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Sex Differences in Magnitude and Direction of Interlimb Asymmetries in Eccentric Hip Abduction Strength

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ABSTRACT

Objectives: This study had three aims 1) explore the relationship between eccentric hip abduction (HABd) and magnitudes of asymmetry in males and females, 2) determine the effect of sex on magnitude of asymmetry and 3) investigate the association of sex on direction of asymmetry. Participants: 61 athletes (39 males, 22 females) participating in multidirectional sports. Main outcome measures: Eccentric HABd strength was tested in both legs for all participants using an eccentric break test with a Handheld dynamometer (HHD). Results: A statistically significant weak positive relationship was found between HABd strength and magnitude of asymmetry in males only. Females demonstrated statistically significant higher magnitude of asymmetry values (15.3%) compared to males (9.8%) (p=0.1). There was no association between sex and direction of asymmetry (absolute: $\chi^2(1) = .24$, $p = .62$, adjusted: $\chi^2(1) = 1.15$, $p = .28$). Conclusion: Female athletes are likely to have greater eccentric HABd asymmetry, but it is not know how this influences performance or injury risk.

Keywords: Asymmetries, hip abduction, eccentric strength.

INTRODUCTION

Dynamic knee valgus (DKV) is a multi-joint, multi-plane movement pattern that includes a combination of hip adduction and internal rotation, knee abduction, and rotation of the tibia (Hewett et al., 2005; Krosshaug et al., 2007; Schmidt et al., 2019). Dynamic knee valgus has been documented in the literature to be an abnormal movement pattern, and excessive DKV during dynamic activities such as cutting, running, and landing has been linked to several lower extremity injuries which include patellofemoral pain (de Marche Baldon et al., 2009), and anterior cruciate ligament injuries (Hewett et al., 2005; Jones et al., 2014). Females have been shown to display greater DKV during athletic movements in comparison to males which may contribute to the increase in injury risk (Ford et al., 2003, 2007; Hewett et al., 2005; Krosshaug et al., 2007; Stickler et al., 2015).

The hip abductors comprise of the gluteus medius (GMed), gluteus minimus (GMin), and tensor fascia lata (TFL) and help stabilise the contralateral pelvis during single leg stance (Flack et al., 2014). The hip abductors act eccentrically to control excessive adduction and internal rotation which are components of DKV (Cashman, 2012; Ferber et al., 2003). It has been suggested that eccentric weakness in these muscles contributes to DKV as they are unable to control the lower limb during movements such as landing and cutting thereby increasing injury risk (Hickey Lucas et al., 2017; Ireland, 2002; Khayambashi et al., 2016; Steffen et al., 2016). Currently, the literature supporting hip abductor (HABd) weakness and increase in DKV is conflicting (Alzahrani et al., 2021; Cashman, 2012). Bin Hussein (2016); Hollman et al. (2009); Khayambashi et al. (2016); Willson and Davis (2009) all found a relationship between DKV and HABd, however DiMattia et al. (2005); Mizner et al. (2008); Sigward et al. (2008), and Thijs et al. (2007) reported no relationship. This may be a reflection on study design as most studies test hip abduction isometrically and there is argument that hip abductors need to be strong eccentrically to provide control in the frontal plane (DiMattia et al., 2005; Jacobs et al., 2007; Khayambashi et al., 2016). Double-leg tasks were more likely to find no relationship with HABD strength (Mizner et al., 2008; Sigward et al., 2008; Thijs et al., 2007) in comparison to single-leg tasks (Claiborne et al., 2006; Dix et al., 2019; Hollman et al., 2009; Jacobs et al., 2007; Lee & Powers, 2014) possibly because single leg tasks are more related to injury mechanism. Furthermore, much of the research has studied female athletes, and there is a gap in the current research which evaluates sex differences in eccentric HABd strength.

Injuries rarely occur to both limbs during the same event, so a popular topic of investigation has been to identify inter-limb asymmetry. Asymmetries have been used to determine whether an individual is at risk of injury or is used to compare the injured limb against the non-injured limb to return from injury (Bishop, Turner, et al., 2018). Previous research advocated that a 10-15% threshold should be used to reduce injury risk (Ardern et al., 2015; Costa Silva et al., 2015; Fort-Vanmeerhaeghe et al., 2016), however Bishop (2020) has recently highlighted the issues of using a specific threshold due to the task, metric and population specific nature of interlimb asymmetries and it has been suggested the use of arbitrary thresholds to determine what is ‘normal’ and what is ‘abnormal’ should be avoided (Parkinson et al., 2021). A plethora of research supports monitoring both the magnitude (% difference between limbs) and the direction (which limb is stronger) over several testing sessions to determine whether a person has asymmetry (Arede et al., 2023; Bishop, Lake, et al., 2018; Bishop et al., 2020) however, if a single testing session is undertaken an interparticipant threshold can be used to determine the presence of true asymmetry (Dos'Santos et al., 2021; Helme et al., 2024).

