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Gender Differences in Patellofemoral Load during the Epee Fencing Lunge

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Clinical analyses have shown that injuries and pain linked specifically to fencing training/competition were prevalent in 92.8% of fencers. Patellofemoral pain is the most common chronic injury in athletic populations and females are considered to be more susceptible to this pathology. This study aimed to examine gender differences in patellofemoral contact forces during the fencing lunge. Patellofemoral contact forces were obtained from eight male and eight female club level epee fencers using an eight-camera 3D motion capture system and force platform data as they completed simulated lunges. Independent t-tests were performed on the data to determine whether gender differences in patellofemoral contact forces were present. The results show that females were associated with significantly greater patellofemoral contact force parameters in comparison with males. This suggests that female fencers may be at greater risk from patellofemoral pathology as a function of fencing training/competition.

KEYWORDS *fencing, patellofemoral pain, chronic injury*

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INTRODUCTION

Epee fencing has been a sport included within every modern Olympics since 1896. Fencing involves the fencer striking the opponent with their sword to score a hit. Previous research has shown that injuries and pain linked specifically to fencing training/competition were evident in 92.8% of fencers, with the majority of these injuries occurring in the lower extremities (Harmer, 2008). High transient forces of the musculoskeletal structures are produced in fencing due to the nature of the movement, especially during the lunge (Greenhalgh, Bottoms, & Sinclair, 2013; Sinclair, Bottoms, Taylor, & Greenhalgh, 2010). Since the lunge is the most commonly used offensive motion it repeatedly exposes the participants to potentially detrimental impact forces (Sinclair *et al*., 2010).

Patellofemoral pain syndrome is the most common chronic pathology in both recreationally active and competitive populations (DeHaven & Lintner, 1986). It is characterized by retro or peri-patellar pain mediated through overuse and excessive loading of the patellofemoral joint (La Bella, 2004). Excessive and habitual loading of the patellofemoral joint during sporting tasks that involve weight bearing and high levels of knee flexion contribute to the aetiology of patellofemoral disorders (La Bella, 2004).

The incidence of patellofemoral disorders has been widely examined and reported across several age groups and athletic populations (Lankhorst, Bierma-Zeinstra, & Middelkoop, 2013). Research has highlighted that, when analysing patients between the ages of 10 and 49, the most common age group to have reported symptoms of patellofemoral disorder was between the ages of 16 and 25 (Devereaux & Lachman, 1984). Research has also demonstrated that females are at significantly greater risk of developing patellofemoral disorders than age-matched males (Wilson, 2007). Furthermore, patellofemoral pain in females has been reported to account for 19.6% of all chronic injuries, compared with 7.4% of all injuries in males (DeHaven & Lintner, 1986). Whilst the prevailing consensus is that patellofemoral disorders occur more frequently in females athletes compared with males, there is a paucity of biomechanical data that supports this gender discrepancy. There are potentially several reasons for the differences in patellofemoral injury occurrences between males and females, which include anatomical, neuromuscular and hormonal differences (Robinson & Nee, 2007). However, the exact mechanisms behind the incidence of patellofemoral pain in female athletes remain unknown.

Despite the potential gender differences in the prevalence of patellofemoral disorders, there is a paucity of research investigating any potential differences in the loading of this joint during epee fencing. The aim of the current investigation was to determine whether gender differences in patellofemoral kinetics exists during the fencing lunge.

METHODS

Participants

Eight male and eight female participants took part in the current investigation. All were injury free at the time of data collection and did not report pain as a result of the data collection protocol. The participants provided written informed consent in accordance with the declaration of Helsinki. Participants were active competitive epee fencers who engaged in a minimum of three training sessions per week and were all right handed. The mean characteristics of the participants were: males, age 29.18 ± 4.30 years, height 1.79 ± 0.05 m and body mass 75.33 ± 6.28 kg; and females, age 23.04 ± 5.57 years, height 1.67 ± 0.06 m and body mass 63.57 ± 3.66 kg. The procedure was approved by the University of Central Lancashire ethics committee.

Procedure

Participants completed ten lunges, during which they were required to hit a dummy with their weapon and then return to a starting point, which was determined by each fencer prior to the commencement of data capture. This allowed the lunge distance to be maintained. The fencers were also required to contact a force platform (Kistler, Kistler Instruments Ltd., Alton, Hampshire) embedded into the floor (Altrosports 6 mm, Altro Ltd,) of the biomechanics laboratory with their right (lead) foot. The force platform sampled at 1000 Hz.

