

Relationships among Isokinetic Knee Strength, Anaerobic Power, and Vertical Jump Performance in Professional Male Volleyball Players

Profesyonel Voleybolcularda İzokinetik Kuvvet, Anaerobik Güç ve Dikey Sıçrama İlişkisi

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Abstract

The purpose of this study is to examine the relationship between isokinetic strength and anaerobic power as well as vertical jump in professional male volleyball players. Twenty-two professional male volleyball players participated in this study. Isokinetic strength of the knee extensor and flexor muscles was measured at an angular velocity of 60°/s. Anaerobic power was evaluated using the Wingate anaerobic power test and vertical jump performance was evaluated through the countermovement jump test. A strong positive significant correlation was found between vertical jump height and right leg extension strength while moderate positive correlation was found between with left leg extension strength. A highly positive significant correlation was found between vertical jump height and right and left leg flexion strengths. A moderate level of positive significant correlation was found between vertical jump height and right and left leg Hamstring/Quadriceps(H/Q) ratios. A highly positive significant correlation was found between Wingate anaerobic peak power and vertical jump height. In addition, significant positive correlations were identified between Wingate anaerobic peak power and Wingate anaerobic mean power and the 60°/s right and left leg extension and flexion peak torque values, while no significant correlations were found between right-left leg extension or flexion peak torque differences and Wingate anaerobic peak power. The findings revealed strong positive correlations between isokinetic strength, Wingate anaerobic peak power output (W), and vertical jump height in volleyball players.

Keywords Isokinetic strength, Anaerobic power, Vertical Jump, Biodex, Wingate.

Öz

Bu çalışmanın amacı, profesyonel erkek voleybolcularında izokinetik kuvvet ve anaerobik güç ile dikey sıçrama arasındaki ilişkiyi incelemektir. Çalışmaya yirmi iki profesyonel erkek voleybolcu katılmıştır. Diz ekstansör ve fleksör kaslarının izokinetik gücü 60°/s açışal hızda ölçülmüştür. Anaerobik güç Wingate anaerobik güç testi ile değerlendirilmiş, dikey sıçrama performansı ise karşı hareket sıçrama testi ile değerlendirilmiştir. Dikey sıçrama yüksekliği ile sağ bacak ekstansiyon kuvveti arasında güçlü pozitif ve anlamlı bir korelasyon saptanmıştır. Dikey sıçrama yüksekliği ile sağ ve sol bacak fleksiyon güçleri arasında yüksek düzeyde pozitif ve anlamlı korelasyonlar tespit edilmiştir. Dikey sıçrama yüksekliği ile sağ ve sol bacak Hamstring/Quadriceps (H/Q) oranları arasında orta derecede pozitif anlamlı korelasyonlar bulunmuştur. Wingate anaerobik zirve gücü ile dikey sıçrama yüksekliği arasında yüksek düzeyde pozitif ve anlamlı korelasyon bulunmuştur. Ayrıca, Wingate anaerobik zirve gücü ile Wingate anaerobik ortalama güç değerleri ile 60°/s sağ ve sol bacak ekstansiyon ve fleksiyon zirve tork değerleri arasında anlamlı pozitif korelasyonlar tespit edilirken, sağ-sol bacak ekstansiyon veya fleksiyon zirve tork farkları ile Wingate anaerobik zirve gücü arasında anlamlı bir ilişki belirlenmemiştir. Sonuçlar, voleybol oyuncularında izokinetik kuvvet, Wingate anaerobik zirve gücü (W) ve dikey sıçrama yüksekliği arasında güçlü pozitif korelasyonlar olduğunu ortaya koymuştur.

Anahtar Kelimeler İzokinetik kuvvet, Anaerobik güç, Dikey sıçrama, Biodex, Wingate.

