

Relationship between Morphometric features and Isokinetic Strength Performance in Elite Modern Pentathlon Athletes

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Abstract

This study was conducted to investigate the relationship between isokinetic strength and some morphometric characteristics in elite level modern pentathlon athletes. Experimental design from quantitative research methods was used in the study. In the first stage, 22 pentathlon athletes who competed individually and participated in elite level competitions participated in the study. However, 3 athletes were excluded from the study for various reasons. As a result, 19 modern pentathlon athletes participated. In the study, tape measure and isokinetic strength device (Isomed 2000®, Ferstl, Germany) were used as data collection tools. The muscle strengths of the athletes at angular velocities of 60°/sec and 180°/sec were evaluated with the isokinetic device, and the waist, hip, thigh and calf circumferences, lower leg, upper leg lengths and shoe sizes of the athletes were evaluated with the tape measure. The results of the study showed that there was a positive correlation between muscle strength measured at both 60°/sec angular velocity and 180°/sec angular velocity and waist circumference, upper leg length, lower leg length and shoe size ($p<0.05$), while there was no significant correlation between muscle strength measured at both 60°/sec angular velocity and 180°/sec angular velocity and hip circumference, thigh circumference and calf circumference ($p>0.05$). As a result, it was determined that there were relationships between anthropometric variables (waist circumference, upper leg length, lower leg length and shoe size) and knee flexion and extension strength.

Keywords: Modern Pentathlon, Isokinetic Strength, Morphometry, Sport.

Introduction

Modern pentathlon consists of five different branches: fencing, swimming, horse riding, shooting and athletics. Pentathlon athletes compete individually in one day. All the degrees obtained by the athletes in a day are converted into points and the rankings of the athletes are determined (Lee et al., 2013). Modern pentathlon is not only a popular sport branch today, but also an Olympic sport branch. Pentathlon sport was first included in the Olympic Games in 1912. It has been in the Olympic Games since then. The fact that it has been in the Olympic Games for more than a hundred years makes this sport popular and requires athletes to have versatile physical skills for success. In addition to technical skills, athletes need to develop skills such as muscular endurance and strength, speed and coordination in a balanced way in order to be successful (Le Meur et al., 2010).

In modern pentathlon, the extremity that athletes use most actively in the five branches is undoubtedly the lower extremity. For this reason, the strength and power of the lower extremity has an important place in modern pentathlon (Chirico et al., 2019). In studies conducted on modern pentathletes, it has been stated that lower extremity strength and power are among the strongest determinants of success in modern pentathlon, especially in fencing, swimming and throwing-running (Ko et al., 2021). In addition, the recent regulatory changes made by the International Modern Pentathlon Association have further increased the importance of the lower extremity in modern pentathlon (Qiao et al., 2022). The regulation changes have reduced the laser-run distance of the athletes in the race format from 4x800 meters to 5x600 meters in the new regulation. Again, the previous use of a 50-meter long lane in swimming has been changed to a 25-meter short lane with the new regulation (UIPM, 2022). These regulatory changes have made it compulsory for athletes to have high lower extremity strength and power at short distances, which has led both coaches and athletes to focus more on lower extremity training in the training periodization (Berryman et al., 2018).

In addition to lower extremity muscle strength in modern pentathlon, the anatomical features of athletes play an important role in lower extremity strength. In this context, it has been stated in various studies that muscle circumference measurements, especially thigh and calf (lower and upper extremity circumference), are effective on maximal force and explosive force, and it has been stated that there are significant relationships between lower extremity muscle strength and lower extremity circumference measurements (Narici & Maffulli, 2010). Especially in multi-sport branches such as pentathlon, it has been reported that the circumference and length of the lower extremities of athletes are positively correlated with force production and force capacity. Nowadays, it is said in various studies that the integration of muscle strength with endurance in running and swimming is a determining factor in terms of performance (Van Praagh & Dore, 2002). Although it is important to develop the lower extremity, excessive muscle mass can cause performance losses such as speed and clumsiness in these five branches. As a matter of fact, excessive muscle mass causes the athlete's body to carry more weight. When we look at today's Olympic athletes, it is seen that most of them have enough muscle mass and do not have excess muscle mass like fitness athletes.

