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Relationship Between Jumping Performance in Various Tasks, Sprint and Agility in Basketball Players

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Research Article

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Abstract

A high level of jumping ability is inherent in elite basketball, but the correlation of jumping ability in various tasks with sprint and agility performances, has not been investigated thoroughly. The main purpose of the present study was to investigate the correlation of jumping performances in various tasks with sprint and agility in basketball players of different ages. Thirty-six (senior: n=12, age 25.75±5.12 years; under 19: n=12, age 17.25±0.45 years; under 17: n=12, age 15.46±0.32 years) male basketball players volunteered to participate in the study. The jumping performance of the players was determined using squat jump, counter-movement jump, and drop jump tests using a force platform. For each test protocol, commonly used power, force, velocity, and acceleration measures were obtained from the official device software. Sprint ability was evaluated by a 20-m sprint test, while agility was measured by the T-Drill test. Pearson's correlation and one-way analysis of variance were used for statistical processing. Jumping performance in each task correlated with sprint and agility (p<.05). Jump height (calculated from take-off velocity) and relative maximal power parameters were determined as the strong predictors of sprint and agility for each jump task (r=.642–.750). Significant differences were observed in all jump tasks, sprint and agility performances among the age groups (p<.05). The study findings indicate a negative correlation between sprint, agility, and different types of jumping performances in basketball players. Considering that explosive movements are important in basketball, especially the correlation of drop jump performance with sprint and agility seems remarkable.

***Keywords**: Drop jump, Change of direction, Field testing, Force plate, Speed, Team sport*

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Basketbolcularda Farklı Tekniklerdeki Sıçrama Performansı ile Sprint ve Çeviklik Arasındaki İlişki

Öz

Yüksek seviyede sıçrama yeteneği elit düzeydeki basketbolun doğasında vardır; ancak farklı tekniklerde gerçekleştirilen sıçrama performansları ile sprint ve çeviklik ilişkisi tam olarak araştırılmamıştır. Bu çalışmanın ana amacı; farklı yaşlardaki basketbolcularda dikey sıçrama performansları ile sprint ve çeviklik arasındaki ilişkiyi incelemektir. Çalışmaya toplam 36 erkek basketbolcu (Yetişkin: n=12, yaş 25,75±5,12 yıl; 19 yaş altı: n=12, yaş 17,25±0,45 yıl; 17 yaş altı: n=12, yaş 15,46±0,32 yıl) gönüllü olarak katılmıştır. Sporcuların sıçrama performansları; skuat, counter-movement ve drop sıçrama testleri kullanılarak bir kuvvet platformu üzerinde gerçekleştirilmiştir. Her test protokolü için cihazın resmi yazılımından kuvvet, güç, hız ve ivmelenme temelli veriler elde edilmiştir. Sıçrama yeteneği 20-m sprint testi; çeviklik ise T-Drill testi ile değerlendirilmiştir. İstatistiksel analizler için Pearson korelasyon ve tek yönlü varyans analizleri kullanılmıştır Sıçrama ve çevikliğin tüm sıçrama tekniklerinde elde edilen perofrmans çıktıları ile ilişkili olduğu tespit edilmiştir (p<,05). Sıçrama yüksekliği (sıçrama hızından hesaplanan) ve relatif maksimum güç parametreleri, sprint ve çevikliğin güçlü prediktörleri olarak belirlenmiştir (r=,642–,750). Sıçrama performanslarına ait parametreler ile birlikte, spirnt ve çeviklik skorlarında yaş grupları arasında istatistiki fark olduğu görülmüştür (p<,05). Çalışma sonuçları, basketbolcularda farklı türlerde gerçekleştirilen sıçrama çıktıları ile sprint ve çevikli arasında negatif yönde korelasyon olduğunu ortaya koymuştur. Patlayıcı formdaki hareketlerin basketboldaki önemi düşünüldüğünde, özellikle drop sıçrama ile sprint ve çeviklik ilişkisi önemli bir bulgu olarak görünmektedir.

Anahtar sözcükler: *Drop sıçrama, Yön değiştirme, Saha testleri, Kuvvet platformu, Hız, Takım sporu*

Introduction

Maximum speed, acceleration, and agility are important requirements in field sports (Lockie, Schultz, Callaghan, Jeffriess & Berry, 2013; Scanlan, Tucker & Dalbo, 2014). The reflection of anaerobic-based movements with a high level of performance is related to developing motor characteristics such as strength, sprinting, and agility (Santos & Janeira, 2011). Basketball is a team sport, which includes high-intensity exercise patterns, and explosive strength in terms of training and competition and in which the anaerobic energy system is used more predominantly (Latorre Román, Villar Macias & García Pinillos, 2018). During a basketball competition, an athlete performs 40–60 short sprints, more than 40 jumps and sudden changes of direction (COD) (Lockie, Beljic, Ducheny, Kammerer & Dawes, 2020). Jumping is an important part of defensive (i.e., block, rebound, steal) and offensive (i.e., lay-up, rebound, shot) movements in basketball (Ziv & Lidor, 2010). Furthermore, sprint and COD are the most used actions in basketball and need to be repeated a lot during the competition (Shalfawi, Sabbah, Kailani, Tønnessen & Enoksen, 2011). Therefore, lower extremity strength significantly affects activities involving plyometric muscle contractions such as sprinting or jumping. Many studies have reported a high correlation between agility and short-distance sprinting (Köklü, Alemdaroğlu, Özkan, Koz & Ersöz, 2015; Negra et al., 2017; Horníková, Jeleň & Zemková, 2021; Falces-

Prieto et al., 2022). Thus, in terms of integrity in athletic performance, it is necessary not to evaluate the two skills mentioned separately in basketball.