There is a paucity of research exploring sex differences in magnitude and direction of asymmetry in HABd strength. Practically, it would be useful to understand whether asymmetry is commonly found in the athletic population and the relationship between strength and asymmetry. Helme et al. (2024) found stronger participants were more symmetrical in a study on 50 rugby league players, and this was associated with better linear and multidirectional speed, which could increase performance. This study is novel in its approach as it explores sex differences in the relationship between eccentric HABd strength and magnitude of asymmetry. It is hypothesised that athletes with lower strength values will have larger magnitudes of asymmetry. The aims of this study are 1) explore the relationship between eccentric HABd and magnitudes of asymmetry in males and females, 2) determine the effect of sex on magnitude of asymmetry and 3) investigate the association of sex on magnitude with direction of asymmetry.

METHODS

Participants

61 (39 males, 22 females) healthy university and club-level athletes participating in multidirectional sports took part in this study. Participant characteristics are summarised in Table 1. The participants sports are outlined in Table 2. Inclusion criteria were: 1) regularly participating in one game, and at least one training session a week, 2) free from a history of lower extremity surgery or any health conditions that may influence foot and ankle function, and 3) free from lower extremity injury six months before testing. Before testing, all participants were briefed on the study procedures, and informed consent was obtained. Participants were also asked to state their dominant leg, defined as the leg that they were most likely to kick a ball with (Thorborg, Couppe, et al., 2011). Ethics were approved by the university ethical committee.

Testing procedures

Participants reported to the laboratory for a single testing session. Testing was conducted by the lead investigator with over 10 years of experience measuring strength using a handheld dynamometer (HHD). Eccentric HABd strength was measured using an HHD with a sampling frequency of 40Hz (model 01163 manual muscle tester. Lafayette Instrument, Lafayette, IN). The hip testing position used has been previously described by (Thorborg, Couppe, et al., 2011). HABd was tested in the side-lying position with the top leg straight. The

Table 1. Mean (± SD) participant characteristics by sex.

Characteristic	Males (n= 39)	Females (n=22)
Age (y)	28.9 ± 9.3	26.8 ± 9.3
Stature (cm)	179.6 ±6.0	165.4 ± 7.0
Body mass (kg)	91.7 ± 13.9	72.0 ± 14.9
Right leg dominant (Count)	34	22
Left leg dominant (Count)	5	0

Table 2. Male and female sports participation

Characteristic	Males (n= 39)	Females (n=22)
Rugby	27	3
Football	8	1
Basketball	3	1
Netball	0	13
Badminton	1	0
Hockey	0	4

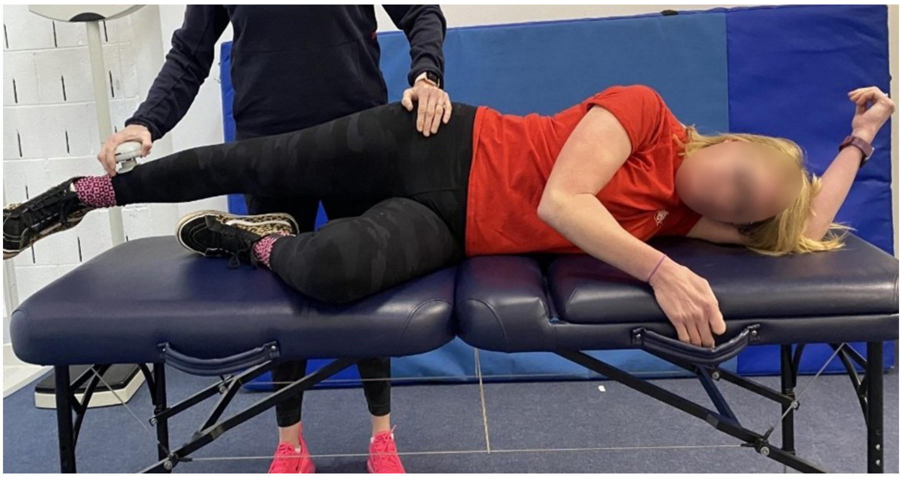

Figure 1. Side lying testing position for eccentric HABd strength using the HHD (Thorborg, Couppe, et al., 2011).

