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THE RELATIONSHIP BETWEEN CONCENTRIC AND ECCENTRIC KNEE STRENGTH AND COMPETITION PERFORMANCE IN ELITE SHORT TRACK SPEED SKATERS

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ABSTRACT

The aim of the study is to examine the relationship between the concentric and eccentric strengths of the knee flexor and extensor muscles and competition performance in elite short track speed skating athletes. Nine elite male speed skating athletes between the ages of 18-22 were included in the study. In order to determine the competition performances of the athletes, 500 m, 1000 m and 1500 m times were taken. Height and body weight measurements were taken from the athletes on the first day of laboratory tests. ISOMED 2000 isokinetic strength device was used to determine the concentric and eccentric muscle strength of the athletes. Isokinetic strength measurements were performed in concentric/concentric and eccentric/eccentric modes for 8 repetitions at a speed of 60o/sec. Measurements were made in the flexion/extension movement of the knee joint. Isokinetic measurements were taken on two separate days, and distance measurements were taken on three separate days. SPSS v25 statistical program was used to analyze the data obtained. Pearson Correlation analysis was performed to reveal the relationship between variables. In statistical analysis, the significance level was determined as 0.05. As a result of the research, it was determined that there is a statistically moderately significant relationship between the concentric and eccentric strength of the knee flexor and extensor muscles and the 500 m distance performance. However, no significant relationship was found with 1000 m and 1500 m distance performances.

Keywords: Athlete, isokinetic, lower extremity, muscle contraction

INTRODUCTION

Speed skating is an Olympic ice sport that is divided into two categories: short track and long track (ISU, 2022). In this sport, 4 or 5 athletes compete simultaneously on an oval track (Haug, Drinkwater, et al., 2015). Short track speed skating includes competitions at distances of 500 meters (4.5 laps), 1000 meters (9 laps), and 1500 meters (13.5 laps). In international competitions, elite athletes typically achieve times ranging from 40 to 44 seconds for the 500 meters, 80 to 90 seconds for the 1000 meters, and 125 to 140 seconds for the 1500 meters (ISU, 2022). The races take place on an oval track with a circumference of 111.12 meters, and they are conducted counterclockwise. Elite athletes cover an estimated average distance of 116-120 meters during the competition and can reach speeds exceeding 40 km/h. Speed skating is primarily characterized by locomotor movements, making physical and physiological parameters crucial for achieving high performance (Felser, Behrens, Fischer, Baeumler, et al., 2016). When evaluated in terms of energy systems, short track speed skating is predominantly reliant on anaerobic energy systems (Maw et al., 2006). As the distances increase, aerobic systems become more active. For short track speed skaters, factors such as strength, speed, speed endurance, balance, coordination, and race tactics play a significant role in determining performance (Behrens et al., 2010; Felser, Behrens, Fischer, Baeumler, et al., 2016). The foundation for producing high power and performing at high speeds lies in the strength parameter (Behrens et al., 2010). Locomotor skills inherently involve concentric and eccentric muscle contractions in a specific sequence. In ice sports, in addition to balance and postural control, muscles need to generate high levels of force during both phases of contraction for high performance. Moreover, speed skating has a physiological structure that reduces oxygen levels and increases lactate levels in lower extremity muscles, especially the quadriceps muscle (Richard et al., 2018). One of the most critical elements for athletic performance is the mechanism of rapidly generating high levels of muscle strength. In short track speed skating, this factor holds significant importance as it contributes to the skater's battle against ice and air resistance (Liebermann et al., 2002).

