Relationship between key performance indicators and force-velocity profile of elite sprinters and football players

DAVID BRŰNN – ROMAN ŠVANTNER

Faculty of Sports Science and Health, Matej Bel University in Banská Bystrica

ABSTRACT

Introduction**:* This study is based on the research of Brűnn and Švantner (1), who compared key performance indicators (KPI) of an elite sprinter and players of national football teams. Although the sprinter excelled in jumping abilities (SJ, CMJ, BJ, RSI), he did not achieve the highest strength values in any of the selected metrics. Švantner and Brűnn (2) also compared sprint acceleration force-velocity profile of elite sprinters and elite football players, and it was found that while football players showed superior force production and application effectiveness, sprinters maintain high efficiency in force at increased velocities. The aim of this study is to follow up and correlate non-specific KPI and force velocity profile of elite sprinters and football players. ***Methods**:* The first part of the research was collecting key performance indicators data of 13 elite level male soccer players and an elite level sprinter, who completed squat jump (SJ), counter-movement jump (CMJ), broad jump (BJ), depth jump (DJ – RSI index) tests, ankle extensors' force assessment (AEF), isometric 30° knee flexion (ISO30), eccentric nordic hamstring (ENH), isokinetic knee extension (IKQ) and knee flexion (IKH). The second part of the research was to complete a 30m linear sprint, which was assessed by 1080 Sprint device. The research sample consisted of 38 male elite soccer players and 6 elite level sprinters. The testing of football players took place on match day +3 days, with RAMP protocol warm up. Macroscopic F-v profiles were calculated based on running speed, body mass and the basic laws of motion applied to the center of mass. Last phase of the research was to correlate non-specific KPI (SJ, SMJ, BJ, DJ, AEF, ISO30, ENH, IKQ, IKH) and force velocity profile (F0, V0, RFmax %, DRF %) of elite sprinters and football players. The statistical analysis was done in Python program. ***Results**:* In our research sample, which consisted of elite football players and sprinters, only one moderate positive correlation (0.63) was found between strength in eccentric nordic hamstring exercise and momentum (kg∗m/s). Weak correlation (0.47) was observed between ankle joint extensors isometric strength and momentum (kg∗m/s), suggesting the importance of adequate strength level of individuals in specific positions. Almost moderate correlation (correlation coefficient: 0.47) between the standing long jump and the value of V0 (m/s) and at the same time no correlation (correlation coefficient: -0.06) between the standing long jump and the value of F0 (N/kg) is a very interesting finding. Given that the standing long jump represents horizontal force production, these findings are rather unforseen. Unexpectedly, only weak relationship was found between RSI and V0 (m/s) (0.41) and no relationship between isometric hamstring strength and F0 and V0 respectively. ***Conclusions: While the sprinter excelled in jumping abilities (SJ, CMJ, BJ, RSI), he did not achieve the highest levels of strength across any of the selected metrics (1). The second part of this study underscores the fact, that while football players demonstrate greater force production and application effectiveness, sprinters exhibit high efficiency in force at elevated velocities (2). No or weak relationships were found between KPI and the force-velocity profile of the research sample in our correlations. Another finding is the fact that despite the different movement strategies to reach maximal speed between football players and sprinters, these facts did not substantially affect the final results.

KEY WORDS: Football, Sprint, Key Performance Indicator, Force Velocity Profile

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INTRODUCTION

A comparison between the 2006/2007 and 2012/2013 English Premier League seasons has already shown a clear pattern, with researchers observing an 80% increase in the number of sprints and a 35% rise in the total sprinting distance (3). During a match, players sprint roughly 17 to 81 times, with each sprint typically lasting 2 to 4 seconds, and most covering distances shorter than 20 meters. In practice, a difference of 30 – 50 cm (~0.04 – 0.06 seconds over 20 meters) is often enough to gain an advantage in a one-on-one duel, preventing the opponent from controlling the ball (4). At first glance, the distance covered during a sprint may appear minor, accounting for only 2 – 3% of the total distance at a pace exceeding 25 km/h (5). But the emphasis on sprinting comes from a study (6) which analyzed 360 goal situations in the German Bundesliga, identifying straight sprints as the most frequent action (45%) leading up to a goal.