bottom hip and knee were placed at 90° of flexion and the participants were told they could stabilise themselves by holding onto the side of the plinth using their hands (Figure 1.). The examiner applied resistance via an HHD on the top leg at a position 5cm proximal to the most prominent point of the lateral malleoli. One familiarisation trial was carried out to ensure that the participant was in the correct position. The examiner then applied a break test where the participants were asked to perform an isometric maximum voluntary contraction (MVC) against the HHD before the examiner applied a force to break the muscle contraction. The standardised instruction by the examiner was "go ahead push-push-push-push" and lasted for 5 seconds (Thorborg, Serner, et al., 2011). As there is measurement variation in the side-lying position, the test was repeated until the participant reached a force plateau which was less than 5% between two consecutive tests. The mean of these values reported in Newtons was recorded (Thorborg et al., 2014). A 60-second rest period between each trial was used to avoid fatigue across trials (Breen et al., 2021).

Limb length for all participants was measured from the most prominent aspect of the anterior superior iliac spine to 5cm from the most prominent part of the lateral malleoli. Maximal eccentric HABd strength values were adjusted to body mass and leg length using the following equation:

$$HABd\ strength\ \left(\frac{Nm}{Kg}\right) = \frac{Peakforce(N)xleglength(m)}{BM(Kg)}$$

(Thorborg, Couppe, et al., 2011).

Adjusting strength to body size is important to negate the effect of body size variability which may influence the ability to generate force and allows for a more appropriate comparison of results (Bazett-Jones et al., 2011).

To establish the reliability of the measurement procedure, intra-tester, within day reliability was examined on 20 (13 men and 7 female) healthy participants before testing (age 28.3 ± 9.8; stature 176.4 ± 9.1; body mass 91.32 ± 18.46). Intra-class correlation coefficient (ICC) and Standard error of measurement (SEM) were, respectively, ICC = 0.99 (0.98-0.99) and SEM = 0.036- 0.032 for HABd on the dominant leg and ICC = 0.96 (0.91-0.98), SEM = 0.07 for HABd on the non-dominant leg. These results demonstrate excellent reliability and support previous findings from (Breen et al., 2021; Krause et al., 2007; Thorborg, Couppe, et al., 2011).

Statistical analysis

Statistical analyses were performed using SPSS software version 29 (Chicago, IL, USA). All data were checked for normality using the Shapiro-Wilk test (P>0.05). Eccentric HABd strength values were shown as absolute and adjusted (adjusted for BM and limb length). Normality was checked using the Shapiro-Wilk test, and Spearman's rank-order coefficients were used to determine the relationships between adjusted HABd and magnitude of asymmetry. Correlations were determined to be statistically significant at $p \leq 0.05$. Correlation coefficients were interpreted as; strong relationship ($0.70 \leq r \leq 1.0$), moderate relationship ($0.4 \leq r \leq 0.7$), and weak relationship ($r<0.4$) (Lomax & Hahs-Vaughan, 2013).

The magnitude of interlimb asymmetry was calculated using:

$$\frac{100}{(maxvalue)(minvalue)} \times -1 + 100$$

(Bishop, Turner, et al., 2018).

To determine the direction of asymmetry (which leg is stronger) an 'IF function' was added to the end of the above formula: *IF(non-dominant<dominant,1,-1) (Bishop, Lake, et al., 2018; Bishop, Read, et al., 2018; Bishop, Turner, et al., 2021). An asymmetry threshold (AT%) was calculated separately for sex, adjusted, and absolute eccentric HABd strength. This was used to determine whether a participant had a true asymmetry and was based on the population mean + smallest worthwhile change (SWC) using the calculation:

$$AT\% = magnitude\ of\ asymmetry\ mean\% + (0.2 \times SD)$$

A high asymmetry threshold (HAT%) was also calculated for both males and females using the calculation:

$$population\ mean + (1.0\ between\ subject\ SD)$$

(Dos'Santos et al., 2021).

An independent t-test was conducted to determine the effect of sex on magnitude of asymmetry. For the third study aim a chi-square test for independence was conducted to investigate the association of sex on the direction of asymmetry.

