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RELATIONSHIP BETWEEN SPRINT AND VERTICAL JUMP FORCE-TIME METRICS IN ELITE MALE PROFESSIONAL FUTSAL PLAYERS

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ABSTRACT

While sprinting capabilities are crucial for success in futsal, there is a lack of research on how they relate to countermovement vertical jump (CMJ) force-time metrics during both the eccentric and concentric phases of the movement. Thus, the purpose of this study was to examine the relationship between short-distance sprint speed and acceleration capabilities over 5m and 10m sprint distances and CMJ performance within a group of professional athletes. Twenty-two male futsal players competing in the top-tier national league volunteered to participate in this study. Following completion of the warm-up protocol, athletes stepped onto a uni-axial force plate and performed two non-consecutive CMJs with no arm swing, followed by two 10m sprints. The body mass-dependent force-time metrics were analyzed in both absolute and relative terms, while sprint analysis included 5m and 10m sprint speed and average acceleration over 0-5m and 5-10m sprint distances. Pearson product-moment correlation coefficients (r) were used to examine the strength of the relationship between performance parameters of interest ($p < .05$). The results revealed that 10m sprint speed was positively associated with CMJ concentric peak velocity ($r = .455$; $p = .032$) and jump height ($r = .457$; $p = .033$). Besides providing sports practitioners working with this specific group of athletes with referent values about sprint and jump performance characteristics, the findings of this study suggest that athletes capable of generating greater CMJ concentric peak velocity and jump height tend to attain greater 10m sprint velocities.

Keywords: force, velocity, speed, power, concentric, eccentric

INTRODUCTION

Futsal, a five-a-side indoor version of soccer (i.e., one goalkeeper and four outfield players), is an internationally popular game played on a smaller court (i.e., 38-42m x 20-25 m) with a reduced number of players (Naser et al., 2017). The rules of futsal differ from those of traditional soccer in several ways, including a smaller, non-bouncing ball, shorter match duration, and the absence of offside (Naser et al., 2017; Spyrou et al., 2020). These unique aspects of this game have a consider-

able impact on the physical and physiological demands placed on the athletes during training and/or competition (Moore et al., 2014). For example, the smaller playing area requires players to rely heavily on speed and agility to gain a competitive advantage over opponents (Moore et al., 2014; Naser et al., 2017; Spyrou et al., 2020). Also, the high frequency of repetitive high-intensity acceleration and deceleration movements solidifies the need for superior aerobic, anaerobic, and lower-body neuromuscular performance capacities that

these players need to possess in order to optimize their on-court performance (Helgerud et al., 2001; Moore et al., 2014; Milioni et al., 2016; Naser et al., 2017; Spyrou et al., 2020; Tomlin et al., 2001).

As in many other team sports (e.g., handball, basketball, soccer), sprinting capabilities are crucial for success in futsal, particularly in offensive and defensive play (Spyrou et al., 2020). Previous research has found that futsal players tend to cover a total distance of 3749 ± 1123 m during a match, with an average sprinting distance of 135 ± 54 m (i.e., >18 km/h) (Ribeiro et al., 2020). These sprinting actions are often comprised of two consecutive high-intensity sprints separated by a 15-second rest interval (Caetano et al., 2015), with an average sprint distance of 10m (Castagna et al., 2009). To date, multiple research reports have examined the sprint performance characteristics of this specific group of athletes (Charlot et al., 2016; Galy et al., 2015; Loturco et al., 2018, 2022; Sekulic et al., 2019). For example, when studying a cohort of Brazilian futsal players, Loturco et al. (2020) found mean 5m and 10m sprint velocities to be 4.79 ± 0.22 m/s and 5.67 ± 0.23 m/s, respectively. In a similar study, the same group of authors found that the average acceleration capabilities of these athletes (i.e., calculated as the rate of change of velocity with respect to time) within the 0-5m and 5-10m sprint segments were 4.64 ± 0.50 m/s² and 1.22 ± 0.22 m/s², respectively (Loturco et al., 2018). Additionally, Dogramaci et al. (2011) found that elite Australian futsal players were able to cover greater distances and perform more sport-specific activities (e.g., backward or sideways movement) than their sub-elite counterparts. Similar findings were reported by Sekulic et al. (2019) in a cohort of Croatian futsal players, who observed superior 10m sprint times among elite compared to sub-elite athletes. Overall, based on the aforementioned

research reports, it is clear that short sprint distances (i.e., 5-10m) seem to be of critical importance for on-court success in futsal, especially given the small court dimensions.