While football isn't solely about sprinting at maximum speed, it is evident that this aspect is crucial in the current playing style, requiring players to meet both specific and general key performance indicators (KPIs).

Elite sprinters can achieve speeds exceeding 40 km/h, while modern football players can run at speeds of over 36 km/h.

What role do strength abilities play there? How strong, is strong enough? These were the research questions of Brűnn's and Švantner's (1) research, who highlighted key performance indicator (KPI) differences between elite sprinters and national team football players.

Table 1 Key performance indicators values of elite sprinter and football players (1)

	SPR	CB	CB2	FB	WB	DM	DM2	DM3	AM	AM2	W	IF	STR	GK
SJ	55.5	45	47.7	48.7	45.9	38.7	36.9	44	48.8	38	41.8	42.8	34.4	42.1
CMJ	59.6	48.5	51	48.5	46.7	42.7	38	42.1	52.6	39.4	44.3	41.4	37.6	43.4
BJ	297	250	288	214	230	258	224	250	234	248	253	255	257	261
RSI	2.86	1.72	1.62	2.48	1.89	2.29	1.79	2.08	1.83	1.92	2.23	2.13	1.59	1.71
AEF	2315	1533	2859	2902.5	2321	2802.5	1650.5	2418	1956	1786.5	2145	2470.5	2336	2752
ENH	437.5	467.5	564.5	401.5	328.5	470.5	456.5	390	449	446.5	412.5	387.5	480.5	427
ISO30	473.5	508.5	565.5	470	410.5	556	564	469.5	469.5	552.5	472	529.5	526.5	526.5
IKQ	193.75	194	205.6	144.15	200.35	195.45	190.4	194.4	165	186.05	189.55	167.9	180.7	175.9
IKH	125.15	136.2	146.2	103.55	119.5	137.7	131.9	120.2	123.8	113.3	132.6	136.3	115.1	116.4
Q/H ratio	64.6	70.2	68.19	78.09	59.64	70.45	69.27	61.83	75.03	60.89	69.95	81.17	63.69	66.17
ENH/ kg	5.43	5.39	6.11	5.05	3.90	5.4	5.44	5.2	5.6	6.04	5.44	4.6	5.16	5.13
ISO30/kg	5.88	5.8	6.1	5.91	4.95	6.39	6.71	6.3	5.9	7.8	6.22	6.39	5.6	6.3
AEF/kg	28.7	17.	30.97	36.5	28	32.2	19.6	32.63	24.79	25.3	28.3	29.8	25	33.07
IKQ/kg	2.4	2.2	2.2	1.81	2.41	2.24	2.26	2.2	2.0	2.63	2.5	2.03	1.9	2.1
IKH/kg	1.55	1.5	1.5	1.3	1.44	1.58	1.57	1.6	1.5	1.6	1.75	1.64	1.2	1.3

Notes: CB – Centre-Back; FB – Full-Back; WB – Wing-Back; DM – Defensive Midfielder; AM – Attacking Midfielder; W – Winger; IF – Inside Forward; STR – Striker; GK – Goalkeeper; SJ – Squat Jump; CMJ – Counter-movement Jump; BJ – Broad Jump; RSI – Reactive strength index; AEF – Ankle extensor force; ENH – Eccentric Nordic hamstring; ISO30 – Isometric hamstring force; IKQ – Isokinetic quadriceps torque; IKH – Isokinetic hamstring torque; Q/H ratio – Quadriceps and hamstring torque ratio; ENH/kg – Relative eccentric nordic force; ISO30/kg – Relative isometric hamstring force; AEF/kg – Relative ankle extensor force; IKQ/kg – Relative isokinetic quadriceps torque; IKH/kg – Relative isokinetic hamstring torque

A sprinter excelled in jumping metrics (SJ, CMJ, BJ, RSI), while he did not achieve the highest levels of strength across any KPI. Although capable of reaching top running speeds, he was unable to produce the highest relative peak force.

