobre-Fernández et al., 2014). Hop height in meters was converted to centimetres. Normalisation of data to leg-length was performed for all SLH test trials (Pincivero, Lephart, & Karunakara, 1997): 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.

2.8. Data analyses

Summary statistics were calculated including the absolute between-limb differences (right mean − left mean). The ± sign was

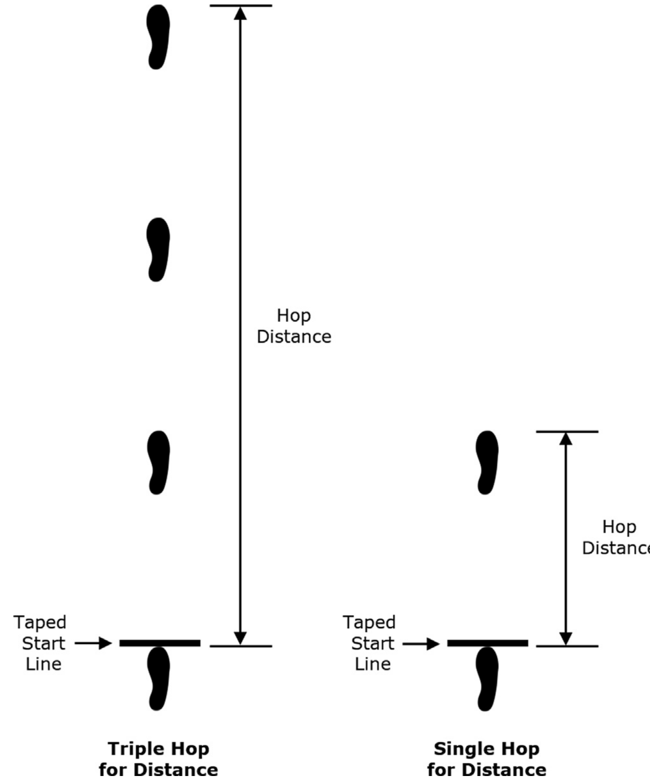

Fig. 2. Triple-hop-for-distance and single-hop-for-distance tests.

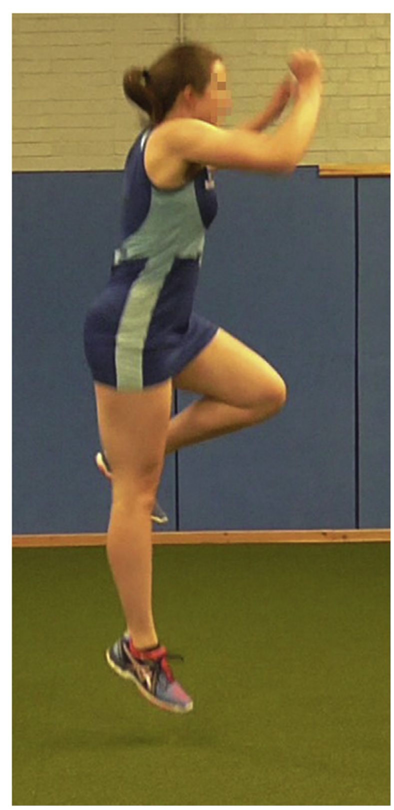

Fig. 3. Vertical-hop test.

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 (Barber et al., 1990; Clark, 2001). Bonferroni-corrected alpha was set *a priori* at 0.01 (Portney & Watkins, 2009; Stovitz, Verhagen, & Shrier, 2017). In addition, 95% confidence intervals (CI) were calculated for within-test right- and left-side values (Dankel et al., 2017; Gardner & Altman, 1986; Stovitz et al., 2017) and Cohen's *d* was estimated for within-test right-left ES (Portney & Watkins, 2009). Effect sizes of 0.20, 0.50, and 0.80 were considered small, medium, and large, respectively (Portney & Watkins, 2009).

For clinical analyses (individual-level), an LSI (%) was calculated for each player: (right mean ÷ left mean) × 100 (Barber-Westin, Hermeto, & Noyes, 2010; Grace et al., 1984; Parr et al., 2015). 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 (Clark, 2001), 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% (Grace et al., 1984; Juris et al., 1997; Sapega, 1990) and an asymmetry >10% has been reported as prospectively associated with first-time noncontact lower limb injury risk (Brumitt et al., 2013, 2019a), an absolute-asymmetry >10% was used in this study to define 'clinically-significant' and players 'at-risk' of injury (Brumitt et al., 2019a, 2019b). 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 (Augustsson, Thomee, & Karlsson, 2006; Rivara, Cummings, Koepsell, Grossman, & Maier, 2001). 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.

3. 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 Tables 1 and 2.

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).

4. Discussion

Netball participation in England is rapidly increasing at community-level versus elite-/professional-level (England Netball, 2018a, 2018b) 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,

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.

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	4.0	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).

mean values of 15.8–20.8s for female netball players aged 15–17yr (Taylor & Lander, 2018) and 28.8s for a mixed-sex group aged 20–29yr (Bohannon, Larkin, Cook, Gear, & Singer, 1984) have been reported. For the THD, mean values of 586.0–590.0 cm for female regional academy netball players aged 17–19yr (Thomas et al., 2016) and 519.4–532.4 cm for female elite basketball players with mean age 20.5yr (Berdejo-del-Fresno, Lara-Sánchez, & González-Ravé, 2012) are recorded. For the SHD, mean values of 153.8–154.6 cm for female elite basketball players with mean age 20.5yr (Berdejo-del-Fresno et al., 2012) and 187.0–188.0 cm for female regional academy netball players aged 17–19yr (Thomas et al., 2016) have been reported. For the VH, mean values of 16.9–17.6 cm for female recreational agility-sport athletes (Barber et al., 1990) and 29.0–30.0 cm for female elite tennis players aged over 16yr (Reid, Sibte, Clark, & Whiteside, 2013) 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 (Bohannon et al., 1984; Östenberg, Roos, Ekdahl, & Roos, 1998). However, such findings are inconsistent with other work that identified statistically significant differences for THD right-left comparisons in uninjured female elite basketball players (Berdejo-del-Fresno et al., 2012) (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 (Stovitz et al., 2017; Gardner & Altman, 1986). Use of the 95% CI is advocated because ES themselves can distort study findings and be misleading (Dankel et al., 2017). 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 (Taylor & Lander, 2018) (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 (Thomas et al., 2016) (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 (Dankel et al., 2017). 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 (Barber et al., 1990; Clark et al., 2018; Hewit et al., 2012b; Parr et al., 2015).

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 (Brumitt et al., 2013, 2019a). 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 (Clark et al., 2018). 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 (Hewett, Lindenfeld, Riccobene, & Noyes, 1999; Steffen et al., 2013; Olsen, Myklebust, Engebretsen, Holme, & Bahr, 2005). 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 (Augustsson et al., 2011; Shrier & Gossal, 2000; Śliwowski, Jadczak, Hejna, & Wieczorek, 2015). 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 (Steffen & Engebretsen, 2010; Verhagen et al., 2018). 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 (Barber et al., 1990; Hewit et al., 2012b; Östenberg et al., 1998). Such comparisons were not performed because dominance changes according to task demands (e.g. skill versus load-bearing) (McGrath et al., 2016; Spry et al., 1993) 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 (Bell, Sanfilippo, Binkley, & Heiderscheit, 2014). 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 (Davidson & Trewartha, 2008). 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 (Verhagen et al., 2018). 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.

Declaration of interest

None

Conflicts of Interest

None declared.

Ethical statement

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

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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