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The Relationship Between the Force Production in the Isometric Squat and Bench Press Exercises and the Lower and Upper Body Anaerobic Power Parameters

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Abstract

The primary aim of this study was to investigate relationships between the muscular force in the isometric bench press and squat movements and the Wingate anaerobic test (WanT) results for the upper and lower body. Secondary purpose was to investigate possible correlations between the WanT and the explosive isometric force. Eighteen healthy male volunteer athletes (age: 23.37 ± 1.65, height: 178.37 ± 5.67, body mass; 76.69 ± 3.73) with at least 2 years of strength training participated in the study. During the two test sessions, one-repetition maximum (1-RM), isometric squat and isometric bench press tests and anaerobic power tests with Wingate anaerobic power and arm ergometer were performed. Results of the study showed a high degree of correlation between isometric squat (Squat$_{iso}$) and lower body Peak Power and Average Power (r (14) = 0.766, p < 0.001 and r (14) = 0.690, p < 0.003 respectively). However, there was no significant relationship between Squat$_{iso}$ and Fatigue Index (FI) (p > 0.05). In isometric bench press, there was also a high level of correlation between upper body peak power and average power (r (14) = 0.620, p < 0.01 and r (14) = 0.749, p < 0.001 respectively). These data can be used to classify the power capabilities of the athletes and determining the training loads to be used in achieving the training goals. In addition, periodic measurements of the maximum power and strength performances of the athletes with field tests and laboratory test batteries according to the characteristics of the sports branch can also provide significant contributions to the coaches and researchers.

Keywords: Explosive strength, Peak power, Average power, Fatigue index, Athletic performance.

İzometrik Squat ve Bench Press Egzersizlerinde Kuvvet Üretimi ile Alt ve Üst Vücut Anaerobik Güç Parametreleri Arasındaki İlişki

Öz

Bu çalışmanın öncelikli amacı, alt ve üst ektremiteye ait kassal izometrik bench press, skuat ve Wingate Anaerobik Test (WanT) parametreleri arasındaki ilişkiyi araştırmaktır. İkincil amacı ise, WanT ve patlayıcı isometric kuvvet arasındaki ilişkilerin incelenmesidir. Çalışmaya kuvvet egzersizlerinde en az iki yıllık deneyime sahip ve gönüllü katılım gösteren 18 sağlıklı erkek sporcu (yaş: 23,37 ± 1,65 y, boy: 178,37 ± 5,67 cm, vücut kütlesi; 76,69 ± 3,73 kg) katılmıştır. İki test seansı olarak gerçekleştirilen ölçümler sırasında, 1 tekrar maksimum (1-TM), izometrik squat ve izometrik bench press testleri ile alt ve üst ekstremiteye yönelik Wingate anaerobik güç testleri uygulandı. Çalışmanın sonuçları, izometrik skuat (Squat$_{iso}$) ile alt ekstremite Zirve Gücü ve Ortalama Güç arasında yüksek derecede korelasyon bulunduğunu göstermekteydi (sırasıyla, r (14) = 0,766, p < 0,001 ve r (14) = 0,690, p < 0,003). Fakat hiçbir Squat$_{iso}$ ile Yorgunluk İndeksi değeri arasında anlamlı bir ilişki bulunmamaktaydı (p >0,05). Bununla birlikte izometrik bench press'te, üst vücut zirve gücü ile ortalama güç arasında da yüksek düzeyde bir korelasyon bulunmaktaydı (sırasıyla r (14) = 0,620, p < 0,01 ve r (14) = 0,749, p < 0,001). Bu veriler, sporcuların güç kapasitelerini sınıflandırmada ve antrenman amaçlarına ulaşmada kullanılacak antrenman yüklerinin belirlenmesinde faydalı olabilir. Buna ek olarak, spor branşının özelliklerine göre saha testleri ve laboratuvar test bataryaları ile sporcuların maksimum güç ve kuvvet performanslarının periyodik olarak ölçülmesi de antrenörlere ve araştırmacılara önemli katkılar sağlayabilir.

