SCIENTIFIC JOURNAL OF SPORT AND PERFORMANCE

ORIGINAL ARTICLE

Relationship between curvilinear sprint performance, hip strength, jump performance and reactive strength in elite youth soccer players

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ABSTRACT

The aim of this study was to investigate the relationships between hip strength, vertical jump performance, reactive strength index, and curvilinear sprint (CS) performance and to compare these variables between different playing positions in youth soccer players. Thirty-four players completed two test sessions. Hip adduction and abduction strength was measured using a hand-held dynamometer. A force plate was used to measure the height of the countermovement jump and the drop jump as well as the contact time, from which the modified reactive strength index and the reactive strength index (RSI) were calculated. The CS was tested on the penalty arch of a soccer pitch. One way ANOVA was used to test the effects of playing position whereas the Pearson's r was used to test the relationship between variables. There were no significant differences in the measured variables between defenders, midfielders and attackers ($p \geq .140$). Along with RSI, which showed significant moderate to large correlations (r = -0.39 to -0.59), hip abduction strength was also significantly associated with CS split times (r = -0.36 to -0.38). Results emphasize the relevance of ankle reactive strength and hip strength for CS performance and supports the inclusion of ankle and hip-specific strength exercises in the training of youth soccer players.

Keywords: Performance analysis, Curvilinear sprint, Hip strength, Reactive strength, Vertical jump, Soccer.

Cite this article as:
Ribič, A., & Sašek, M. (2026). Relationship between curvilinear sprint performance, hip strength, jump performance and reactive strength in elite youth soccer players. *Scientific Journal of Sport and Performance*, *5*(2), 269-279. https://doi.org/10.55860/LRIO9376

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Submitted for publication October 14, 2025.
Accepted for publication November 25, 2025.
Published December 09, 2025.
Scientific Journal of Sport and Performance. ISSN 2794-0586.

doi: https://doi.org/10.55860/LRIO9376

INTRODUCTION

In soccer sprinting is the action which in most cases precedes decisive situation that can change the outcome of the game (Chmura et al., 2018). Due to tactical demands sprinting context differs significantly between playing positions. External load metrics in soccer demonstrate considerable positional variation, with central midfielders typically covering greater total distances at different speeds, while wide midfielders, full-backs, and forwards engage in higher volumes of high-speed running and sprinting (Buchheit et al., 2010). Nonetheless, pure liner sprinting is rarely present in multidirectional team sports. Recent research highlights that maximal effort sprints in soccer are mainly performed on a curved trajectory (Caldbeck & Dos'Santos, 2022a).Specifically, wide and attacking positions have more curved sprints as they must manoeuvre around opponents, adjust to ball trajectories, or execute tactical runs along arced paths (Lobo-Triviño et al., 2024). Thus, curvilinear sprint (CS) performance might depend on the playing position of soccer players.

Curvilinear sprinting (CS) places distinct mechanical and neuromuscular demands on the body compared with linear sprinting (Ishimura & Sakurai, 2016; Millot et al., 2024). CS in soccer typically involve directional changes within angles of 5° to 30° (Fitzpatrick et al., 2019) and radii between 3.5 and 11 meters (Brice et al., 2004). The demands of CS require the athletes to adjust their sprint mechanics to generate centripetal force by leaning toward the centre of the curve while simultaneously propelling themselves forward, a combination that limits maximal sprint velocity relative to straight-line sprinting (Caldbeck & Dos'Santos, 2022a). Due to that curved sprinting is asymmetrical, which is reflected through longer ground contact times (Filter et al., 2020), reduced step length, and step frequency of the inside leg in comparison to the outside (Caldbeck, 2020). Moreover, curved trajectory also induces task-specific muscle activation with greater hip adductor (HADD) activation on the inside leg and higher hip abductor (HABD) and external rotator activation on the outside leg (Churchill et al., 2016; Filter et al., 2020). Due to its specificity, CS might require distinct strength and power related neuromuscular qualities compared to linear sprinting.