Vertical jumping capacity comes to the fore as a preferred method, especially in determining the anaerobic power of the lower extremity indirectly (Sales et al., 2018; Theodorou et al., 2013). Squat jump (SJ) and counter-movement jump (CMJ) tests are the most commonly used methods for jumping ability (Hughes, Warmenhoven, Haff, Chapman & Nimphius, 2021; Makaracı, Özer, Soslu & Uysal, 2021). However, there are few studies investigating SJ and CMJ performances and their relationship with short sprints and agility-based tests in basketball players even though vertical jumping, sprint and agility with/without the ball playing an crucial role in basketball-spesific movoments, technique, and tactics (Alemdaroğlu, 2012; Asadi, 2016). This relationship seems remarkable to use the available training time more efficiently for the coaches. In this context, in terms of movement mechanics (especially block, rebound, and repetitive jumps (Walsh, Arampatzis, Schade & Brüggemann, 2004), the drop jump (DJ), which occurs with an explosive jump following a drop from a particular height, comes to the fore in basketball. DJ test is also another method that focuses on the stretch-shortening cycle (SSC) just as the CMJ (Young, Pryor & Pryor, 1995) since both tests involve fast SSC responses (Markwick, Bird, Tufano, Seitz & Haff, 2015). Therefore, the relationship between DJ and sprint/agility is a unique point that should be analysed for basketball players.

Shallaby (2010) mentioned that jumping, sprinting, COD speed, and technical abilities should be evaluated together in basketball. Some of the studies have investigated the relationships between high-intensity (explosive) movements in basketball (Alemdaroğlu, 2012; Asadi, 2016; Shalfawi et al., 2011). A high level of jumping ability is inherent in elite basketball, but the relationship between sprint/agility performances and jumping ability in different techniques (SJ, CMJ, and DJ) has not been studied thoroughly. As mentioned above, there is a relationship between speed, agility and SJ/CMJ performances, but the relationship with DJ is not clear. Since the jumping technique has a substantial effect on jumping variables (Struzik, Pietraszewski & Zawadzki, 2014), it is necessary to reveal the relationship between DJ and speed/agility. So, if a significant relationship can be found between speed, agility, and DJ performance, it can help coaches and trainers to use more training models based on the DJ movement technique, which plays a critical role in basketball.

Age is one of the determining factors in the interpretation of the relationship between the physical level and game performance of basketball players (Mancha-Triguero, Garcia-Rubio, Calleja-Gonzalez & Ibanez, 2019). So, it is thought that revealing possible athletic performance differences among the competitive group (senior) and the developmental groups (under 19 and 17 years) will be a useful finding for the coaches and trainers in the process of training programmes of the athletes. Moreover, the participation of athletes from different age ranges in the present study will be ensured for the relationship between jumping performances, sprints and agility. The main purpose of the present study was to investigate the correlation of jumping performances in various tasks with sprint and agility in basketball players of different ages. In line with this, the study hypotheses were established as follows: (1) jumping performances performed in different tasks correlate with sprints, (2) jumping performances performed in different tasks correlate with agility, and (3) the athletic performance outcomes of basketball players in different age categories are different.

Methods

Participants

Thirty-six male basketball players participated in this study. Twelve players were members of the under 17-year-old team (U17; age 15.46 ± 0.32 years). Twelve players belonged to the under 19-year-old team (U19; age 17.25 ± 0.45 years). Twelve players belonged to the senior team (age 25.75 ± 5.12 years (Table 1). U17 and U19 players were members of the same team competing in national youth leagues, while the senior group was a member of a team competing in a professional basketball league.

Table 1. Anthropometric characteristics of the subjects (mean ± SD)

Group	N	Age (years)	Height (cm)	Body mass (kg)	Body mass index ($kg \cdot m^{-2}$)
Senior	12	25.75 ± 5.12	192.25 ± 9.00	91.33 ± 14.21	24.65 ± 3.83
U19	12	17.25 ± 0.45	185.92 ± 6.41	78.11 ± 11.14	23.38 ± 3.59
U17	12	15.46 ± 0.32	181.46 ± 10.23	76.64 ± 10.82	24.15 ± 2.88

The criteria for inclusion in the study were to being a competetive male basketball player, basketball experience of at least three years, and not to use any kind of ergogenic substance (e.g., creatine, caffeine). The exclusion criteria were, any lower-extremity operation in the last two years, the inability to attend in team basketball training, and musculoskeletal injury in the past six months (Zagatto et al., 2022).