Anahtar kelimeler: Patlayıcı güç, Zirve güç, Ortalama güç, Yorgunluk indeksi, Atletik performans.

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INTRODUCTION

Rapid change of direction is a key factor for a successful performance in sprint races and many team sports, such as the ability to accelerate and reach maximum speed in very short times and distances (10 – 20 – 30 m) (Bradley et al., 2010). In addition to the peak power production in limited time during these efforts, it is an indispensable requirement to maintain the maximal values reached until the end of the exercise or the competition (Girard et al., 2011; Tillin et al., 2013a). As a result of strength and endurance training to encounter these requirements, the energy systems specific to the type of training performed and the stimulation mechanisms associated with these energy systems, marked changes occur in the adaptation of the central nervous system and in the quality of eccentric and concentric contractions (Cantrell et al., 2014; Komi & Gollhofer, 1997; Wilson et al., 1993). The success in the sportive performance determined by the race grades or the result of the competition also emerges because of the positive or negative effects of these changes. For this reason, the evaluation of the variables that may have an effect on the result of the competition and the determination of the level of their effect on the results are the most studied subjects by the researchers (Acevedo & Goldfarb, 1989; Harris et al., 2008; Iaia et al., 2009; Jones & Carter, 2000).

Although upper and lower muscle groups are measured separately according to the requirements of sports branches, it is seen that researchers have focused on tests for lower body muscle groups in determining the relationship between explosive strength, maximal strength, power and acceleration and reaching maximal speeds in short distances in most sports branches (football, tennis, handball) (Beretić et al., 2013; Tillin et al., 2013a). Many studies have reported a low correlation between leg strength values measured in a single-joint movement such as "leg extension" and explosive movement patterns and sprinting, whereas values in a multi-joint "squat" exercise have reported high to moderate correlations between these parameters (Wisløff et al., 2004). Recently, multi-joint isometric bench press and squat applications have been used in the evaluation of these strengths as valid and reliable tests in the evaluation of peak strength levels due to their simplicity and less risk of injury (Brady et al., 2018; Drake et al., 2018; Thomas et al., 2015; Young et al., 1993; Young et al., 2014). It is also seen that isometric strength assessments are also used to determine dynamic strength. However, some studies show a relationship between isometric and dynamic strength at different levels, while others show a weak relationship between these two characteristics (Young et al., 2014). Regarding the upper body, Murphy and Wilson (1996) found a low correlation between isometric bench press exercise and dynamic exercises such as seated shot put (Pryor, 1994), while Ignjatović and Stanković (2009) observed a similar level of correlation between isometric bench press and dynamic movements in different forms.

Apart from muscular strength characteristics, anaerobic power characteristics are also an important criterion for sportive performance where short-term and intense efforts are required (Issurin & Tenenbaum, 1999). Moreover, jumps are one of the basic skills performed by the rapid contraction and relaxation of the leg muscles. It is also possible to analyse the tests measuring the contraction force, including dynamics and isometrics in the feet by dividing them into sections (Fox, 1984). Leg strength and athletic achievement could be accurately predicted in anaerobic type of sports by using the traditional “jump and reach” test (Sheety, 2002). Because the dynamic and static contraction power of the legs is closely related to the anaerobic power performance. One of the methods used to measure this performance is the Wingate Anaerobic Test (WAnT). WAnT cycling ergometer test is a practical and useful method for measuring muscle metabolism and anaerobic power (Bar-Or, 1987, Beneke et al., 2002). Although there is no test method that could fully reflect anaerobic power characteristics, it is known that lower-upper body of WAnT showed high validity and reliability in determining the muscle strength, muscle endurance and fatigue (Manning, 1987; Ratel et al., 2002). It was reported that there was a relationship between various power parameters (peak-average power, fatigue index) of the WAnT (Arslan, 2005; Potteiger et al., 2010). The ability to produce force was expressed as the rate of increase in contractile force at the beginning of contraction in the early phase of increased muscle strength (Häkkinen et al., 1986). Moreover, it was stated that the ability to perform rapid increases in muscle strength in time-limited situations (<200 ms) [in other words, rate of force development (RFD) – force/time) was more important than maximal strength and power production (Suetta et al., 2004). Performance in basic motor skills such as running and jumping were highly correlated with leg strength, moreover, leg strength was one of the essential components of modern sport (Arslan, 2005). Although only one study has examined the relationship between leg isometric strength and wingate test results, there is no study in the literature that examined the correlations between upper body isometric strength levels and upper body wingate test results together. Therefore, and additional purpose of our study the was to determine the relationships between the muscular strength in isometric bench press and squat exercises and the results of the WAnT for the upper and lower body.