Based on that, Bašek et al. (Sašek et al., 2024) reported significant negative correlations between HABD and HADD strength and CS split times in recreational athletes. These findings highlight the functional importance of frontal-plane hip strength for executing curved runs, which remains unexplored in soccer players. Moreover, several studies found that squat jump and countermovement jump (CMJ) are highly associated with faster CS performance (r = 0.44 – 0.67) (Araújo do Rego Barros et al., 2024; Grazioli et al., 2024; Loturco et al., 2020), which shows that the ability to produce high power via concentric and slow eccentric-concentric contractions is related to better CS performance. However, sprinting performance is fundamentally influenced by an athlete's ability to generate high levels of force within extremely short time frames (Weyand et al., 2010). This capability is largely governed by the efficiency of the stretch-shortening cycle (SSC), a physiological mechanism involving a rapid transition from eccentric to concentric contractions (Crotty et al., 2024; Nicol et al., 2006; Young et al., 1995). The reactive strength index (RSI), calculated as jump height divided by ground contact time during plyometric activities like drop jumps, serves as a practical measure of an athlete's explosive strength and SSC efficiency (Southey et al., 2024). The relationship between RSI and linear sprint performance has been the subject of extensive research, yielding varied findings from strong to trivial correlation between RSI and linear sprint performance (Healy et al., 2019; Hennessy & Kilty, 2001; Smirniotou et al., 2008; Young et al., 1995). Given the significant technical and biomechanical demands of CS, the role of ankle complex, and limited research, assessing RSI in contexts of CS in soccer players is essential.

The present study aimed to investigate (a) the differences in CS performance between defenders, midfielders and attackers, and (b) assess the correlations between hip strength, lower limb power, and reactive strength on one side and CS performance on the other. This could deepen our understanding of CS and its neuromuscular performance determinants in youth soccer players, ultimately guiding more effective training strategies and performance monitoring. We hypothesized to observe significant differences in CS performance between positions and correlations between hip strength, reactive strength and vertical jump performance.

MATERIALS AND METHODS

Study design and procedures

For this cross-sectional study youth male soccer players from elite [*country*] football academy were recruited. Curvilinear sprint test, vertical jump and strength tests were completed over two consecutive days. During the first visit to the laboratory, body mass and stature were recorded on a stadiometer with a built-in scale (Seca 704 s; Seca Ltd, Hamburg, Germany), followed by assessments of isometric HABD and HADD strength, CMJ and drop jump (DJ) performance. On the second visit, the performance of CS to the right and left was evaluated on an outdoor artificial turf pitch.

Participants

The study involved 34 youth soccer players of which 12 were forwards (16.5 ± 1.2 years, 71.9 ± 9.7 kg, 183.3 ± 5.0 cm), 12 were defenders (16.3 ± 1.1 years, 70.7 ± 7.2 kg, 183.3 ± 5.0 cm) and 10 were midfielders, (15.9 ± 1.1 years, 65.4 ± 8.7 kg, 179.9 ± 5.7 cm). On average, the players could be classified as Tier 3 athletes (McKay et al., 2022). Their usual training regime consisted of five soccer training sessions, three strength and conditioning sessions and one match during one week. All participants had prior experience with CS as such type of sprint is commonly performed as a part of their training and testing regime. Only the academy players who were healthy, with no injuries or illnesses reported in the past 6 months were included in the study. Before testing, participants and/or their legal guardians were fully informed about the study procedures and provided written informed consent. The study protocol was approved by University of Primorska's Commission for Ethics in Human Subjects Research (approval number: 4264-19-6/23) and conducted in accordance with the principles of the Declaration of Helsinki Procedures.

Isometric hip strength test

Before the strength and jump testing the participants underwent a standardized warm-up, which included 5 min of self-paced, low intensity running, dynamic stretching exercises strength and power exercises for the lower limbs (heel raises, squats, crunches, push-ups and vertical jumps; five each). After the warm-up bilateral isometric HABD and HADD strength was assessed with a handheld dynamometer (MusTec HD, MusTec, Almere, Netherlands).