Are sprinters and football players applying force differently? They are, based on the research of Švantner et al. (2). While football players show superior force production and application effectiveness (F0), sprinters maintain high efficiency in force at increased velocities (V0 and DRF) (2). Preparing players for the demands of today's football may not be possible through football-specific training alone. Enhancing short-sprint performance requires increasing either the magnitude or direction of the force athletes generate during sprints (7). Optimal results can be achieved by developing non-specific physical qualities based on an analysis of the athlete's force-velocity profile and tailoring their development work accordingly (8).

High-speed running (HSR) and sprint training are crucial not only for developing physical abilities and enhancing sports performance in football players but also for preventing injuries (9). A study indicated that up to 57% of hamstring injuries occur as a result of sprinting, making hamstring injuries the most running stride cycle (10). Regularly incorporating sprints into training in appropriate volumes can have a positive impact not only on performance, but also on injury prevention (11).

While this study is more about linear sprint performance, Švantner and Brűnn (12) found, that isometric muscle strength of the knee flexors correlated with sprinting speed over 30 meters. They concluded that the 30-meter sprint and the average isometric strength of the knee flexors in the Nordbord ISO30 test are significantly correlated, with a correlation coefficient of -0.3805 and a p-value of 0.00992. The sprinting speed over 30 meters is significantly related also to the magnitude of relative isometric strength of the knee

prevalent in football. "Sprinter-type" injuries are most likely to happen during eccentric muscle contractions in the late swing phase of the

flexors in football players. The correlation coefficient in this case was -0.4135, with a p-value of 0.00475.

Although Švantner and Brűnn (12) were not establishing a causal relationship and it is challenging to isolate a single factor related to speed (13), their findings contribute to a deeper understanding of the connections between isometric strength of the hamstring muscles and maximum movement speed in football.

In this study, we would like to build on the study of Švantner and Brűnn (12) and find relationships between full spectrum of key performance indicators and force-velocity profile in selected athletes.

AIM

The aim of this study is to correlate non-specific KPI and force velocity profile of elite sprinters and football players.

METHODS

The first part of the research was collecting key performance indicators data of 13 male football players of Slovak and Georgian national teams (n = 13; mean ± SD: age 28.361 ± 4.99; height 182.61 ± 8.81 cm; weight 82.21 ± 6.35 kg) and an elite level sprinter (European 60 m indoor champion, personal best: 6.55 s) (n = 1; age 26.19; height 179.71 cm; weight 80.5 kg) who completed squat jump (SJ), counter-movement jump (CMJ), broad jump (BJ), depth jump (DJ – RSI index) tests

(Optojump - Microgate, Bolzano, Italy), ankle extensors' force assessment (AEF) (ForceDecks - Vald Performance, Newstead, Australia), isometric 30° knee flexion (ISO30), eccentric nordic hamstring (ENH) (NordBord – Vald Performance, Newstead, Australia), isokinetic knee extension (IKQ) and knee flexion (IKH) tests (Biodex S4 – Shirley, New York, USA). The average performance of both limbs was assessed in the strength tests.

The second part of the research was to complete a 30m linear sprint, which was assessed by 1080 Sprint device (1080 Motion, Lidingö, Sweden, linear encoder 333 Hz). The research sample consisted of 38 male elite football players (n = 38 mean ± SD: age 24.5 ± 4.3; height 180.1 ± 5.7 cm; mass 77.3 ± 5.6 kg) and 6 elite level sprinters - one of them European 60m indoor champion, personal best: 6.55 s (n = 6; age 22.3; height 179.8 cm; mass 73.2 kg). The testing of football players took place during the speed session, typically conducted in the middle of the week (over 72 hours after a match). Their warm-up was based on a RAMP protocol with minor variations for each team. Sprinters were evaluated during the off-season after an individualized warm-up tailored to their specific habits and needs. Macroscopic F-v profiles were calculated based on running speed, body mass and the basic laws of motion applied to the center of mass. Maximal force in the direction of running F0 (N/kg), and velocity V0 (m/s) were used to characterize the sprint acceleration profile, and the more "technical" characteristics of ground force application were described through values of maximal ratio of forces RFmax (%) and decrease in the ratio of forces DRF (%).

