ISOKINETIC STRENGTH PROFILE OF FEMALE SOCCER PLAYERS: BETWEEN LIMB COMPARISONS.

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The purpose of this study was to provide an isokinetic strength profile of female soccer players and examine whether limb preference influences bilateral and reciprocal knee joint muscle balance. Gravity corrected isokinetic ($60°\cdot s^{-1}$) concentric and eccentric moment-angle profiles of both limbs were collected from 25 female soccer players from the 2nd tier of English women's soccer. Bilateral muscle imbalances were present, but limb preference only had small effects on muscle strength asymmetry and reciprocal muscle balance ratios. Trivial to small non-significant differences between preferred and non-preferred limbs were observed throughout isokinetic range for each muscle group in each mode, suggesting that injury mitigation strategies for female soccer players should focus on developing global knee extensor and flexor strength, rather than on regional strength deficits.

KEYWORDS: Anterior cruciate ligament, eccentric, concentric, muscle balance, asymmetry.

INTRODUCTION: It is important for biomechanists and sports medicine practitioners to have a battery of assessments to provide an 'injury risk profile' (e.g., assessment of a range of modifiable risk factors associated with a specific sports injury) of the athlete. Thus, if the athlete underachieves in certain related qualities, then steps can be taken in training to address these deficiencies to provide an overall more rounded and robust athlete.
Low isokinetic knee flexor strength and reciprocal knee joint muscle balance has been associated with non-contact anterior cruciate ligament (ACL) injury in female athletes (Myer et al., 2009), suggesting the use of isokinetic assessment when injury risk profiling female athletes. Generating normative isokinetic strength data is important in order to identify deficits in players during injury profiling. Often, reciprocal knee muscle balance data are reported as traditional (concentric knee flexors/ concentric knee extensors) or dynamic control (eccentric knee flexors/ concentric knee extensors) ratios. A limitation of these approaches is that peak moments from different angles are used in the calculation of muscle balance ratios and they do not consider the muscle balance at specific regions of the knee flexion range of motion (ROM). Angle-specific ratios or the angle of crossover (Graham-Smith et al., 2013) are alternative methods that consider muscle balance throughout the knee joint flexion ROM. Consideration of angle specific muscle balance may be more prudent given that non-contact ACL injuries typically occur in the first 17-50 ms of contact and at 5-30° of knee flexion during landing or change of direction (COD) manoeuvres (Koga et al., 2010). Poor hamstring co-contraction strength in this region may place the ACL vulnerable to elevated anterior shear forces from the quadriceps (Myer et al., 2009).
Non-contact ACL injury patterns in soccer players have been shown to differ between sexes in regard to limb preference (Brophy et al., 2010), with the majority of injuries in female soccer players occurring with the non-preferred kicking limb and a reverse pattern for preferred kicking limb in males. Limited literature has examined whether limb preference influences bilateral and reciprocal knee joint muscle balance in female soccer players. Moreover, often bilateral muscle imbalances are examined by comparing peak moments, rather than compare limbs throughout the ROM. Examining bilateral muscle balance with the limb close to full knee extension may help provide information to identify whether muscle imbalances exist at critical regions of joint position (Koga et al., 2010). Therefore, the aim of this study was to provide an isokinetic strength profile of female soccer players and examine whether limb preference influences bilateral and reciprocal knee joint muscle balance.

METHODS: Twenty-five female soccer players (mean ± SD; age, height and mass was; 21.2 ± 4.1 years, 1.66 ± 0.06 m and 60.3 ± 6.1 kg, respectively) from the 2nd tier of English women's soccer participated in the study. Twenty-three of the players preferred to kick a ball with the right leg, whereas 2 favoured the left. All players were free from injury at the time of the study and none had suffered any prior traumatic knee injury. Approval for the study was provided by the University's Ethics committee. All participants provided written informed consent or parental assent was attained for any players under 18 prior to participating in the study.