Participants were positioned supine on the table with hips and knees at anatomical zero (i.e. 0º flexion). When testing the dynamometer was placed 5 cm proximal to the most prominent point on the medial malleolus. When testing HADD, distance between the participant's legs corresponded to the length of the tester's forearm and the dynamometer. The forearm and the dynamometer were placed between the ankles, and the subject was subsequently instructed to perform a bilateral hip adduction squeeze (Light & Thorborg, 2016). For the H_{ABD} strength test the non-test side was placed against a wall for stabilization and prevention of undesired movement. The examiner was braced to oppose the force of H_{ABD} from the participants while keeping the dynamometer stationary. The participant's legs were slightly abducted to simulate the position of HADD test. Prior to testing three submaximal contractions were allowed to familiarize themselves with the procedure. The HABD and HADD tests was repeated three times in randomized order with 60 s rest between trials. During all trials, the participants were given instructions to push as "*fast and hard*" as possible for five seconds and were verbally encouraged (Maffiuletti et al., 2016). Raw force data in newtons (N) were collected and peak force (PF) was calculated for left and right leg. To account for inter-individual differences in body size, PF was normalized to body mass.

Vertical jump testing

Lower limb power was evaluated through the CMJ and DJ with a 1-dimension force plate (ForceDecks, Vald, Queensland, Australia). Data were recorded at a sampling rate of 1000 Hz with ForceDecks software (Vald Performance, Newstead, Australia) and furtherly analysed with ForceDecks software V.2.0. Prior to vertical jump testing, participants performed one to two submaximal familiarization jumps to ensure proper understanding of the technique. Following the familiarization, three maximal DJ and CMJ jumps were performed in a randomized order. An experienced researcher supervised each trial and only properly executed jumps were used for further analyses. Throughout all vertical jump assessments, participants were instructed to keep their hands on their hips. For the CMJ participants started from a standing position legs hip width apart. They were instructed to initiate a fast downward movement until preferred depth followed by a maximal take-off action, with the aim of maximizing jump height. The DJ was performed from a 40 cm box. Participants were instructed to initiate the movement by stepping off the box with their preferred foot, lightly tipping it forward over the stance leg, without lowering their centre of mass or actively jumping off the box. Upon landing, they were instructed to minimize ground contact time, avoid letting their heels touch the ground, and immediately rebound with maximal height and speed. A minimum rest period of two minutes was provided between two consecutive vertical jumps to ensure adequate recovery. Jump height was calculated from impulse-momentum method (Linthorne, 2001) and the reactive strength index (RSI) and RSI modified (RSI_{mod}) were calculated using the Equations 1 and 2, respectively.

Equation 1:
$$RSI_{(\mathrm{m \cdot s^{-1}})} = \frac{DJ\ height_{(m)}}{DJ\ contact\ time_{\ (s)}}$$

Equation 2:
$$RSI_{mod\,(\mathrm{m \cdot s^{-1}})} = \frac{CMJ\ height_{(m)}}{CMJ\ contact\ time_{\ (s)}}$$

Sprint performance tests

For CS testing the participants were instructed to wear their usual soccer boots. Before CS testing participants completed a standardized warm-up consisting of 5 min of self-paced jog, dynamic stretching exercises, strength (lunges, side luges, hip bridges and heel raises; 5 per side), running and power drills (skipping, high knees, hopping and consecutive single leg broad jumps) and two submaximal CS to the right and to the left. The CS test was conducted in accordance with the protocol described by Filter et al. (Fílter et al., 2020). Participants were instructed to sprint along with the curvature of the penalty arc, covering a 17-m distance with a radius of 9.15 m in both, left and right, directions. Split times were recorded at 8.5 meters and 17 meters using electronic timing gates (Brower, TCi-System B13283, Utah, USA). Each participant performed three sprints in each direction. Approximately three minutes of rest between attempts was used to minimize sprint induced fatigue. Sprints were initiated from a split-stance start position, with the front foot placed 0.5 meters behind the first timing gate. The fastest time and slowest 17 m time sides were determined to obtain stronger and weaker curvilinear sprint side (CS_{strong} and CS_{weak}, respectively).