RESULTS

Mean and SD data for absolute and adjusted eccentric HABd strength for males and females are reported in Table 3. Fifty-six (82%) of participants (34 males, 22 females) reported their right leg to be dominant.

Spearman's Rank correlation coefficient found a statistically significant positive weak relationship between magnitude of asymmetry and HAbd strength in males (rs (39) =0.32, p=0.04), but no statistically significant relationship for females (rs (22) =-0.2., p=0.3).

Table 4. shows mean interlimb asymmetry data for eccentric HABd. Results from the independent t-test showed that females had statistically significant

Table 3. Mean ± standard deviation for absolute and adjusted eccentric HABd strength for males and females.

Test/metric	Males (n= 39)	Females (n=22)
Absolute strength (N)		
Dominant	229 ± 56.9	169± 36.9
Non-Dominant	216 ± 48.9	152 ± 32.8
Adjusted (Nm/Kg)		
Dominant	2.2 ± 0.6	2.0 ± 0.5
Non-Dominant	2.1 ± 0.5	1.8 ± 0.5

Table 4. Mean inter-limb asymmetry (%), asymmetry threshold and high asymmetry threshold for absolute and adjusted eccentric HABd values.

Test/metric	Males (n= 39)	Females (n=22)
Absolute asymmetry %	9.7 ± 6.2	15.3 ± 8.4*
AT%	10.9	16.9
HAT%	15.9	23.7
Adjusted asymmetry %	9.9 ± 6.9	15.4 ± 9.1*
AT%	11.3	17.2
HAT%	16.8	24.5