METHODS

Study Design

This research was a quantitative and experimental study. Participants were included in this study if they i) did not have any disease or disability, ii) did not regularly use any medication or antioxidant substance, iii) had at least 2 years of strength training history and no back pain or upper extremity injury. Eighteen healthy male subjects (age: 23.37 ± 1.65 years, height: 178.37 ± 5.67 cm, body mass; 76.69 ± 3.73 kg) with at least 2 years of strength training experience were recruited and volunteered to take part in this study. However, the evaluation of the results was carried out with the data of 16 participants who completed all test procedures (Two participants were excluded from the study due to non-compliance with the application procedures and shoulder pain). According to post-hoc analysis of sample size [correlation H_1= 0.55, power size (1-β) = 0.80, sample size= 16, type-1 error (α) = 0.05], actual power of this study was found 0.75 via G*Power 3.1. This study was carried out in two sessions at 48-h intervals. Participants were warned not to change their diet, not to use any ergogenic substance, and not to do individual training during the sessions.

Ethical Approval

The Experimental procedures undertaken were approved by Ege University's Medical Research Ethics Committee (2014; No: 14-10/1).

Data Collection

Anthropometric Data and Determining One Repetition Maximum: During the first session, the subjects were familiarized with the testing protocols and anthropometric data (height and body mass), were recorded (Tanita BC 418, Tanita Corp., Tokyo, JPN). One repetition maximum (1-RM) bench press was performed on a flat bench, using an Olympic barbell (19.6 kg) and additional weight plates (Esjim Fitness Equipment, Eskisehir, TUR). 1-RM was determined using estimation equations to minimize the risk of possible strain or injury that may be encountered during maximum loading. Equations selected among 5 different linear and 2-different nonlinear equations examined by Reynolds and Gordon (2006). One linear and one non-linear equation with the lowest error rate was used in this study to determine the 1-RMs of the participants. The average of the values obtained from the two different equations. This value was recorded as participants 1-RM. Equations used are presented below:

(1) $1\text{-RM (kg)}=100\times m\times[(55.51\times e-0.0723\times n)+48.47]-1$

(2) $1\text{-RM (kg)}=(0.033\times m\times n)+m$

The abbreviation “m” in the equations was used to express the load (kg) during the test, “n” was used to express the maximum number of repetitions with this load, and “e” was used to express the base of the natural logarithm (Euler number= 2.718). In order to determine a possible imbalance in the right and left extremity strengths of the athletes, the 1-RMs were determined for both single and double extremities. The steps were followed during the sessions: i) warming up (various dynamic activities in which the muscle group tested were predominantly used as general warm-ups), ii) specific warm-up with light load 10 reps [45-60 sec rest and 8 reps with approximately participants’ 15-RM, 45-60 sec rest; 5 reps with approximately participants’ 10-RM, 3-5 min rest, iii) Test session: The participants performed repetitions at 2:0:1:0 tempo until exhaustion, using a load that was estimated to be in range 3-8 repetitions.