When all these situations are evaluated, it is aimed to evaluate the muscle strength of the athletes at 60°/sec and 180°/sec angular velocity and to examine the relationship between these muscle strengths and the lower extremity circumference measurements of the athletes. In this context, our hypothesis is that there may be a linear relationship between muscle strength and lower extremity circumference measurements.

Material and Method

Ethics committee permission

Ethical approval was obtained for this research from Çanakkale Onsekiz Mart University, Health Sciences Ethics Committee, with the decision number 2025-YÖNP-0119, dated 25.06.2025 and numbered 01/14.

Research Model and Participants

The research was conducted using an experimental design from quantitative research methods. The sample selection in the research was made using convenience sampling. Convenient sampling is when a person conducts research on a sample that is easily accessible. The sample size for the study was made with G*Power (v3.1.9.7). Considering the 5% significance level and 80% statistical power ($1-13 = 0.80$) criteria for one-way correlation analysis, it was determined that at least 20 participants would be sufficient. In this context, 22 pentathlon athletes who competed individually and participated in elite level competitions participated in the study. While 11 of the participating athletes were male pentathlon athletes, 11 were female pentathlon athletes. However, 2 athletes (female) who were in situations that would cause confounding factors such as smoking, alcohol, supplements and acupuncture before starting the study were not included in the study and 1 athlete (male) was not included in the study because he voluntarily left the study. Finally, 19 athletes, 10 male pentathlon athletes and 9 female pentathlon athletes, participated in the study. The physical characteristics of the athletes participating in the study are given in Table 1. The average age of the participating pentathlon athletes was 20.78 ± 2.78 . Lower extremity isokinetic strength, lower body circumference and diameter measurements were taken from the athletes participating in the study.

Table 1. Distribution of physical characteristics of elite level modern pentathlon athletes participating in the study.

	Min.	Max.	X	Sd.
Height (cm)	157.00	183.00	168.81	7.60
Body Weight (kg)	48.00	72.00	59.61	7.27
Body Mass Index (BMI) (kg/m ²)	18.52	24.39	20.89	1.51

Data Collection

Isokinetic Strength Measurement: Isokinetic strength was measured with Isomed 2000® isokinetic dynamometer (Ferstl, Germany) in the physiology laboratory. The measurement was performed by expert sports scientists. Before the measurement, the athletes were asked to warm up on the bicycle ergometer for 10 minutes. After warming up, the muscle strength of the athletes was measured in the sitting position. The expert sports scientist had each athlete perform three repetitions before starting the test. The athletes were verbally motivated during the measurements. Muscle strength of the athletes was evaluated concentrically (dominant foot) at angular velocities of 60°/sec and 180°/sec. Peak Torque (PT), Peak Torque/weight (PT/W) values of the athletes at 60°/sec and 180°/sec angular velocities were recorded from the isokinetic strength device (Nizam & Punduk, 2025).

Body circumference and length measurements: Waist circumference measurements were taken with the athlete standing, feet shoulder-width apart and in a comfortable position. The measurement was taken with a tape measure at the midpoint between the lowest rib and the hip bone (iliac crest), usually at the level of the belly button (Tamer, 1995). Hip circumference was measured by passing a tape measure through the widest part of the hip

(maximum point of the gluteal prominence) while the athlete was standing in an upright position. The tape measure was positioned parallel to the ground and was in contact with the skin (Tamer, 1995). Thigh circumference was measured by passing the tape measure through the widest part of the thigh (usually a few cm below the gluteal fold) with the athlete standing upright. Care was taken to ensure that the muscles were relaxed during the measurement (Tamer, 1995). Calf circumference was measured with the athlete in standing position. The tape measure was passed through the widest part of the calf muscle (gastrocnemius) (Tamer, 1995). Upper leg length was measured with a tape measure from the upper edge of the patella (kneecap) to the inguinal ligament (groin area) while the athlete was lying down (Tamer, 1995). Lower leg length was measured by measuring the distance between the tibial plateau (below the knee) and medial malleolus (inner ankle prominence). The athlete was measured in the supine position with the legs straight and parallel (Tamer, 1995).