**significant sex difference*

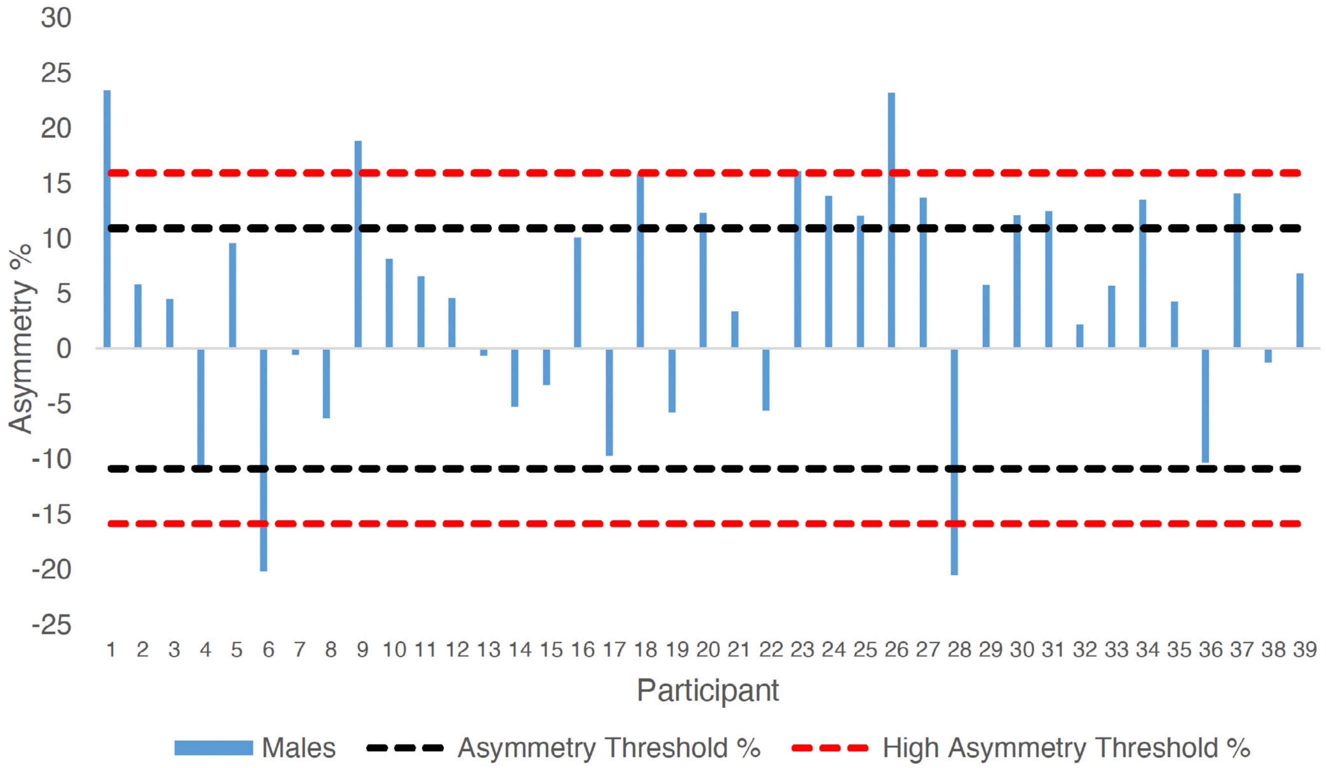

Figure 2. Individual inter-limb magnitude with direction data for absolute eccentric HABd.
Note: Above 0 asymmetry favours the dominant limb and below 0 indicates asymmetry favours the non-dominant limb.

higher absolute and adjusted magnitudes of asymmetry compared to males (absolute: t(59)= -2.9, *P*= 0.0, adjusted: t(59) =-2.7, *p*=0.1).

Asymmetry thresholds (AT%) and HAT% were higher in females than males for both absolute and adjusted eccentric HABd strength. Sixteen (41%) of males exhibited asymmetries above the asymmetry threshold for absolute eccentric strength, compared to 8 (36.3%) of the female population. When adjusted for BM, 15 (38.4%) of males and 8 (27.8%) of females exhibited asymmetries above their asymmetry threshold. Six (15.3%) of males and 4 (18.2%) of females were reported to have high asymmetries when calculated for absolute strength. Six (15.3%) of males and 5 (22.7%) of females were found to have high asymmetry values for the adjusted values.A chi-square test of independence was performed to investigate the association of sex and direction. There was no statistically significant association between sex and direction of asymmetry (absolute: $\chi^2(1) = .24$, $p = .62$, adjusted: $\chi^2(1) = 1.15$, $p = .28$). 66.7% of males and 72.7% of females had stronger absolute eccentric HABd values in their dominant leg. When eccentric HABD was adjusted for limb length and body mass, 72.7% of females and 59% of males were found to have stronger values in their dominant leg

DISCUSSION

The first study aim was to explore the relationship between eccentric HABd strength and magnitude