Isometric Squat and Bench Press Applications: Isometric squat movement was performed on the force platform (SPS Platform 60x60 cm, CAS Electronic Industry and Trade Inc., KOR) under the fixed bar at a height corresponding to 100° knee angle for 3 seconds (Stone et al., 2003). The bar height and foot stance width of each participant were measured and recorded. Isometric bench press was performed in 2 different positions on the force platform placed under the bench. In the first position, the bar was positioned 2-3 cm away from the participant’s chest at the initial of the movement (Hartmann, 2009), and in the second position, the bar was positioned 30-50 cm away from the chest with the elbows at 135°. In order to determine the desired angles during the sessions, a video motion analysis system (Dartfish Software, TeamPro, Friborg, CHE) was used. Each participant performed a total of 3 repetitions of bench press and squat thrusts with 60 seconds between repetitions (Ignjatović et al., 2009, Tillin et al., 2013a). The highest ground reaction force out of the 3 maximal isometric thrusts was determined as the maximal and according to the allometric scale. Participants were not allowed to lift their waist-hips from the bench during the bench press exercise. During the squat movement, the fingers were allowed to touch the underside of the bar, however the bar was not allowed to be grasped by the hands. This method ensured the weight of the arms was not removed from the force platform during effort (Tillin et al., 2013b). The thrusts were applied withexplosive effort (not gradually) at the beginning, and the participants continually sought to increase the maximal force as they could produce until the test was terminated by the researcher. The ground reaction forces were recorded by the data acquisition system (BIOPAC MP150, Biopac Systems, Goleta, CA, USA). The data was recorded using 1.000 Hz sampling rate, 20 kHz sampling rate, 20-500 Hz band-pass filter and analysed using Acqknowledge 4.2 software (Biopac Systems, Goleta, CA, USA). The system was reset to zero (load cell signal range; 0–0.15 kg) after the participant stepped on (and lying on bench) load-cells as their body weight.

Wingate Test for Lower Extremities: The anaerobic power of the participants was determined in the form of a 30-second test with maximal effort on the Monark 894E Peak Bike (Monark, Stockholm, SWE) bicycle ergometer using 75 $g \cdot kg^{-1}$ of their body weight. During the test, participants were asked to pedal as fast as possible against a load for the entire 30-second test. WAnT 4-different muscle strength levels were determined ($W \cdot kg^{-1}$) as peak power (PP_{low}), average power (AP_{low}) and fatigue index (FI_{low}). Peak power was calculated as the highest value in the first 5 seconds of the test and expressed as the highest mechanical and anaerobic power produced during the test. Average power was reflected the average mechanical strength achieved during the 30 second test and determined as the ability to sustain high power requirements (Sbriccoli et al., 2007). Minimum power was calculated as the lowest power from the WAnT. The fatigue index was also determined by the formula [(peak power output – lowest power output) / peak power output] x 100.

Wingate Test for Upper Extremities: Upper extremity anaerobic strength test was performed using a Monark 881E arm ergometer (Monark 881E Monark-Crescent, Varberg, SWE). Anaerobic strength testing was performed in a sitting position with the arm ergometer adjusted so that the pedalling position creates a 90° shoulder angle (with the ergometer crank axis positioned with the ergometer centre to the shoulder). During pedalling, the upper extremity was bent at right angles to the body for a position close to maximal reach, allowing slight flexion at the elbow joint. This position was used to simulate the pedalling structure of the lower extremity and to provide maximum mechanical efficiency (Franklin, 1985). The ergometer crank arm length was 0.14 m. The alignment of the shoulder and crank axle was determined using the Kinovea motion analysis software (Version, 0.8.15). The warm-up protocol and the determination of power from the WAnT were performed as described in previous studies (Bar-Or, 1987, Inbar & Bar-Or, 1986). It was used to calculate the average flywheel frequency scaled to the crank frequency, allowing the instantaneous power output (crank frequency x resistance) to be determined. Three indices were determined from the WAnT; i) Peak power (PP_{up}): during the test was taken as the highest average power over any 5 second period during the test, ii) Average power: sustained over 30 s (AP_{up}) and iii) Fatigue index (FI_{up}) or power loss during the test (PP - AP over the last 5 s / PP x 100).

Statistical Analysis

Descriptive statistics data were expressed as mean ± standard deviation. The relationship between isometric force and WAnT values was determined by the Pearson correlation coefficient. The significance levels of the correlations were determined according to Hopkins' classification as negligible (≤0.1), small (0.1-0.3), moderate (0.3-0.5), strong (0.5-0.7), very strong (0.7-0.9), near perfect (>0.9) and excellent (≥1.0). Data analysis was performed using SPSS software (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp). The statistical significance level was set at $p \leq 0.05$.