When the literature related to speed skating is reviewed, various studies assessing different physical, physiological, and technical-tactical parameters can be found. Fereshtian et al. (2017) conducted research on female speed skaters, examining the effects of high-intensity interval training (HIIT) on certain physiological characteristics and performance. The study concluded that HIIT workouts positively impacted VO2max and competition performance. In another study, Stangier et al. (2016) investigated the effects of running and cycling-based training on maximal speed and endurance in speed skaters. The research found similar results for both training methods. Hofman et al. (2017) conducted a study to determine whether the Wingate test protocol could serve as an indicator of performance in the 1500 meters. The study suggested that the Wingate test could provide insights into 1500-meter performance. Noordhof et al. (2017) evaluated the historical development of energy expenditure and VO2max in speed skating athletes through their research. Han et al. (2022) assessed the predictability of physiological parameters in speed skating athletes under hypoxic conditions. Felser, Behrens, Fischer, Heise, et al. (2016) conducted a study to uncover the relationship between competition performance and strength quality in young speed skating athletes. In another study, the same research group explored the neuromuscular activations of speed skating athletes (Felser, Behrens, Fischer, Baeumler, et al., 2016). Haug, Drinkwater, et al. (2015) investigated the impact of 500-meter start performance of speed skating athletes on competition results. In a different study, Haug, Spratford, et al. (2015) compared the kinetic and kinematic differences in joint motion during vertical jumps between elite speed skaters and weightlifters. Xia (2012) conducted a comparative analysis of the muscular systems of short and long-distance speed skating athletes. Brunelle et al. (2015) examined the effects of yoga practices on the postural control of short track speed skating athletes. Hettinga et al. (2016) revealed differences in fatigue, recovery, and muscle oxygenation levels between short and long track speed skating athletes. Purevsuren et al. (2018) used a motion analysis model to investigate the effects of knee joint forces and moments on sports performance. These studies provide valuable insights into various aspects of speed skating, including training methods, physiological responses, performance indicators, and biomechanical considerations.

When the literature on speed skating is reviewed, it has been determined that although various studies have been conducted on athletes, there is a lack of research that specifically examines the relationship between isokinetic muscle strengths and different types of contractions and sports performance. The knee and hip joint strengths of speed skating athletes are crucial for athletic performance. Therefore, establishing the relationship between knee strengths and sports performance can contribute to training program design of athletes, periodization planning, strength training methods, and preferences. In this context, the primary aim of the research is to investigate the relationship between concentric and eccentric knee joint strengths and the sports performance (500m; 1000m; 1500m) of elite short track speed skating athletes.

METHOD

Participants

The sample group of the study consisted of nine male short track speed skating athletes aged between 18-22 years. When selecting the athletes for the research, criteria such as being a national athlete, being right-handed, and regularly training were considered. Additionally, exclusion criteria included not having undergone any surgical operations in the last six months, being left-handed, and having experienced a sports injury. The sample size was determined using GPower analysis. According to the GPower analysis, 10 athletes were deemed sufficient for the research. However, due to one of the athletes experiencing a lower extremity injury during the measurement period, the research was completed with a total of 9 participants. All participating athletes were informed about the measurement processes and tests. The research was conducted following the principles outlined in the Helsinki Declaration, and ethical approval was obtained from the Atatürk University Faculty of Sports Sciences Ethics Committee for the research. This article was presented as an oral presentation at ERPA International Congresses on Education 2023.

Research Design

All participating athletes were tested under the same conditions. Participants visited the laboratory on two separate days and participated in tests on the ice skating rink on three different days. On the first day of laboratory measurements, height and weight measurements were taken initially. Then, a warm-up procedure, as determined by the researcher, was conducted, followed by concentric strength tests on the isokinetic strength device. On the second day of laboratory measurements, after completing the warm-up procedure, eccentric strength tests were carried out. After the completion of laboratory measurements, a 48-hour rest period was observed, and measurements related to competition performance on the ice skating rink were conducted. In the tests to be conducted on the ice skating rink, on the first day, performance of athletes in the 500 meters (4.5 laps) event was conducted according to competition rules. On the second day, the 1000 meters (9 laps) event was held, and on the third day, the 1500 meters (13.5 laps) event was performed. Prior to each measurement, athletes were required to warm up specifically for their sport. Athletes were instructed not to engage in training and not to consume caffeinated foods on the day before both laboratory and ice rink measurements. Additionally, athletes were advised to refrain from eating at least three hours before the measurements.

Warm-Up Procedure

All participants included in the research were instructed to perform both general and specific warm-up exercises before isokinetic muscle strength measurements. A 10-minute general warm-up and a 15-minute specific warm-up were conducted. The general warm-up consisted of 5 minutes of low-intensity running, followed by 5 minutes of cycling. After completing the general warm-up, athletes performed a specific warm-up targeting their knee flexors and extensors. The first part of the specific warm-up included static stretching exercises, while the second part involved dynamic stretching and stretching movements. Following the general and specific warm-ups, athletes completed the warm-up procedure by performing seated leg extension exercises (leg extension) in a seated position.