Concentric and eccentric moment-angle profiles were collected for the right and left knee extensors and flexors at 60°.s^{-1} using a Kin Com (Chattanooga Group, Tennessee) isokinetic dynamometer. Each subject was seated with the hip joint at 90°. The axis of rotation of the dynamometer shaft was aligned with the best approximation of the knee joint axis of rotation, midway between the lateral condyles of the femur and tibia. The cuff of the dynamometer lever arm was attached to the ankle, just proximal to the malleoli. Extraneous movements were prevented by straps, positioned at the hip, shoulders and tested thigh with the subjects told to 'relax' the calf muscle group to maintain a natural ankle position throughout testing. Subjects were instructed to hold onto the handles located underneath the seat. Knee ROM was set as close to 90° as possible (0º = full knee extension). The anatomical zero position was standardised for each subject using a spirit level, before setting each subject's ROM relative to this position. Eight sub-maximal concentric knee extension and flexion movements were performed as a warm-up following 3 minutes of stationary cycling (60 rpm) on a cycle ergometer. Following the warm-up, each player performed 4 maximal repetitions (10 s between each) in the following order concentric-eccentric knee extensors (CON EXT/ ECC EXT) followed by eccentric-concentric knee flexors (ECC FLEX/ CON FLEX). The order of each limb was counter-balanced across subjects. The weight of the limb was taken at 20° of knee flexion and subsequently used to gravity correct the moment readings.

Data were exported in ASCII format into Microsoft Excel for analysis. Each profile was inspected to ensure peak and angle-specific moments were established within isokinetic range with a tolerance of 1°.s^{-1}. Traditional CON FLEX/ EXT (TRAD) and dynamic control (DCR) [ECC FLEX/ CON EXT] peak moment and angle-specific ratios at 30° (TRAD30; DCR30), 40° (TRAD40; DCR40), and 50° (TRAD50; DCR50) were determined. A dynamic control profile (Graham-Smith et al., 2013) which represents the net joint moment (ECC FLEX minus CON EXT) throughout the full ROM was created for each subject for each limb. The point at which the net joint moment corresponds to zero is defined as the angle of crossover (AOC), which was subsequently determined for each player. The AOC indicates the range from full-extension whereby the knee flexors eccentrically are stronger than the knee extensors concentrically.

All statistical analysis was conducted in SPSS for Windows (Chicago, Ill) or Microsoft Excel. Paired t or Wilcoxon signed-ranks (non-normally distributed data based on a Shapiro Wilks test) tests and Cohen's *d* effect sizes were used to compare between preferred (PREF) (the limb each player preferred to kick maximally with) and non-preferred (NPREF) and strong (STG) (limb that recorded the highest peak moment) and weak (WK) limbs. Effect sizes were interpreted as trivial (<0.19), small (0.19-0.59) and moderate (0.6-1.0) (Hopkins, 2002). Asymmetry due to limb preference was determined as a raw difference and using the formula; ((PREF - NPREF)/ PREF) × 100, whereas absolute asymmetry was determined as a raw difference and using the formula; ((STG - WK)/ STG) × 100). Finally, bilateral comparisons were made across the entire isokinetic range using paired samples t-tests and Cohen's d effect sizes to identify any differences in regions of knee flexion. P values were Bonferroni corrected for adjacent multiple pairwise comparisons. Significance was set as p<0.05.

RESULTS: Significant (p<0.05) moderate differences in peak moments between STG and WK limbs were observed (Table 1). Non-significant (p>0.05) small differences were revealed between PREF and NPREF limbs for ECC EXT peak moment (Table 1), whilst all other peak moment values revealed trivial differences between PREF and NPREF limbs.

A significant (p = 0.04) small (d = 0.58) difference was observed between PRE and NPREF limbs for TRAD50 (Figure 1). Non-significant (p>0.05) small differences were revealed for TRAD (d = 0.35), DCR (d = 0.2), AOC (32.7 ± 8.1° vs. 30.2 ± 9°; d = 0.29), TRAD30 (d = 0.29), TRAD40 (d =0.37), DCR40 (d = 0.35), and DCR50 (d = 0.49) between PREF and NPREF limbs (Figure 1). A trivial difference (d = 0.17) was revealed for DCR30 between PREF and NPREF limbs (Figure 1).

Table 1. Mean ± SD peak, raw and percentage difference in moments for each muscle group in each mode for preferred and non-preferred and strongest and weakest limbs.