RESULTS

Participants performed 82.91±5.03 kg 1-RM bench press and 135.3±20.69 kg 1-RM squat exercise. Descriptive features of participants and the performances of the lower and upper extremities are shown in Table 1.

Table 1. Descriptive statistics for lower/upper extremity performance variables of participants

		M±SD
Descriptive Features	Age (y)	23.37±1.65
	Body Mass (kg)	76.69±3.73
	Height (cm)	178.37±5.67
	Body fat ratio (%)	14.15±1.87
	Arm Segment Muscle Mass (kg)	9.72±0.41
	Trunk Segment Muscle Mass (kg)	30.26±0.69
	Leg Segment Muscle Mass (kg)	23.82±1.13
Performance Variables	Bench Press 1-RM (kg)	82.91±5.03
	Squat 1-RM (kg)	135.3±20.69
	$\text{Squat}_{\text{iso}}$ (N)	1976.29±189.58
	$\text{Bench}_{\text{iso}}$ (N)	772.87±25.83
	PP_{low} (W)	1116.56±135.61
	AP_{low} (W)	850.12±32.03
	FI_{low} (%)	41.30±1.46
	PP_{up} (W)	786.75±42.38
	AP_{up} (W)	545.93±36.74
	FI_{up} (%)	38.02±1.31

M±SD: Mean±standard deviation; 1-RM: One repetition maximum; Iso: Isometric exercise; $_{\text{Up}}$: Upper extremity variable; $_{\text{Low}}$: Lower extremity variable; PP: peak power; AP: average power; FI: Fatigue index.

Pearson product-moment correlation test was applied to evaluate the relationship between normally distributed variables. A high level of correlation was determined between isometric squat ($\text{Squat}_{\text{iso}}$) and lower extremity of peak power (PP_{low}) and AP_{low} [r (14) = 0.766, $p <0.001$ and r (14) = 0.690, $p < 0.003$, respectively] and $\text{Squat}_{\text{iso}}$ explained that part of 58% - 47% in these variations. In addition, a high level of correlation was determined between PP_{low} and AP_{low} with Squat 1-RM [r (14) = 0.738, $p < 0.001$ and r (14) =0.638, $p < 0.009$, respectively] and Squat 1-RM explained that 54%-40% of these variations. No significant correlation was found between Squat 1TM and $\text{Squat}_{\text{izo}}$ values and FI_{low} ($p > 0.05$) [Table 2].

Table 2. Relationships between isometric strength, 1-RM and lower extremity anaerobic power

	Squat 1-RM	$\text{Squat}_{\text{iso}}$	$\text{Bench}_{\text{iso}}$	PP_{low}	AP_{low}	FI_{low}
Bench 1-RM	0.837**	0.771**	0.967**	0.571*	0.386	-0.300
Squat 1-RM		0.979**	0.907**	0.738**	0.627**	0.004
$\text{Squat}_{\text{iso}}$			0.851**	0.766**	0.690**	0.027
$\text{Bench}_{\text{iso}}$				0.633**	0.467	-0.254
PP_{low}					0.932**	0.001
AP_{low}						-0.032
FI_{low}						

**p≤0.001; *p≤0.05; 1-RM: One repetition maximum; $\text{Squat}_{\text{iso}}$: Isometric squat performance; $\text{Bench}_{\text{iso}}$: Isometric bench press performance; PP_{low}: Lower extremity peak power; AP_{low}: Lower extremity average power; FI_{low}: Fatigue index of lower extremity

A high level of correlation was determined between isometric bench press ($\text{Bench}_{\text{iso}}$) and upper extremity of peak power (PP_{up}) and average power (AP_{up}) and $\text{Bench}_{\text{iso}}$ explained that part of 38%- 56% in these variations. In addition, a high level of correlation was determined between Bench press-1RM and PP_{up}, AP_{up}, FI_{up} and Squat 1-RM explained that 27%-50% of these variations. No significant correlation was found between FI_{up} and $Bench_{iso}$ ($p > 0.05$). Between isometric strength, repetition maximum tests and upper extremity correlations of anaerobic strength tests are shown in Table 3.