Procedures

All study tests and measurements were conducted a week before the pre-season camping period when the players who participated in the study were not attend in different training sessions and/or games. The study protocol consisted of two testing sessions (on separate days). In the first session of the study, anthropometric and vertical jump measurements of the participants were tested. A standardized warming up process prior to the jumping test protocols, which involved five minutes of jogging, five minutes stretching (passive), and three sub-maximal vertical jumps (Köklü, Alemdaroğlu, Koçak, Erol & Fındıkoğlu, 2011). The warming up process was followed by five minutes of resting. The order of vertical jump testing was consistent: SJ, CMJ and DJ. In the second session of the study, all players underwent sprint and agility tests. Before the sprint and agility test protocols, a standardized warming up for five minutes consisting of running and agility-based drills was performed (Sonesson, Lindblom & Hägglund, 2021).

Participants were allowed to do a trial session before the data collection process to ensure their familialization with the test protocols. Both test sessions were conducted at the same hours of the day (12-5 pm). Strong verbal encouragement was provided during study measurements.

The experimental design of the study is presented in Figure 1.

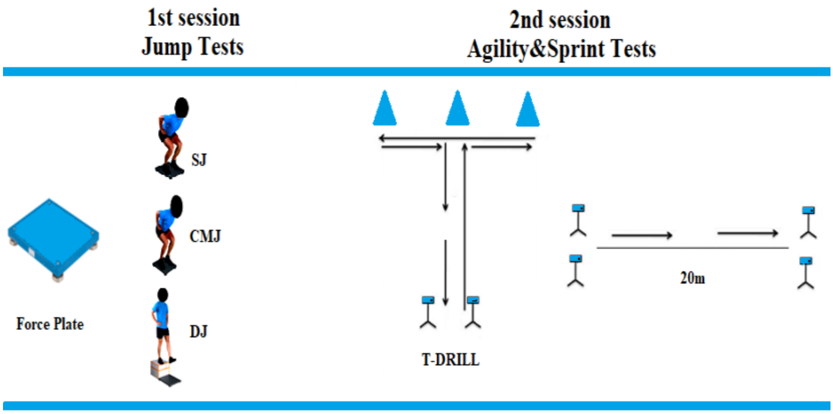

Figure 1. Experimental design

Anthropometric measurements

Body mass was measured by the force plate (automatically before jumping testing), and body height was obtained by a stadiometer (seca 220, seca, Hamburg, Germany).

Vertical jump measurements

A portable piezoelectric force plate (Kistler, Winterthur, Switzerland; type 9260AA6, 50x60 cm) was used to determine the jumping performances of the players. Players performed SJ, CMJ, and DJ test protocols respectively. Participants performed each jump task for three times, with approximately a two minutes recovery time between attempts. They were asked to jump as high as possible in the valid technique and the highest score of three repetition was recorded.

During the assessment of the SJ test, the participants were instructed to stand and flex their knees to almost 90° and perform a vertical jump. The SJ test performed hands on hips condition to prevent any effect of arm movements on the test task. Players had to avoid any kind of counter-movement as much as possible (Coratella et al., 2018). The CMJ test was performed bilaterally with a fast counter-movement at approximately 90° of knee flexion angle. To minimize the influence of possible upper-body movements on the centre of mass point all CMJ measures were performed with the hands on the hips (Pérez-Castilla, Jiménez-Reyes, Haff & García-Ramos, 2019). The DJ task involved standing on a 30-cm jump box with feet shoulder-width apart. At a distant equal to half the body height of each player away from the front of the jump box a target point was placed to standardize each trial.

Following landing process, the participants jumped vertically as high as possible without restricting arm movements to provide counter-movement (Beardt et al., 2018; Makaracı, Pamuk & Soslu, 2022).

The movement characteristics of each jumping test obtained from the Kistler's Measurement, Analysis & Reporting Software (MARS, S2P, Ljubljana, Slovenia) are presented in Figure 2.

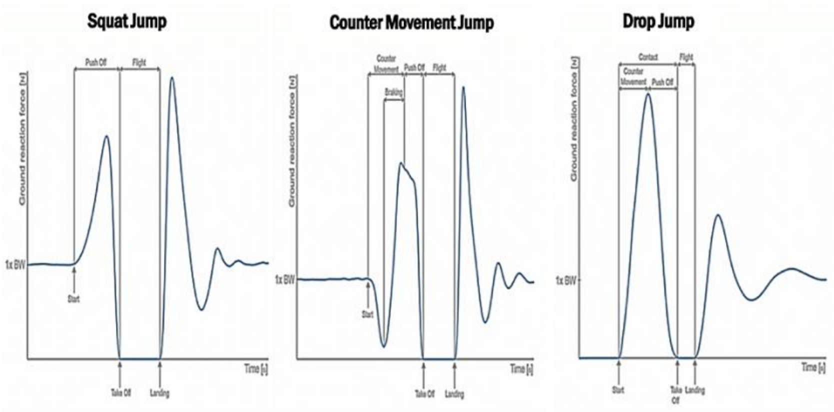

Figure 2. Movement characteristics of SJ, CMJ, and DJ test obtained from the MARS

Force plate-based vertical jumping parameters involving jump height from take-off velocity (JHTOV), relative maximal power (RMP), acceleration (ACL), vertical take-off velocity (VTOV), average power (AP), average force (AF), average velocity (AV), and flight time (FT) obtained from the MARS were used for statistical analysis (Makaracı et al., 2021).