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Introduction

In high-intensity sports, measuring the physical and physiological performance levels of athletes is very important for the athlete to reach the optimal performance level. Since constantly displaying rapid and explosive power is vital in volleyball, measuring and evaluating parameters such as explosive power is crucial in designing athletes' training plans and reducing injury risks. It is known that jumping ability, which is one of the fundamental movements of the branch, is essential in the highest level of application of technical skills such as spiking, serving, and blocking during the match (Çakır & Ergin, 2022; Brazo-Sayavera et al., 2017). Studies in the literature show that the jumping capacity of volleyball players positively affects their match performance and increases match efficiency (Marques et al., 2006; Schons et al., 2019).

Anaerobic power and anaerobic capacity directly affect the performance of athletes in volleyball. While high anaerobic capacity allows athletes to perform short-term but high-intensity movements efficiently during the match, independently of oxygen (Challoumas & Artemiou, 2018; Schons et al., 2018; Yel et al., 2023) it is seen as one of the main factors determining sports performance, especially in short-term and high-intensity rallies (Zerf et al., 2018). When the literature is reviewed, it is seen that there were correlations between anaerobic power and jumping performance (Marszalek et al., 2015; Rouis et al., 2016; Gross & Lüthy, 2020). Also, previous studies have shown that there is a significant positive relationship between isokinetic strength and anaerobic power in athletes (Harbili, 2015; Song et al., 2021; Yılmaz et al., 2023). This relationship highlights the contribution of neuromuscular strength to short-term high-intensity performance, especially in sports requiring explosive movements such as volleyball, football, and basketball

The explosive power required for vertical jumping is mainly obtained from the lower extremities. During volleyball matches, athletes perform vertical jumps repeatedly, leading to frequent landings throughout the game. In addition, due to the nature of the sport, it includes repetitive ballistic movements in addition to lateral movements in response to external stimuli (James et al., 2014). Consistent execution of jumping and landing actions increases the likelihood of injuries in the lower limbs (Young et al., 2023). To manage these risks, specific injury prevention strategies are needed (James et al., 2014). Therefore, evaluating hamstring and quadriceps strength via isokinetic tests holds critical importance for volleyball performance and injury prevention.

Research suggests that athletes with hamstring-to-quadriceps ratios under 0.6 may face a heightened likelihood of sustaining injuries (Coombs & Garbutt, 2022; Costa et al., 2009; D'Onofrio et al., 2021; Dedinsky et al., 2017) and the ratio is decisive for performance and effective in reducing injuries (Wilkosz et al., 2021; Pelegrinelli et al., 2019; Kafkas et al., 2019; Hadzic et al., 2010). There are some studies that analyzed Muscle strength evaluations are often conducted using isokinetic protocols, with 60°/s being a standard speed to determine maximum strength. At this speed, the relationship between maximal isokinetic knee strength, anaerobic power and vertical jump may provide meaningful information, especially in sports where explosive performance is important. However, studies examining these three variables together in volleyball players are limited. This study aims to determine the relationship between 60°/s isokinetic knee strength, anaerobic power, and vertical jump in volleyball players.

Materials and Methods

Research Model

This study was designed as a cross-sectional observational study to investigate the relationships among isokinetic knee strength, anaerobic power, and vertical jump

performance in professional male volleyball players. All tests were conducted in Performance Laboratory of Kocaeli University, Faculty of Sports Sciences. Before the study, Approval for the research was granted by the Kocaeli University Non-Interventional Clinical Research Ethics Board (Approval No: KU GOKAEK 2023/184).

Research Group

This study included 22 athletes competing in a professional volleyball league. The mean age of the athletes was 21.73 ± 2.58 years, and their average height was 190.54 ± 12.03 cm. On average, the athletes had been actively engaged in their sports careers for 9.55 ± 2.70 years. Athletes were informed about the study procedures in advance and were assured that their participation would be entirely voluntary. The research protocol was explained to the athletes who participated in the study again and their consent was obtained. The study was conducted with the principles in Declaration of Helsinki to ensure the rights, safety, and well-being of the participants.