Last phase of the research was to correlate non-specific KPI (SJ, SMJ, BJ, DJ, AEF, ISO30, ENH, IKQ, IKH) and force velocity profile (F0, V0, RFmax %, DRF %) of all mentioned elite sprinters and football players. The statistical analysis was done in Python program.

RESULTS

From the first part of the research, we highlight the results of the elite sprinter (SPR) (SJ: 55.5 cm; CMJ: 59.6 cm; BJ: 297 cm; DJ: 2.86 RSI; AEF: 28.7 N/kg; ENH: 5.43 N/kg; ISO30: 5.88 N/kg; IKQ: 2.4 Nm/kg; IKH: 1.55 Nm/kg) which represent values for comparison with individual players.

The second part of the research showed, that elite football players exhibited a significantly higher theoretical maximum horizontal force (F0) of 7.57 N/kg (SD = 0.46) compared to elite sprinters, who had a mean of 7.10 N/kg (SD = 0.21), with a significant difference ($p = 0.0011$) and a large effect size (ES = 1.07). These players also demonstrated significantly greater effectiveness in force application (RFmax), with values of $p = 0.00024$ and a large effect size (ES = 1.11). In contrast, the theoretical maximal velocity (V0) did not show a significant difference ($p = 0.63$; ES = -0.34) between elite football players (mean = 9.86 m/s; SD = 0.40) and elite sprinters (mean = 10.01 m/s; SD = 0.69). The substantial effect sizes for both F0 and RFmax underscore the importance of generating high horizontal ground reaction forces in the initial phase of sprint acceleration for football players through a horizontally-oriented push. Conversely, no significant differences were found in V0 and DRF, indicating that both athlete groups possess similar abilities to achieve high velocities and maintain mechanical effectiveness (i.e., minimizing the decrease in the initial force ratio) during sprints (2).

The third part of the research examined the relationships between mentioned variables, which brought interesting findings.