20-m sprint test

20-m sprint (linear) test was performed to reveal acceleration ability of the players. Three maximal 20-m sprint were performed. The recovery period was three minutes between the sprint trials. Test times were measured using a portable wireless photocell system (Witty, Microgate, Bolzano, Italy) connected to an electronic timer. The photocell gates were placed at the starting and finishing line at a 120 cm height. The fastest of the 3 sprint time was recorded (Garcia-Gil et al., 2018).

T-Drill agility test

The T-Drill agility test was used to determine the COD and agility performances. The test includes runnings in different sides (lateral, forward, and backward) to measure the ability for defensive actions and speed with directional changes. For basketball players, the T-Drill agility test is considered one of the most valid and useful test protocols in agility-based measurements (Garcia-Gil et al., 2018). According to the test protocol, firstly each participant was asked to sprint forward 9 m and touch the the cone on the ground. Then a 4.5 m lateral slides (shuffle) to the left side with touching to the cone with the left hand was performed. The participant then suddenly shuffled opposite direction (to the right) 9 m to touch the cone with the right hand. Then a 4.5 m a shuffle was performed to the left to touch the cone in the middle with the right hand. Finally, the participant back-peddled 9 m, passing through the finish point (Garcia-Gil et al., 2018). Three maximal T-Drill test were performed and the fastest of 3 trials was recorded for further analysis. A portable wireless photocell system (Witty, Microgate, Bolzano, Italy) connected to an electronic timer was used to measure the test time.

Statistical analysis

Data were analysed using IBM SPSS Statistics (Version 24.0 for Windows; IBM, Armonk, NY, USA). Descriptive statistics presented as mean ($\bar{X}$) and standard deviations (SDs). After normal distribution was examined and confirmed using the Kolmogorov-Smirnov test Pearson's correlation coefficient was used to establish correlations among jumping performance parameters in different tasks, sprint and agility. The following criteria were applied to interpret the magnitude of the correlation (r) between the test measures was assessed with the following thresholds: ≤ .1, trivial; .1–.3, small; .3–.5, moderate; .5–.7, large; .7–.9, very large; and .9–1.0, almost perfect (Hopkins, Marshall, Batterham & Hanin, 2009).

Differences in the jump performances among the age groups (Senior, U19, and U17) were tested by one-way analyses of variance (ANOVA) with Tukey's post hoc follow-up testing when necessary for each jump test. To estimate effect sizes, eta squared ($\eta 2$) was computed with $\eta 2 \geq .01$ indicating small, ≥ .06 medium and ≥ .14 large effects (Cohen, 1988). Statistical significance was set at $\alpha < .05$.

Ethics Statements

The study measurements and design, possible risks and benefits of the research were fully explained to all players, and they all gave their written informed consent. Participants were assured that they could withdraw from the test sessions without penalty at any time. Parental signed consent was obtained for U17 team players. Ethical approval was granted by the the Karamanoğlu Mehmetbey University, Faculty of Medicine Ethics Committee (no. 2021-2/10) in accordance with the Declaration of Helsinki.

Results

A negative correlation was found between sprint, agility and jumping performances in each jumping task ($p < .05$). JHTOV and RMP parameters were determined as strong predictors of sprint and agility ($p < .001$). Statistical differences were observed among the groups (senior, U19, and U17) in SJ, CMJ, DJ tests and sprint/agility performances ($p < .05$). In the differences detected, the U19 group was observed to have the highest scores, particularly for SJ and DJ test performances.

Table 2 shows the correlations between the 20-m sprint, T-Drill agility, and SJ, CMJ, and DJ test parameters.

Table 2. Correlation coefficients between sprint/agility scores and jumping during each test

	Test	JHTOV *(m)*	RMP *(W/kg)*	ACL *(m/s2)*	VTOV *(m/s)*	AP *(W)*	AF *(N)*	AV *(m/s)*	FT *(s)*
20 m sprint (s)	**SJ**	-.643**	-.685***	-.525**	-.480**	-.414*	-,300	-.349*	-.397*
	CMJ	-.711***	-.706***	-,264	-.668***	-.545**	-.335*	-.655***	-.623***
	DJ	-.719***	-.718***	-,310	-.735***	-.547**	-.348*	-,019	-.737***
T-Drill Agility (s)	**SJ**	-.706***	-.716***	-.585***	-.511**	-.421*	-,259	-.417**	-.410**
	CMJ	-.642***	-.722***	-,226	-.740***	-.537**	-,284	-.726***	-.682***
	DJ	-.750***	-.707***	-,269	-.749***	-.488**	-,238	-,075	-.742***

*JHTOV: Jump height from take off velocity; RMP: Relative maximal power; ACL: Acceleration; VTOV: Vertical take off velocity; AP: Average power; AF: Average force; Average velocity; FT: Flight time; SJ= Squat jump; CMJ = Counter-movement jump; DJ= Drop jump. *p < .05; **p < .01; *** p < .001.*

For the SJ test, all parameters except for AF were significantly correlated with 20-m sprint and T-Drill agility (p < .05). For the CMJ test, all parameters except for ACL were significantly correlated with 20-m sprint, and all parameters except for ACL and AF were significantly correlated with T-Drill agility. For the DJ test, all parameters except for ACL and AV were significantly correlated with the 20-m sprint, and all parameters except for ACL, AF, and AV were significantly correlated with T-Drill agility. JHTOV and RMP parameters in each jump task demonstrated a high significance/correlation with both sprint and agility (p < .001, r = .642–.750).

