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Comparison and Analysis of Isokinetic Strength in Elite Junior Triathletes and Cyclists

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ABSTRACT

The aim of this study was to analyze and compare differences in the peak torque, peak power, hamstring/quadriceps muscles ratio and range of motion between Turkey National Junior Team cyclists and triathletes. Seven triathletes (age 16.88±0.64 yr) and 8 cyclists (age 17.38±0.52 yr) were recruited to the study. Measurements of lower-extremity knee-joint movement were made with an isokinetic dynamometer at velocities 60 and $240^{\circ}\cdot s^{-1}$. No significant differences were noted between the groups in the right hamstring and quadriceps at velocities of $60^{\circ}\cdot s^{-1}$ and $240^{\circ}\cdot s^{-1}$. However, a significant difference was observed between the left limbs of the athletes at a velocity of $60^{\circ}\cdot s^{-1}$ in the hamstring PT, the hamstring average curve, the hamstring/quadriceps ratio and the hamstring/weight ratio. The cyclists exhibited higher differences compared to the triathletes in hamstring/weight, quadriceps/weight, hamstring peak torque, hamstring peak torque angle, hamstring average curve, hamstring peak power, hamstring average power, quadriceps peak torque and quadriceps average curve of the left limbs at a velocity of $240^{\circ}\cdot s^{-1}$. The triathletes' left and right limb range of motion was significantly increased compared with the cyclists' left and right limbs at a velocity of $240^{\circ}\cdot s^{-1}$. In conclusion, cyclists produced isokinetic strength at shorter hamstring and quadriceps muscle fiber lengths and larger peak torque angles compared with triathletes.

Keywords: knee flexion and extension, peak torque, hamstring: quadriceps ratio, isokinetic strength.

INTRODUCTION

The correct assessment of muscle strength in athletes, the creation of appropriate training programs, the enhancement of athletic performance and the prevention of training injuries and disabilities caused by a lack of athlete strength and power all play important roles in the design of appropriate exercise programs (Mjølsnes et al., 2004; Erdogan, 2021). Therefore, technical analysis of the physiological and morphological aspects of athletes' performance should be performed (Zakas et al., 2006). A systemic evaluation of the knee during the season is useful in evaluating the athletes during the optimization of the training process. Furthermore, comparing the relationship between paired agonist and antagonist muscles and range of motion (ROM) may identify particular weaknesses in certain muscle groups and gives valuable information regarding muscular strength and power balance (McCurdy and Langford, 2005). Therefore, to maximize the physical performance of athletes, these parameters must be analyzed in detail (Miller et al., 2006).

A variety of types of power and endurance tests can be performed. One of these, isokinetic assessment, allows the trainer to objectively assess muscular performance in a way that is safe, valid and reliable (Van Tittelboom et al., 2022; Dvir, & Müller, (2020); Harput et al., 2022). Isokinetic dynamometers are the most commonly used instruments for the comparison of isokinetic muscle strength between dominant/non-dominant and agonist/antagonist muscle groups (Rosa et al., 2022; Padasala et al., 2020; Olyaei, 2006). One advantage of isokinetic testing is that it provides numerous objective parameters of an athlete's performance. Isokinetic testing data commonly used to analyze muscular performance include PT, time rate of torque development, acceleration, deceleration, ROM, total work and average power.

Isokinetic strength profiles of athletes in different sports and the fulfillment of the requirements of high-level performance of athletes are of great importance in terms of continuity (Magalhães, 2004; Lanferdini et al., 2023;). Although the sports represented in our study (triathlon and cycling) require similar muscles (quadriceps and hamstring), different motor abilities may be responsible for the difference in the H/Q muscle ratios between the two. Moreover, the quadriceps and hamstring muscle groups are involved in several important motor abilities, including running, swimming and biking. The triathlon (running, swimming and biking) also includes three types of activities with similar technical skills and training procedures.

The isokinetic strength evaluation of the quadriceps (Q) and hamstrings (H) in the concentric mode of contraction is an important part of the comprehensive evaluation and analysis of athletes. For this reason, the main aim of this study was to analyze and compare data on the mean concentric quadriceps and hamstring strength of Turkey National Junior Team cyclists and triathletes using an isokinetic dynamometer. Therefore, the cyclists and triathletes performed tests to define the following: (a) the level of strength as expressed by peak torque (PT), PT angle, PT average curve, peak power (PP) and average power; (b) the ratio of knee flexors and extensors (hamstrings/quadriceps – H/Q) and (c) range of motion (ROM) at the testing speeds of $60°{\cdot}s^{-1}$ and $240°{\cdot}s^{-1}$. The velocities were chosen based on similar velocities used in previous investigations.