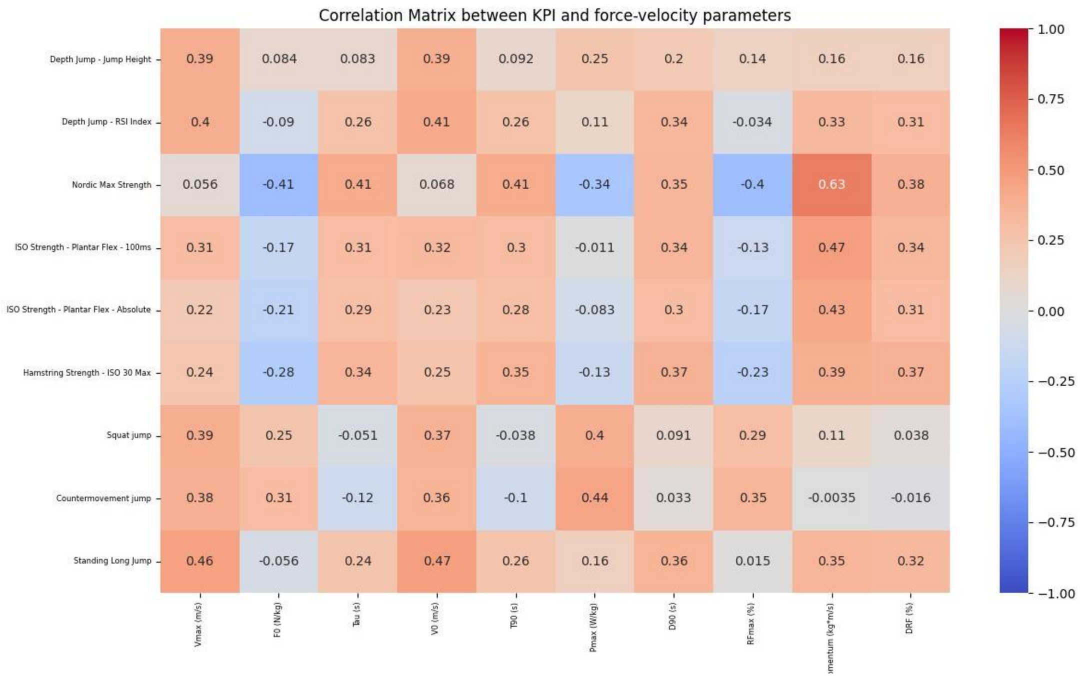

Figure 1 Correlation Matrix between KPI and force-velocity parameters

Only one moderate positive correlation ($-0.5 \leq r < 0.7$) with the coefficient 0.63 was found in the research sample consisting of elite football players and sprinters. In this case, the relationship between strength in eccentric nordic hamstring exercise and momentum (kg∗m/s) was found.

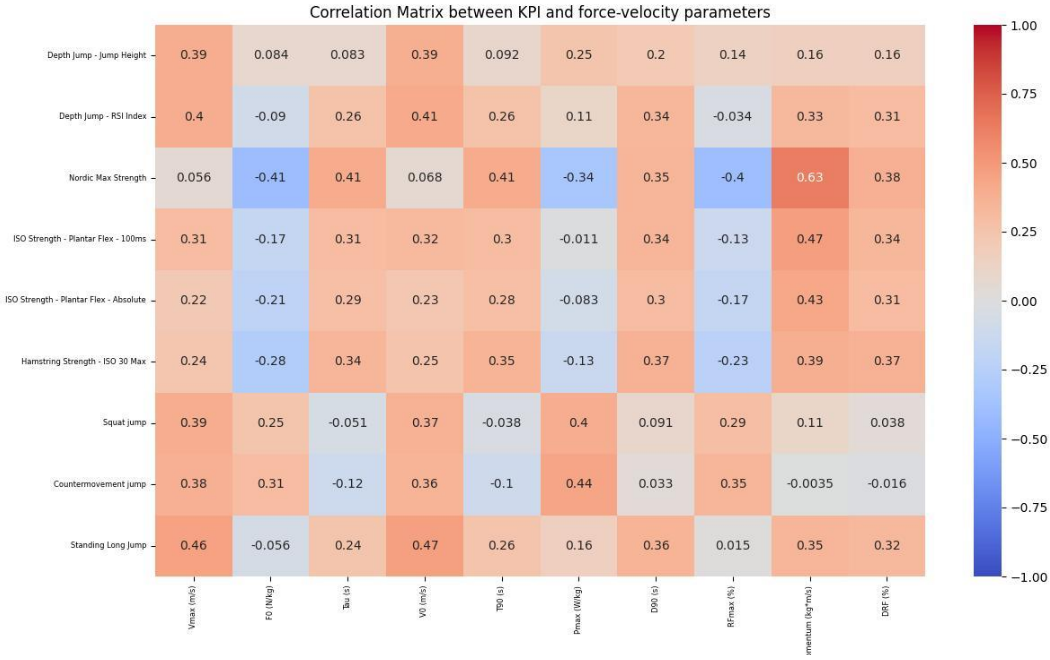

Figure 2 Correlation Matrix between KPI and force-velocity parameters in the group of football players

Firstly, it was assumed, that it happened because of different force production strategies between football players and sprinters. Based on this assumption, sprinters were excluded from the sample, but the result stayed almost the same. We state that our assumption was not confirmed, which is demonstrated in Figure 2.