The correlation graphs of both the JHTOV and RMP parameters for the 20-m sprint and T-Drill agility scores are presented in Figures 3 and 4.

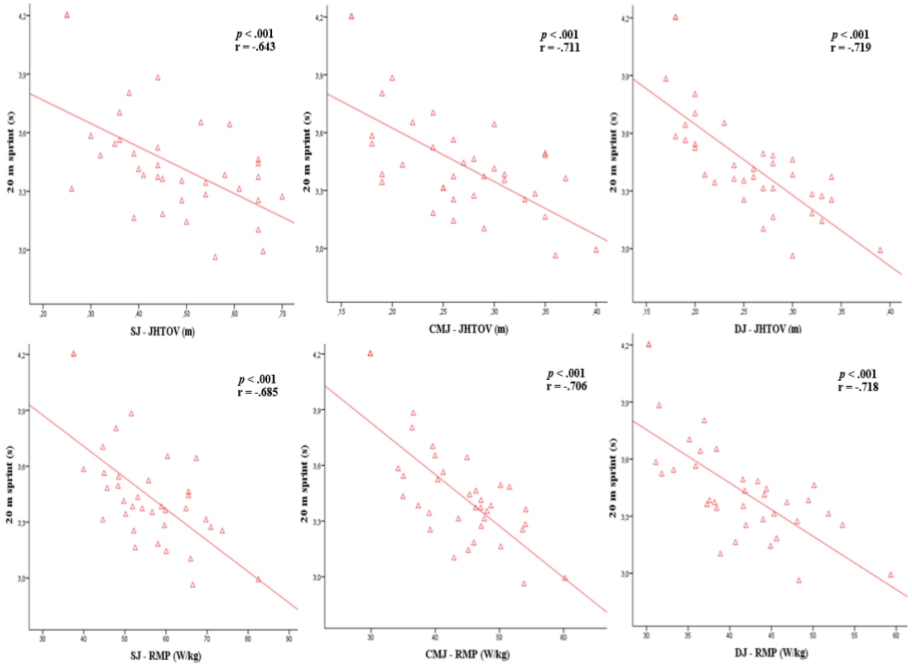

Figure 3. Correlation of JHTOV and RMP parameters with with 20-m sprint scores

Figure 3 demonstrates the correlation graph of JHTOV and RMP parameters with the 20-m sprint scores. There was a negative correlation between the JHTOV, RMP parameters of SJ, CMJ, DJ and 20-m sprint performance. In addition, JHTOV and RMP parameters had both high statistical significance and a large correlation with sprint scores for CMJ and DJ performances ($p < .001$, $r \geq .70$)