Data Analysis

SPSS 25 program was used to analyze the data obtained from the study. For the data, normality analysis was evaluated according to skewness and kurtosis values and it was determined that the data showed normal distribution. While descriptive statistics were used for descriptive data, correlations analysis was used to analyze the data between isokinetic data and circumference measurements. The significance value for this study was determined as $p < 0.05$.

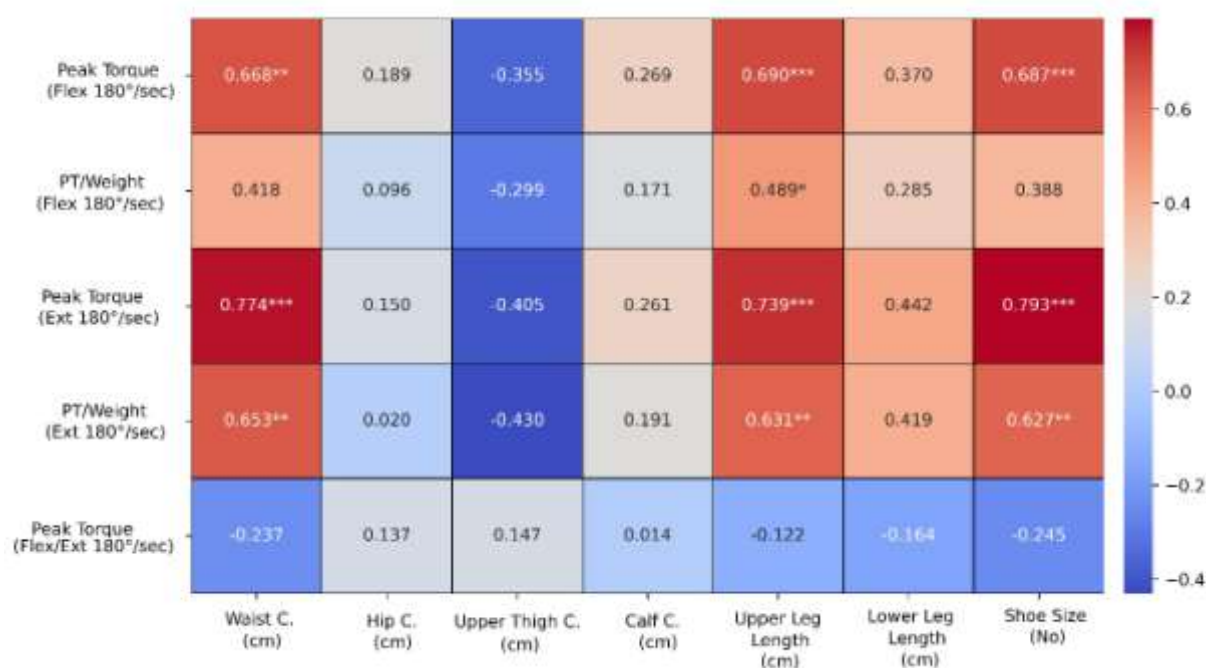
Findings

Table 2. Distribution of dominant foot isokinetic strength data of the pentathlon athletes participating in the study.

	Min.	Max.	X	Sd.
Peak Torque (Flex 60°/sec)	47.40	116.40	88.28	21.29
Peak Torque/weight (Flex 60°/sec)	0.99	1.79	1.44	0.23
Peak Torque (Ext 60°/sec)	94.30	224.40	166.50	37.74
Peak Torque/weight (Ext 60°/sec)	1.78	3.36	2.73	0.42
Peak Torque (Flex/Ext 60°/sec)	40.10	84.10	53.72	10.72
Peak Torque (Flex 180°/sec)	45.90	113.80	76.08	20.95
Peak Torque/weight (Flex 180°/sec)	0.94	1.63	1.24	0.23
Peak Torque (Ext 180°/sec)	86.40	224.40	133.56	39.24
Peak Torque/weight (Ext 180°/sec)	1.63	3.21	2.16	0.38
Peak Torque (Flex/Ext 180°/sec)	46.00	75.10	57.58	8.40
Waist Circumference (cm)	77.00	92.00	83.73	5.78
Hip Circumference (cm)	87.00	94.00	90.57	1.86
Upper Thigh Circumference (cm)	49.00	59.00	53.68	2.62
Calf Circumference (cm)	35.00	39.00	36.57	1.21
Upper Leg Length (cm)	46.00	54.00	49.36	2.69
Lower Leg Length (cm)	40.00	48.00	42.78	2.29
Shoe Size (Number)	39.00	46.00	41.63	2.62