Data Collection Tools

Height, Body Weight Measurements:

A demographic information form was filled out to collect demographic information about the participants. The height of the participants was measured using a "SECA" brand height measuring device after they were positioned in anatomical posture with their heels together and their heads in the frontal plane, and recorded in "cm". The body weight of the participants was measured using "Tanita" and recorded in "kg".

Countermovement Jump Test ;

The participants were allowed to warm up on a treadmill for 10 min before the countermovement jump test. After the warm-up, athletes' countermovement jump measurements were made using Vald Performance SmartJump. The participants were given two countermovement jumps and the best score was recorded. A 2-minute rest period was provided between the jumps.

Isokinetic Strength Test ;

Participants warmed up by walking on a treadmill for 5 min. Following this, they continued their warm-up on the Biodex Isokinetic Dynamometer without any load, performing two sets of five repetitions with a 1-minute rest in between. The isokinetic strength of the right and left legs of the study group were measured using a Biodex System 3 Isokinetic Dynamometer at $60^\circ/s$. For right and left leg strength measurements, five repetitions were performed at $60^\circ/s$ speed and a 3-minute rest period was given between the right and left leg strength tests.

Anaerobic Power Test;

To prevent neuromuscular fatigue from influencing results, anaerobic power testing was scheduled four hours after jump and strength assessments. Monark 894E Ergometer was used for anaerobic power measurements and Wingate Anaerobic Test Protocol was applied. For the weight to be used in the test, an amount corresponding to 7.5% of the participants' weight was added to the ergometer basket. Because the specific weight of the basket was 1 kg, this amount was included in the calculation. Athletes were applied a 5-minute warm-up protocol specific to the Wingate Test on the ergometer before the test. During the warm-up, they were asked to pedal without load in the 0-1 and 1-2nd minutes and to sprint at 5 rpm with the weight to be used in the test in each minute starting from the 2nd minute. After the warm-up, the participants were given a 3-minute

recovery period. The test was completed by the athlete pedalling at the maximum speed for 30 s, with the basket automatically dropping when the pedal speed exceeded 70 rpm.

Data Analysis

Statistical evaluations were carried out with IBM SPSS version 26 software. Descriptive statistics were used to analyse the demographic information of the participants. Spearman’s Rho test was used for correlations between isokinetic strength, anaerobic power, and vertical jump tests. The significance level was set at $p < 0.05$.

Results

The findings are presented below.

Table 1: Descriptive statistics of the participants.

Variables	N	Min	Max.	\bar{X}	SD
Age	22	19	26	21.73	2.58
Height (cm)	22	160	204	190.54	12.03
Weight (kg)	22	55	103	83.82	13.25
Active sports age	22	6	16	9.55	2.70

As shown in Table 1, the average age of the participants was 21.73 ± 2.58 years, average height was 190.54 ± 12.03 cm, average weight was 83.82 ± 13.25 kg, and sports age was 9.55 ± 2.70 years. Active sports age is 9.55 ± 2.7 years.

Table 2: Demographic characteristics of the participants

Variable	Group	n	%
Dominant foot	Right leg	12	55
	Left leg	10	45
Education level	High school	6	27
	University	16	73
Injury history	Upper	6	27
	Lower injury	14	64
	No injury history	2	9
Total		22	100

As shown in Table 2, the right foot of 12 participants was dominant, and the left foot of 10 participants was dominant. It was seen that 6 participants were high school graduates and 16 participants had university level education. Six athletes reported experiencing an upper extremity injury, while 14 athletes reported a lower extremity injury. Two athletes indicated no history of injuries.

Table 3: Descriptive statistics of vertical jump and Wingate power variables.

Variables	N	Min	Max.	\bar{X}	SD
Vertical Jump(cm)	22	52.5	82.1	64.12	7.22
Wingate Peak Power(W)	22	713.0	1467.5	1085.50	199.53
Wingate Mean Power(W)	22	424.0	816.1	663.30	114.87
Wingate Minimum Power(W)	22	172.7	412.1	321.57	71.25
Wingate Power Drop(W)	22	429.4	1055.4	764.01	180.00

As seen in Table 3, participants' vertical jump height was determined as 64.12 ± 7.22 cm, Wingate anaerobic peak power as 1085.5 ± 199.53 W, Wingate mean power as

663.3±114.87 W, Wingate minimum power as 321.57±71.25 W and Wingate power drop as 764.01±180 W.