The current investigation utilized the calibrated anatomical systems technique (CAST) to quantify kinematic information (Cappozzo, Catani, Leardini, Benedeti, & Della, 1995). To define the anatomical frame of shank and thigh, retroreflective markers were positioned unilaterally to the medial and lateral malleoli, medial and lateral epicondyle of the femur and greater trochanter. Rigid technical tracking clusters were positioned on the shank and thigh segments. The tracking clusters comprised four retroreflective markers mounted to a thin sheath of lightweight carbon fibre with length-to-width ratios in accordance with Cappozzo, Cappello, Croce, and Pensalfini (1997). Static trials were obtained with participants in the anatomical position in order for the positions of the anatomical markers to be referenced in relation to the tracking clusters, following which the markers not required for tracking were removed.

Data Processing

Ground reaction force (GRF) and marker data were filtered at 50 Hz and 12 Hz using a low-pass Butterworth fourth-order filter and processed using Visual 3-D (C-Motion, Germantown, MD, USA). Knee joint kinetics were computed using Newton–Euler inverse-dynamics, allowing knee joint moments (Nm.kg) to be calculated. To quantify net joint moment's segment mass, segment length, GRF and angular kinematics were utilized using the procedure described by Selbie, Hamill, and Kepple (2014). Knee loading was examined through extraction of peak knee extensor moment, patellofemoral contact force (PCF) and patellofemoral contact pressure (PP).

A previously utilized algorithm was used to quantify PCF and PP (Ward & Powers, 2004). This method has been utilized previously to resolve differences in PCF and PP when using different footwear (Bonacci, Vicenzino, Spratford, & Collins, 2013; Kulmala, Avela, Pasanen, & Parkkari, 2013; Sinclair, 2014) and between those with and without patellofemoral pain (Heino & Powers, 2002). PCF (B.W) was estimated using knee flexion angle (*KFA*) and knee extensor moment (*KXT*) through the biomechanical model of Ho, Blanchette, and Powers (2012). The moment arm of the quadriceps (*QMF*) was calculated as a function of *KFA* using a non-linear equation, based on cadaveric information presented by van Eijden, Kouwenhoven, Verburg, and Weijs (1986):

$$QMF = 0.00008KFA^3 - 0.013KFA^2 + 0.28KFA + 0.046$$

Quadriceps force (*FQ*) was calculated using the formula:

$$FQ = KXT/QMF$$

PCF was estimated using the *FQ* and a constant (*KN*):

$$PCF = FQ\ KN$$

The *KN* was described in relation to *KFA* using a curve-fitting technique based on the non-linear equation described by van Eijden et al. (1986):

$$\begin{aligned} KN = {} & \left(0.462 + 0.00147KFA^2 - 0.0000384KFA^2\right) \\ & /\left(1 - 0.0162KFA + 0.000155KFA^2 - 0.000000698KFA^3\right) \end{aligned}$$

PP (MPa) was calculated using the PCF divided by the patellofemoral contact area. The contact area was described using the Ho et al. (2012) recommendations by fitting a second-order polynomial curve to the data of Powers, Lilley, and Lee (1998) showing patellofemoral contact areas at varying levels of *KFA* (83 mm^2 at 0°, 140 mm^2 at 15°, 227 mm^2 at 30°, 236 mm^2 at 45°, 235 mm^2 at 60°, and 211 mm^2 at 75° of *KFA*).

$$PP = PCF/contact\ area$$

PCF loading rate (B.W.s^{-1}) was calculated as a function of the change in PCF from initial contact to peak force divided by the time to peak force.

Statistical Analyses

Means and standard deviations were calculated as a function of gender for each outcome measure. Gender differences in knee load parameters were examined using independent samples t-tests with significance accepted at the $p \leq 0.05$ level. Effect sizes for all significant observations were calculated using Cohen's *D*. All statistical procedures were conducted using SPSS v21.0.

RESULTS

Table 1 presents the gender differences in patellofemoral load during the fencing lunge.

Patellofemoral Load

The results show that peak knee extensor moment was significantly $t\,(7) = 2.99$, $p < 0.05$, $D = 2.26$ greater in female fencers in comparison to males. The results show that time to PCF was significantly $t\,(7) = 2.58$, $p < 0.05$, $D = 1.95$ shorter in female fencers compared with males. Finally, PCF loading rate was found to be significantly $t\,(7) = 2.58$, $p < 0.05$, $D = 2.31$ greater in female fencers compared with males.