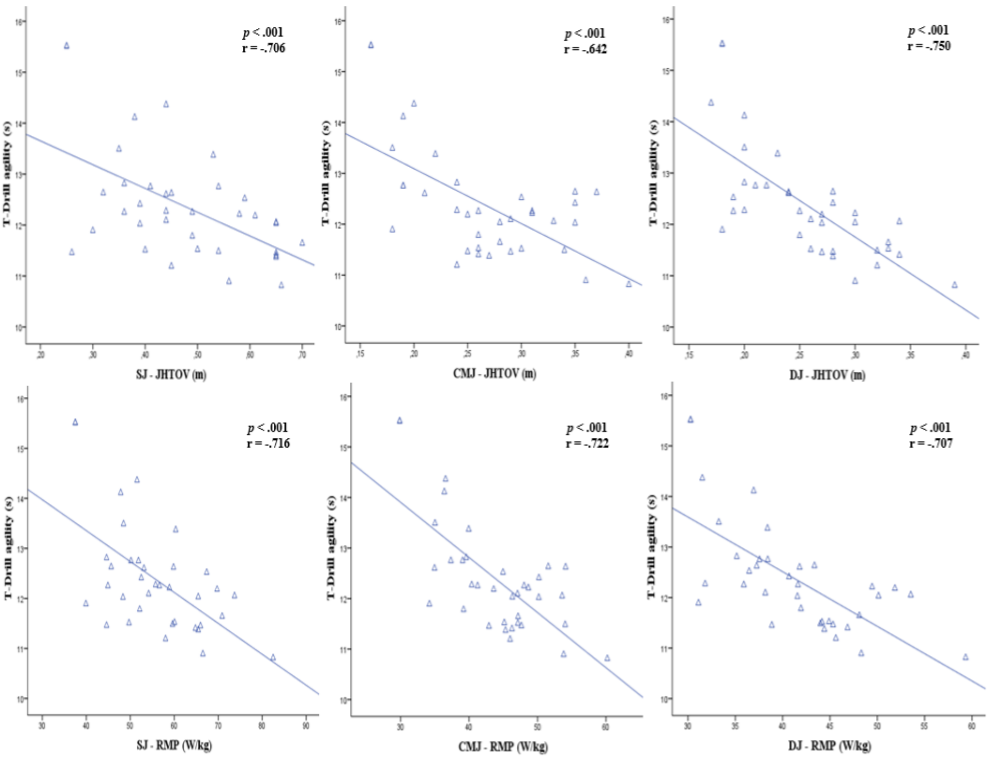

Figure 4. Correlation of JHTOV and RMP parameters with T-Drill agility scores

Figure 4 demonstrates the correlation graph of JHTOV and RMP parameters with the T-Drill agility performance. There was a negative correlation between the JHTOV, RMP parameters of SJ, CMJ, DJ and T-Drill agility performance. RMP had both high statistical significance and a large correlation with sprint score for each jump task ($p < .001$, $r \geq .70$).

One-way ANOVA and post hoc (Tukey) test results of SJ, CMJ and DJ tests among the age groups are presented in Table 3, Table 4, and Table 5 respectively.

Table 3. One-way analysis of variance (ANOVA) of squat jump performances among the groups

Squat Jump					
Group	**Variables**	**X̄**	**SD**	***p***	**Tukey's post hoc**
Senior U19 U17	JHTOV *(m)*	0.45 0.57 0.41	0.12 0.10 0.11	p = .005 η^2 =.391	U19>Snr (p = .050) U19>U17 (p = .004)
Senior U19 U17	RMP *(W/kg)*	55.15 64.44 48.42	5.18 6.56 4.33	p < .001 η^2= .396	U19> Snr (p = .027) U19>U17 (p < .001)
Senior U19 U17	ACL *(m/s²)*	5.88 6.56 4.33	1.16 1.50 1.09	p < .001 η^2= .402	U19>U17 (p < .001) Snr >U17 (p = .014)
Senior U19 U17	VTOV *(m/s)*	2.40 2.44 2.10	0.21 0.39 0.24	p = .026 η^2= .205	Snr >U17 (p = .040) U19>U17 (p = .049)
Senior U19 U17	AP *(W)*	1980.75 2095.25 1408.17	555.32 483.90 313.93	p = .002 η^2= .310	U19>U17 (p = .003) Snr >U17 (p = .013)
Senior U19 U17	AF *(N)*	1456.42 1261.68 1085.36	185.75 203.31 254.62	p = .001 η^2= .350	Snr >U17 (p = .001)
Senior U19 U17	AV *(m/s)*	1.29 1.67 1.32	0.31 0.31 0.21	p = .003 η^2= .302	U19> Snr (p = .005) U19>U17 (p = .009)
Senior U19 U17	FT *(s)*	0.51 0.50 0.42	0.06 0.10 0.05	p = .019 η^2= .210	Snr >U17 (p = .016)

Table 4. One-way analysis of variance (ANOVA) of counter-movement jump performances among the groups

Counter-Movement Jump					
Group	**Variables**	**X̄**	**SD**	***p***	**Tukey's post hoc**
Senior U19 U17	JHTOV *(m)*	0.30 0.30 0.21	0.04 0.06 0.04	p < .001 η^2 = .436	U19>U17 (p < .001) Snr >U17 (p < .001)
Senior U19 U17	RMP *(W/kg)*	46.86 48.16 37.29	4.14 6.65 5.09	p < .001 η^2 = .465	U19>U17 (p < .001) Snr >U17 (p < .001)
Senior U19 U17	ACL *(m/s²)*	3.23 2.75 2.32	0.88 0.95 0.65	p = .040 η^2 = .170	Snr >U17 (p = .031)
Senior U19 U17	VTOV *(m/s)*	2.27 2.46 1.98	0.15 0.20 0.17	p < .001 η^2 = .580	U19> Snr (p = .032) U19>U17 (p < .001) Snr>U17 (p = .001)
Senior U19 U17	AP *(W)*	2088.67 1932.17 1438.35	469.62 313.23 373.30	p = .001 η^2 = .358	Snr>U17 (p = .001) U19>U17 (p = .011)
Senior U19 U17	AF *(N)*	1643.42 1430.75 1263.68	275.97 182.56 255.45	p = .002 η^2 = .315	Snr>U17 (p = .001)
Senior U19 U17	AV *(m/s)*	1.33 1.48 1.21	0.19 0.18 0.21	p = .008 η^2= .258	U19>U17 (p = .006)
Senior U19 U17	FT *(s)*	0.46 0.50 0.39	0.03 0.04 0.02	p < .001 η^2= .690	U19>Snr (p = .014) U19>U17 (p < .001) Snr>U17 (p < .001)

JHTOV: Jump height from take off velocity; RMP: Relative maximal power; ACL: Acceleration; VTOV: Vertical take off velocity; AP: Average power; AF: Average force; Average velocity; FT: Flight time; Snr: Senior. η2 effect size. where η2 ≥ 0.01 small, ≥0.059 medium and ≥0.138 large effects.