Alongside the sprint performance qualities, countermovement vertical jump (CMJ) has been extensively used in an applied sports setting as a measure of lower-body power-producing capabilities (Cabarkapa et al., 2024a; Cabarkapa et al., 2024b; Merrigan et al., 2024; Merrigan et al., 2021; Philipp et al., 2023; Philipp et al., 2024). When examining a cohort of professional futsal players competing in the top-tier Spanish league, DeFritas et al. (2019) found an average vertical jump height of 36.6 ± 4.1 cm. These findings are consistent with those of Cuadrado-Panafiel et al. (2014), who studied a similar group of futsal athletes (i.e., 35.9 ± 5.29 cm). However, when comparing athletes competing at the elite vs. sub-elite levels of futsal, Naser and Ali (2016) found no statistically significant difference in vertical jump height (i.e., $\sim 4.2\%$). These findings suggest that vertical jump ability may not have the same impact on determining on-court performance in futsal athletes as it may have in other team sports (Spyrou et al., 2020). For example, in soccer, CMJ performance has been found to be a critical determinant of many sport-specific actions, as it depicts a player's ability to rapidly apply greater force into the ground (Loturco et al., 2020). Specifically, when examining a cohort of one of the most successful soccer teams in Norway, which won 11 national titles, Wislof et al. (2004) found a strong, significant relationship between vertical jump height and 10m sprint times. However, none of the previously mentioned research reports included a detailed analysis of CMJ force-time metrics (e.g., concentric peak power, eccentric mean force) and their relationships with sprint performance parameters in profes-

sional futsal athletes. Moreover, considering an exponential rise in the use of portable force plate systems in an applied sports setting for non-invasive, time-efficient lower-body neuromuscular performance assessment, this information can be of great benefit to sports practitioners working with this specific group of athletes.

Therefore, to bridge a gap in the scientific literature, the purpose of the present study was to examine the relationship between short-distance sprint performance characteristics (i.e., sprint speed and acceleration capabilities) and CMJ force-time metrics during both the eccentric and concentric phases of the jumping motion in a group of professional futsal athletes.

METHODOLOGY

Participants

Twenty-two professional male futsal players (age: 25.8 ± 4.8 years; height: 180.1 ± 6.1 cm; body mass: 78.3 ± 9.3 kg) volunteered to participate in the present study. The cohort consisted of two teams competing in the same first-tier futsal league in Europe (i.e., Serbia) and included athletes selected for the official national team. All athletes were a) free of any type of musculoskeletal injuries that could limit sprinting and/or jumping performance, b) cleared for participation in team training activities by their respective sports medicine staff, c) participated in team training sessions ≥ 3 times per week, d) participated in strength and conditioning training sessions ≥ 2 times per week, and e) previously exposed to similar types of jump/sprint testing procedures. The testing procedures performed in this investigation were previously approved by the University's Institutional Review Board, and all participants signed an informed consent document.

Procedures

The testing procedures were conducted approximately two weeks prior to the start of the official futsal competitive season, 24-36 hours post-completion of the last team practice session (i.e., 17:00-19:00h). Each athlete completed a standardized warm-up procedure (i.e., 15 min), consisting of dynamic stretching exercises (e.g., A-skips, butt-kicks, high knees, side-to-side lunges, high-knee-pulls) and futsal-specific movements (e.g., low-intensity ball passing and kicking). Following completion of the warm-up protocol, athletes stepped onto a uni-axial force plate system (ForceDecks Max, VALD Performance, Brisbane, Australia). They performed two non-consecutive CMJs with no arm swing (i.e., hands on the hips throughout the movement). The force plate sampling rate was 1,000 Hz. Strong verbal encouragement was provided by research assistants to ensure that athletes provided maximum effort. The athletes were constantly reminded to focus on pushing the ground as forcefully as possible (Kershner et al., 2019). Also, athletes were instructed to perform the jumping movement using a self-selected countermovement depth. The force plate system was recalibrated between participants, and the mean across two jump trials was used for performance analysis. Based on previously published research reports that demonstrated adequate measurement validity and reliability (Anicic et al., 2023; Cabarkapa et al., 2024a; Cabarkapa et al., 2024b; Collings et al., 2024; Merrigan et al., 2022), the VALD software was used to compute the following force-time metrics of interest: vertical jump height (i.e., impulse-momentum calculation), countermovement depth, reactive strength index (RSI)-modified (i.e., jump height divided by contraction time), eccentric and concentric peak velocity, and eccentric and concentric mean and peak force and power. Also, consid-

ering that force and power are body-mass-dependent variables, the analysis procedures incorporated both absolute and relative values for these specific metrics.

