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ORIGINAL RESEARCH

The investigation of isokinetic knee strength and muscle balance of taekwondo and wrestling athletes

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Abstract. Taekwondo and wrestling are two different Olympic combat sports that need lower extremity strength in different ways. During the training process that lasts for many years, the harmony in the leg muscles may be dissimilar. This study aims to determine (1) the knee extension and flexion strength values of elite taekwondo and wrestling athletes with similar physical and demographic characteristics and (2) the muscle balances formed after long-term taekwondo and wrestling training. This study was conducted with the voluntary participation of 20 elite taekwondo and wrestling athletes (age: 20.4±1.27 years; experience: 10.6±1.98 years; height 176.65±5.86 cm; weight 72.96±6, 96 kg; BMI 23.35±1.47 kg/m^2). Following the determination of the demographic and physical characteristics of the athletes, their isokinetic knee strengths were examined at an angular velocity of 60^0/s and compared between taekwondo and wrestling. Accordingly, the differences between the extension relative and average peak torque strengths of the athletes were significant in favour of the taekwondo players in the extension strength. On the other hand, the hamstring/quadriceps strength ratios of the taekwondo athletes were lower ($p<0.05$). In addition, the differences between the peak torque, flexion relative peak torque and flexion average peak torque of the athletes were not statistically significant ($p>0.05$). The study results showed that taekwondo players have higher extension strength. In the observed groups, it was determined that the muscular asymmetry occurred at different levels because of the adaptation specific to the sport type. Taekwondo trainings allows more balanced hamstring/quadriceps muscle harmony than wrestling. It is recommended to develop training programs in which the flexor muscles are trained against muscular imbalances in wrestling.

Keywords. Muscular balance, isokinetic, knee, taekwondo, wrestling.

Introduction

It is important to safely, accurately, and efficiently practice the combinations required in taekwondo and wrestling techniques, including knee stretching, bending, jumps, turns and slides. These combinations require flexion (FLX) and extension (EXT) of the knee joint. Developing knee FLX and EXT strength in combat sports is vital to effective combat. To date, very few studies have focused on evaluating the effect of taekwondo and wrestling athletes' training on this issue (Martinez Hernandez et al., 2014).

Taekwondo and wrestling are two different Olympic sports branches where competition is exhibited on special mats. In these sports, general strength is crucial, specially the lower extremity strength (Bridge et al., 2014; Do Kim & Pieter, 2020; Hammami et al., 2014; Kurdak et al., 2005). For this reason, isokinetic strength studies with taekwondo and wrestling athletes are vital for establishing strength standards specific to sports, determining the strength production values of athletes, or possible muscle imbalances. Previous studies have shown that knee FLX and EXT strength results measured with isokinetic dynamometers are highly reliable (Brown et al., 2005; Feiring et al., 1990; Hartmann et al., 2009; Jenkins et al., 2015; Maffiuletti et al., 2007; Sole et al., 2007). Therefore, in sports like taekwondo and wrestling where the legs are actively used, isokinetic

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dynamometers are widely preferred for measuring knee flexion and extension strength or quadriceps (Q) and hamstring (H) muscle strength (Coban et al., 2021; Hammami et al., 2013; Harbili et al., 2022; Kang et al., 2021; Tatlici et al., 2021).

Taekwondo kicks are biomechanically performed with an explosive kick toward the target, first with an FLX at the knee, then with an explosive EXT (Diniz et al., 2021; Preuschl et al., 2016). This kinematics of taekwondo enables the determination of EXT and FLX strengths measured by isokinetic dynamometers and Q and H muscle strength under the nature of taekwondo. Similarly, strength is essential in modern wrestling, and thus it requires a high level of athletic performance and technique (Utter et al., 1997). Since a wrestling match requires upper and lower body muscle strength for various techniques, evaluation of these variables can be crucial to determine athletic performance capacity (Horswill, 1992).