MATERIAL AND METHODS

Participants

The Turkey National Junior Team triathletes consisted of 7 males (age: 16.86±0.69 years, weight: 63.04±3.61 kg, height: 176.56±4.65 cm, body mass index: 20.30±0.80 kg/m^2, body fat %: 6.13±3.67), and the Turkey National Junior Team cyclists consisted of 8 males (age: 17.38±0.52 years; weight: 65.88±7.08 kg, height: 174.75±4.65 cm, BMI: 21.03±0.93, body fat %: 4.35±2.39). All of the participants were fully informed of the goals and methodology of the test and signed a consent agreement. The participants agreed with the testing process and the use of the data for further research. The day before testing, the players were not subjected to any intense training.

Prior to participation in the study, the athletes were interviewed about their medical records and completed an injury questionnaire. Participants were excluded from participation in the study if they had any current hip, knee, leg or ankle injuries. The participants were all right leg-dominant. Before the testing session started, the subject was allowed a 10-minute warm-up at a light intensity on the leg curl and leg extension machine.

Physical measurements

Body height and body weight were measured with an electronic scale (708 Seca, Hamburg, Germany). Body mass index (BMI), body fat and fat mass were measured with a Tanita Body Composition Analyser BC-418, using the electrical bioimpedance method.

Measurement of muscle isokinetic strength

Participants were tested in the sitting position on IsoMed 2000 isokinetic dynamometers. Participants were seated for testing in the dynamometer’s chair with the backrest angle at 90°. The axis of rotation of the right knee was aligned with the axis of rotation of the dynamometer’s armature, and the ankle cuff was attached approximately 3 cm above the dorsal surface of the foot. Gravity correction was performed throughout the test. Stabilization straps were placed over the pelvis and chest, and participants positioned their arms across their chests during familiarization and testing. To synchronize themselves with the testing device, participants were instructed to perform three active repetitions of knee movement ranging from maximal flexion to maximal extension. To adapt to the test conditions, subjects were allowed three submaximal contractions of the quadriceps and hamstring muscle groups at the beginning of the tests. Standardized verbal motivation techniques were used to encourage maximal work from the test participants. All participants performed 10 maximal (the first and the last of the 10 were dismissed) concentric contractions (i.e., knee flexion and extension) of both legs at velocities of $60°{\cdot}s^{-1}$ and $240°{\cdot}s^{-1}$ (Brockett et al. 1999). A rest period of three minutes was allowed between test speeds, and five minutes were allowed between test limbs.

Hamstring/Quadriceps muscles strength ratio

The conventional H/Q muscle ratio was calculated according to its formal definition by dividing the maximal isokinetic hamstring (knee flexor) strength by the maximal quadriceps (knee extensor) strength for a given contraction mode and joint angular velocity.

Statistical Analysis

The data were processed with SPSS 15.0 for Windows (SPSS Inc., USA). Basic statistical parameters were calculated for all of the variables, and a one-way analysis of variance (ANOVA) was applied to determine the statistically significant differences between cyclists and triathletes. Statistical significance was set at the levels of $P<0.05$ and $P<0.01$.

RESULTS

No significant between-group differences in age, weight, height, BMI and body fat % were noted.

Hamstring/Quadriceps muscles ratio

Among the data concerning the H/Q ratio at angular velocities of $60°{\cdot}s^{-1}$ and $240°{\cdot}s^{-1}$, no statistically significant difference appeared between cyclists' and triathletes' right limbs. However, the cyclists' left limb H/Q ratio at a velocity of $60°{\cdot}s^{-1}$ was significantly higher than that of the triathletes. No significant difference was observed between cyclists' and triathletes' left limbs for the parameter of H/Q ratio at a velocity of $240°{\cdot}s^{-1}$ (Table 1).

Table 1. Quadriceps and hamstring peak torque ratios (H/Q, H/W and Q/W) of left and right legs in cyclists and triathletes. (Values are the means ± standard deviations).

