

A LOW HAMSTRING/QUADRICEPS RATIO MAY INCREASE THE RISK OF KNEE INJURY IN INACTIVE YOUNG WOMEN: CROSS SECTIONAL STUDY

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Abstract This study aimed to evaluate the isokinetic hamstring/quadriceps (H/Q) performance in male and female individuals with different physical activity levels and to examine the interaction between gender and activity level. A total of 84 volunteers (42 males and 42 females) with varying physical activity levels (inactive, minimally active, active) participated in the study. Based on the International Physical Activity Questionnaire Short Form (IPAQ-SF) scores, participants were categorized into three activity groups by gender (n=12–15 per group). Isokinetic muscle strength measurements were performed at angular velocities of 60°/s and 180°/s. Both gender and physical activity level had significant effects on quadriceps and hamstring muscle strength ($p<0.001$). A significant interaction between gender and activity level was observed ($p<0.01$). For the H/Q ratio, only gender showed a significant effect ($p<0.01$). Inactive females had notably lower H/Q ratios than males ($p<0.01$, Cohen's $d>1.3$). A similar but less pronounced gender difference was also observed in active individuals. The gender difference in H/Q ratio is more pronounced among individuals with low physical activity levels. These findings suggest that inactive females may be at greater risk for knee injuries compared to males.

Key words: h/q ratio, isokinetic measurement, risk of knee injury, inactivite

Introduction

The stability of the muscles of the knee (quadriceps and hamstrings) is one of the parameters that are utilised in the assessment of injuries to the lower extremity. In particular, the evidence suggests that a lower hamstring strength in comparison to quadriceps strength (H/Q ratio) may serve as a potential mechanism that increases the

risk of injury to the lower extremities (Knapik et al., 1991; Myer et al., 2004). This torque ratio indicates the strength imbalance between the agonist and antagonist muscle groups surrounding the knee joint (Baltzopoulos & Brodie, 1989; Kellis & Baltzopoulos, 1995). The determination of the H/Q ratio can be achieved through the utilisation of concentric, eccentric and isometric contraction types, angular velocities (60°/s and 180°/s) and torque types (peak or angle-specific torque) within the isokinetic dynamometer measurement system (Kellis, 1998). The majority of studies have indicated that the peak torque ratio is the concentric hamstring-quadriceps peak torque ratio (Hcon/Qcon) of the knee muscles at a speed of 60°/s (Coombs & Garbutt, 2002). In relevant reviews, it seems to be generally accepted that the reference value ratio for this conventional peak torque H/Q ratio at the slow speed of isokinetic measurement is 0.60 (Coombs & Garbutt, 2002; Croisier et al., 2008; Hewett et al., 2008; Kellis et al., 2023). For example, it has been proposed that a minimum Hcon/Qcon ratio of 0.60 at an angular velocity of (60°/s) should be used as a basis for detecting muscle imbalances and preventing injury (6,7). It has also been suggested that a concentric H/Q ratio of less than 0.55 (Con 60/Con 60) is associated with an elevated risk of injury (Croisier et al., 2008).

It is well established that the strength profiles of the hamstring and quadriceps muscles exhibit significant disparities between males and females during and following the process of puberty (Hewett et al., 2004). Women with lower H/Q peak torque ratios may be at higher risk of knee injury (Knapik et al., 1991). Knapik et al. (1991), established that a lower H/Q ratio, as determined by high-speed isokinetic parameters, was associated with a higher incidence of anterior cruciate ligament (ACL) injury in female collegiate athletes.

Insufficient hamstring torque relative to quadriceps torque has been demonstrated to impair the control of coronal and sagittal plane knee movements in female athletes, thereby increasing knee joint loading and predisposing them to a greater injury risk than their male counterparts (Kellis & Baltzopoulos, 1995; Markolf et al., 1995).

In the literature searched, the H/Q ratio showed significant differences between genders, depending on sports activity, isokinetic test speed, and number of study participants (Hewett Hewett et al., 2008). However, these differences in the H/Q ratio have not been well reported in the young population at different speeds by sex according to certain physical activity levels. Therefore, in this study, we aimed to compare H/Q ratios according to different activity levels in young men and women according to physical activity score.

Methods

The study has been approved by Balıkesir University Health Sciences Non-Interventional Research Ethics Committee on October 12, 2021 (No: 2021/16) and all participants have signed an informed consent form.