Statistical analysis

Descriptive statistics are presented as means and standard deviations (SD). The assumption of normality was assessed using the Shapiro–Wilk test. To assess differences in outcome variables between positions, a one-way analysis of variance (ANOVA) was performed. Homogeneity of variances was evaluated using

Levene's test. When significant main effect was identified, Bonferroni post-hoc correction was used to determine pairwise differences. To assess the correlation between CS and other variables, a Pearson's correlation coefficient (r) was used. The strength of correlations was interpreted as follows: trivial (<0.1), small (0.1–0.3), moderate (0.3–0.5), large (0.5–0.7), very large (0.7–0.9), and nearly perfect (>0.9) (Hopkins et al., 2009). All statistical analyses were performed using SPSS version 29.0 (IBM Corp., Armonk, NY), with statistical significance set at $p < .05$.

RESULTS

All variables showed normal distribution of data. Descriptive data of soccer players and differences between positions are presented in Table 1. The one-way ANOVA showed no significant differences in the outcome variables between positions.

Table 1. Vertical jump, reactive strength, hip strength, and curvilinear sprint performance variables presented as mean (standard deviation) for defenders (DEF), midfielders (MID), attackers (ATT), and as total.

	DEF (n = 12)	**MID (n = 10)**	**ATT (n = 12)**	**One-way ANOVA**		**Total (n = 34)**
				F	*p*	
CMJ (cm)	34.23 (2.80)	34.43 (2.92)	33.38 (4.79)	0.26	.772	33.99 (3.58)
RSI_{mod} ($m \cdot s^{-1}$)	0.55 (0.09)	0.57 (0.08)	0.54 (0.08)	0.56	.576	0.55 (0.09)
DJ (cm)	30.19 (6.55)	31.99 (6.18)	32.68 (4.91)	0.36	.702	31.60 (5.82)
RSI ($m \cdot s^{-1}$)	1.55 (0.33)	1.65 (0.29)	1.39 (0.35)	1.86	.172	1.53 (0.33)
ABD_R ($N \cdot kg^{-1}$)	0.51 (0.08)	0.55 (0.08)	0.52 (0.07)	1.39	.265	0.53 (0.08)
ABD_L ($N \cdot kg^{-1}$)	0.50 (0.08)	0.52 (0.11)	0.51 (0.06)	0.09	.912	0.51 (0.08)
ADD_R ($N \cdot kg^{-1}$)	1.31 (0.31)	1.48 (0.32)	1.39 (0.29)	0.91	.413	1.39 (0.31)
ADD_L ($N \cdot kg^{-1}$)	1.36 (0.41)	1.47 (0.27)	1.40 (0.34)	0.32	.729	1.41 (0.34)
CS_{weak} 8.5 (s)	1.80 (0.07)	1.84 (0.07)	1.77 (0.08)	0.03	.971	1.80 (0.08)
CS_{strong} 8.5 (s)	1.71 (0.04)	1.71 (0.09)	1.71 (0.09)	2.09	.140	1.71 (0.08)
CS_{weak} 17 (s)	2.93 (0.08)	2.99 (0.11)	2.90 (0.11)	0.51	.604	2.94 (0.10)
CS_{strong} 17 (s)	2.89 (0.07)	2.92 (0.11)	2.88 (0.12)	2.12	.137	2.89 (0.09)

Note. CMJ – countermovement jump height; RSI_{mod} – modified reactive strength index DJ – drop jump height; RSI – reactive strength index; ABD_R – peak force of right leg hip abductors; ABD_L – peak force of left leg hip abductors; ADD_R – peak force of right leg hip adductors; ADD_L – peak force of left leg hip adductors; CS_{weak} 8.5 – weaker side curvilinear sprint split time at 8.5 m; CS_{strong} 8.5 – stronger side curvilinear sprint split time at 8.5 m; CS_{weak} 17 – weaker side curvilinear sprint split time at 17 m; CS_{strong} 17 – stronger side curvilinear sprint split time at 17 m; p – p-value; ANOVA – analysis of variance; F – F statistics.