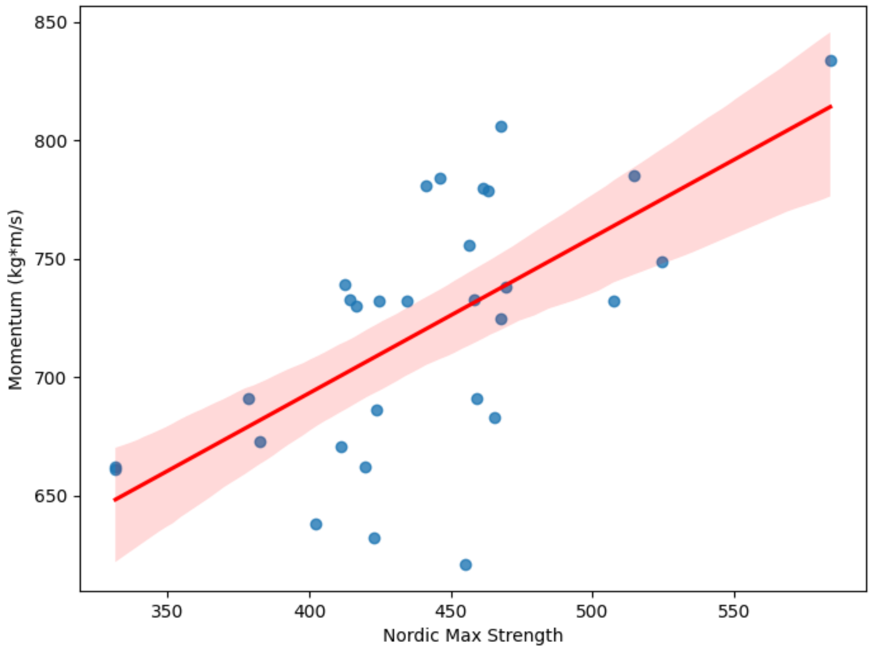

Figure 2 Correlation between Eccentric Nordic Hamstring strength and Momentum (kg∗m/s)

The moderate positive correlation (correlation coefficient: 0.63) between the eccentric hamstring's strength and momentum (kg∗m/s) is explained by the fact, that the hamstrings are significant hip extensors and thus a muscle group, that generates big amount of horizontal force (14). Hamstrings can withstand overloads equal to several times the runner's weight (15). In both cases, these are absolute values.

Almost moderate correlation (correlation coefficient: 0.47) was observed between ankle joint extensors isometric strength and momentum (kg∗m/s), suggesting the importance of adequate strength level of individuals in specific positions.

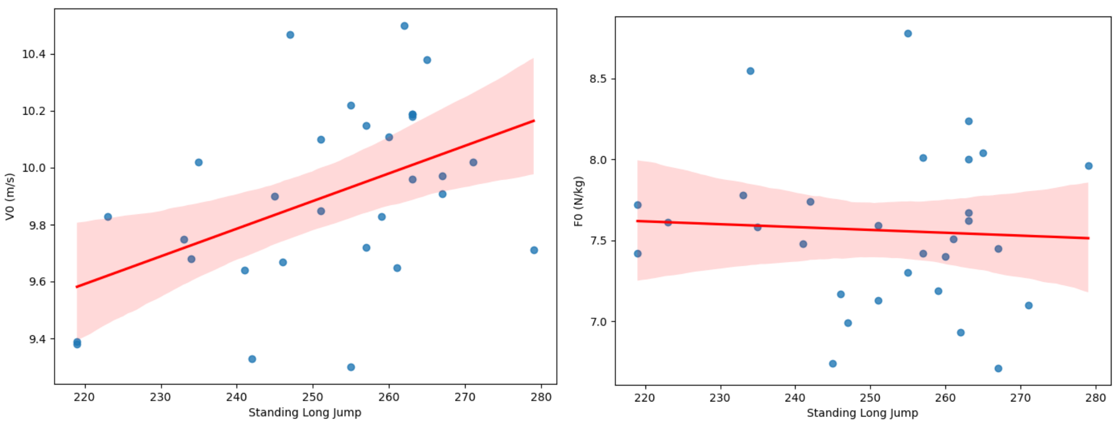

Figure 3 Correlation between standing long jump and V0 (m/s) and F0 (N/kg)

A very interesting finding is almost moderate correlation (correlation coefficient: 0.47) between the standing long jump and the value of V0 (m/s) and at the same time no correlation (correlation coefficient: -0.06) between the standing long jump and the value of F0 (N/kg). Given that the standing long jump represents horizontal force production, these findings are rather unexpected.