Table 4: Minimum, maximum, arithmetic mean, and standard deviation values of the isokinetic strength parameters of the participants

Variables	N	Min	Max.	\bar{X}	SD
Right Leg 60°/s Extension Peak Torque (Nm)	22	156.5	324.2	260.20	49.39
Left Leg 60°/s Extension Peak Torque (Nm)	22	155.6	288.6	243.54	42.87
Right-Left Leg 60°/s Extension Peak Torque Difference (Nm)	22	0.1	16.0	7.40	5.46
Right Leg 60°/s Flexion Peak Torque (Nm)	22	97.5	163.7	135.87	20.45
Left Leg 60°/s Flexion Peak Torque (Nm)	22	88.5	157.9	130.18	19.87
Right-Left Leg 60°/s Flexion Peak Torque Difference (Nm)	22	1.4	19.0	7.65	5.05
Right Leg H/Q %	22	43.9	62.3	53.03	6.47
Left Leg H/Q %	22	44	69.5	54.17	7.04

As seen in Table 4, the average peak torque for right leg extension of the participants at an angular velocity of 60°/s was recorded as 260.2±49.39 Nm, and the average peak torque for left leg extension was recorded as 243.54±42.87 Nm. The difference in peak torque observed between right and left leg extensions was found to be 7.40±5.46 Nm. The average peak torque for right leg flexion at the same angular velocity was determined as 135.87±20.45 Nm, and for left leg flexion as 130.18±19.87 Nm. The difference in peak torque between right and left leg flexions was found to be 7.65±5.05 Nm. While the hamstring/quadriceps (H/Q) ratio of the participants' right leg was 53.03±6.47, the H/Q ratio of the left leg was found to be 54.17±7.04.

Table 5: Spearman's rho correlation analysis of vertical jump heights and isokinetic strength values of the participants

Variables	Vertical Jump(cm)
Right Leg 60°/s Extension Peak Torque (Nm)	.787**
Left Leg 60°/s Extension Peak Torque (Nm)	.510*
Right Leg 60°/s Flexion Peak Torque (Nm)	.828**
Left Leg 60°/s Flexion Peak Torque (Nm)	.747**
Right-Left Leg 60°/s Extension Peak Torque Difference (Nm)	-.323
Right-Left Leg 60°/s Flexion Peak Torque Difference (Nm)	.005
Right Leg H/Q %	.347*
Left Leg H/Q %	.406*

*p<0.05, **p<0.001

As shown in Table 5, a positive correlation was determined between vertical jump performance and both 60°/s right leg extension and flexion peak torque and left leg extension and flexion peak torque (p<0.001). In addition, a positive correlation was found between vertical jump performance and right leg H/Q and left leg H/Q strength ratios (p<0.05). Conversely, no significant correlation was determined between 60°/s extension peak torque difference and 60°/s flexion peak Torque difference with vertical jump performance (p>0.05).

Table 6: Spearman's rho correlation analysis of vertical jump and wingate anaerobic power of the participants

Variables	Vertical Jump(cm)
Wingate Peak Power(W)	.832**
Wingate Mean Power(W)	.746**
Wingate Minimum Power(W)	-.041
Wingate Power Drop(W)	.251

**p<0.001

As shown in Table 6, a strong positive correlation was found between vertical jump and Wingate peak power and Wingate average power ($p<0.001$). No significant correlation was found between vertical jump and Wingate minimum power and Wingate power drop ($p>0.05$).

