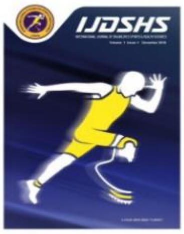

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RESEARCH ARTICLE

The Effect of Biomechanical and Viscoelastic Properties of Gastrocnemius (Lateral-Medial) Muscle and Achilles Tendon on Jumping Performance in Professional Soccer Players

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Abstract

Anaerobic performance (vertical jumps) is an important indicator in determining athletic performance in soccer. The aim of this study was to investigate the effects of biomechanical and viscoelastic properties of lateral and medial gastrocnemius (LG&MG) muscle and achilles tendon (AT) on jumping performance of professional soccer players. A total of 21 male professional soccer players with a mean age of 18.19±0.40 years, a mean height of 180.48±6.25 cm, a mean body weight of 70.71±7.82 kg, and a mean BMI of 21.66±1.65 kg/m^2 were included in this study. LG and MG muscle, as well as AT biomechanical and viscoelastic properties were evaluated with Myoton Pro device. Measurements were performed in the prone position of the soccer players, LG and MG at 50° plantar flexion, and AT at 0° (neutral position) at an angle of 4 cm above the calcaneal tubercle. Counter movement jump (CMJ) were recorded with the high-speed camera in the validated My Jump 2 application. A significant correlation was observed between the LG (F) tension value and CMJ (P) value and between the MG (R&C) values and the CMJ (F&P) value of professional soccer players (p<0.05). There was no significant relationship between AT values and CMJ values (p>0.05). It should not be forgotten that training coaches on this subject and applying this information to soccer players by conscious coaches will bring about increases in the athletic performance of soccer players, and all these performance characteristics can be achieved with planned and programmed training.

Keywords
Soccer, Achilles Tendon, CMJ

INTRODUCTION

Flexibility, i.e. increased range of motion (ROM), can be expressed as the ability of joints and series of joints to move at the maximum possible level (Bisanz & Gerisch, 1993). Flexibility; It is affected by factors such as "muscle strength, joint structures, muscle coordination, general body temperature, specific muscle temperature, fatigue, muscle tone, central nervous system functions, muscle contraction and relaxation ability, warm-up, training quality and intensity, injuries, time of exercise, age, climate and gender" (Corbin & Noble, 1986). Muscle elasticity, which is often confused with the concept of flexibility, can be defined as the ability of that object to return to its original state after the end of the application after the contraction in the muscle by applying an effective force to any object. It has been determined that the muscles of the athletes get tired faster as a result of the loss of muscle elasticity in the athletes due to factors that directly affect the performance of the athlete such as the lack of appropriate warm-up protocols, previous injury, poor and inadequate nutrition, and wrong training programming, and as a result, their contraction rates are limited (Gervasi et al., 2017; Masi & Hannon, 2008; Chuang et al., 2012).

Muscle stiffness, which adversely affects flexibility, is the resistance of the muscle against

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deforming forces (Masi & Hannon, 2008; Panjabi, 1992). In line with the efforts of the athletes in exhibiting their individual performances, the movements of the existing muscles participating in the work are likened to the resistance they show in practice. These muscles, that is, agonist muscles, need more energy to produce movement, causing more energy to be spent. This leads to muscle stiffness. It has been shown that differences in stiffness between the two legs, along with increased muscle stiffness, can lead to impaired coordination, one of the determinants of athletic performance of the athlete (Gapeyeva & Vain, 2008). In the literature, there are many different measurement applications such as vertical stiffness, tendon stiffness, muscle stiffness, joint stiffness and muscle joint stiffness (Brazier et al., 2014; Brughelli & Cronin, 2008; Butler et al., 2003). In terms of athlete performance, the presence of too much or too little stiffness in the muscle mass of athletes is a risk factor for injury (Butler et al., 2003). This is because muscle stiffness is vital in the body's load-bearing capacity and ability to perform work such as jumping (Lacroix et al., 2013).