The Study Procedure and Participants

Study data were collected on separate days. First, participants' physical activity levels were determined using the self-administered International Physical Activity Questionnaire-Short Form (IPAQ-SF) questionnaire (Lee et al., 2011). Then, the physical composition of the participants were measured, and right leg isokinetic knee muscle strength tests were performed. Forty-two men and 42 women, totalling eighty-four people, participated in this study. All volunteers had no musculoskeletal or neurological injuries or disabilities or use any anti-inflammatory drugs or any treatments during the research period.

At the first visit, participants were given a week before the test to familiarize themselves with the isokinetic testing protocol. Isokinetic test measurements were performed on the right leg at similar times of the day (± 2 h) for all and one researcher performed all measurements.

Assessment of the Physical Activity Level Using IPAQ-SF

The participants physical activity level was determined by Turkish version of IPAQ-SF (Saglam et al., 2010). The physical activity levels of the participants in the last 7 days were assessed in accordance with the scale. This scale consists of seven questions. It assesses the duration of sitting, walking, moderate and vigorous activity. The walking, moderate and vigorous activity scores are summed to give a total score. The final scores of the IPAQ-SF are reported in units of MET minutes-week⁻¹. This calculating protocol for walking= $(3.3 \times \text{walking minutes} \times \text{walking days})$; moderate activity= $(4.0 \times \text{moderate activity minutes} \times \text{moderate activity days})$; and vigorous activity= $(8.0 \times \text{vigorous activity minutes} \times \text{vigorous activity days})$. Based on the total PA score, participants are classified as "Active, Minimally Active, and Inactive person." The sitting score is calculated separately, it indicates sedentary behaviour (Saglam et al., 2010; Craig et al., 2003).

Isokinetic Test Evaluation

The Isokinetic test, concentric/concentric active mode knee flexion and extension strength of the participants were evaluated by ISOMED 2000 (D.& R. Ferstl GmbH, Hemau, Germany). Before the test, participants were informed about the evaluation process with visual feedback. All participants were verbally motivated for maximum effort. Participants were allowed to hold the handles on the edge of the seat and asked how to stop the test in case of an emergency. Knee, hip, and waist positions were automatically adjusted by software to position the hips at the correct angle. The upper part of the body, shoulders, hips, and upper leg were fixed with a belt to stabilise them. The distal part of the lower leg articulating arm is attached to the lateral malleolus of the ankle. The swivel axis in the knee is positioned with the lateral femoral condyle of the knee joint at 90° knee flexion. The range of motion of the knee was adjusted between 0 and 90° with mechanical limits. Also, the effect of gravity correction was calculated before the test. The test protocol was performed at two different angular speeds, from slow to fast (60°/s and 180°/s) with flexion/extension and concentric/concentric mode. Before the actual test, three submaximal extension/flexion trials were performed to warm up and familiarise with the speed and resistance. Participants actual test performed at the 60°/s 6 repetitions and 20 repetitions at the 180°/s angular velocity of knee flexion/extension. All isokinetic muscle strength parameters were analysed at the end of the test.

Statistical Analysis

The analysis of the data was carried out using the SPSS software package (version 30). Descriptive data are expressed as numbers, percentages, and in the form of mean and standard deviation. Normality of data distribution was evaluated using Shapiro-Wilk test. The effects of gender and physical activity on isokinetic parameters (Hamstring PT, Quadriceps PT and H/Q PT Ratio) were evaluated by two-way analysis of variance (ANOVA). When a significant two-factor interaction or main effect was observed, Tukey's HSD was applied as a post hoc test. A priori power analysis was performed using G*Power software (version 3.1) to determine the required sample size for the two-way ANOVA design (3 activity levels $\times$ 2 gender=6 groups). Assuming a large effect size (Cohen's $f=0.40$), an alpha level of 0.05 and a power of 0.80, the analysis indicated that a total of 52 participants would be sufficient to detect statistically significant differences. This corresponds to a minimum of 9 participants per group. Accordingly,

the study was designed with three physical activity groups of 12 to 15 participants each. Variables between genders were compared using an independent t-test (Student's t-test). The significance level was determined as $\alpha=0.05$.