Table 7: Spearman's rho correlation analysis of isokinetic strength and wingate anaerobic power of the participants

Variables	Wingate Peak Power(W)	Wingate Mean Power(W)
Right Leg 60°/s Extension Peak Torque (Nm)	.800**	.655**
Left Leg 60°/s Extension Peak Torque (Nm)	.836**	.627**
Right Leg 60°/s Flexion Peak Torque (Nm)	.764**	.800**
Left Leg 60°/s Flexion Peak Torque (Nm)	.770**	.743**
Right-Left Leg 60°/s Extension Peak Torque Difference (Nm)	.255	.309
Right-Left Leg 60°/s Flexion Peak Torque Difference (Nm)	-.336	-.282
Right Leg H/Q %	-.400	-.273
Left Leg H/Q %	-.128	.050

**p<0.001

As shown in Table 7, a significant positive correlation was determined between Wingate peak power and 60°/s right and left leg extension and flexion peak torque values ($p<0.001$). Similarly, significant positive correlations were observed between Wingate mean power and 60°/s right and left leg extension and flexion peak torque ($p<0.001$). Conversely, no significant correlation was determined between Wingate peak power and mean power and 60°/s extension peak torque difference, flexion peak torque difference, right leg H/Q and left leg H/Q ($p>0.05$).

Discussion and Conclusion

The present research explored the associations between isokinetic knee strength, anaerobic output, and vertical jump performance in elite male volleyball players. Findings demonstrated that muscular strength assessed at 60°/s significantly associated with Wingate test outcomes—especially regarding peak and average power values. Furthermore, vertical jump performance showed positive correlations with anaerobic power, isokinetic strength and H/Q ratio of both the right and left legs. These findings emphasise the important role of isokinetic strength and anaerobic power in vertical jump performance, which is a fundamental skill in volleyball. The current results align with prior investigations focused on elite female volleyball players, where a link between

isokinetic strength and jumping capacity was also noted (Uslu et al., 2021; Fischer et al., 2017).

Consistent with the present study, previous studies have also emphasised the importance of lower extremity strength, particularly for explosive movements such as vertical jumps (Fischer et al., 2017; Atwood et al., 2017). Enhancing isokinetic strength may contribute to improvements in athletic performance. While certain studies (Chen et al., 2023; Rouis et al., 2015) have employed 240°/s angular velocities to assess the association between muscle strength and jumping ability, we chose to test the athletes at an angular velocity of 60°/s to capture maximal strength and force outputs and the relationship with vertical jump performance. Future studies may examine the relationship between vertical jump performance and isokinetic strength assessed at higher angular velocities, such as 240°/s. Another parameter used in isokinetic assessments is the H/Q ratio, which is considered optimal between 50% and 80 % (Grace et al., 1984; Kong & Burns, 2010). Differences in asymmetry assessment exceeding 10% and 15% are interpreted as an indicator of injury risk (Abad et al., 2022). The H/Q ratios obtained in this study ranged from 43.9% to 69.5%. At this point, it is suggested that some athletes may be at risk of injury due to their H/Q ratios and that they should perform strength training targeting the hamstring region to reduce this risk. Similarly, in a study examining the relationship between isokinetic strength, strength asymmetry and jump performance in female volleyball players, it was reported that muscle strength imbalances affect sports performance and should be optimised (Atik et al., 2024).

According to the this study's findings, a strong correlation was determined between Wingate peak power, Wingate mean power and vertical jump. Similar results were obtained in studies involving volleyball players and athletes from different disciplines regarding the relationship between horizontal and vertical jumps and Wingate power output (Nikolaidis et al., 2016; Krishnan et al., 2017; Atabek et al., 2009). Although the Wingate anaerobic power test used a bicycle ergometer test, it effectively reveals the correlation between the anaerobic power output and vertical jumping ability. According to our findings, no correlation was observed between the Wingate minimum power and Wingate power drop, and vertical jump. This was the expected result because the vertical jump test was not repetitive. If a test protocol including repetitive jumps is used, power drop can be assessed.