It is known that, depending on lower extremity muscle stiffness, achilles tendon (AT) stiffness is exposed to 4 times more pressure than many other tendons, and therefore Achilles tendon health affects athletic performance in athletes (Kongsgaard et al., 2005; Usgu et al., 2020). Although the AT is the longest, thickest and strongest tendon of our body, this tendon forms an association with the lateral and medial gastrocnemius (LG & MG) muscles, one of the lower extremity muscles, and causes plantarflexion movement of the foot, especially in activities such as running, jumping and walking (O'Brien, 2005; Doral et al., 2010). AT stiffness may vary depending on age, training, neural, hormonal and biomechanical changes (Usgu et al., 2020; Kubo et al., 2001). Counter movement jump (CMJ) test, which is frequently used to measure the strength of lower extremity muscles, can provide information about the structure of athletes' AT. Considering that a large part of the movements applied in daily activities and training involve eccentric and concentric phases, jump tests to determine the athletic performance of athletes can determine the hardness of the AT and, accordingly, its functionality (Finnamore, 2018)

The aim of this study, which was carried out on the assumption that the strength of the lower extremity muscles and the optimal elasticity and stiffness of the AT structures can be effective in increasing the jumping performance (explosive force) of the soccer players, is to examine whether the LG and MG muscles, as well as the AT biomechanical and viscoelastic properties of professional soccer players, have effects on their jumping performance.

MATERIALS AND METHODS

Research Design

The research was carried out in the facilities of Gaziantep Soccer Club and the universe of the research consisted of the soccer players playing in Gaziantep Soccer Club, and the sample consisted of the soccer players who met the inclusion criteria. Ethical approval was obtained from Manisa Celal Bayar University Faculty of Medicine Health Sciences Ethics Committee with the date and number 24.04.2024/2393. Participant provided informed consent, with the volunteer form covering research details, risks, benefits, confidentiality, and participant rights. The research strictly adhered to the ethical principles of the Declaration of Helsinki, prioritizing participant's rights and well-being in design, procedures, and confidentiality measures.

The study included 21 elite soccer players between the ages of 18 and 40 who had no history of orthopedic injuries to the lower extremities in the last 12 months. Also athletes were excluded from the study if they had any back pain and attended any rehabilitation program. A descriptive evaluation form containing the demographic information of the athletes was used as a data collection tool. Individuals who agreed to participate in the study were made to sign an informed consent form. It was stated to the athletes that they should inform the researcher in case of any side effects during the evaluations and application. The evaluations lasted an average of 6 minutes for each soccer player.

Demographic and anthropometric measurements (gender, age, height, weight, body mass index (BMI) of the participants were recorded. The position in which he took part in training and the match and the dominant lower extremity were questioned. Evaluations were made on the dominant side. To ensure the accuracy of the measurements, participants were instructed to avoid strenuous activity five hours before the test and not to take any medication that would interfere with the test.

Sample and Data Collection

Achilles Tendon (AT)

AT viscoelastic properties were evaluated with a highly reliable MyotonPro device (Myoton AS, Estonia). The AT measurements of the participants were taken in the position where the athletes were lying face down with their ankles hanging from the table in a neutral position. Measurement; It is based on the free-swing technique after the excitation of the probe. AT measurement was performed 4 cm above this point after the distal insertion of the tendon (calcaneal tubercle) was determined (Liu et al., 2018). The myonometric measurement was repeated three times and the averages were recorded. Only measurements with a coefficient of variability of less than 3% were considered. Otherwise, the measurements were repeated. In determining the dominant side, the foot on which the athlete hit the ball was questioned.

Counter Movement Jump (CMJ)

Participants were given a standard 10-minute warm-up consisting of running, lower extremity dynamic warm-ups, and vertical jumps. Participants were asked to jump up with maximum force after making a rapid collapse motion from the knees down with the hands at the sides in the normal upright posture. Each participant recorded their vertical jumps using their Iphone 13 Pro (Apple Inc USA) phone with the high-speed camera in the validated My Jump 2 app (Balsalobre-Fernandez et al., 2015). Each participant was asked to make a vertical jump as high as possible 3 times. At the end of each jump, they were given a 2-minute passive rest period. From the video, the take-off and landing of the participants' feet were determined. He then calculated the jump distances using the equation (h= t2 x 1.22625) that determines the jump height. The best results were evaluated (Bosco et al., 1983).