Table 2. Correlation coefficients between vertical jump, reactive strength and curvilinear sprint performance variables with 95% confidence intervals.

	CMJ	**RSI_{mod}**	**DJ**	**RSI**
CS_{weak} 8.5	-0.16 (-0.47 to 0.19)	-0.1 (-0.51 to 0.14)	-0.03 (-0.36 to 0.32)	-0.26 (-0.44 to 0.23)
CS_{strong} 8.5	-0.19 (-0.50 to 0.15)	-0.30 (-0.58 to 0.04)	-0.23 (-0.52 to 0.12)	-0.56** (-0.76 to -0.28)
CS_{weak} 17	-0.26 (-0.55 to 0. 90)	-0.32 (-0.59 to 0.03)	-0.14 (-0.46 to 0.21)	-0.39* (-0.64 to -0.06)
CS_{strong} 17	-0.24 (-0.54 to 0.10)	-0.38* (-0.64 to -0.05)	-0.17 (-0.48 to 0.18)	-0.59** (-0.73 to -0.22)

Note. CMJ – countermovement jump height; RSI_{mod} – modified reactive strength index DJ – drop jump height: RSI – reactive strength index; CS_{weak} 8.5 – weaker side curvilinear sprint split time at 8.5 m; CS_{strong} 8.5 – stronger side curvilinear sprint split time at 8.5 m; CS_{weak} 17 – weaker side curvilinear sprint split time at 17 m; CS_{strong} 17 – stronger side curvilinear sprint split time at 17 m. * $p < .05$; ** $p < .01$.

Because there were no significant differences between playing positions, the correlation analyses were performed on a total sample (see Table 1 for descriptive statistics). Correlations between CS_{strong}, CS_{weak}, CMJ, DJ, RSI and RSI_{mod} are presented in Table 2. The RSI showed significant large correlation with CS_{strong} split times at 17 m and 8.5 m together with moderate correlation with CS_{weak} split time at 17 m. The RSI_{mod} showed significant moderate correlation only with CS_{strong} split time at 17 m.

The correlations between hip strength and CS performance are presented in Table 3. Only the CS_{strong} showed significant correlations with hip strength. Specifically, ABD_L PF was moderately correlated with CS_{strong} split times at 17 m and 8.5 m.

Table 3. Correlation coefficients between hip strength and curvilinear sprint performance variables with 95% confidence intervals.

	ABD_R	**ABD_L**	**ADD_R**	**ADD_L**
CS_{weak} 8.5	0.03 (-0.31 to 0.37)	-0.19 (-0.50 to 0.16)	-0.10 (-0.42 to 0.25)	-0.02 (-0.35 to 0.32)
CS_{strong} 8.5	-0.25 (-0.54 to 0.10)	-0.38* (-0.64 to -0.05)	0.10 (-0.24 to 0.43)	0.08 (-0.27 to 0.41)
CS_{weak} 17	-0.10 (-0.42 to 0.25)	-0.30 (-0.58 to 0.04)	0.00 (-0.34 to 0.34)	-0.02 (-0.36 to 0.32)
CS_{strong} 17	-0.16 (-0.47 to 0.19)	-0.36* (-0.62 to -0.02)	-0.04 (-0.37 to 0.31)	-0.04 (-0.38 to 0.30)

*Note. ABD_R – peak force of right leg hip abductors; ABD_L – peak force of left leg hip abductors; ADD_R – peak force of right leg hip adductors; ADD_L – peak force of left leg hip adductors; CS_{weak} 8.5 – weaker side curvilinear sprint split time at 8.5 m; CS_{strong} 8.5 – stronger side curvilinear sprint split time at 8.5 m; CS_{weak} 17 – weaker side curvilinear sprint split time at 17 m; CS_{strong} 17 – stronger side curvilinear sprint split time at 17 m. * $p < .05$.*

DISCUSSION

This study investigated effect of playing position and the correlations between hip strength, reactive strength, vertical jump, and CS performance in male youth soccer players. In this population there are no differences in CMJ height, DJ height, RSI, RSI_{mod}, hip strength, and CS performance between defenders, midfielders and attackers. Of all neuromuscular factors, the RSI showed the strongest correlation with CS, together with the HABD strength. Interestingly, no significant correlations were found between CS performance and CMJ and DJ height.