Table 5. One-way analysis of variance (ANOVA) of drop jump performances among the groups

Group	Variables	X̄	SD	*p*	Tukey's post hoc
		Drop Jump			
Senior U19 U17	JHTOV *(m)*	0.25 0.31 0.21	0.03 0.04 0.04	$p < .001$ $\eta^2 = .562$	U19>Snr ($p = .002$) U19>U17 ($p < .001$) Snr >U17 ($p = .028$)
Senior U19 U17	RMP *(W/kg)*	40.71 47.06 36.25	5.13 5.72 5.62	$p < .001$ $\eta^2 = .410$	U19> Snr ($p = .021$) U19>U17 ($p < .001$)
Senior U19 U17	ACL *(m/s^2)*	7.63 7.29 6.24	1.55 2.02 1.33	$p = .120$ $\eta^2 = .125$	-
Senior U19 U17	VTOV *(m/s)*	2.30 2.50 2.08	0.15 0.15 0.12	$p < .001$ $\eta^2 = .620$	U19> Snr ($p = .003$) U19>U17 ($p < .001$) Snr >U17 ($p = .003$)
Senior U19 U17	AP *(W)*	2001.92 2050.50 1396.42	317.09 384.41 486.23	$p < .001$ $\eta^2 = .375$	U19>U17 ($p = .001$) Snr >U17 ($p = .002$)
Senior U19 U17	AF *(N)*	1569.00 1457.75 1195.96	216.98 249.87 330.71	$p = .006$ $\eta^2 = .279$	Snr >U17 ($p = .005$)
Senior U19 U17	AV *(m/s)*	1.39 1.57 1.36	0.13 0.16 0.26	$p < .001$ $\eta^2 = .447$	U19>U17 ($p < .001$) Snr >U17 ($p = .019$)
Senior U19 U17	FT *(s)*	0.47 0.51 0.42	0.03 0.03 0.02	$p < .001$ $\eta^2 = .679$	U19> Snr ($p < .001$) U19>U17 ($p < .001$) Snr >U17 ($p = .001$)

JHTOV: Jump height from take off velocity; RMP: Relative maximal power; ACL: Acceleration; VTOV: Vertical take off velocity; AP: Average power; AF: Average force; Average velocity; FT: Flight time; Snr: Senior. η2 effect size. where $\eta 2 \geq 0.01$ small, ≥0.059 medium and ≥0.138 large effects.

There was a statistically significant difference among the groups in all jumping test protocols except for the ACL parameter during the DJ test. For the SJ, CMJ, and DJ test results significant differences among the groups were found to be a large effect according to Cohen's classification ($\eta^2 \geq .138$).

One-way ANOVA and post hoc test results of sprint and agility tests among the age groups are presented in Table 6.

Table 6. One-way ANOVA analysis of sprint and agility scores among the groups

Group	Test	X̄	SD	One-Way ANOVA	Tukey's post hoc
Senior **U19** **U17**	20 m sprint (s)	3.43 3.23 3.65	0.14 0.16 0.32	$p < .001$ $\eta^2 = .390$	U19<U17 ($p < .001$)
Senior **U19** **U17**	T-drill agility (s)	12.16 11.60 13.33	0.49 0.53 1.37	$p < .001$ $\eta^2 = .435$	U19<U17 ($p < .001$) Senior<U17 ($p = .006$)

Table 6 shows that sprint and agility performances among the groups were found to be statistically significant ($p < .001$, $\eta^2 = .390$ and $\eta^2 = .435$ respectively). The differences among the groups were found to have a large effect. It was determined that the U19 was better than the U17 group in 20-m sprint performance ($p < .001$). It was also determined that U19 and the senior group were better than the U17 group in T-Drill agility performance ($p < .001$ and $p = .006$, respectively).

Discussion and Conclusion

An explosive and force-prevailing profile has been noticed in basketball players (Laffaye, Wagner & Tombleson, 2014). Vertical jump protocols such as SJ, CMJ, and DJ include fast SSC and explosive mechanisms. While there are previous studies on vertical jump performance, sprint, and agility, no study examining the relationship between three different jumping tasks and sprint/agility in basketball players was found. In this context, the main purpose of the present study was to investigate the correlation of jumping performances in different tasks with sprint and agility in basketball players. The second purpose was to reveal the jump, sprint and agility performances of basketball players in different age groups. Players from different age groups who were actively playing in the basketball teams were chosen in terms of interpreting this possible correlation in the present study.