Anthropometric Measurements

To determine the descriptive characteristics of the athletes, information regarding age, sports age, history of surgical operations, and history of sports injuries was collected through a personal information form. Subsequently, measurements of height and body weight were taken. Height measurements were obtained using a wall-mounted stadiometer 282 device (Seca GmBH & Co Kg, Hamburg, Germany) and recorded in centimeters. Body weight and body fat measurements were performed using a Tanita TBF 300 body composition device (TANITA, Middlesex, UK). The body mass index (BMI) of the athletes was calculated using the formula "body weight/height2.

Isokinetic Strength Measurements

The ISOMED 2000 isokinetic strength device (IsoMed 2000, D&R Ferstl, Hemnau, Germany) was used to determine the concentric and eccentric strengths of the knee flexor and extensor muscles. Isokinetic strength measurements were conducted on two separate days, and a warm-up procedure was applied before each measurement. After completing the warm-up, the device settings were adjusted. The dynamometer axis of the device was set to 90^o to the ground, the dynamometer direction was set to 0^o, the seat direction was set to 90^o to the ground, and the seat inclination was set to a range of 70-85^o. After making these adjustments, the participants were asked to sit in the device. To ensure the isolation of movement during measurements, bodies of participants were secured using apparatus and belts at the shoulders and waist. Subsequently, the leg to be measured was fastened with a belt near the knee joint of the quadriceps muscle. After completing the securing process, the height and direction of the dynamometer in the sagittal plane, which served as the reference point for the dynamometer's rotation axis, were adjusted. Once the adjustments were completed, the dynamometer arm was secured onto the tibia bone to allow free movement of the foot. Gravity calibration of the device was performed before all measurements. The starting point for knee flexion/extension measurements was selected as the full extension position. Isokinetic knee strength measurements of the participants were performed at an angular velocity of 60^o/s for 10 repetitions. A 180-second rest period was given between measurements. During the measurements, verbal encouragements were provided by the researcher to motivate the athletes. All measurements were automatically recorded within the device software.

Determination of Performance Durations

To determine competition performances of the athletes, times for the 500m, 1000m, and 1500m distances were recorded. Athletes participated in the measurements using valid materials in accordance with competition rules. Athletes completed each distance on different days with a 24-hour rest period in between. All distances were performed individually at maximal performance. Prior to all distance performances, athletes were instructed to warm up specifically for their sport (on the track and on ice), and they were measured when ready. Times were measured using Microgate brand high-precision photocells. The obtained times were automatically recorded in seconds.

Statistical Analysis

The SPSS v25 statistical program was used for the analysis of the data obtained from the research. Shapiro-Wilk tests were conducted to assess the normality of the data. It was determined that the kurtosis and skewness values were within the range of -2 to +2 (George, 2011). As a result of the normality tests, it was concluded that the data exhibited a normal distribution ($p>0.05$). All data are presented as mean and standard deviation. The relationships between variables were determined using Pearson correlation analysis. A significance level of 0.05 was adopted for all statistical evaluations.

FINDINGS

In this section, the data obtained from the research has been presented in tables. The tables include means, standard deviations, and statistical data.

Table 1. Descriptive Characteristics of Participants

Variable	n	Min.	Max.	X̄ ± SD.
Age (Year)	9	18.00	22.00	19.33±1.58
Sport Age (Year)	9	6.00	10.00	8.00±2.00
Body Weight (kg)	9	56.00	82.00	68.44±7.81
Height (cm)	9	171.00	185.00	178.00±2.45
Body Mass Index (kg/m²)	9	18.10	22.45	20.15±1.85
Body Fat (%)	9	7.50	12.00	9.75±1.55

Table 1 shows the descriptive characteristics of the participants included in the study. The participants in the study were found to have the following average characteristics: age, 19.33 ± 1.58 years; years of sports experience, 8.00 ± 2.00 years; body weight, 68.44 ± 7.81 kg; height, 178.00 ± 2.45 cm; body mass index (BMI), 20.15 ± 1.85; and body fat percentage, 9.75 ± 1.55%.

Table 2. Performance Times of Participants

	Distance	n	Min.	Max.	X̄ ± SD.
Performance Times (sec)	***500 m***	9	41.21	43.90	42.70±0.98
	1000 m	9	83.35	90.35	87.35±2.39
	1500 m	9	132.51	150.14	140.22±6.52

Table 2 shows the average performance times of the participants included in the study for short track speed skating at 500 m, 1000 m, and 1500 m distances. The performance times were found to be as follows: 500 m distance, 42.70 ± 0.98 seconds; 1000 m distance, 87.35 ± 2.39 seconds; and 1500 m distance, 140.22 ± 6.52 seconds.