	Left Leg			Right Leg		
	Cyclists (N=8)	Triathletes (N=7)	P-value	Cyclists	Triathletes	P-value
60°·s^{-1}						
PT H/Q (%)	57.24±9.74	46.40±6.24	0.03*	55.26±11.59	51.81±3.17	0.46
PT H/W (Nm/Kg)	1.70±0.16	1.35±0.13	0.00**	1.65±0.15	1.64±0.08	0.86
PT Q/W (Nm/Kg)	3.02±0.41	2.94±0.22	0.62	3.07±0.43	3.18±0.21	0.56
240°·s^{-1}						
PT H/Q (%)	63.54±13.81	62.44±14.47	0.88	66.31±9.81	71.01±6.13	0.29
PT H/W (Nm/Kg)	1.48±0.26	1.19±0.27	0.04*	1.50±0.28	1.44±0.11	0.60
PT Q/W (Nm/Kg)	2.40±0.45	1.92±0.14	0.02*	2.30±0.53	2.04±0.07	0.21

*The asterisks denote significant differences: *– P<0.05; **– P<0.01, Nm: newton meter, Kg: kilogram, PT: peak torque, H: hamstring, Q: quadriceps, W: weight*

The comparison of PT H/W between cyclists' and triathletes' left limbs at a velocity of 60°·s^{-1} showed significant differences, and the cyclists' left limbs showed the largest value. Additionally, a significant difference was observed between the athletes' left limbs at a velocity of 240°·s^{-1} in PT H/W. The cyclists' left limb PT Q/W at 240°·s^{-1} was significantly higher than that of the triathletes (Table 1).

Isokinetic hamstring strength (flexion)

There was no significant difference in the PT at angular velocities of 60°·s^{-1} and 240°·s^{-1} between the cyclists' and the triathletes' right limbs. However, the cyclists' left limb PT was significantly higher than that of the triathletes at a velocity of 60°·s^{-1}, and a similar result was noted at an angular velocity of 240°·s^{-1} (Table 2).

Table 2. Hamstring (flexion) peak torque, peak torque angle, peak torque average curve, peak power and average power of the left and right legs in cyclists and triathletes. (Values are the means ± standard deviations)

	Left Leg			Right Leg		
	Cyclists (N=8)	Triathletes (N=7)	P-value	Cyclists	Triathletes	P-value
60°·s^{-1}						
PT (Nm)	111.86±15.55	85.43±10.78	0.00**	108.88±16.04	103.71±9.20	0.47
PT angle (°)	40.,57±5,68	35,29±8,34	017	39,13±12,79	42,43±8,08	0.57
PT of AC (Nm)	98.43±10.83	76.00±12.00	0.01*	98.88±14.26	95.00±10.42	0.56
PP (W)	102.14±46.44	66.00±9.27	0.07	95.88±44.45	83.14±9.06	0.47
AP (W)	87.00±32.82	60.29±9.91	0.06	84.75±32.67	74.71±10.08	0.45
240°·s^{-1}						
PT (Nm)	98.00±21.73	75.29±18.53	0.04*	99.00±21.99	91.00±8.77	0.39
PT angle (°)	36,57±5,10	26,43±10,08	0.03*	38,25±7,27	33,14±1,68	0.09
PT of AC (Nm)	80.43±18.97	58.29±13.63	0.02*	88.13±22.87	76.00±12.15	0.23
PP (W)	139.86±23.41	109.57±22.804	0.02*	140.50±30.06	139.57±16.64	0.94
AP (W)	119.57±17.82	90.00±18.95	0.01*	124.63±23.96	118.29±14.37	0.55

The asterisks denote significant differences: *– P<0.05; **– P<0.01, W: Watt, PT: peak torque, PT of AC: peak torque of the average curve, PP: peak power, AP: average power

There were no significant differences concerning hamstring performances at angular velocities of 60°·s^{-1} or 240°·s^{-1} between the cyclists' and triathletes' right limbs. Furthermore, no significant differences in peak power (PP) or average power (AP) were observed between cyclists' and triathletes' left limbs at a velocity of 60°·s^{-1}. However, the cyclists' left limb PT of the average curve was significantly higher than that of the triathletes at a velocity of 60°·s^{-1}. A statistically significant difference was observed between the left limbs of the athletes at a velocity of 240°·s^{-1} in the PT angle, PT of the average curve, PP and AP (Table 2).

Isokinetic quadriceps strength (extension)

There were no significant differences between the cyclists' and triathletes' right limb PT at angular velocities at 60°·s^{-1} or 240°·s^{-1} (P<0.967 and P<0.174, respectively). The comparison of cyclists' and triathletes' left limb PT values at a velocity of 60°·s^{-1} revealed no significant difference (P<0.257). However, the cyclists' left limb PT at a velocity of 240°·s^{-1} was significantly higher than that of the triathletes (P<0.028) (Table 3).