Results

In Table 1, participants were categorised as inactive, minimally active, and active according to IPAQ-SF scores in men and women. The age, weight, and BMI of all participants were not significantly different according to activity level by gender ($p>0.05$), whereas the height of the active group was significantly higher than the height of the other groups ($p<0.05$) (Table 1).

Table 1. Classification of groups according to international physical activity questionnaire-short form scores in women and men

Activity level	Gender	n	Age (y)			Height (cm)			Weight (kg)			IPAQ-SF score		
			Min.	Max	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Inactive	W	15	20	23	21.40	154	175	164	45	75	55.54	00	594	214.6
	M	12	20	28	22.75	167	183	176.3	60	115	79.70	00	594	162.0
Minimally Active	W	12	20	23	20.66	157	180	168.6	49	80	62.65	780	2772	1557.7
	M	15	20	25	21.50	167	186	175.1	58	93	75.40	676	2950	1902.4
Active	W	15	18	23	20.93	157	178	167.0	48	77	58.40	3012	7572	5574.7
	M	15	20	28	22.13	171	200	184.1	68	109	85.66	3177	6657	4555.8

W=Women, M= Men, n=number; IPAQ-SF=International Physical Activity Questionnaire–Short Form.

Table 2 shows the mean $\pm$ SD values of isokinetic muscle performance variables according to the participants' gender and activity level.

Table 2. Mean $\pm$ SD Values of Isokinetic Muscle Performance Variables According to Gender and Activity Level.

Degree & PT	^a Inactive (n=27)		^b Minimally Active (n=27)		^c Active (n=30)	
	Women (n=15)	Men (n=12)	Women (n=12)	Men (n=15)	Women (n=15)	Men (n=15)
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
60°/s						
Q	112.40 $\pm$ 15.03	185.41 $\pm$ 35.76	147 $\pm$ 31.12	197.50 $\pm$ 33.03	141 $\pm$ 22.17	252.20 $\pm$ 46.01
H	55.13 $\pm$ 7.59	111.58 $\pm$ 22	81.33 $\pm$ 22.01	118.28 $\pm$ 24.02	82.93 $\pm$ 15.40	163.33 $\pm$ 27.58
H/Q Ratio	0.49 $\pm$ 0.08	0.60 $\pm$ 0.09	0.55 $\pm$ 0.11	0.59 $\pm$ 0.07	0.58 $\pm$ 0.06	0.65 $\pm$ 0.11
180°/s						
Q	91 $\pm$ 14.35	150.66 $\pm$ 40.81	121.58 $\pm$ 21.6	165.92 $\pm$ 33.81	121.46 $\pm$ 19.36	222.20 $\pm$ 30.01
H	47.53 $\pm$ 9.24	98.58 $\pm$ 19.84	68 $\pm$ 17.77	102.35 $\pm$ 21.53	72.40 $\pm$ 14.80	139.66 $\pm$ 28.03
H/Q Ratio	0.52 $\pm$ 0.10	0.67 $\pm$ 0.12	0.55 $\pm$ 0.13	0.61 $\pm$ 0.09	0.59 $\pm$ 0.09	0.63 $\pm$ 0.13

Q=Quadriceps, H= Hamstring, Mean $\pm$ SD, mean $\pm$ standard deviation; PT, peak torque (Nm); H/Q Ratio, hamstring/quadriceps ratio

According to the Two-Way ANOVA results (Table 3), at an angular velocity of 60°/s, quadriceps strength was significantly affected by gender ($F=123.180$, $p=0.001$), activity level ($F=15.758$, $p<0.001$), and their interaction ($F=6.489$, $p=0.002$). Similarly, hamstring strength was significantly influenced by gender ($F=161.177$, $p<0.001$), activity level ($F=26.545$, $p<0.001$), and the interaction between them ($F=7.736$, $p<0.001$). For the H/Q ratio, gender ($F=14.548$, $p<0.001$) and activity level ($F=4.487$, $p<0.001$) had significant effects, while the interaction effect was not significant ($F=0.930$, $p=0.399$).

Table 3. Two-Way ANOVA Results of Gender, Activity Level and Interaction on Isokinetic Muscle Performance Variables.