Table 3. Peak Torque Values of Knee Flexor/Extensor Muscles in Concentric and Eccentric Contractions

Variables	Muscles	Concentric Contraction				Eccentric Contraction		
		n	Min.	Max.	X̄ ± SD.	Min.	Max.	X̄ ± SD.
Peak Torque (nm)	***Right Flexor Muscles***	9	98.40	147.60	126.07±18.59	100.60	180.10	142.87±29.79
	Left Flexor Muscles	9	90.90	154.30	123.48±21.89	86.40	159.10	134.77±23.70
	Right Extensor Muscles	9	176.80	296.40	242.24±34.78	171.90	384.10	264.14±71.60
	Left Extensor Muscles	9	144.90	279.10	225.15±42.45	158.40	410.80	254.81±76.17
Relative Peak Torque (nm/kg)	***Right Flexor Muscles***	9	1.57	2.17	1.84±0.21	1.48	2.79	2.10±0.46
	Left Flexor Muscles	9	1.47	2.04	1.79±0.18	1.39	2.68	1.98±0.37
	Right Extensor Muscles	9	2.85	4.17	3.55±0.49	2.26	5.65	3.88±1.05
	Left Extensor Muscles	9	2.34	4.10	3.29±0.57	2.08	6.04	3.75±1.14

Table 3 presents the peak torque and relative peak torque values of the knee flexor and extensor muscles of the participants bilaterally. The peak torque values for the right flexor and extensor muscles of the participants were found to be 142.87 ± 29.79 nm and 264.14 ± 71.60 nm, respectively, while the peak torque values for the left flexor and extensor muscles were found to be 134.77 ± 23.70 nm and 254.81 ± 76.17 nm, respectively. Regarding the relative peak torque values, it was determined that the right flexor and extensor muscles had relative peak torque values of 2.10 ± 0.46 nm/kg and 3.88 ± 1.05 nm/kg, respectively. On the other hand, the left flexor and extensor muscles had relative peak torque values of 1.98 ± 0.37 nm/kg and 3.75 ± 1.14 nm/kg, respectively.

Table 4. Relationship Between Performance Times and Concentric/Eccentric Strength of Knee Flexor/Extensor Muscles

Contraction Type & Variable	Muscles		500 m (sec)	1000 m (sec)	1500 m (sec)
Concentric Peak Torque (nm)	*Right Flexor Muscles*	r	-.701	-.513	-.280
		p	**.035***	.158	.465
	Left Flexor Muscles	r	-.678	-.378	-.129
		p	**.045***	.315	.742
	Right Extensor Muscles	r	-.750	-.401	-.308
		p	**.020***	.284	.420
	Left Extensor Muscles	r	-.646	-.333	-.258
		p	**.049***	.381	.503
Eccentric Peak Torque (nm)	*Right Flexor Muscles*	r	-.806	-.496	-.298
		p	**.009****	.175	.435
	Left Flexor Muscles	r	-.630	-.416	-.280
		p	**.045***	.265	.465
	Right Extensor Muscles	r	-.815	-.458	-.338
		p	**.007****	.215	.374
	Left Extensor Muscles	r	-.663	-.365	-.290
		p	**.048***	.335	.448

***p<0.05, **p<0.01**

Table 4 shows the relationship between 500m, 1000m, and 1500m race times and the concentric and eccentric peak torque values. Statistical analysis revealed a negative relationship between concentric and eccentric peak torque values and the 500m race performance time ($p<0.05$). However, there was no statistically significant relationship between the performance times for the 1000m and 1500m races and the concentric and eccentric peak torque values ($p>0.05$). It can be concluded that as the concentric and eccentric peak torque values of speed skaters increase, there is a decrease in their performance in the 500m race.