The H and Q muscle groups may have different levels of strength according to the characteristics of the sport or the training model exposed (Daneshjoo et al., 2013; Gioftsidou et al., 2006). The fact that these muscle groups show different levels of strength development, or the difference in strength levels among them, negatively affects athletic performance and can even cause serious injuries (Gioftsidou et al., 2006; Impellizzeri et al., 2008).

The ipsilateral (H/Q) ratio reflects the percentage ratio of the peak torque of the agonist and antagonist muscle groups in the same limb (Ermiş et al., 2019). According to most of the study reports, the ipsilateral (H/Q) ratio should be between 50-80% (Calmels et al., 1997; Chena et al., 1991; Kannus, 1988; Orchard et al., 1997; Rosene et al., 2001). It has been previously reported that decreased H/Q ratio causes increased muscle asymmetry, which negatively affects sportive performance (Maly et al., 2018).

The asymmetrical strength or muscle imbalance may occur due to sport-specific factors, although it is associated with various pathological conditions. The strength and muscular balance of the lower extremities can affect taekwondo and wrestling performance because both sports require the lower extremities intensely. Both sports require knee flexion and extension strength, but the muscular asymmetry rate may change due to adaptation to the sports discipline. This poor adaptation may adversely affect their sportive development or general health. However, pursuantly such studies conducted with taekwondo and wrestling athletes are limited. For this reason, studies investigating muscle strength asymmetry specific to sports are vital.

Therefore, in this study, it is aimed to examine the H and Q strengths and muscular balances of elite taekwondo and wrestling athletes. The results of the study may be useful in understanding the adaptation of the muscles of healthy individuals who have been interested in taekwondo and wrestling for a long time, determining the muscle balance, and creating training programs.

Methods

Participants

The study was conducted with the voluntary participation of 20 elite athletes (10 taekwondo, 10 wrestling) who have been training regularly for 10.6±1.98 years and actively participated in national and international competitions. The athletes declared that they did not have any health problems before the training and did not have any injuries or surgical operations related to their lower extremities, especially their knees.

Right before the isokinetic measurements, which are the subject of the study, their physical and demographic characteristics such as height, weight, body mass index, and age were examined. Table 1 shows detailed information about the characteristics of the athletes.

The details of the study were verbalized to all athletes, and they were informed about the possible benefits and risks of the study. After the oral declaration, all athletes were given a written informed consent form prepared following the Declaration of Helsinki, and their consent was obtained. Also, the study was conducted under the ethical principles of the European Convention on Human Rights and the Declaration of Helsinki (ethical principles regarding human experimentation). Besides, this study was approved by the Clinical Research Ethics Committee of Ordu University (Decision No: 2022-200).

Design and Procedures

This study, which examine the isokinetic knee EXT and FLX strength performances of taekwondo and wrestling athletes, determine the H/Q ratios, and assess the differences between branches, was completed in four stages. The stages of the study are shown in Figure 1.

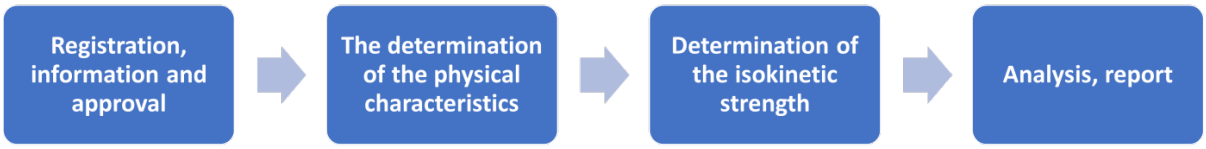

Figure 1. Phases of the research.

The physical and isokinetic measurements were completed in two consecutive days, with 10 athletes (5 taekwondo-5 wrestling) each day. Measurements started at 11:00 every day, and the athletes were allowed to come while they were full, provided that they had eaten two hours before the process.

Determination of demographic and physical measurements

The characteristics of the athletes, such as age, training background, level of success in sports, and health status, were recorded in the information form developed by the researchers. Then, their height and body weights were determined. After obtaining their results, their BMI values were calculated.