Angular Velocity & Isokinetic Muscle Strength Variables		Gender		Activity Group		Activity Level * Gender Interaction	
		F	p	F	p	F	p
60°/s	Quadriceps	123.180	<0.001**	15.758	<0.001**	6.489	0.002**
	Hamstring	161.177	<0.001**	26.545	<0.001**	7.736	<0.001**
	H/Q Ratio	14.548	<0.001**	4.487	<0.001**	0.930	0.399
180°/s	Quadriceps	124.715	<0.001**	24.122	<0.001**	7.851	<0.001**
	Hamstring	140.772	<0.001**	20.976	0.001**	4.979	0.009**
	H/Q Ratio	10.038	0.002**	0.411	0.664	1.726	0.185

PT, peak torque (Nm); H/Q Ratio, hamstring/quadriceps ratio

* The degree of significance was set at $p<0.05$; **= $p<0.001$.

At 180°/s, quadriceps strength was again significantly affected by gender ($F=124.715$, $p<0.001$), activity level ($F=24.122$, $p<0.001$), and their interaction ($F=7.851$, $p<0.001$). The same pattern was observed for hamstring strength (gender: $F=140.772$, $p<0.001$; activity: $F=20.976$, $p<0.001$; interaction: $F=4.979$, $p=0.009$). However, for the H/Q ratio at this velocity, only gender had a significant effect ($F=10.038$, $p=0.002$), while activity level ($F=0.411$, $p=0.664$) and the interaction ($F=1.726$, $p=0.185$) were not significant.

Table 4. Independent samples t-test results of PT H/Q ratios by gender

Degree & Activity Level	PT H/Q Ratio		<i>t</i>	<i>P</i> -value	Cohen d
	Women	Men			
	Mean±SD	Mean±SD			
60°/s					
Inactive	0.49±0.08 (n=15)	0.60±0.09 (n=12)	-3.392	0.002**	-1.314
Minimally Active	0.55±0.11 (n=12)	0.59±0.07 (n=15)	-1.211	0.238	-0.476
Active	0.58±0.06 (n=15)	0.65±0.11 (n=15)	-2.132	0.042*	-0.778
180°/s					
Inactive	0.52±0.10 (n=15)	0.67±0.12 (n=12)	-3.405	0.002**	-1.319
Minimally Active	0.55±0.13 (n=12)	0.61±0.09 (n=15)	-1.250	0.223	-0.492
Active	0.59±0.09 (n=15)	0.63±0.13 (n=15)	-0.887	0.191	-0.324

Mean±SD, mean±standard deviation; PT, peak torque (Nm); H/Q Ratio, hamstring/quadriceps ratio

* The degree of significance was set at $p<0.05$. **= $p<0.01$.

As shown in Table 4, at 60°/s, inactive females had a significantly lower H/Q ratio (0.49 ± 0.08) than inactive males (0.60 ± 0.09 ; $t = -3.392$, $p = 0.002$, Cohen's $d = -1.314$). A similar gender difference was observed in active participants (females: 0.58 ± 0.06 , males: 0.65 ± 0.11 ; $t = -2.132$, $p = 0.042$, Cohen's $d = -0.778$). No significant gender difference was found in the minimally active group ($p = 0.238$). At 180°/s, inactive females again had a significantly lower H/Q ratio (0.52 ± 0.10) than males (0.67 ± 0.12 ; $t = -3.405$, $p = 0.002$, Cohen's $d = -1.319$). No significant gender differences were observed in the minimally or active groups ($p = 0.223$ and $p = 0.191$, respectively).

Discussion

In this study, the H/Q ratio was analyzed according to physical activity level and gender. The most striking finding of the study was that at low angular velocity (60°/s), the PT H/Q ratio (0.49) was lower in inactive women compared to activity level. In addition, in men, the H/Q ratio did not differ significantly at low and high speeds according to activity level. When evaluated on the basis of gender, inactive women had a lower H/Q ratio than inactive men at both angular velocities; when the activity level increased, a gender difference was observed only at low angular velocity. Inactivity reduced the H/Q ratio in both men and women, but the risk of knee injury may be significantly increased in women compared to men.