*Flex: Flexion, Ext: Extension

Table 2 shows that the mean Peak Torque (Flex 60°/sec) of the pentathlon athletes who participated in the study was 88.28 ± 21.29 mn, and the mean Peak Torque/weight (Flex 60°/sec) was 1.44 ± 0.23 , Peak Torque (Ext 60°/sec) was 166.50 ± 37.74 nm, Peak Torque/weight (Ext 60°/sec) was 2.73 ± 0.42 , Peak Torque (Flex/Ext 60°/sec) was 53.71 ± 10.72 , Peak Torque (Flex 180°/sec) was 76.08 ± 20.95 nm, Peak Torque/weight (Flex 180°/sec) was 1.24 ± 0.23 , Peak Torque (Ext 180°/sec) was 133.56 ± 39.24 nm, Peak Torque/weight (Ext 180°/sec) averages were 2.1 ± 0.38 , Peak Torque (Flex/Ext 180°/sec) averages were 57.58 ± 8.40 , and the mean waist circumference of the pentathlon athletes participating in the study was 82.73 ± 5.78 cm, the mean hip circumference was 90.57 ± 1.86 cm, the mean thigh circumference was 53.68 ± 2.62 cm, the mean calf circumference was 36.57 ± 1.21 cm, the mean upper leg vertical length was 49.36 ± 2.69 cm, the mean lower leg vertical length was 42.78 ± 2.29 cm and the mean shoe size of the athletes was 41.63 ± 2.62 .