Table 3. Relationships between isometric strength, 1-RM and lower extremity anaerobic power

	Squat 1-RM	$Squat_{iso}$	$Bench_{iso}$	PP_{up}	AP_{up}	FI_{up}
Bench 1-RM	0.837**	0.771**	0.967**	0.521*	0.711	-0.673
Squat 1-RM		0.979**	0.907**	0.830**	0.886**	0.713
$Squat_{iso}$			0.851**	0.861**	0.901**	-0.726**
$Bench_{iso}$				0.620*	0.749**	-0.681**
PP_{up}					0.877**	0.426
AP_{up}						-0.742**
FI_{up}						

**$p \leq 0.001$; *$p \leq 0.05$; 1-RM: One repetition maximum; $Squat_{iso}$: Isometric squat performance; $Bench_{iso}$: Isometric bench press upper performance; PP_{up}: Upper extremity peak power; AP_{up}: upper extremity average power; FI_{up}: Fatigue index of extremity

Moderate and high correlations were determined between the participants' lean body mass (FFM), arm segment muscle mass (AFFM), trunk segment muscle mass (TFFM), and PP_{low} and AP_{low} (between 0.552 and 0.932). However, no significant correlation was determined between in the leg segment (LFFM) and anaerobic power parameters ($p > 0.05$). Correlations between body mass and lower extremity anaerobic strength are shown in Table 4.

Table 4. Relationships between body mass and lower extremity anaerobic strength tests

	FFM	AFFM	TFFM	LFFM	PP_{low}	AP_{low}	FI_{low}
FFM		0.688**	0.792**	0.721**	0.741*	0.763	-0.163
AFFM			0.808**	0.099	0.639**	0.552**	-0.257
TFFM				0.197	0.670**	0.637**	-0.374
LFFM					0.392	0.380	0.588**
PP_{low}						0.932**	0.001
AP_{low}							-0.032
FI_{low}							

**$p \leq 0.001$; *$p \leq 0.05$; FFM: Fat free mass; AFFM: Arm segment fat free mass; TFFM: Trunk segment fat free mass; LFFM: Leg segment fat free mass; PP_{low}: Lower extremity peak power; AP_{low}: Lower extremity average power; FI_{low}: Fatigue index of lower extremity

Moderate and high correlations were determined between the participants' FFM, AFFM, TFFM and PP_{up} and AP_{up} (between 0.586 and 0.877). However, no significant correlation was found between LFFM and anaerobic power parameters ($p > 0.05$). Correlations between body mass analysis and upper extremity anaerobic strength are shown in Table 5.

Table 5. Relationships between body mass and upper extremity anaerobic strength tests

	FFM	AFFM	TFFM	LFFM	PP_{up}	AP_{up}	FI_{up}
FFM		0.688**	0.792**	0.721**	0.676*	0.670**	-0.483
AFFM			0.808**	0.099	0.586**	0.766**	-0.636**
TFFM				0.197	0.599**	0.673**	-0.643**
LFFM					0.301	0.212	0.046
PP_{up}						0.877**	0.426
AP_{up}							-0.742**
FI_{up}							

**$p \leq 0.001$; *$p \leq 0.05$; FFM: Fat free mass; AFFM: Arm segment fat free mass; TFFM: Trunk segment fat free mass; LFFM: Leg segment fat free mass; PP_{low}: Upper extremity peak power; AP_{low}: Upper extremity average power; FI_{low}: Fatigue index of upper extremity

DISCUSSION AND CONCLUSION

The aim of the present study was to examine the relationships between multiple athletic performance variables for the lower and upper extremities in trained athletes. Moderate to high correlations between $\text{Squat}_{\text{iso}}$ and $\text{Bench}_{\text{iso}}$ and between peak upper-upper and average upper-upper peak force obtained from the study were consistent with the results of isometric strength training obtained in previous studies (Albracht & Arampatzis, 2013; Kordi et al., 2020; Lum et al., 2021).