In this study, the mean H/Q ratio for inactive women (0.49) was lower than for inactive men (0.60). This result seems to be consistent with the results of a meta-analysis of twenty-two studies in the literature. This meta-analysis included 1145 men and 423 women. Isokinetic test speeds ranged from 30°/s to 360°/s and the mean H/Q ratio over all test speeds was 51.9% (Hewett et al., 2008). These meta-analyses also showed that there was a significant increase in H/Q ratio as speed increased, but there was no relationship between H/Q ratio and test speed in women. In men, the H/Q ratio increased significantly with speed. In addition, it was determined that the H/Q ratio of men was statistically significantly higher than that of women (Hewett et al., 2004). However, in our study, a significant gender difference was found among inactive participants at 60°/s. This suggests that especially inactivity may affect the H/Q ratio between genders.

In this study, it was also observed that PT H/Q ratio showed gender-related differences in individuals with high physical activity level according to IPAQ-SF scores, and active males had higher values in slow speed ($p < .05$) compared to active females. In previous studies by Holm & Vøllestad (2008), it was shown that there were significant gender differences in terms of H/Q ratio and static balance in children aged 7, 8, 9, 10 and 12 years, and that the hamstring muscle strength of boys was higher than that of girls at all ages. In adolescents and adults, sedentary lifestyle, physical activity and type of sport may affect the H/Q ratio. Indeed, no significant difference was found in the strength ratio between the anterior and posterior thigh muscles between active men and women with similar activity levels (Bojsen-Møller et al., 2007; Kong & Burns, 2010). In a study by Kong & Burns (2010), no difference was found between isokinetic and isometric H/Q ratios at any angular velocity (60°/s, 180°/s, 330°/s) between physically active adult men and women. In addition, it was reported that gender differences in isokinetic H/Q ratio were generally observed in different sports activities and it was stated that women could not increase their hamstring muscle strength as much as the amount of quadriceps torque unlike men (Hewett et al., 2008). In Myer's study, no gender difference was found in H/Q ratios at slow angular velocities (Myer et al., 2004).

In another study, no difference was found between men and women with the same training level in isometric and functional isokinetic eccentric H/Q ratios performed at speeds of 60°/s and 180°/s at different knee flexion positions (40°, 50°, 60°, 70°, 80°) (Pellicer-Chenoll et al., 2017). In another study, angularly specific H/Q ratios

of soccer players were compared with recreationally active individuals and no difference was found between the groups at any speed (Evangelidis et al., 2015). However, in our study, a gender difference was observed between active men and women at low angular velocity. This difference may be related to hamstring and quadriceps peak torque (PT) values, which may vary depending on sport-specific activity levels and training type.

This shows that the H/Q ratio is affected by inactivity and activity level. The results of this study suggest that knee problems may be more common in women than in men. According to related studies, the lowest ratios between the mean values of H/Q at slow speeds (30°/s and 60°/s) in women were reported as 0.41, 0.46, 0.47 and 0.48, respectively (Aagaard et al., 1997; Griffin et al., 1993; Richards, 1981; Westing & Seger, 1989). These existing findings have been analyzed; Aagaard et al. (1997) studied elite female sailors (n=8), Westing & Seger (1989) studied twenty women but did not provide clear information about their training history. Griffin et al. (1993) studied fifty untrained women between the ages of 21–67, but did not analyze the effect of age. Our findings regarding H/Q ratio are similar to these studies. In addition, for example, in our findings, the difference in quadriceps peak torque (PT) between active men and women was 36%, while the difference in hamstring PT reached 98%. Among inactive subjects, these differences were 65% for quadriceps and nearly 100% for hamstrings. Also, in our study, the inactivity level of women was clearly determined by IPAQ-SF score and young women (18–30 years) were included in the study. In addition, according to the physical activity score, inactive women spent a greater proportion of the day sitting compared to men (Female=8 hours; Male=5 hours).

In conclusion, in this study, we found a gender difference in H/Q ratios. This difference is affected by inactivity and sport-specific activity types. We think that this effect is due to hamstring peak torque values. Notably, the disparity in hamstring strength was greater than that in quadriceps strength, indicating that females have comparatively weaker hamstring muscles than males.

Conclusion

In conclusion, our findings show that inactive young women have a lower H/Q ratio than inactive men at both velocities. This indicates that inactivate higher knee injury risk of the women than men. However, according to the IPAQ-SF score, we found that at 4 METs and above, there was a significant gender difference, with males demonstrating higher values of the PT H/Q ratio compared to females. In terms of velocity, our results confirm the H/Q ratio did not differ according to activity level at high speed (180°/s).

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