DISCUSSION

The aim of the current investigation was to determine whether gender differences in patellofemoral load exist during the epee fencing lunge. This represents the first investigation to examine the magnitude of patellofemoral kinetics during the lunge movement in epee fencing.

TABLE 1 Patellofemoral Kinetics as a Function of Gender (* = Significant Difference p < 0.05)

	Male		Female		
	Mean	SD	Mean	SD	
Peak knee extensor moment (Nm.kg)	1.72	0.25	2.05	0.22	*
PCF (B.W)	2.18	0.43	2.90	0.58	*
PP (MPa)	9.23	1.29	9.52	3.13	
Time to PCF (s)	0.16	0.19	0.13	0.03	
PCF loading rate (B.W.s^{-1})	14.14	6.36	22.12	5.74	*

The first key observation from the current investigation is that knee extensor moment and PTC loading rate were shown to be significantly greater in female fencers. Females have been shown to exhibit reduced strength in the hip musculature and lack of neuromuscular control of the knee in the sagittal plane during dynamic landing activities (Mizuno et al., 2001; Stefanik et al., 2011). As such, there is an increased reliance on eccentric quadriceps contraction in order to oppose knee flexion during the deceleration phase following landing. The quadriceps moment arm decreases as a function of increased knee flexion angle (Powers, Lilley, & Lee, 1998). Sinclair and Bottoms (2013) showed that knee flexion was greater for females than males throughout the lunge movement. Therefore, the moment arm of the quadriceps as determined using the knee flexion angle is likely to be shorter for female fencers. This may help clarify the mechanism by which increases in PCF were observed in female fencers as PCF is governed by the force generated in the quadriceps. Given the lunge's popularity as an attack in fencing this finding has potential clinical significance regarding the aetiology of injury in female fencers. The consensus regarding the development of patellofemoral disorders is that symptoms are the function of habitual and excessive patellofemoral joint loads (Fulkerson & Arendt, 2000; Ho et al., 2012). Although additional work using a retrospective design in fencers is required, it is highly likely that female fencers, like the majority of female athletes, are at greater risk from the development of patellofemoral disorders.

To the authors' knowledge, the current investigation is the first to show that female fencers exhibit greater PCF parameters during the fencing lunge in comparison to males. Patellofemoral pain is the most common chronic injury in athletic populations and female athletes are considered to be at much greater risk from this pathology (Fulkerson & Arendt, 2000; Ho et al., 2012). Therefore, it may be prudent for training/technique adaptations to be made that are designed to decrease the knee injury risk in females via reduction of the patellofemoral joint loading. This may be achieved through strengthening of the quadriceps muscles, which would reduce the amount of knee flexion required to decelerate the body during the impact phase of the lunge. Reducing the knee flexion would serve to increase the moment arm of the quadriceps, reducing the eccentric force generation in this muscle and also the PCF, which is determined by the force generated in the quadriceps.

A limitation of the current investigation is that a predictive model was used to quantify patellofemoral kinetics. This was unavoidable due to the impracticality of obtaining direct measurements of patellofemoral loads during dynamic movements. Furthermore, this model has been utilized previously to resolve differences in knee kinetics (Bonacci et al., 2013; Heino and Powers, 2002; Kulmala et al., 2013; Sinclair, 2014). Nonetheless this method may have led to an underestimation of PCF and PP, as the net knee extensor moments served as a principal input parameter and thus do not take into account the antagonist force generation that acts in the opposing direction of the joint.

Furthermore, that the current predictive model was used in order to resolve differences in knee loading between male and female fencers may also serve as a limitation. Whilst the model has previously been used singularly to examine knee kinetics in both male and female participants (Bonacci et al., 2013; Kulmala et al., 2013; Sinclair 2014), the efficacy of the model has yet to be determined in terms of its effectiveness in resolving gender differences in different sports movements.

In conclusion, the observations of the current investigation show that female fencers were associated with significant increases in PCF parameters compared with males. Given the proposed relationship between knee joint loading and patellofemoral pathology, the current investigation does appear to provide some understanding of the high incidence of patellofemoral disorders in females. Future analyses may therefore seek to implement strategies aimed at reducing knee loading in female fencers.

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