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The impact of joint angle and movement velocity on sex differences in the functional hamstring/quadriceps ratio

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ABSTRACT

Background: Females are two to eight times more likely to suffer a non-contact injury compared with males thus the purpose of this study was to explore the influence of joint angle and movement velocity on sex differences in the functional hamstring to quadriceps ratio (H/Q_{FUNC}).
Methods: Isokinetic concentric and eccentric torque were determined in 110 participants (55 males and 55 females) through a 90° range of movement at 60, 120, and 240°/s. Testing was performed with the hip flexed at 10°. The H/Q_{FUNC} was determined at three specific joint angles (15, 30 and 45° flexion) and where peak torque occurred for concentric knee extension.
Results: A significant interaction effect ($P < 0.01$) for sex and joint angle was observed with women demonstrating a lower H/Q_{FUNC} than males, especially at more extended knee positions. A significant sex by velocity interaction ($P < 0.01$) indicated a lower H/Q_{FUNC} in women as velocity increased. Significant main effects ($P < 0.01$) indicated that irrespective of sex the H/Q_{FUNC} increased as the knee extends and velocity increases.
Conclusion: Given the reduced H/Q_{FUNC} in females compared to males at more extended knee positions and faster velocities, this may contribute to the observed sex bias in reported injury rates.

1. Introduction

It is well recognised that based on hours of exposure to sporting activity females are more likely to suffer a non-contact anterior cruciate ligament (ACL) injury compared to males [1] with the proposed mechanisms for this increased relative risk multifactorial [2]. It has been suggested that irrespective of sex it is important that the muscles produce efficient muscular control to provide compression to maintain joint stability (dynamic stability), by co-activating and producing joint stiffness and net joint moment [3]. Their co-activation improves joint stiffness and decreases ACL strain [4], however, functional stability changes during movement since both static stability and dynamic stability are affected by joint angle and movement velocity. Previous studies have identified a link between injury incidence, especially ACL rupture, and low hamstring to quadriceps (H/Q) ratios, indicating that compromised H/Q ratios are a risk factor for injury [5,6].

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The functional ratio (H/Q_{FUNC}) (eccentric hamstrings/concentric quadriceps) has been proposed to appropriately reflect co-contraction of the limb [3,7] but despite a growing literature base exploring the H/Q_{FUNC} little regard has been given to joint angle specific determination of the ratio. Most studies divide the velocity specific eccentric peak torque value for the hamstrings by the concentric peak torque value for the quadriceps [8–11]. However, this method of determination lacks functional relevance as it does indicate co-contraction capability of the muscle around the joint. Simply using peak torque also fails to examine the ratio at joint angles where injury is most likely to occur (e.g. 0–30° of knee flexion). Peak torque values for the hamstrings and quadriceps during concentric and eccentric muscle actions occur during the mid-range of the movement and previous studies have demonstrated that the muscle specific torque generating capability during concentric and eccentric actions is altered at decreased joint angles [12,13]. An additional problem of using peak torque values to calculate the H/Q_{FUNC} ratio is that concentric and eccentric peak torque (PT) will most likely not occur at the same joint angle.

Only a few studies appear to have examined the angle specific H/Q_{FUNC} ratio using small sample sizes, from males only, and do not all include joint angles near full knee extension [3,14,15]. However, these studies have reported an increase in the H/Q_{FUNC} as the knee approaches extension with one reporting ratios as high as 3.14 at 180°/s in pubertal males [16]. Current data would suggest that muscular control of the knee is highly dependent upon the angular position examined in males however, it remains to be established if this is similar in females. Determination of the H/Q_{FUNC} at more extended knee positions may be more important for females seeing as biomechanical analysis indicates that females tend to land with the knees in more extended joint positions [17]. Additionally, studies determining the H/Q_{FUNC} have tended to determine torque in a seated position with the hip flexed (80–90° of flexion). It is well recognised that injury is most likely to occur when the hip is extended (around 10° of hip flexion) and therefore determination of torque with the hip flexed might be considered not functionally relevant. For example, a recent study indicated that the H/Q_{FUNC} is significantly lower when the hip is flexed at 10° compared with 80° [18].

A number of studies have examined changes in the H/Q_{FUNC} with increasing velocity and as peak torque has been used to calculate the H/Q_{FUNC} most studies have demonstrated a significant increase in the ratio with increasing velocity [7,10,16]. This is attributed to the decrease in concentric force production with increasing velocity compared to the plateauing of torque production with increasing velocity during eccentric actions. However, whether this relationship remains when the H/Q_{FUNC} is calculated using angle specific data remains to be identified. This muscular control of the knee during fast velocity movements (such as sprinting) has important implications for injury risk.

Data exploring sex differences in the H/Q_{FUNC} are conflicting [7,19,20] and may be related to the different age ranges and training background of participants. Others have suggested that sex differences in H/Q_{FUNC} are generally observed only at high knee angular velocities that approach those during sports activities [21]. These data suggest that muscular control of the knee during fast extension movements may be less optimal in females compared to males, but this hypothesis requires investigation at joint angles where injury is likely to occur.

The combination of hip position, joint angle and movement velocity may all have a cumulative effect on sex differences in muscle control since both static stability and neuromuscular function can be affected. Thus, the purpose of this study was to examine the effect of joint angle and movement velocity on sex differences in the H/Q_{FUNC}.

2. Material and methods

2.1. Participants

One hundred and ten participants, consisting of 55 males (age = 29 ± 5 years; stature = 1.81 ± 0.07 m; body mass = 82 ± 7 kg) and 55 females (age = 27 ± 6 years; stature = 1.61 ± 0.08 m; body mass = 68 ± 9 kg) who were recreationally active adults (engaging in two to five hours of moderate physical activity three to five days per week, but not involved in systematic sports training) completed the study. Participants were instructed to avoid their regular training regimens throughout the experimental period and not to take part in any vigorous physical activity 48 h preceding each testing day. There were four exclusion criteria in this study: (1) previous surgery of the knee; (2) histories of orthopaedic problems, such as episodes of hamstrings injuries, fractures, surgery or pain in the spine or hamstring muscles over the past six months; (3) evidence of self-reported delayed onset muscle soreness (DOMS) at a testing session; and (4) for female participants being in the luteal phase of the menstrual cycle which was self-reported by the participant. None of the participants reported any form of musculoskeletal disorder at the time of testing. The participants were verbally informed about the study procedures before testing and provided written informed consent. The study was approved by the University's Research Ethics Committee. Participants visited the laboratory one week prior to testing to familiarise themselves with the laboratory and the experimental procedures.

2.2. Isokinetic assessment

A Biodex System-3 Isokinetic dynamometer (Biodex Corp., Shirley, NY, USA) and its respective manufacture software were used to determine peak torque during knee extension and flexion movements. The dynamometer was calibrated according to the manufacturer's instructions before the start of each test session.

Testing began with a standardised warm-up consisting of five minutes of cycling at 60 W on a Monark cycle ergometer 814E (Varberg, Sweden). Two minutes after the warm-up was completed, maximal concentric and eccentric isokinetic peak torque for knee flexion and extension of the dominant leg, determined through interview and defined as the leg preference when kicking a ball was tested. Participants were secured in a prone position on the dynamometer with the hip passively flexed at 10° and the