Analyzing of Data

Statistical analyses were performed using SPSS v23 software. To determine the normality of the data, the Kolmogorov-Smirnov test was used. Mean and standard deviation values were taken to describe the data. Independent sample t-test was used to compare the groups. Pearson correlation analysis was used for the relationship between bounce CMJ performance and achilles tendon viscoelastic properties. The confidence interval was selected as 95% and values below <0.05 were considered statistically significant.

RESULTS

21 professional soccer players, all men, participated in the study. The mean age of the athletes was 18.19±0.40 years, the mean height was 180±6.25 cm, the mean body weight was 70.71±7.82 kg, and the mean BMI was 21.66±1.65 kg/m². The descriptive information of the soccer players is shown in table 1.

Table 1. Descriptive information

Professional Soccer Players (n=21)	Mean±Std
Age (years)	18.19±0.40
Height (cm)	180.48±6.25
Weight (kg)	70.71±7.82
BMI (kg/m²)	21.66±1.65

kg: kilogram, m: metres, cm: centimeter, mean: average, std: standard deviation, BMI: body mass index, n: number of individuals

Table 2. Relationship between jump (CMJ) performance and lateral gastrocnemius (LG), tone, biomechanical and viscoelastic properties

CMJ Properties	F	S	D	R	C
JH	0.213	-0.025	-0.145	0.028	0.038
FT	0.215	-0.022	-0.159	0.023	0.031
F	0.324	-0.340	0.212	0.342	0.321
V	0.217	-0.024	-0.159	0.024	0.033
P	0.438*	-0.361	0.129	0.355	0.333

CMJ:Counter Movement Jump, LG: Lateral Gastroknemius, JH: Jump Height, FT: Flight Time, F: Force V: Velocity, P: Power, F:Tone [Hz], S: Dynamic Stiffness [N/m], D: Elasticity, R: Relaxation Time [m/s], C: Relaxation and Deformation Time, *p<.05.

A significant correlation was observed between the LG (F) voltage value and the CMJ (P) value (p<0.05). There was no significant relationship between LG other values and CMJ values.

Table 3. Relationship between jump (CMJ) performance and medial gastrocnemius (MG), tone, biomechanical and viscoelastic properties

CMJ Properties	F	S	D	R	C
JH	-0.088	-0.057	-0.073	-0.006	-0.007
FT	-0.078	-0.048	-0.067	-0.019	-0.021
F	-0.189	-0.393	-0.143	0.468*	0.489*
V	-0.078	-0.049	-0.068	-0.018	-0.020
P	-0.219	-0.415	-0.165	0.466*	0.486*

CMJ: Counter Movement Jump, MG: Medial Gastroknemius, JH: Jump Height, FT: Flight Time, F: Force V: Velocity, P: Power, F:Tone [Hz], S: Dynamic Stiffness [N/m], D: Elasticity, R: Relaxation Time [m/s], C: Relaxation and Deformation Time, *p<.05.

A significant relationship was observed between MG (R&C) values and CMJ (F&P) values (p <0.05). No significant relationship was observed between other MG values and CMJ values.

Table 4. Relationship between jump (CMJ) performance and achilles tendon (AT), tone, biomechanical and viscoelastic properties

CMJ:

CMJ Properties	F	S	D	R	C
JH	-0.129	-0.119	0.127	0.268	0.327
FT	-0.124	-0.115	0.131	0.269	0.330
F	0.214	0.071	0.021	-0.170	-0.163
V	-0.124	-0.115	0.131	0.268	0.329
P	0.200	0.043	0.064	-0.090	-0.063

Counter Movement Jump, AT: Achilles Tendon, JH: Jump Height, FT: Flight Time, F: Force V: Velocity, P: Power, F:Tone [Hz], S: Dynamic Stiffness [N/m], D: Elasticity, R: Relaxation Time [m/s], C: Relaxation and Deformation Time, *p<.05.

There was no significant relationship between AT values and CMJ values (p>0.05).

DISCUSSION

It is known that anaerobic performance (vertical jump) is an important feature in determining athletic performance in soccer, and in order to develop this feature, the strength of the lower extremity muscles and the optimal elasticity and rigidity of the AT structure are needed. For this reason, it is known that determining the individual AT structure can be effective in increasing the jumping performance (explosive force) of soccer players. Based on this, the aim of this study was to examine whether the biomechanical and viscoelastic properties of the LG and MG muscles and AT affect the jumping performance of professional soccer players.