In some sports, including basketball, jumping ability and capacity are among the primary conditions for success (Blanco, Nimphius, Seitz, Spiteri & Haff, 2019). The importance of anaerobic actions such as sprint and agility, which take place in a short time and at high intensity, comes to the fore (Latorre Román et al., 2018). Simenz, Dugan and Ebben (2005) stated that motoric features such as strength, power, agility, and speed were associated with jumping performance. According to the present study results, a negative correlation was found between sprint, agility, and jumping performances in each technique ($p < .05$; Table 2). Asadi (2016) found a moderate relationship between sprint, agility, and CMJ ($r = –.61$ and $r = –.60$). Stojanovic, Ostojic, Calleja-González, Milosevic and Mikic (2012) reported that there was a high negative correlation between CMJ and repeti- tive sprinting in basketball players ($r = –.74$). In the same direction, Suarez-Arrones et al. (2020) stated a moderate negative correlation between jump height and linear sprint ($r = –.43$). Alemdaroğlu (2012) reported a strong relation- ship between sprint, agility, and jump height in SJ and CMJ protocols. The results of the studies mentioned confirm the relationship of agility and speed with SJ and CMJ performances. However, the results are evaluated mostly on the jump height parameter. The force plate-based measurements allow the jump performance to be evaluated in different ways (Lake et al., 2018). In our study, it was also observed that JHTOV and RMP parameters in each jump test protocol were highly correlated with sprint and agility scores ($p < .001$, $r \geq .70$; Figures 3 and 4). So, JHTOV and RMP can be considered the strong predictors of sprint and agility in basketball players. Likewise, Chaouachi et al. (2009) indicated that one repetition maximum squat output expressed the best single predictor of short distance sprint performance in basketball players. Therefore, it is an important finding that a power-related (jumping force) value such as RMP is associated with sprint and agility performances. On the other hand, Barr and Nolte (2011) explored that the drop jump height (0.84 m) was correlated to sprint times (0- to 10-m and 10- to 30-m) in female athletes. Unlike other studies, the results obtained from the DJ test used in our study are similar to those of SJ and CMJ protocols. One of the possible reasons for this may be that DJ, SJ, and CMJ have eccentric contractions that occur following a concentric contraction in the form of SSC movements (Ruffieux, Wälchli, Kim & Taube, 2020). When the results are analyzed, it is thought that the correlation between the jumps performed in the vertical axis and short-distance sprint/agility is due to the similarity of acceleration, application of force in different axes, biomechanical/neuromuscular structures and energy systems. On the other hand, the importance of the study findings increases considering the very low number of studies examining the mentioned correlation in basketball players.

According to another result of the study hypothesis; statistical differences were observed among the age groups in SJ, CMJ, DJ tests, and sprint/agility performances ($p < .05$; Tables 3 and 4). In the differences detected in the jumping performances, the U19 group had the highest cores, particularly in SJ and DJ tests. It was determined that CMJ performance was similar in both the senior and U19 groups (Table 3). Ciacci and Bartolomei (2017) stated that the senior group had better performance than the U19 and U17 groups in the pre-test measurements in the study, which examined the effect of explosive power training on vertical jump performance of basketball players. It was also determined that there was no difference in CMJ performance between the senior and U19 groups. In a study conducted on handball players, Saavedra et al. (2018) reported that A-Team players were better in CMJ performance (height and power) than U19-U17-U15 teams' players. On the other hand, Pavillon et al. (2021) mentioned that the U19 group exhibited better CMJ performance (jump height) than the U17 and U15 groups in football players. These studies suggested that the SJ performance of the U19 group might be better than the senior group. In our study, in the differences detected in the sprint and agility performances, the U19 group was observed to have better scores than the U17 group, but no significant difference was revealed between the senior and U19 groups (Table 4). Los Arcos et al. (2020) stated that the U19 group performed better than the elite group in agility test scores, but both groups exhibited similar performance in acceleration scores in football players. On the contrary, Doyle, Browne and Horan (2021) stated that the senior group was better than the U19 and U17 groups in 10–20-m and 30-m sprint performances. The differences in favour of the U19 group for jump, sprint, and agility performances can be explained by the possibility that the U19 group players are more likely to be affected by the effects of physical training because they are in the developmental period. Another possible reason could be the physical characteristics of the U19 group. Therefore, coaches and physical trainers should consider the developmental process and peak performance periods of the players before preparing long-term training programs.

In the present study, factors such as the fact that jump, agility, and sprint tests were carried out on different days and adequate rest periods were provided between the test protocols. The participants were allowed to perform trial exercises before measurements with the force plate device were effective. These factors increase the validity and reliability of the findings. The main limitation of this study is that the lower limb muscle strength of the players is not assessed. Because the short sprint and agility performances could be related to the power output of the muscle. Another limitation of this study was that the differences between sexes were not determined, and the findings of the study could not be fully discussed because scientific studies using the data of the force plate device utilized in the study were not sufficient quantitatively.

The findings of the present study indicate a negative correlation between sprint, agility, and different types of jumping performances in basketball players. The correlation of DJ performance with sprint and agility is a remarkable finding since the importance of explosive movements in basketball. Therefore, it can be suggested that focusing on SJ, CMJ, and DJ based exercises/applications can be an effective method to optimize agility and speed skills in basketball players. The study results also showed that jumping performance was significantly the highest in the U19 group in many parameters, particularly for SJ and DJ tests. This finding can provide information to trainers for athletic profiles of basketball players in different age groups.

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Conflict of Interest

The authors report no conflict of interest.

Author Contributions

Research Idea: YM, RS; Research Design: YM, RS; Analysis of Data: YM; Writing: YM; Critical Review: RS

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