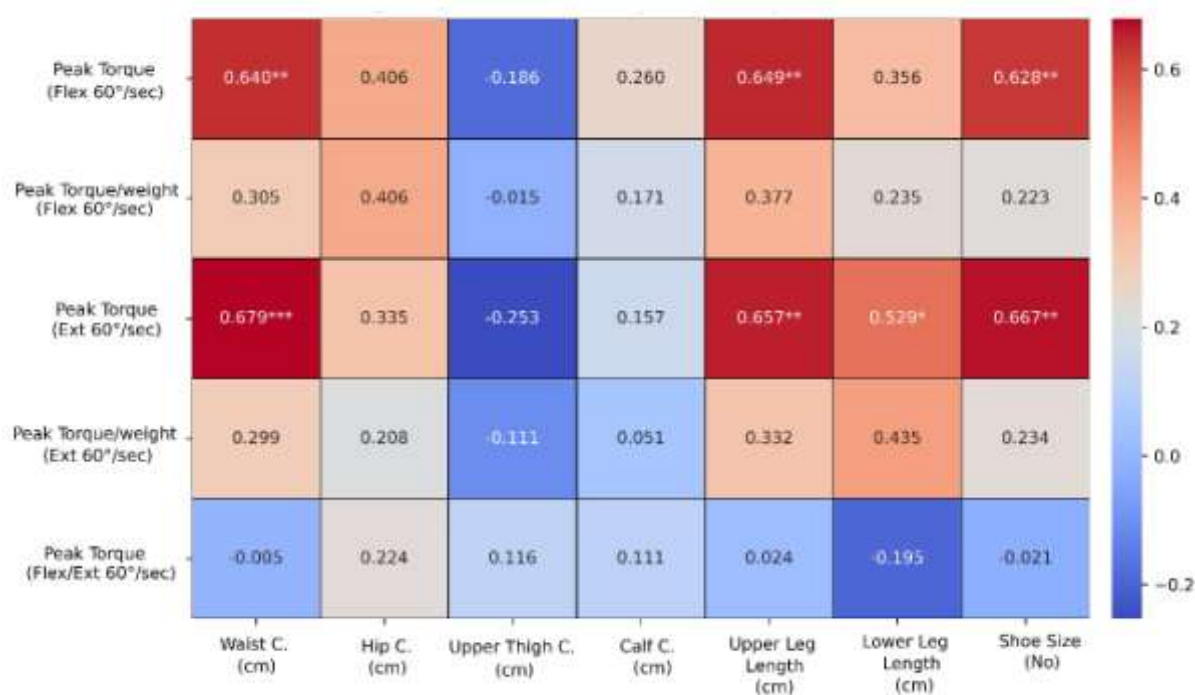


* $p < 0.05$, ** $p < 0.10$, *** $p < 0.001$, C: Circumference, cm: Centimeter

Figure 1. Analysis of the relationship between dominant foot 180° isokinetic data and circumference measurements of pentathlon athletes participating in the study.

Figure 1 shows that there was a moderate and positive significant relationship between Peak Torque (Flex 180°/sec) and waist circumference, upper leg length and shoe size ($p < 0.01$). Accordingly, it was observed that as waist circumference, upper leg length and shoe size increased, the force obtained from Peak Torque (Flex 180°/sec) also increased. There was no significant relationship between Peak Torque (Flex 180°/sec) and hip, thigh, calf circumference and lower leg length ($p > 0.05$). A positive and moderately significant relationship was found between Peak Torque/weight (Flex 180°/sec) and upper leg length ($p < 0.05$). Accordingly, it was observed that as the upper leg length increased, the force ratio obtained from Peak Torque/weight (Flex 180°/sec) also increased. There was no significant relationship between Peak Torque/weight (Flex 180°/sec) and waist, hip, thigh, calf circumference, lower leg length and shoe size ($p > 0.05$). Peak Torque (Ext 180°/sec) was found to have a high level and positive significant relationship with waist circumference and shoe size, while a medium level and positive significant relationship was found with upper leg

length ($p < 0.001$). According to these differences, it was observed that as the waist circumference, shoe size and upper leg length increased, the force obtained from Peak Torque (Ex 180°/sec) also increased. There was no significant relationship between Peak Torque (Ext 180°/sec) and hip, thigh, calf circumference and lower leg length ($p > 0.05$). A moderate and positive significant relationship was found between Peak Torque/weight (Ex 180°/sec) and waist circumference, upper leg length and shoe size ($p < 0.01$). Accordingly, it was observed that as waist circumference, upper leg length and shoe size increased, the force ratio obtained from Peak TorqueAveight (Ext 180°/sec) also increased. There was no significant relationship between Peak TorqueAveight (Ext 180°/sec) and hip, femur, calf circumference and lower leg length ($p > 0.05$). No significant correlation was found between Peak Torque (Flex/Ext 180°/sec) and waist, hip, thigh, calf circumference, upper leg, lower leg length and shoe size ($p > 0.05$).



* $p < 0.05$, ** $p < 0.10$, *** $p < 0.001$, C: Circumference, cm: Centimeter

Figure 2. Analysis of the relationship between dominant foot 60° isokinetic data and circumference measurements of the pentathlon athletes participating in the study.

Figure 2 shows that there was a moderate and positive significant relationship between Peak Torque (Flex 60°/sec) and waist circumference, upper leg length and shoe size ($p < 0.01$). Accordingly, it was observed that as waist circumference, upper leg length and shoe size increased, the force obtained from Peak Torque (Flex 60°/sec) also increased. There was no significant relationship between Peak Torque (Flex 60°/sec) and hip, thigh, calf circumference and lower leg length ($p > 0.05$). There was no significant relationship between Peak Torque/weight (Flex 60°/sec) and waist, hip, thigh, calf circumference, upper leg, lower leg length and shoe size ($p > 0.05$). Moderate significant differences were found between Peak Torque (Ext 60°/sec) and waist circumference, upper leg length, lower leg length and shoe size ($p < 0.05$). According to these differences, it was observed that as waist circumference, shoe size, upper leg and lower leg length increased, the force obtained from Peak Torque (Ex 60°/sec) also increased. There was no significant relationship between Peak Torque (Ext 60°/sec) and hip, thigh and calf circumference ($p > 0.05$). There was no significant relationship

between Peak Torque/weight (Ext 60°/sec) and waist, hip, thigh, calf circumference, upper leg, lower leg length and shoe size ($p>0.05$). No significant correlation was found between Peak Torque (Flex/Ext 60°/sec) and waist, hip, thigh, calf circumference, upper leg, lower leg length and shoe size ($p>0.05$).