After completion of the CMJ testing procedures, each athlete performed two 10m sprints (Harper et al., 2020; Harper et al., 2023; Philipp et al., 2023). The start position (0 m) was marked with a set of cones, and the athletes were instructed to stand still in a staggered stance position. A radar device (Stalker ATS II, Applied Concepts, Inc., Dallas, TX, USA) was used to collect sprint-related performance characteristics. It was positioned on a portable tripod 5m behind the start line (0m). The height of the radar was adjusted between each participant so that it was approximately in line with the athlete's estimated center of mass (i.e., lower back/hip region). The radar's sampling frequency was 47 Hz. Following a "3-2-1-go" command, athletes sprinted as fast as possible through the second set of cones positioned at the 10m mark. The athletes were instructed not to slow down before crossing the finish line. The rest time between sprint trials was 4-5 minutes to minimize fatigue-related effects, and the average value was used for performance analysis. To ensure athletes sprinted with maximum effort, research assistants were present to provide strong verbal encouragement. The raw and instantaneous horizontal velocity data provided by the radar were manually processed using the device's software program (Version 5.0, Applied Concepts Inc., Dallas, TX, USA). Then, custom-made MatLab software (MathWorks Inc., V9.15, Natick, MA, USA) was

used to analyze 5m and 10m sprint velocity and average accelerations within both 0-5m and 5-10m sprint distances.

Statistical Analysis

Descriptive statistics, mean and standard deviation ($M \pm SD$), were calculated for each dependent variable. Shapiro-Wilk test and Q-Q plots corroborated that the assumption of normality was not violated. Pearson product-moment correlation coefficients (r) were used to examine the strength of relationships between sprint performance characteristics (e.g., 5m speed) and CMJ force-time metrics of interest (e.g., eccentric peak power; concentric mean force). The magnitude correlation thresholds (r) were interpreted as trivial ($<.10$), small ($.10-.29$), moderate ($.30-.49$), large ($.50-.69$), very large ($.70-.89$), and nearly perfect ($\geq.90$) (Nimphius et al., 2010). All statistical analyses were conducted in SPSS (Version 28.0; IBM Corp., Armonk, NY), and the α level of $p < .05$ was used as the criterion for statistical significance.

RESULTS

Descriptive statistics, including means and standard deviations, for all sprint and force-time metrics of interest in this study are presented in Table 1. A statistically significant positive relationship of moderate magnitude was observed between 10m sprint speed and CMJ concentric peak velocity ($r = .455$; $p = .032$) and jump height ($r = .457$; $p = .033$). No other relationships between sprint and CMJ force-time metrics reached the level of statistical significance, and all were trivial to small in magnitude (Table 2).

Table 1. Descriptive statistics ($M \pm SD$) for each dependent variable examined in this study.

Variable [unit]	Value ($M \pm SD$)
<i>Sprint performance metrics</i>	
5m speed [m/s]	5.8 ± 0.3
10m speed [m/s]	6.6 ± 0.2
AVG acceleration 0-5m [m/s^2]	3.8 ± 0.4
AVG acceleration 5-10m [m/s^2]	2.8 ± 0.2
<i>CMJ Force-time metrics</i>	
ECC peak velocity [m/s]	-1.2 ± 0.2
ECC mean force – A [N]	769.7 ± 91.6
ECC mean force – R [N/kg]	9.8 ± 0.1
ECC peak force – A [N]	1915.6 ± 320.5
ECC peak force – R [N/kg]	24.5 ± 3.2
ECC mean power – A [W]	477.0 ± 135.8
ECC mean power – R [W/kg]	6.0 ± 1.2
ECC peak power – A [W]	1380.0 ± 494.5
ECC peak power – R [W/kg]	17.3 ± 4.7
CON peak velocity [m/s]	2.7 ± 0.2
CON mean force – A [N]	1618.0 ± 164.4
CON mean force – R [N/kg]	20.8 ± 1.7
CON peak force – A [N]	2003.5 ± 238.9
CON peak force – R [N/kg]	25.7 ± 2.7
CON mean power – A [W]	2341.9 ± 308.2
CON mean power – R [W/kg]	30.0 ± 3.2
CON peak power – A [W]	4122.5 ± 488.5
CON peak power – R [W/kg]	52.9 ± 5.2
Jump height [cm]	35.4 ± 5.0
RSI-modified [ratio]	0.5 ± 0.1
Countermovement depth [cm]	-29.1 ± 6.5

Note: ECC – eccentric; CON – concentric; CMJ – countermovement vertical jump; RSI – reactive strength index; A – absolute value; R – relative value; AVG – average.