CONCLUSION and DISCUSSION

The research aimed to investigate the relationship between concentric and eccentric knee joint muscle strengths and competition performances in short track speed skating athletes, as well as to reveal the concentric and eccentric muscle strength profiles of the knee joint. The results of the study showed that the peak torque values produced by athletes during concentric contractions were lower than those produced during eccentric contractions for both flexor and extensor muscles. Similar results were observed in the relative peak torque values. Furthermore, the study found a statistically significant negative relationship between knee joint concentric and eccentric strength and the 500m race performance of the participants. As concentric and eccentric knee extensor and flexor muscle strengths of the athletes increased, their performance times in the 500m race decreased. However, there was no statistically significant relationship between 1000m and 1500m race performances and concentric and eccentric peak torque values.

Concentric and eccentric contractions are different both physiologically and functionally (Ruas et al., 2022). Concentric contractions have the ability to overcome maximum resistances, whereas eccentric contractions allow the muscle to work at supramaximal loads (Bompa & Buzzichelli, 2019). In a study by Blazevich et al. (2007), the effects of knee extensor muscle training performed concentrically and eccentrically on muscle hypertrophy, length, and force production mechanisms were examined. The research concluded that the eccentric contraction group achieved greater hypertrophy and muscle strength in the quadriceps muscle. Another study by Maeo et al. (2018) investigated the neuromuscular adaptations to training involving concentric and eccentric contractions and found that training involving eccentric contractions resulted in greater neuromuscular adaptations, total work, and relative work capacity in the muscles. Liebermann et al. (2002) conducted a study to investigate whether lower extremity strength is an indicator of short track speed skating performance. The study concluded that lower extremity strength was an important indicator for short track speed skating performance, and as lower extremity strength increased, performance times decreased. Similarly, Wang (2011) examined the relationship between lower extremity strength characteristics and 500m short track speed skating performance and found a significant relationship between lower extremity strength and performance. The results of the present study are consistent with these findings. In another study, Xia (2012) compared the strength of the flexor and extensor muscles of short track speed skaters at low isokinetic speeds and reported that the relative peak torque values (flexor right 1.68 nm; left 1.66 nm; extensor right 3.48 nm; left 3.44 nm) of short track skaters were lower than those of long track skaters. The current study's participants also had lower relative peak torque values for both flexor and extensor muscles in both the right and left sides. Haug, Drinkwater, et al. (2015) investigated the relationship between start performance and race performance in short track speed skating and found that start performance significantly affected race performance. They emphasized that one of the key factors influencing start performance was the force generated by the lower extremity muscles and that an increase in lower extremity strength had a positive impact on start performance and race performance. These findings align with the results of the current study. Bullock et al. (2008) conducted an analysis of the performance of elite short track speed skaters in 500m, 1000m, and 1500m distances. They found that short track skaters required significantly more muscle strength for the 500m distance compared to the 1000m and 1500m distances. They reported that there were no significant differences in lap times between the 1000m and 1500m distances, but the lap times for the 500m distance were significantly lower than those of the other distances. van der Kruk et al. (2018) investigated the effect of propulsion force during short track speed skating performance and found that race performance was influenced by propulsive force. They also found that as peak force outputs of athletes increased, their performances improved. Overall, the results of this study are consistent with the findings of previous research in the literature. Strength is crucial for short track speed skating performance, especially in short-distance races characterized by high speed and explosiveness. The need for high strength and power mechanisms is essential for achieving high speed and explosiveness, which are necessary for success in short track speed skating, particularly in the 500m race.

SUGGESTIONS

Taking into consideration the research results, especially for short track speed skaters, particularly those competing in the 500 meters event, incorporating both concentric (positive) and eccentric (negative) strength exercises into their strength training programs can have a positive impact on their performance. When athletes perform on the ice, analyzing their body kinetics and kinematics can reveal the time spent during concentric and eccentric phases, providing valuable insights for optimizing their training programs. In light of the research findings, it is recommended that short track speed skating athletes, particularly those specializing in the 500 meters event, include both concentric and eccentric strength exercises in their strength training programs. Analyzing body kinetics and kinematics during on-ice performance can help identify the durations of concentric and eccentric phases, contributing to improved training specificity and overall performance enhancement.

ETHICAL TEXT

This article adheres to journal writing standards, publication principles, research and publication ethics, and journal ethical guidelines. The responsibility for any potential violations related to the article lies with the author(s). The research was conducted following the principles outlined in the Helsinki Declaration, and Ethics committee permission for the article was received by Atatürk University Sports Sciences Ethics Committee with the decision numbered 2023/8-135 dated 21.06.2023.

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