Determination of isokinetic strength performance

The isokinetic tests were performed at Ordu University, Sports Sciences Faculty, Sports Sciences Research Laboratory. The isokinetic strength performances of the athletes were examined using the Humac NORM isokinetic dynamometer (CSMI, Stoughton, MA). Earlier in the tests, the dynamometer was calibrated according to company procedures.

The knee isokinetic strengths of the athletes were tested with their dominant (D) extremities. In the isokinetic measurements, their knee EXT and FLX peak torque (PQ_{NM}), relative peak torque (%BW), average power (AP_{watts}) levels, and H/Q ratios (%) were determined.

The accuracy of gravity was calculated for each athlete during the measurements. The torque was determined by calculating the effect of gravity using computer software. Additionally, the concentric/concentric protocol was used in the study. All tests were performed by the same laboratory assistant trained in the Humac NORM test.

Before the measurements, each athlete was allowed to warm up aerobically on an ergometric bicycle at medium speed for approximately 10 minutes. Then, stretching was performed in the H and Q muscles of the lower extremities, and the FLX and EXT movements were performed with the knee joint. After the general warm-up, the isokinetic warm-up was performed. A warm-up set of five repetitions was performed for each joint at a perceived exertion of 50% earlier than the testing. The purpose of the warm-up was to introduce subjects to the isokinetic test sensation and provide a movement-specific exercise for the muscle to be tested (Perry et al., 2004). After warming up, the athletes were allowed to recover for 90 seconds. The laboratory assistant gave verbal encouragement to the athletes during the measurements to motivate them and convince them to show their maximum effort.

The knee EXT and FLX range of motion (ROM) rates of the athletes were determined as 90° (0-90). The isokinetic D-EXT and D-FLX measurements were tested with five repetitions at an angular velocity of 60°/sec.

Statistical Analyses

Earlier than the analysis, the data distribution was examined using the Shapiro-Wilks test for normality, and it was determined that all data showed normal distribution ($p>0.05$). The mean and standard deviations (Mean±SD), 95% confidence intervals (CI), minimum and maximum value ranges (Range) of the variables to be analyzed were determined. The statistical differences between taekwondo and wrestling of isokinetic strength parameters (PQ, %BW and APQ) of the athletes were determined with the One-Way ANOVA, and statistical differences between knee isokinetic EXT_{PQ} and FLX_{PQ} strengths were determined with the Repeated Measures ANOVA. The ipsilateral H/Q ratios of the athletes were calculated with the "$[(H/Q=FLX_{PQ}/EXT_{PQ})*100]$" equation and the %BW force values were calculated by the Humac Norm software with the "(PQ/BW*100)" equation.

Results

After examining the age, experience, height, weight, and BMI values of the taekwondo and wrestling athletes, the PQ, %BW, and APQ parameters of their EXT and FLX strength performances were examined and compared among the dependent variables.

The results indicate that taekwondo and wrestling athletes have similar physical and demographic characteristics. Accordingly, taekwondo and wrestling athletes whose isokinetic strength performances were compared form a homogeneous structure (Table 1).

The results of the EXT stage of the knee isokinetic strength performances of taekwondo and wrestling athletes indicate that the differences between PQ_{Nm} performances were insignificant ($p>0.05$), but the differences between %BW and APQ_{watts} values were significant in favour of taekwondo athletes ($p<0.05$; Table 2).

Table 1
The results of the analysis of the descriptive and physical characteristics of the athletes.

Variables	Groups	n	Mean±SD	%95 CI	Range	F	p
Age (Year)	WRS	10	20.5±1.08	19.73-21.27	19-22	0.118	0.736
	TKD	10	20.3±1.49	19.23-21.37	18-22		
Experience (Year)	WRS	10	10.9±1.66	9.71±12.09	8-13	0.444	0.514
	TKD	10	10.3±2.31	8.65±11.95	7-14		
Height (cm)	WRS	10	174.5±7.44	169.18-179.82	163-185	2.971	0.102
	TKD	10	178.8±2.62	176.93-180.67	174-182		
Weight (kg)	WRS	10	72.79±8.44	66.75-78.83	61-88.4	0.011	0.917
	TKD	10	73.13±5.57	69.15-77.11	66.27-81.8		
BMI (kg/m^2)	WRS	10	23.82±0.99	23.11-24.53	22.14-25.83	2.149	0.16
	TKD	10	22.88±1.76	21.62-24.14	20.01-25.25		

WRS: Wrestling; TKD: Taekwondo; CI: Confidence interval.