An equally significant relationship between RSI and V0 (m/s), which in our case came out at a correlation coefficient of 0.41 would have been expected.

In the case of the relationship between isometric hamstring strength and F0 and V0 respectively, we found no correlation. Even though football players and sprinters have different movement strategies to reach their maximal speed, a contradictory result is noted with the research of Švantner and Brűnn (12) who found, that isometric muscle strength of the knee flexors correlated with sprinting speed over 30 meters.

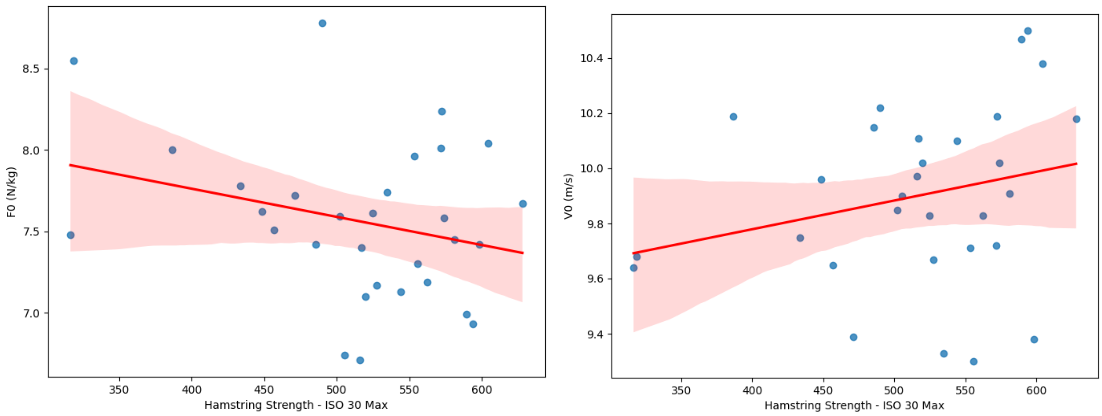

Figure 4 Correlation between hamstring strength (ISO 30) and F0 (N/kg) and V0 (N/kg)

They concluded that the 30-meter sprint and the average isometric strength of the knee flexors in the Nordbord ISO30 test are significantly correlated (-0.3805 and a p-value of 0.00992) in absolute values and the same result for the relative isometric strength (-0.4135, with a p-value of 0.00475).

CONCLUSIONS

While the sprinter excelled in jumping abilities (SJ, CMJ, BJ, RSI), he did not achieve the highest levels of strength across any of the selected metrics. This observation suggests a significant correlation between jumping and speed abilities, indicating that optimal non-specific speed or plyometric training intervention could enhance these parameters. While sprinter can achieve the highest running speed, on the other hand, he struggles to generate the highest relative peak force. These findings raise a question about the role of strength abilities. How strong is considered strong enough? The second part of this study underscores the importance of sport-specific resistance training methods, given the different kinetic profiles and force production strategies in football and sprinting. While football players demonstrate greater force production and application effectiveness, sprinters exhibit high efficiency in force at elevated velocities. These findings also highlight the necessity for customized training programs aimed at developing the specific force production essential for optimal performance. Additionally, variations in velocity among player positions should be considered, as each position has unique performance characteristics.

From our correlations, surprising findings are noted and thus predominantly no or weak relationships between KPI and the force-velocity profile of the research sample may be seen. Another finding is the fact, that despite the different movement strategies to reach maximal speed between football players and sprinters, these facts did not substantially affect the final result

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