In the study, which included 21 professional male soccer players, the mean age was 18.19±0.40 years, the mean height was 180.48±6.25 cm, the average body weight was 70.71±7.82 kg, and the mean BMI was 21.66±1.65 kg/m². It is known that the amount of fat tissue negatively affects the physical, physiological and psychological performance characteristics of the athlete. It can be thought that the muscle viscoelastic performance characteristics of soccer players may differ positively or negatively depending on their current physical and physiological characteristics. When the body mass indexes of the soccer players are examined, we can say that the fat tissue values are not high in the soccer players participating in the study, but the elasticity levels of the LG and MG muscles are not affected by this. In such studies, taking the fat percentages of athletes is likely to provide researchers with more accurate information in terms of understanding whether AT and fat tissue ratio are related. As a matter of fact, while it was argued that there was a negative relationship between fat layer and muscle hardness values in the study conducted on professional badminton athletes, other studies showed a low and moderate relationship (Bravo-Sánchez et al., 2019; Frohlich et al., 2014; Agyapong-Badu et al., 2016). For adaptation to training, it is of great importance to know the lower extermite muscle strength output of soccer players, AT functionality and to determine these values. In line with the data obtained from our study, there was a significant relationship between the LG (F) voltage value and the CMJ (P) value and between the MG (R&C) values and the CMJ (F&P) value of professional soccer players ($p<0.05$). There was no significant relationship between AT values and CMJ values ($p>0.05$). Unlike our study in the literature, one study found that there is a relationship between strength output and AT hardness in athletes, which affects athletic performance (Bojsen-Moller et al. 2005). In another study, Wu et al., (2010) stated that AT hardness was associated with CMJ performance characteristics. In the posture position, which is the first stage of the jump, the LG and MG muscle provides the current power output to the extent that it can contract, while the AT creates the optimal jumping performance criterion by extending depending on its elasticity. Brughelli et al. Thought that high muscle stiffness values could be beneficial in terms of performance, as in soccer, which is one of the branches where eccentric and concentric phases are one after the other (Brughelli & Cronin, 2008).

There are many studies showing that explosive force performance values are at optimal values in athletes with high AT stiffness ratio. In studies that put forward this idea and examined the relationship between AT stiffness and jumping performance, it was argued that high AT stiffness values of athletes may be more beneficial in terms of athletic performance (Burgess et al., 2007; Kalkhoven & Watsford, 2018). In another study, Cristi-Sanchez et al., (2019) included 98 elite soccer players and showed that the AT stiffness of soccer players playing in different positions in the same team was similar, and the reason for this was that they did the same training. In another study conducted with athletes from different branches, it was emphasized that AT mechanical properties did not show a significant difference between athletes (Kurihara et al., 2012).

Conclusion

The biomechanical and viscoelastic properties of LG, MG and AT soccer players are very important for optimal jumping performance, which is one of the requirements of the branch. The fact that everyone in the team did the same training and that measurements were applied to soccer players with regionally similar body structure affected the characteristics of the data obtained. In this sense, it is thought that examining the Gastrocnemius-AT structures will contribute to changes in force output and prevention of injuries. It can be said that training coaches on this subject and applying this information to soccer players by conscious coaches will increase the athletic performance (jumping performance, strength, body structure, etc.) of soccer players.

Recommendations

In line with all this information, it should not be forgotten that the optimal performance characteristics that athletes will achieve can be realized through planned, programmed trainings and trainings.

Limitations

The higher number of soccer players involved in the study could have further increased the reliability of the data obtained from the study. At the same time, we do not have the device used for measurements, and we only used this device in a research project. Device support is needed for different studies.

Conflict of Interest

No conflict of interest is declared by the authors. In addition, no financial support wasreceived.

Ethics Statements

This study followed ethical standards and received approval was obtained from Manisa Celal Bayar University Faculty of Medicine Health Sciences Ethics Committee with the date and number 24.04.2024/2393.

Author Contributions

Study design, data collection, statistical analysis, data ınterpretation, article preparation, literature review processes were carried out by the author. The author has read and accepted the published version of the article.

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