Table 2
The results of the analysis of the knee isokinetic strength performances of the athletes for the EXT stage.

Variables	Groups	Mean±SD	%95 CI	Range	F	p
PQ_{Nm}	WRS	219.22±33.65	195.15-243.3	183.07-295	1.930	0.182
	TKD	237.46±24.31	220.07-254.85	204.17-287.1		
%BW	WRS	306.97±22.81	290.65-323.29	265.33-351.23	4.481	0.048*
	TKD	327.95±21.5	312.57-343.33	291.3-351.3		
APQ_{watts}	WRS	119.42±20.86	104.5-134.34	94.5-154.5	6.563	0.020*
	TKD	141.37±17.3	129-153.75	117.17-170.93		

PQ_{Nm}: Peak torque; %BW: Relative peak torque; APQ_{watts}: Average power; WRS: Wrestling; TKD: Taekwondo; CI: Confidence interval; *p<0.05.

Table 3
The results of the analysis of athletes' knee isokinetic strength performances for the FLX stage.

Variables	Groups	Mean±SD	%95 CI	Range	F	p
PQ_{Nm}	WRS	139.33±22.98	122.89-155.77	116.63-194.3	0.152	0.701
	TKD	135.36±22.57	119.22-151.5	93.67-168.83		
%BW	WRS	195.12±18.29	182.04-208.21	174.73-231.37	0.083	0.777
	TKD	192.43±23.38	175.7-209.15	165.63-232.4		
APQ_{watts}	WRS	96.06±16.15	84.51-107.62	76.1-131.03	0.408	0.531
	TKD	100.18±12.47	91.26-109.1	78.83-117.23		

PQ_{Nm}: Peak torque; %BW: Relative peak torque; APQ_{watts}: Average power; WRS: Wrestling; TKD: Taekwondo; CI: Confidence interval.

Table 4
The results of the analysis of athletes' H and Q ratios.

Variable	Groups	Mean±SD	%95 CI	Range	F	p
H/Q (%)	WRS	63.88±5	60.31-67.46	56.47-73.04	5.089	0.037*
	TKD	57.18±7.95	51.5-62.87	40.86-66.61		

WRS: Wrestling; TKD: Taekwondo; CI: Confidence interval; *p<0.05.

The results of the analysis of the knee isokinetic strength performances of taekwondo and wrestling athletes for the FLX stage show that the differences between the variables are insignificant (p>0.05), and that the athletes have similar isokinetic strength performances (Table 3).

When the H/Q ratios of the athletes were examined, it can be indicated that the H/Q ratios of the taekwondo athletes were lower than the H/Q ratios of the wrestling athletes. In addition, the difference between the H/Q ratios of taekwondo and wrestling athletes was found to be statistically significant (p<0.05; Table 4).

Discussion

The aim of this study was to determine the isokinetic knee strength of elite taekwondo and wrestling athletes and to examine their muscular balance. For this purpose, the dominant knee EXT and FLX strengths and agonist and antagonist strength ratios (H/Q) of the athletes at an angular velocity of 60°/sec were determined, and the results were compared between taekwondo and wrestling athletes. The study results are crucial in understanding the isokinetic strength values of the athletes, the characteristics of the lower extremity strength formation of taekwondo and wrestling, and the state of balance in the muscles that adapt to long-term exercises.