Observed trivial differences in vertical jump performance and strength between playing positions in our study are not surprising as previous studies have shown minimal to no differences in these variables between defenders, attackers and midfielders (Ben Hassen et al., 2023; Harry et al., 2018; Myftiu & Dalip, 2021; Ruas et al., 2015). This indicates that from the context of jumping and hip musculature workload, the playing position in soccer might not be very specific. In contrast, sprint performance was found to be very position specific in youth soccer players (Al Haddad et al., 2015). Although we expected significant differences between defenders, midfielders and attackers, no differences in CS were observed. This is in contrast with the literature showing that youth attackers sprint faster during linear sprint as the midfielders and defenders (Ben Hassen et al., 2023). However, we believe that the CS is specific type of sprint and require distinct neuromuscular control as linear sprinting (Loturco et al., 2020; Šašek et al., 2025). It could be speculated that trough development and positional specialization, CS performance start to diverge based on soccer player specific roles and tactical demands. For example, defenders often perform overlapping runs that involve curved sprints along the sideline, attackers typically engage in explosive linear sprints, and midfielders frequently execute rapid directional changes in confined spaces. This specialization curvilinear sprint performance with maturation is supported by the findings of (Filter-Ruger et al., 2022) who observed a decrease in the correlation between linear and curved sprint performances from the U-15 age group (r = 0.75–0.76) to the U-20 group (r = 0.27–0.41). Over time, these position-specific activities contribute to the specialization of physical skills and could cause the ability such as CS to become increasingly dependent of the playing position. However, there is lack of studies that assessed the differences in CS performance between position in adult elite soccer players and such studies are necessary in the future.

The relationship between vertical force production (via DJ testing) and CS has received little interest in scientific literature, although important role of plantar flexors during curve sprinting (McBurnie & Dos'Santos, 2021). Our findings suggest that athletes with superior RSI demonstrate better CS performance. To our knowledge this is the first evidence confirming the ability to utilize elastic energy rapidly through eccentric-concentric muscle actions of the ankle when sprinting in a curve. Moreover, we found non-significant correlations between CS split times, DJ and CMJ height which is in contrast with previous studies that reported moderate to large correlations ranging from r = -0.47 to -0.61 (Grazioli et al., 2024; Loturco et al., 2020). In female youth soccer players, (Sašek et al., 2025) observed moderate to large negative correlations (r > -0.40) between CMJ and single-leg CMJ performance and CS times, but no significant relationship with DJ performance in female soccer players. While these studies highlight a link between vertical jump height and CS performance, they did not assess reactive strength. Similar as in linear sprinting, ankle joint could play a pivotal role in CS mechanics, serving as the important source of tangential propulsion during curvilinear acceleration and furthermore as net dissipater of energy in maximum velocity phase (Crotty et al., 2024). Enhanced SSC efficiency of knee and ankle muscle–tendon unit, outlined through RSI and RSI_{mod}, likely facilitates more effective energy transmission from proximal joints to ground during CS, thereby improving performance. Because the causality cannot be confirmed based on the results of this study, future research should be devoted to explaining the role of ankle and knee MTU in curved sprint performance of soccer players.