Table 2. Pearson product-moment correlation coefficients (*r*) and their statistical significance.

Variable [unit]		5m speed [m/s]	10m speed [m/s]	AVG ACC 0-5m [m/s ²]	AVG ACC 5-10m [m/s ²]
ECC peak velocity [m/s]	<i>r</i>	.073	.207	.033	.091
	<i>p</i>	.764	.354	.885	.687
ECC mean force - A [N]	<i>r</i>	.113	-.210	.191	.051
	<i>p</i>	.617	.347	.395	.820
ECC mean force - R [N/kg]	<i>r</i>	-.349	-.319	-.265	-.273
	<i>p</i>	.111	.148	.233	.218
ECC peak force - A [N]	<i>r</i>	-.123	-.261	-.156	-.239
	<i>p</i>	.586	.241	.488	.284
ECC peak force - R [N/kg]	<i>r</i>	-.276	-.146	-.390	-.366
	<i>p</i>	.214	.516	.073	.094
ECC mean power - A [W]	<i>r</i>	.071	-.202	.098	-.010
	<i>p</i>	.754	.368	.665	.963
ECC mean power - R [W/kg]	<i>r</i>	.027	-.124	.000	-.054
	<i>p</i>	.904	.582	.999	.813
ECC peak power - A [W]	<i>r</i>	-.081	-.378	.013	-.128
	<i>p</i>	.718	.083	.954	.571
ECC peak power - R [W/kg]	<i>r</i>	-.166	-.384	-.099	-.213
	<i>p</i>	.460	.078	.661	.342
CON peak velocity [m/s]	<i>r</i>	.245	.455	.153	.288
	<i>p</i>	.272	.032*	.496	.193
CON mean force - A [N]	<i>r</i>	-.002	-.191	-.050	-.148
	<i>p</i>	.992	.395	.825	.511
CON mean force - R [N/kg]	<i>r</i>	-.171	.045	-.339	-.265
	<i>p</i>	.446	.843	.123	.233
CON peak force - A [N]	<i>r</i>	-.002	-.316	-.025	-.189
	<i>p</i>	.993	.152	.913	.401
CON peak force - R [N/kg]	<i>r</i>	-.132	-.126	-.243	-.273
	<i>p</i>	.558	.576	.275	.219
CON mean power - A [W]	<i>r</i>	.059	.003	-.018	-.041
	<i>p</i>	.793	.989	.938	.857
CON mean power - R [W/kg]	<i>r</i>	-.041	.251	-.241	-.110
	<i>p</i>	.855	.259	.281	.625
CON peak power - A [W]	<i>r</i>	.204	.107	.213	.198
	<i>p</i>	.363	.636	.341	.378
CON peak power - R [W/kg]	<i>r</i>	.134	.395	.036	.184
	<i>p</i>	.553	.069	.874	.412
Jump height [cm]	<i>r</i>	.251	.457	.151	.284
	<i>p</i>	.260	.033*	.503	.201
RSI-modified [ratio]	<i>r</i>	-.068	-.119	-.295	-.332
	<i>p</i>	.764	.599	.183	.131
Countermovement depth [cm]	<i>r</i>	-.228	-.269	-.281	-.345
	<i>p</i>	.308	.227	.205	.116

Note: (*) – statistically significant ($p < .05$); ECC – eccentric; CON – concentric; AVG – average; RSI – reactive strength index; A – absolute value; R – relative value; ACC – acceleration.

DISCUSSION

To the best of our knowledge, this was the first study to examine the relationship between short-distance sprint performance characteristics (i.e., sprint speed and acceleration) and CMJ force-time metrics in both the eccentric and concentric phases of the jumping motion in professional futsal athletes. The results revealed that 10m sprint speed was positively associated with CMJ concentric peak velocity ($r = .455$) and jump height ($r = .457$).