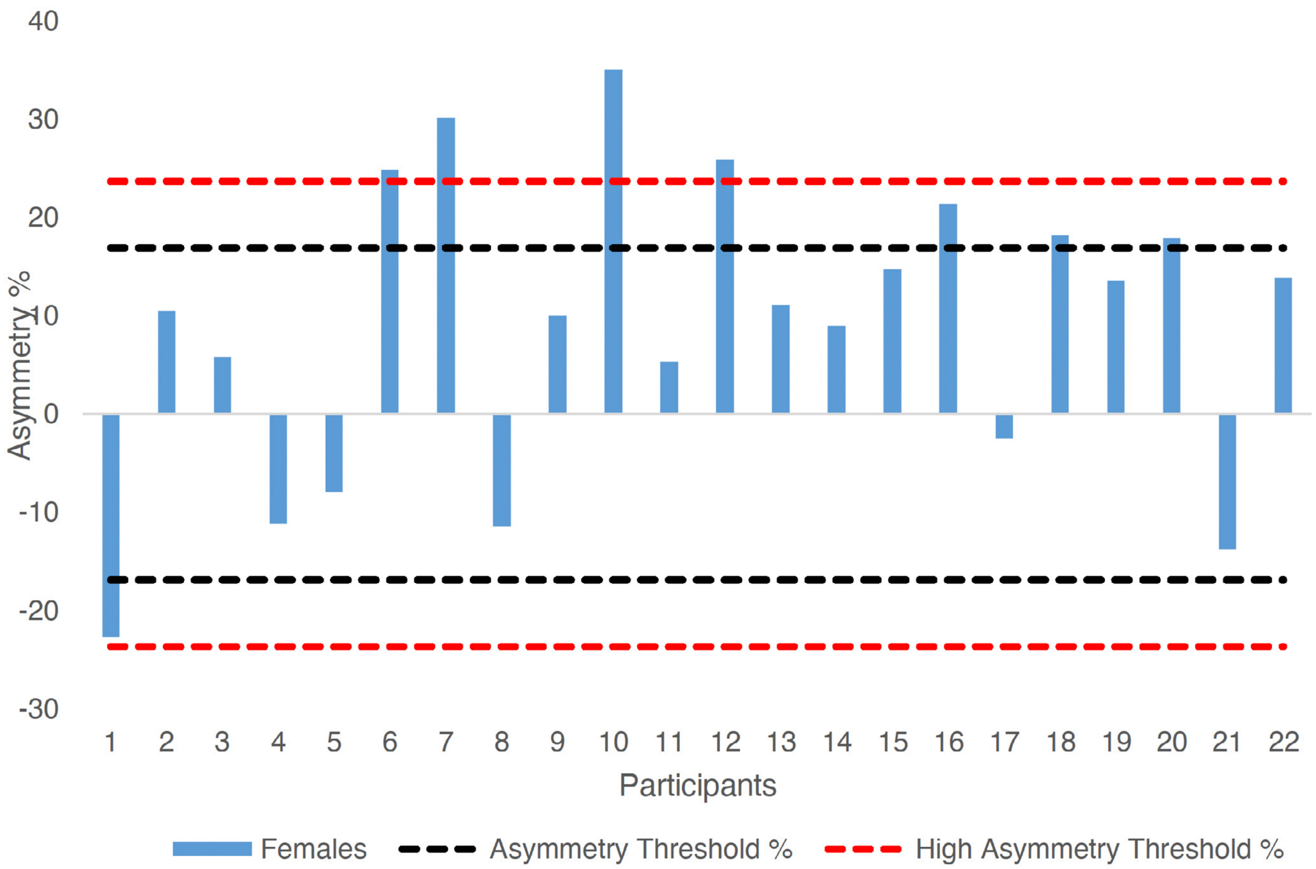

Figure 3. Individual inter-limb magnitude with direction asymmetry data for females for absolute eccentric HABd. *Note: Above 0 asymmetry favours the dominant limb and below 0 indicates asymmetry favours the non-dominant limb.*

of asymmetry. Spearman's Rank correlation coefficients found a statistically significant positive weak relationship between magnitude of asymmetry and HABd strength in males (rs (39) =-0.32, *P*=0.04), but no statistically significant relationship was reported for females (rs (22) =-0.2., *P*=0.3). It was hypothesised that athletes with lower strength values would have increased asymmetry, but this was not reported in this study. Although not a strong relationship, as strength increased, so did the magnitude of asymmetry for this study's male population. This differs to findings reported by Helme et al. (2024) who reported higher magnitudes of asymmetry in weaker athletes, however this study measured leg strength using the rear foot elevated split squat, in male rugby league players, and so results reported may be specific to the sample, and measurement used. The AT% was reported as 10.9% (males) and 16.9% (females) for absolute values, and 11.3% (males) and 17.2% (females) for adjusted values. This study found that approximately one-third (39.3%, absolute, 37.7%, adjusted) of all participants reported asymmetries over the asymmetry threshold and therefore can be considered as having a true asymmetry. Furthermore, 10 (16.4%; 5 males and 4 females) for absolute strength and 11 (18%; 6 males and 5 females) for adjusted strength were found to have high asymmetry.

The second study aim was to determine the effect of sex on magnitude of asymmetry. Magnitude of asymmetry was significantly different between the sexes (absolute: t(59)= -2.9, *P*= 0.0, adjusted t(59) =-2.7, *p*=0.01) (Table 3). In females a magnitude above 15% (absolute 15.3%, adjusted 15.4%) was found, however in males asymmetry magnitudes were below 10% (absolute 9.7%, adjusted 9.9%). To the author's knowledge, there are no other studies that have investigated magnitude of asymmetry for eccentric HABd, and it is difficult to make comparisons. Some authors suggest that a greater magnitude of asymmetry is frequently seen in females compared to males but there is no consensus in the literature. For example, Fort-Vanmeerhaeghe et al. (2020) reported sex differences in asymmetry for the anterior star excursion balance test but not for the single leg counter-movement jump. In comparison Bailey et al. (2015) and Fort-Vanmeerhaeghe et al. (2016) found that females had statistically significant higher asymmetry values in comparison to males during different jumping tasks. Therefore, sex differences in magnitude of asymmetry may vary depending on the test, metric used, and population studied (Bishop, 2020; Boccia et al., 2022). Female athletes have been shown to display greater DKV during athletic movements when compared to male athletes (Ford et al., 2003; Hewett et al., 2005), and a plethora of research shows that an increase in DKV predisposes the female athlete to higher incidence of knee injuries such as ACL rupture and patellofemoral pain. The present study shows a statistically significant larger magnitude of asymmetry for eccentric HABd in the female athlete and therefore may predispose the athlete to DKV. It is not known how these asymmetries may affect sports specific performance measures, and future research would be useful to investigate the effect of magnitude of asymmetry on lower extremity biomechanics during sports specific movements where DKV may be a predisposing factor. Furthermore, although females are reported to have higher magnitudes of asymmetry, individuals from both sexes were found to have asymmetries above the asymmetry threshold and may benefit from strengthening programmes to reduce the magnitude of asymmetry. However, careful monitoring should take place, as it is not known how high asymmetry magnitudes influence performance or injury risk, and there is argument that addressing asymmetry could be detrimental to the athlete.