In this study, the statistical difference between EXT_{PQ} and FLX_{PQ} strength values of taekwondo and wrestling athletes was insignificant, and they had similar PQ values. However, while the differences between %BW and APQ values were insignificant in FLX strength, they were significant in favour of taekwondo athletes in EXT strength. According to these results, taekwondo athletes have more powerful EXT strengths. In addition, the statistical difference between H/Q ratios (p<0.05) shows that taekwondo athletes have lower H/Q strength ratios. In previous isokinetic studies, it was determined that the knee isokinetic strength of taekwondo (Choi et al., 2021; El-Ashker et al., 2022; Hammami et al., 2013; Harbili et al., 2022; Kang et al., 2021) and wrestling (Çimen Polat et al., 2018; Drid et al., 2009; Hoseini et al., 2022; Kraemer et al., 2001; Tatlici, 2021; Tatlici et al., 2021) athletes supported our research results. This result may be due to the fact that taekwondo explosively trains roundhouse and rotating kicks that require lower extremity FLX and EXT strength. Studies show that taekwondo kicks need strong extensor muscles and strong flexor muscles that support these muscles in order to be highly effective. Rectus femoris activation could predominantly contribute to the powerful taekwondo roundhouse kicks. Moreover, high biceps femoris co-activation could help achieve the high impact force (Thibordee & Prasartwuth, 2014). Therefore, the nature of taekwondo ensures that the knee extensor and flexor muscles of the athletes are strengthened. In addition, the fact that these kicks have to be used frequently explains their balanced muscle development.

Wrestling is one of the sports branches where muscle strength is most needed. Movements such as pulling, pushing and lifting during wrestling exercises cause different physiological requirements for athletes (Horswill, 1992). Tatlici et al. (2021) reported that 8-week wrestling training reduced the H/Q muscle ratio, strengthened the extensor quadriceps muscle, but did not cause a significant change in the strength of the flexor hamstring muscle, and recommended that specific hamstring exercises should be added to the training programs to prevent injuries. Studies have shown that the muscular balance in the lower extremities is related to the general body balance and oxygen utilization capacity, and that a developed muscular balance positively affects these parameters (Heitkamp et al., 2001; Silva et al., 2018). These variables are of vital importance for wrestling and it is known that an athlete with advanced motor features is advantageous during the wrestling match (Kuzmina et al., 2017; Moran-Navarro et al., 2015; Murlasits, 2004). Without any special strength training, pure wrestling training does not provide a significant improvement on the flexor muscles of the athletes (Tatlici et al., 2021). However, we believe that the advantages of an improved muscle balance during the competition will also affect the overall wrestling performance. For this

reason, wrestlers must give due importance to the extensor and flexor muscles in the knee joints and take care to keep the H/Q ratios at optimum levels.

The biggest limitation of this study is that there is no control group. Future studies should be strengthened with the control group and studies investigating different sports branches should be done. Besides, it is known that different wrestling styles have different physical and physiological demands (Basar et al., 2014). For this reason, the demands and needs of muscle balance in different wrestling styles should also be investigated in future studies.

Conclusion

An elite taekwondo athlete can kick from many different angles and directions. Straight and spinning kicks at the trunk and head can be effective as a result of the active and explosive power of all leg muscles. Taekwondo training for many years ensures that the hamstring and quadriceps muscle groups work together and develop in a balanced way. However, in a combat sport such as wrestling that does not require kicking, the task of the legs is more about providing resistance and lifting the opponent, which is apparent that the extensor muscles of the legs work more. Although the results obtained show that the H and Q strength ratios of wrestling athletes are within acceptable limits, it is obvious that the exercises in which the flexor muscles are more activated and worked will bring the muscular balance to optimum levels. As a result, taekwondo, by its nature, can develop the lower extremity muscles of the athletes in a balanced way. In sports such as wrestling, where strength is crucial, yet the flexor muscles are less active, supplementary strength training may be required to prevent injuries and muscular imbalance.

Author Contributions

Study Design: CÖ; Data Collection: CÖ; Statistical Analysis: CÖ; Manuscript Preparation: CÖ.

Ethical Approval

The study was approved by the Ordu University of Clinical Research Ethics Committee (2022/200) and it was carried out in accordance with the Code of Ethics of the World Medical Association also known as a declaration of Helsinki.

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Conflict of Interest

No funding was received for this research. There are no conflicts of interest with the authors related to this research.

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