Previously published research reports have found that the vertical jump height of elite professional futsal players competing in the Brazilian and Spanish national leagues tends to range between 35.9 and 39.7 cm (Cuadrado-Penaflor et al., 2014; Freitas et al., 2019; Gomes et al., 2011), which is similar in magnitude to the results observed in the present investigation. However, the 5m sprint speed seems to be greater than the one observed by Loturco et al. (2018), who focused on examining the 2016 National Brazilian League winners (4.8 ± 0.3 vs. 5.7 ± 0.2 m/s), while absolute acceleration measures across 0-5m sprint distance were lower (4.6 ± 0.5 vs. 3.8 ± 0.4 m/s²). This discrepancy in the measurement may be primarily attributed to the differences in body mass (73.6 ± 6.9 vs. 78.3 ± 9.3 kg), testing methodology (i.e., photocells vs. radar gun) (Jovanovic et al., 2024), as well as the athletes' training status (e.g., off-season vs. in-season). In addition, a recent study by Spyrou et al. (2023) assessed season-long changes in CMJ eccentric and concentric peak power and velocity. The magnitude of each of the aforementioned metrics was almost identical to our findings (e.g., concentric peak power, 54.7 ± 5.2 vs. 52.9 ± 5.2 W/kg; eccentric peak velocity, -1.3 ± 0.2 vs. -1.2 ± 0.2 m/s), which is expected if taking into account that both groups of athletes are competing on a similar level of play (i.e., first national league). Moreover, despite eccentric and concentric force metrics not being reported by Spyrou et

al. (2023), we can assume that they would be in direct agreement as well, as CMJ movement velocities were almost identical (i.e., $power = force \times velocity$) (Fry et al., 2019).

A positive relationship between sprint performance and CMJ capabilities has been observed across multiple studies of sprinters, basketball players, and youth and professional soccer players (Koklu et al., 2015; Mero et al., 1991; Shalfawi et al., 2011; Wisloff et al., 2004). This is in direct agreement with the results of the present investigation, as vertical jump height showed a moderate-to-strong positive relationship with 10m sprint velocity ($r = .457$). Conversely, a weak, non-statistically significant relationship ($r = .251$) was observed between vertical jump height and 5m sprint velocity. While further research is warranted on this topic, these findings align with those of Washif & Kok (2022), suggesting that the association between CMJ and an athlete's sprint capabilities becomes stronger with increasing sprint distance (e.g., 10m, 30m, 60m). In addition, a moderate positive relationship ($r = .455$) has been found between CMJ concentric peak velocity and 10m sprint speed. Also, relative CMJ concentric mean force revealed a trivial relationship with 10m sprint speed ($r = .126$), while relative concentric mean power was close to reaching the level of statistical significance ($r = .395$; $p = .069$). Thus, this may lead us to assume that an increase in 10m sprint speed may be more dependent on increased movement velocity than on the athlete's strength capabilities (Fry et al., 2019). Moreover, movement velocity may more directly reflect the neuromuscular ability to rapidly apply force during short ground contact times (e.g., rate of force development), making it a potentially better predictor of sprint performance than force or power-producing capabilities alone (Nagahara et al., 2024). Yet, it is important to note that the cohort participants examined in this study were professional futsal athletes competing in

the top-tier national league, suggesting that they likely already possessed adequate levels of strength and that the importance of strength development should not be minimized (Baker et al., 2008). This assumption can be further supported by the previously discussed strong agreement regarding the magnitudes of multiple force-time metrics observed in this study and in other research reports examining similar groups of professional futsal athletes (Spyrou et al., 2023).

While offering further insight into CMJ force-time metrics of professional futsal players and their relationships with sprint performance characteristics, this study is not without limitations. One limitation pertains to a homogenous cohort of participants (i.e., professional athletes) and the inability to account for position-specific differences (e.g., pivot, defender, goalkeeper). Also, an increased testing frequency would be beneficial, as the testing procedures in this investigation were conducted at a single testing time point (i.e., pre-season). Hence, further research is warranted to examine these longitudinal performance changes and whether these findings hold following specific training interventions. Lastly, despite adequate rest before the start of testing procedures, another limitation of this study is the lack of external load quantification (e.g., distance covered, number of accelerations), which could also provide directions for further research projects.

CONCLUSION

In conclusion, the findings of this study provide sports practitioners working with this specific group of athletes with reference values for sprint performance and force-time metrics examined during both the eccentric and concentric phases of the CMJ motion. Also, the results reveal that 10m sprint speed was positively associated with CMJ concentric peak velocity and jump height. Specifically, athletes capable of generating greater CMJ concentric

peak velocity and greater jump height tend to attain greater 10m sprint velocities. Hence, incorporating ballistic exercises and Olympic lifts, targeting rapid force production and movement velocity into an athlete's regular training regimen design may be particularly effective for enhancing short-distance sprint acceleration capabilities.

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