A threshold of asymmetry is not always practical or suitable for every test. The magnitude of asymmetry may differ depending upon the sport (Bishop, 2020; Bishop, Read, et al., 2021; Madruga-Parera et al., 2021; Madruga-Parera et al., 2019) and the participation level (Hart et al., 2016) therefore, it has been proposed that asymmetry values are interpreted alongside the coefficient of variation (CV) (Bishop, 2020; Exell et al., 2017) or the direction of asymmetry (Impellizzeri et al., 2007; Maloney, 2018). Direction of asymmetry is useful to determine which limb is stronger and needs to be interpreted along with the magnitude of asymmetry. It has been postulated that strong HABd in the dominant limb helps to stabilise the contralateral pelvis during change of direction (COD) activities (Kak et al., 2016) and landing (Neamatallah et al., 2020) which may prevent lower extremity biomechanical changes associated with injury (Bourne et al., 2020). This has been supported by the findings of this study as eccentric HABd was found to be stronger in the dominant limb in the athletes that were tested (absolute: p=<0.01, η^2=0.22, adjusted: p=0.00, η^2=0.16). However, there was no association of sex on direction of asymmetry and the dominant limb is not always the stronger limb for both males and females. Sixty three point nine percent (63.9%) of males and females (67% and 73% absolute strength and 59% and 73% adjusted strength in males and females respectively) were stronger in the dominant limb (the limb that participants were most likely to kick a ball with) irrespective of how strength is expressed (Table 4). These data suggest that both sexes with a stronger dominant leg are less likely to demonstrate adverse lower extremity biomechanics. However, previous research has indicated that males are more likely to sustain an injury in their dominant limb (Brophy et al, 2010 and Ruedl et al 2012) in comparison to females who are more likely to injure their non-dominant limb. Therefore, it may be postulated that females should focus more on unilateral strengthening of both limbs to prepare for sport. Monitoring the direction of asymmetry alongside magnitude is key to determine true asymmetry. However, further research is required to investigate the effect of magnitude and direction of asymmetry in HABd strength on performance and injury.

This study presents some useful findings, but it does have some limitations which must be acknowledged. Eccentric HABd was carried out in the side lying position with the leg straight, which does not mimic the rapid eccentric contractions that take place during cutting, and landing. Testing the rate of force development in standing position may have more ecological validity and should be considered in future studies. Furthermore, testing only occurred on one occasion and although an interparticipant asymmetry threshold has been determined, it has been suggested that monitoring consistency of magnitude and direction over several testing sessions and against performance is important. Furthermore, this study used athletes from differing levels and from different cutting and pivoting sports. Asymmetry is task, metric, and population specific, and it would be useful to look at the asymmetry profiles in specific sports to understand how this affects performance and injury risk.

CONCLUSION

A statistically significant positive weak relationship was reported between adjusted HABd strength and magnitude of asymmetry in males only. As strength increased, so did the magnitude of asymmetry, therefore, it can be postulated that strength does not influence HABd asymmetry. Approximately one third of participants were reported to have a true asymmetry, and it could be argued that these athletes would benefit from a HABd strength programme, however, clinicians should monitor this carefully as it is not known whether addressing asymmetry affects performance and injury rate. Direction of asymmetry shows that 66-73% of athletes have a stronger dominant leg but whether this affects performance or increases risk of injury has yet to be determined and warrants further investigation.

FUTURE RECOMMENDATIONS

Future studies may investigate sex differences in the magnitude and asymmetry of eccentric HABd strength on lower extremity biomechanics whilst performing cutting and landing manoeuvres as these are movements linked with injuries such as ACL rupture and PFP. Furthermore, It may be useful to investigate these in a variety of different sports across a full season.

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CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

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ETHICAL APPROVAL

Ethics were approved by the university ethical committee.

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