Variable	Preferred	Non-preferred	Difference	d	%
Con Ext (Nm)	142.2 ± 24.6	144.5 ± 22.3	-2.3 ± 18.4	-0.10	-2.48 ± 12.20
Con Flex (Nm)	76.9 ± 15.5	74.2 ± 14.0	2.6 ± 9.7	0.18	-5.48 ± 14.21
Ecc Ext (Nm)	204.4 ± 39.0	214.0 ± 37.5	-9.6 ± 28.9	-0.25	2.53 ± 12.36
Ecc Flex (Nm)	99.9 ± 22.3	98.4 ± 22.3	1.4 ± 18.0	0.06	0.21 ± 17.64
Variable	**Strong**	**Weak**	**Difference**	**d**	**%**
Con Ext (Nm)	150.6 ± 23.3	136.1 ± 21.4	14.6 ± 11.1*	0.65	9.54 ± 6.31
Con Flex (Nm)	79.6 ± 15.0	71.5 ± 13.4	8.1 ± 5.8*	0.57	10.95 ± 6.89
Ecc Ext (Nm)	221.6 ± 38.2	196.8 ± 34.4	24.9 ± 16.9*	0.68	9.92 ± 6.32
Ecc Flex (Nm)	106.4 ± 23.1	91.9 ± 18.8	14.6 ± 10.2*	0.69	13.05 ± 8.05

Note: Con = concentric; Ecc = eccentric; Ext = extensor; Flex = flexor; *p<0.05.

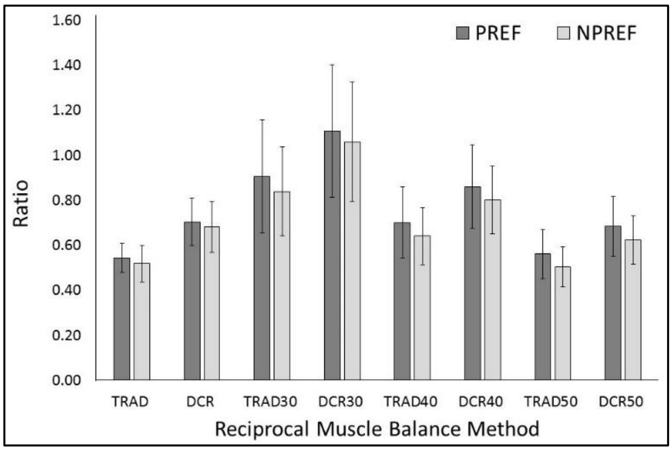

Figure 1: Reciprocal peak moment and angle-specific ratio comparisons between preferred (PREF) and non-preferred (NPREF) limbs. TRAD = traditional; DCR = Dynamic control ratio; TRAD30; DCR30 = ratios at 30°; TRAD40; DCR40 = Ratios at 40°; TRAD50; DCR50 = ratios at 50°.

No significant (p>0.05) trivial to small differences were observed within the available isokinetic range between PREF and NPREF limbs for CON EXT, ECC EXT and ECC FLEX, whilst trivial to moderate differences (p>0.05) were observed for CON FLEX (Figure 2).

DISCUSSION: The present study revealed trivial to small (p>0.05) differences between PREF and NPREF limbs in regard to peak moments and throughout isokinetic range for each muscle group in each mode. Moreover, only trivial to small differences between limbs were observed for all measures of reciprocal knee joint muscle balance. Fifteen out of the 25 players recorded the highest peak moment for the PREF limb for knee flexors (both modes), whilst for knee extensors (both modes) 15 players reported the highest peak moment with the NPREF limb. Collectively, the results suggest that limb preference has only a small effect on bilateral and reciprocal muscle balance. Thus, any trend toward higher risk for the NPREF limb (Brophy et al., 2010) in female soccer players is unlikely to be due to strength differences between PREF and NPREF limbs. Given the observed presence of bilateral imbalances when comparing STG and WK limbs suggests that this approach should be used to explore bilateral asymmetry on an individual basis during injury risk profiling. The absolute asymmetry data (STG vs. WK) presented in Table 1 could be used to identify female soccer players with problematic asymmetry for profiling or return to play criteria.
The absolute (Table 1) and relative peak moment (PREF: 2.36 ± 0.33 $Nm·kg^{-1}$; NPREF: 2.41± 0.36 $Nm·kg^{-1}$) values for CON EXT recorded are similar to that previously reported (PREF: 148 ± 23.5 Nm; 2.33 ± 0.35 $Nm·kg^{-1}$; NPREF: 146 ± 24.9 Nm; 2.30 ± 0.36 $Nm·kg^{-1}$) for elite female soccer players at 60°$·s^{-1}$ (Risberg et al., 2018). Absolute (Table 1) and relative peak moment (PREF: 1.28 ± 0.22 $Nm·kg^{-1}$; NPREF: 1.23 ± 0.21 $Nm·kg^{-1}$) values for CON FLEX are slightly lower than previously reported for elite female soccer players (PREF: 87.4 ± 13.6 Nm; 1.38 ± 0.21 $Nm·kg^{-1}$; NPREF: 85.0 ± 13.7 Nm; 1.34 ± 0.2 $Nm·kg^{-1}$) (Risberg et al., 2018), which would suggest a concern with this cohort of player. Śliwowski et al. (2017) reported relative peak moment (60°$·s^{-1}$) values for CON EXT ranging from 2.81 ± 0.46 $Nm·kg^{-1}$ [NPERF limb central