Altered lumbo-pelvic control during linear sprinting is important hamstring injury factor (Bramah et al., 2024). In the CS it was suggested that hip musculature significantly determine performance, with the HABD of the outside leg serving as important propulsors and the HADD of the inside leg serving as stabilizers (McBurnie & Dos'Santos, 2021). Such role was supported by the findings of our study, indicating that HABD strength is significantly correlated with CS performance in youth male soccer players. The results are in agreement with Sašek et al. (2024), where the authors found significant correlations between HABD strength measured using fixed dynamometer and CS sprint performance. From both biomechanical and neuromuscular perspectives, HABD strength is crucial for generating radial speed and force during curved sprinting. However, the authors also reported a significant relationship between HADD strength and CS performance, which contrasts with the findings of our study. This discrepancy may be attributed to differences in the methodologies employed, particularly concerning the curvature used to assess CS performance. In our study, we utilized a 17.5-meter arc, corresponding to the penalty arc, while more recent studies have employed longer sprint arcs ranging from 30 to 40 meters, encompassing the entire acceleration phase of the sprint. Longer arcs may place greater emphasis on the late acceleration phase, during which hip adductors, functioning also as hip extensors, play a more prominent role in propulsion and stabilization, which, could explain the stronger correlation observed between HADD strength and CS performance (Królikowska et al., 2023). Furthermore, Sašek et al. (2024) used a fixed dynamometer to measure hip strength, which could provide better measurement reliability and isolate joint-specific force output more accurately than handheld dynamometry. These methodological differences may underline the contrasting findings across studies. Future research should aim to standardize CS testing protocols and strength assessment methods to improve comparability and further elucidate the role of hip musculature in curvilinear sprint performance.

The findings of this study could support the importance of incorporating specific strength training modalities that enhance ankle reactive strength and hip strength to improve CS performance in youth soccer players. Such interventions may include plyometric exercises, eccentric-concentric strength training, drills targeting ankle propulsion, and HABD strengthening exercises. Potentially, stronger hip abductors could provide better lumbo-pelvic stability and force generation of the outside limb during CS whereas efficient SSC of ankle MTU could allow for more effective energy transmission in the acceleration and maximum speed phases of curved sprint. These observations warrant further interventional studies to assess the effects of targeted strength training interventions on CS performance in soccer players.

This study has several limitations that should be considered when interpreting the findings. First, we assessed hip muscle strength using isometric tests with a handheld dynamometer. While this method is practical and reliable for measuring maximal voluntary contraction, it may not fully capture the dynamic and sport-specific movements involved in CS. Isometric assessments lack the movement specificity and velocity components inherent in dynamic actions, potentially limiting their ecological validity in predicting CS performance. Previous research has indicated that isometric strength measures may not strongly correlate with dynamic performance tasks such as sprinting or jumping, suggesting the need for more movement-specific assessments in future studies (Requena et al., 2009; Spudić et al., 2025). Second, the shorter arc used in our study may have not fully captured the biomechanical and neuromuscular demands of longer sprints, potentially affecting the generalizability of our findings. Future research should consider utilizing longer sprint arcs to provide a more comprehensive assessment of CS performance across different phases of acceleration. Lastly, although handheld dynamometry offers greater practicality and field applicability, its reliability is limited due to tester-dependent variability. This variability may affect the accuracy and consistency of strength measurements, particularly in high-force outputs. Therefore, we recommend the use of fixed dynamometers, which provide higher measurement precision and standardization across testing sessions.

CONCLUSION

The results of the present study highlight the critical role of reactive strength for CS performance as shown by significant correlations between RSI, RSI_{mod}, and CS times. Greater HABD strength was also correlated with better CS performance, emphasizing frontal plane force production in CS. However, no significant relationships were found between CMJ, DJ, or HADD strength and CS time. This suggests that reactive strength and HABD force production capacity should be key training targets for youth soccer players, when aiming to improve curvilinear sprint specific strength capacity.

AUTHOR CONTRIBUTIONS

Conceptualization, A.R. and M.S.; methodology, A.R. and M.S.; software, A.R. and M.S.; validation, A.R. and M.S.; formal analysis, A.R. and M.S.; investigation, A.R. and M.S.; resources, A.R. and M.S.; data curation, A.R. and M.S.; writing – original draft preparation, A.R.; writing – review and editing, M.S.; visualization, A.R. and M.S.; supervision, A.R. and M.S.; project administration, A.R. and M.S; funding acquisition, M.S. All authors have read and agreed to the published version of the manuscript.

SUPPORTING AGENCIES

The author M.S. was funded by Slovenian Research Agency under project KINSPO—Kinesiology for the effectiveness and prevention of musculoskeletal injuries in sports, number P5-0443.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

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