Exercises such as isometric squat, bench press and mid-thigh pull can be used effectively as an informative monitoring tool for the performance of the athlete, especially when performed using joint angles associated with branch performances. At this stage, as the literature sheds light on, the use of joint angles (90° for isometric squats, 130°-140° for mid-thigh pulls, 90° for bench press) during isometric force applications that can provide higher force production and power outputs are recommended to trainers and practitioners in certain body positions. It can provide important contributions in determining the changes in the force-time curve in certain body positions (Bazyler et al., 2015; Beckham et al., 2013; Blazevich et al., 2002; Downey et al., 2022; Newton et al., 2002). Therefore, following the effects of force production on the performances in the branch with the evaluations in specific angles as well as the dynamic form measurements can create more beneficial results (Ozbay & Ulupınar, 2022). For example, while elite Greco-Roman wrestlers are interested in changes in lower and upper extremity strength levels (hand grip, back grip, leg isometric measurement results) in different parts of the competition (Bazyler et al., 2015; Wilson & Murphy, 1996), sprinters may want to know how pushing characteristics change over certain time intervals (from 0 to 90 milliseconds thrust). The high correlations between $\text{Squat}_{\text{iso}}$, PP_{low} and AP_{low} obtained in this study, where squat explained 58%—47% of these variations, that was supported the above explanations. In addition to these, the high level of correlation between 1-RM of squat, PP_{low} and AP_{low} was similar. Therefore, the results showed that isometric strength and dynamic maximal strength properties may provide important contributions to the evaluation of athletes regarding anaerobic processes.

Each of the multi-joint movement to be performed by the lower and upper extremities involves the activation of various muscles together, and each muscle might cause a maximum strength. Therefore, practitioners and researchers avoided from isometric tests for the measurements of athletes when multi-joint dynamic movements need to be evaluated (Kawamori et al., 2006). However, in previous studies, multi-joint isometric tests such as vertical jump (Stone et al., 2004), bicycle sprint time (West et al., 2011), 10 m sprint time (McGuigan & Winchester, 2008), 1-RM of squat, jerk, and snatch (Stone et al., 2004) performances had moderate and strong relationships between these dynamic movements. As one of the main results of this study, there was a high level of correlation between $\text{Squat}_{\text{iso}}$, PP_{low} and AP_{low}, and explaining these results for 58% - 47% of $\text{Squat}_{\text{iso}}$. The results obtained from the lower extremities were similar to the upper extremity. High correlation between $\text{Bench}_{\text{iso}}$, PP_{up} and AP_{up}, and $\text{Bench}_{\text{iso}}$ may explained 38%-56% of these variations. In addition, these results showed similar results with the bench press 1-RM in a dynamic testing form. The isometric squat may be used to complement isoinertia test results by providing kinetic data in a more comprehensive description of changes in strength and explosiveness in a training program. The isometric squat may also be used to assess bilateral force asymmetries in the lower extremities, which can be an effective method for detecting injury.

The measurements of strength and power characteristics of muscle groups of the lower-upper extremities features; helps athletes, coaches, and rehabilitation specialists to select, treat and train athletes for a particular sport. Although not all studies agree, isometric squats and bench press performed at various joint angles may be used as a reliable indicator for monitoring and determining strength and explosive characteristics of training. Because, both isometric and eccentric strength levels are important performance criteria in almost every sport. The development and maintenance of these strength characteristics, as well as similar muscle contraction components, should be implemented as long-term performance goals. Coaches also need to access and use easily administered field tests that also allow the assessment of athletic performance status without measuring the entirety of sports performance with very detailed testing. It may be important for trainers and researchers to periodically measure the maximum power and strength performance (At these stages, isometric tests may provide advantages such as being relatively easy to standardize compared to dynamic tests, having high reliability and being effective in monitoring changes over time) of the athletes with a field test or laboratory test batteries suitable for the characteristics of the sports branch.

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Ethics Committee Approval

Committee: The Experimental procedures undertaken were approved by Ege University's Medical Research Ethics Committee.
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