defenders] to 3.47 ± 0.22 Nm·kg^{-1} [PREF limb forwards] and CON FLEX ranging from 1.51 ± 0.25 Nm·kg^{-1} [NPREF limb central defenders] to 2.11 ± 0.29 Nm·kg^{-1} [PREF limb external midfielders] for professional male soccer players, which are higher than that observed in this study. This suggests that enhancing relative knee extensor and flexor strength maybe an important goal for knee injury mitigation strategies in female soccer players.

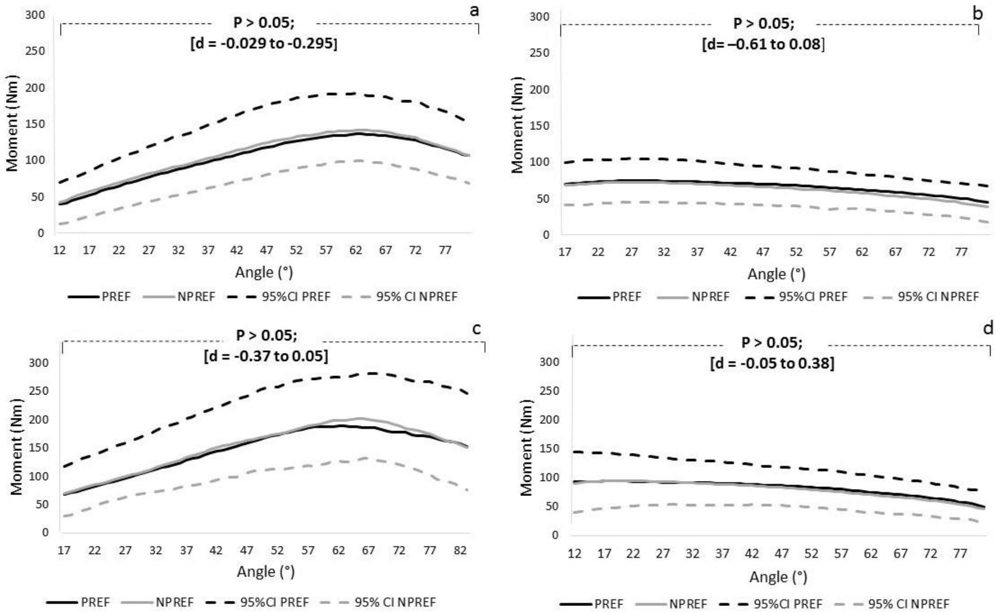

Figure 2. Mean ± 95%CI moment-angle profiles between PREF and NPREF limbs for concentric; knee extensors (a), knee flexors (b); and eccentric; knee extensors (c), knee flexors (d).

No significant regional differences were observed bilaterally (Figure 2) particularly at low knee flexion angles (<30°). Also in comparison to literature (Graham-Smith et al., 2013) the respectable AOC and DCR30 ratios reported (Figure 1) suggests sufficient hamstring strength in relation to the reciprocal quadriceps in this region (<30°). Thus, it would appear that regional specific bilateral and reciprocal strength deficits may not be a concern for female soccer players. The generally low absolute and relative peak moment values particularly for the knee flexors are likely to be of greater concern and highlight the need to develop strength with female players to allow such players to be more resilient for the COD demands associated with soccer.

CONCLUSION: These results suggest limb preference has only small effects on muscle strength asymmetry and reciprocal muscle balance ratios. It is likely that global knee extensor and flexor strength deficits are an important consideration for injury mitigation in female soccer players, rather than focusing on regional specific strength.

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