Discussion and Conclusion

The study was conducted to evaluate the muscle strength of athletes at 60°/sec and 180°/sec angular velocities and to examine the relationship between these muscle strengths and the lower extremity circumference measurements of the athletes. The findings of the study showed that there was a positive correlation between muscle strength measured at both 60°/sec angular velocity and 180°/sec angular velocity and waist circumference, upper leg length, lower leg length and shoe size, but there was no significant relationship between muscle strength measured at both 60°/sec angular velocity and 180°/sec angular velocity and hip circumference, thigh circumference and calf circumference.

When the studies in the literature on lower extremity leg strength and circumference, diameter and length measurements were examined, it was found that lower extremity strength (isokinetic strength and knee flexion and extension forces) of elite modern pentathlon athletes were evaluated in a study (Ko et al., 2021). In the research findings, significant relationships were found between Peak Torque values obtained at 180°/sec and 60°/sec speeds, especially waist circumference and shoe size. As a result of the research, it was stated that modern pentathlon athletes with larger foot structure and improved trunk stability may have higher force production capacity (Ko et al., 2021). In another similar study, a significant relationship was found between waist circumference and trunk flexion and extension strength (Ben Moussa Zouita et al., 2019). On the other hand, in our study, no significant relationship was observed between some parameters such as hip circumference, thigh circumference and calf circumference and strength variables. This finding is supported by some researchers in the literature. In a study conducted on professional soccer players, it was found that strength and body anthropometry did not differ significantly (Pietraszewska et al., 2020). Researchers have stated that the relationship of lower extremity circumferential measurements with strength is related to muscle quality rather than morphological characteristics of the muscle. In this direction, it is emphasized that an increase in circumference does not always mean an increase in strength, especially when the proportion of adipose tissue increases, force production may be negatively affected (Claessens et al., 1994). In our study, the findings related to Peak Torque/Weight variable showed significant relationships especially with upper leg length and waist circumference. This indicates that pentathletes with longer limb segments can produce higher isokinetic force compared to their body weight. However, more research is needed to generalize this result. Another study was conducted on female elite pentathletes. Significant increases in knee extension strength were found after complex training in the research group. They stated that this increase became more pronounced, especially when evaluated in relation to body weight (Qiao et al., 2022). From this point of view, the evaluation of strength not only in absolute values but also in relation to body weight may lead to more meaningful results in terms of performance indicators. Thigh circumference was found to be correlated with isometric and isotonic strength; an increase in muscle volume positively affected maximal strength with the development of nerve-muscle coordination (Miyatani et al., 2004). In addition, a positive correlation between circumferential measurements and isokinetic knee extensor strength has been shown (Halckinen et al., 1998). Thigh circumference was reported to be moderately positively correlated with isokinetic performance of knee flexor and extensor muscles. Similarly, in this study, significant positive relationships were found between upper leg length and Peak Torque and Peak Torque/Weight. This suggests that with

the increase in thigh muscle inns% force production capacity also increases (Faisal et al., 2020). In this context, lower extremity circumference measurements in modern pentathletes are not only a morphological parameter, but also a practical and economical tool that can be used to predict strength level.

In conclusion, some anthropometric variables determined in this study were found to be correlated with knee flexion and extension strength. These findings are similar to previous studies in various branches. As in every research, there are some limitations in this study. The first of these limitations is the sample size. The research group consisted of 19 participants. This makes the generalizability of the study difficult. Another limitation is that force parameters vary according to gender. In this context, in our study, both genders were evaluated together without any gender distinction during the analysis. This situation causes the differences that may occur between genders to be overlooked. However, for future research, the effect of anthropometric structures on force production should be evaluated multidimensionally in sports such as modern pentathlon, which involves multiple branches and requires complex motor characteristics. In this direction, examining variables such as muscle composition, tendon stiffness and training type together with isokinetic strength tests will contribute to future studies.

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