Examining of isokinetic strength and anaerobic power revealed strong positive correlation was observed between the 60°/s isokinetic strength of the athletes and their Wingate anaerobic peak power and average power outputs. Similar findings to those obtained in our study have been reported in the literature (Harbili, 2015; Atabek et al., 2009). The high-strength parameters of athletes directly affect their power outputs. This is important in terms of both performance and reducing the risk of injury (Zhang et al., 2019). In addition to developing branch-specific motor characteristics, developing isokinetic strength and anaerobic power parameters may enhance anaerobic performance.

Kısaltmalar / Abbreviations

SD	Standart sapma (Standard deviation)
X	Ortalama (Mean)
SPSS	Sosyal bilimler için istatistik paketi (Statistical package for the social sciences)
p value	Anlamlılık değeri (Significant value)
N	Katılımcı sayısı (Number of participant)
Min	Minimum (Minimum)
Max	Maksimum (Maximum)
Kg	Kilogram (Kilogram)
Cm	Santimetre (Centimeter)
W	Watt (Watt)
H/Q	Hamstring/Quadriceps
Nm	Newton-metre(Newton-meter)

Beyanlar / Declarations

Etik Onay ve Katılım Onayı / Ethics approval and consent to participate

Bu çalışmanın hazırlanma ve yazım sürecinde "Yükseköğretim Kurumları Bilimsel Araştırma ve Yayın Etiği Yönergesi" kapsamında bilimsel, etik ve alıntı kurallarına uyulmuş olup; toplanan veriler üzerinde herhangi bir tahrifat yapılmamış ve bu çalışma herhangi başka bir akademik yayın ortamına değerlendirme için gönderilmemiştir. Makale ile ilgili doğabilecek her türlü ihlallerde sorumluluk yazara aittir. Çalışma için etik onay, Kocaeli Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu tarafından verilmiştir (belge no. KU GOKAEK 2023/184). Tüm katılımcılar bu çalışmaya gönüllü olarak katılmıştır. /

During the preparation and writing of this study, scientific, ethical and citation rules were followed in accordance with the 'Higher Education Institutions Scientific Research and Publication Ethics Guidelines'; no alterations were made to the collected data, and this study has not been submitted for evaluation to any other academic publication medium. The author is solely responsible for any violations that may arise in connection with this article. The Ethical approval for the study was granted by the Ethical approval for the study was granted by the Non-Interventional Clinical Research Ethics Committee of Kocaeli University,(Approval no. KU GOKAEK 2023/184). All participants voluntarily participated in this study.

Veri Ve Materyal Erişilebilirliği / Availability of data and material

Bu çalışmanın bulgularını destekleyen veriler, makul talepler üzerine sorumlu yazardan temin edilebilir. Veri seti yalnızca akademik amaçlar için erişilebilir olacak ve verilerin herhangi bir kullanımı, orijinal çalışmayı referans gösterecek ve katılımcıların gizliliğini koruyacaktır.

The data that support the findings of this study are available from the corresponding author upon reasonable request. The dataset will be accessible only for academic purposes, and any use of the data will recognize the original study and maintain the confidentiality of the participants.

Çıkar Çatışması / Competing interests

Yazarlar, bu makalede sunulan çalışmayı etkileyebilecek herhangi bir çıkar çatışması veya kişisel ilişkiye sahip olmadıklarını beyan etmektedirler.

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Yazar Katkıları / Authors' Contribution Statement

Çalışmanın tasarımı ve planlanması: U.G., A.G.; Veri toplama, analizi veya yorumlanması: U.G., A.G.; Makalenin yazımı: U.G., A.G.; Veri düzenleme, yöntem belirleme, yazım – özgün taslak, yazım – gözden geçirme ve düzenleme: U.G., A.G.; Tüm yazarlar, makalenin önemli noktalarını eleştirel bir şekilde gözden geçirmiştir. Tüm yazarlar makalenin son halini onaylamıştır. /

Design and planning of the study: U.G., A.G.; Data collection, analysis or interpretation: U.G., A.G.; Manuscript preparation: U.G., A.G.; Data organization, methodology development, writing - original draft, writing - review and editing: U.G., A.G.; All authors critically reviewed the key points of the manuscript and approved the final version.

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