Table 3. Quadriceps (extension) peak torque, peak torque angle, peak torque average curve, peak power and average power of left and right legs in cyclists and triathletes. (Values are the means ± standard deviations)

	Left Leg			Right Leg		
	Cyclists (N=8)	Triathletes (N=7)	P-value	Cyclists	Triathletes	P-value
60°·s^{-1}						
PT (Nm)	197.86±24.26	185.29±14.89	0.26	201.38±29.13	200.86±15.87	0.97
PT angle (º)	61,43±5,34	58,43±3,36	0.22	60,25±6,11	58,57±3,15	0.53
PT of AC (Nm)	185.86±24.58	171.57±15.48	0.21	186.63±25.95	185.71±15.52	0.94
PP (W)	157.86±65.65	127.86±7.82	0.25	157.13±49.93	143.86±11.52	0.51
AP (W)	146.86±61.48	116.57±11.24	0.22	144.63±44.05	129.00±13.60	0.39
240°·s^{-1}						
PT (Nm)	159.14±38.65	121.29±12.02	0.03*	152.38±42.56	128.71±8.69	0.17
PT angle (º)	66,43±4,20	63,71±3,40	0.20	63,25±3,28	63,00±4,97	0.91
PT of AC (Nm)	145.57±36.84	112.71±12.20	0.04*	140.50±39.16	117.29±8.92	0.15
PP (W)	240.57±30.57	234.29±25.56	0.68	240.25±43.51	251.43±24.60	0.56
AP (W)	223.86±29.64	211.57±27.28	0.42	218.63±39.37	226.43±20.67	0.65

The asterisks denote significant differences: *– P<0.05; **– P<0.01, W: Watt, PT: peak torque, PT of AC: peak torque of the average curve, PP: peak power, AP: average power

There were no significant differences in any of the quadriceps variables at velocities of 60°·s^{-1} or 240°·s^{-1} between the cyclists' and triathletes' right limbs. Similarly, there was no significant difference in any of the parameters at a velocity of 60°·s^{-1} between the cyclists' and triathletes' left limbs. Additionally, no significant differences in PT angle, PP or AP were observed between cyclists' and triathletes' left limbs at a velocity of 240°·s^{-1}. However, the cyclists' left limb PT of the average curve was significantly higher than that of the triathletes at a velocity of 240°·s^{-1} (Table 3).

Comparison of range of motion

The comparison between cyclists' and triathletes' left and right limbs for the parameter of ROM at a velocity of 60°·s^{-1} revealed no significant differences (*P*<0.40 and *P*<0.25, respectively). However, the triathletes' left and right limb ROM was significantly higher than those of the cyclists' left and right limbs at a velocity of 240°·s^{-1} (*P*<0.00 and *P*<0.00, respectively) (Figure 1).

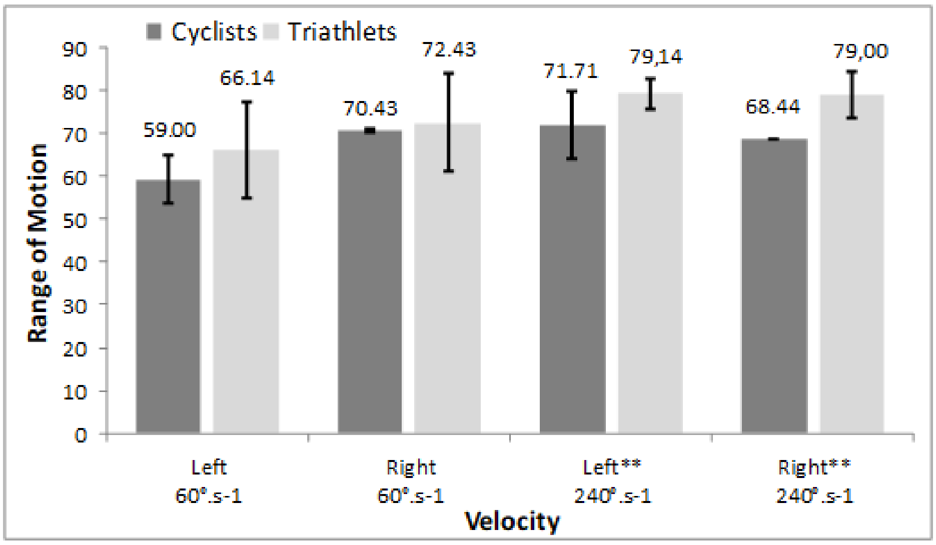

Figure 1. Range of motion (ROM) of left and right legs for cyclists and triathletes.
The asterisks denote significant differences: **– P<0.01.

DISCUSSION

The main findings of this study demonstrated that there was no significant difference in the performance of the right (dominant) quadriceps or hamstring muscles between cyclists and triathletes at velocities of 60°·s^{-1} and 240°·s^{-1}. Additionally, there was no significant difference in the left quadriceps between cyclists and triathletes at velocity of 60°·s^{-1}. When we compared PT, only the hamstring PT at a velocity of 60°·s^{-1} and 240°·s^{-1} and quadriceps PT at a velocity of 240°·s^{-1} of the non-dominant left leg differed between the cyclists and triathletes. However, the differences were due to bilateral strength differences between triathletes' left and right legs in the peak torque. There were no bilateral strength differences between cyclists' left and right legs in peak torque.

The findings of the present study appear to be similar to others reported in the literature. Ullrich and Brueggemann (2008) reported that PT did not differ significantly between groups (cyclists, tennis players, endurance runners and triathletes) in right (dominant) knee flexion or extension. Savelberg and Meijer (2003) also found that the optimum angles of the monoarticulate muscles (i.e., muscles that cross only 1 joint) produced PT at longer lengths in cyclists.

We measured significant differences in the mean left hamstring power results, including peak power and average power (P<0.05), between cyclists and triathletes at a velocity of 240°·s^{-1}. Additionally, the mean PT of the cyclists' average curve was higher than that of triathletes at a velocity of 60°·s^{-1}.

In our study, no significant differences in quadriceps PT angle were observed between cyclists' and triathletes' left and right limbs at velocities of 60°·s^{-1} and 240°·s^{-1}, but a significant difference was observed in hamstring PT angle (P<0.05). We found that cyclists produced isokinetic strength at a larger hamstring PT angle in left limbs at a velocity of 240°·s^{-1} compared with triathletes. By contrast, another study (Brughelli et al. 2010) investigated differences in the optimum PT angle (knee extensors and flexors) and muscle architecture (vastus lateralis) between 9 cyclists and 9 Australian rules football players. They determined that the angles of peak torque of the football players were significantly (P<0.05) greater during knee extension (70.86±3.5 vs. 66.66±5.9°) and smaller during knee flexion (26.26±2.9 vs. 32.36±3.8°) compared with the cyclists. In another research study, Ullrich and Brueggemann (2008) reported that cyclists did not produce PT (quadriceps femoris) at significantly different joint angles compared with tennis players, endurance runners and triathletes.

In this study on H/Q (flexors-extensors) muscle ratios, the dominant (right) limb H/Q muscle ratio between cyclists and triathletes was not significantly different at velocities of 60°·s^{-1} and 240°·s^{-1}, and neither was the left limb H/Q ratio at a velocity of 60°·s^{-1}. In prior studies of H/Q (flexors-extensors) muscle ratios, researchers (Bamac et al., 2008; Brughelli et al., 2010; Thompson, (2020); Rosene et al., 2001; Kurdak, 2005) reported similar results in sports other than cycling and triathlon. The mean left hamstring flexion H/Q muscle ratio (P<0.05) of cyclists was much greater than that of triathletes at a velocity of 60°·s^{-1}. Therefore, the cyclists' left limb presented the largest H/Q muscle ratio. Related research does not support our findings: other authors (Brughelli et al., 2010) reported that there were no significant differences between groups (cyclists and Australian rules football players) regarding PT ratios between quadriceps and hamstrings. A recent comparison (Bamac et al., 2008) noted that the mean H/Q muscle ratios at a velocity of 60°·s^{-1} were similar to each other. They also noted no significant differences between volleyball and basketball players for H/Q muscles ratios at 180°·s^{-1}.

The triathletes' left and right leg ROM values (at a velocity of 240°·s^{-1}) were larger than those of the cyclists (P<0.00). However, there were no significant differences in the ROM values (at a velocity of 60°·s^{-1}) between the triathletes and cyclists. When we analyzed the ROM data (especially left and right limbs at a velocity of 240°·s^{-1}, p<0.00), cyclists produced isokinetic strength at shorter H and Q muscle fiber lengths and a larger PT angle compared with triathletes. The results of Herzog et al., (1991) and Savelberg and Meijer (2003) support our finding. They reported that cyclists produced PT at shorter rectus femoris muscle fiber lengths compared with endurance runners.

In conclusion cyclists produced a higher peak torque than triathletes, although the ROM values of cyclists were lower than those of triathletes. Furthermore, the peak torque angles of cyclists were higher compared with triathletes. Additionally, we found a significant difference in the performance of the left quadriceps and hamstring muscles between cyclists and triathletes at velocities of 60°·s^{-1} and 240°·s^{-1}. However, the differences were due to bilateral strength differences between triathletes' left and right legs. There was no bilateral strength difference between cyclists' left and right legs. Future research needs to investigate this assertion. Our research encourages further study on cyclists and triathletes and more specifically on the relationship of flexors and extensors of the knee. Such research would provide valuable information for sports coaches, athletes and practitioners

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