ORIGINAL ARTICLE

Curvilinear sprint in floorball: Association with linear and angle-dependent change of direction performance

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ABSTRACT

The study aimed to determine associations between curvilinear sprint (CS), angle-dependent change of direction (COD) and linear sprint (LS) performance times and deficits. Forty-eight male floorball players performed 20 m CS and LS, 45º COD (5 + 5 m) and 180º COD (5 + 5 m) tests. The deficit was calculated as the difference between the limb CS, 45º COD or 180º COD, and LS time. Significant differences were found between right and left limb performance in CS (5 m, 10 m and 15 m), 180º COD and deficits ($p < .05$), but no differences in 45º COD times and deficits ($p > .05$). The CS and 45º COD deficits were higher when the distance length increased, whereas the CS deficit stabilized at 20 m from both sides. Only the left limb 5 m CS deficit was associated with 45º COD deficits (r = 0.31 to 0.34, $p < .05$). These findings suggest that a deficit is a useful practical tool for assessing the effectiveness of athletes LS capabilities across different trajectories, as well as for identifying potential biomechanical similarities among components. Practitioners can benefit from integrating different speed components in training to enhance CS performance in floorball.
Keywords: Performance analysis, Multi-directional speed, Floorball, Change of direction, Linear speed, Curvilinear.

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INTRODUCTION

Floorball is an indoor contact team sport in which athletes must perform frequent technical and high-intensity multi-directional movements, such as linear and non-linear accelerations and sprints, rapid change of directions from different angles, and decelerations (Tervo & Nordström, 2014). A well-developed combination of multi-directional movement components ensures the effective implementation of tactical and technical elements, creating advantages over opponents and influencing the overall dynamics and outcome of the game. Linear sprint (LS) (e.g., maximal-effort sprint acceleration) and forward movements are frequently used activities by the athlete before scoring a goal, providing a convenient position for the shot, the ball's trajectory and greater speed in the decisive moments of the game (Faude et al., 2012; Martínez-Hernández et al., 2023). LS is one of the most assessed components in field-based team sports (Simperingham et al., 2016). In outdoor team sports, athletes perform LS up to 20 m or an average of 2 to 4 seconds (Spencer et al., 2005) and mostly do not reach maximal velocity during the game. Thus, the activity profile mostly consists of accelerations (Sweeting et al., 2017), recommending to include <20 m LS in testing protocols for team sports (Simperingham et al., 2016). However, in indoor team sports, accelerations are mostly performed over shorter distances (<10 m), emphasising the horizontal-oriented ground reaction force generation efficiency (Bezodis et al., 2017). Overall, athletes in game perform not only LS but implementing more curvilinear sprint (CS) and changes of direction (COD) manoeuvres to achieve the goal of the movement (Conte et al., 2015; Fitzpatrick et al., 2019). Therefore, understanding the associations between multi-directional speed movements enables practitioners to more effectively optimise athlete performance and design targeted and sport-specific training interventions.

In team sports, athletes must adapt to the contextual situations of the game, such as avoiding opponents, intercepting the ball, or creating space for offensive and defensive manoeuvres, implementing CS as a technical skill. According to Fílter et al. (2020a), CS can be defined as the "*athlete's ability to sprint in a curved trajectory with a certain degree of curvature and a continuous change of direction, without a deceleration phase, and generating centripetal forces that provide the movement along a curved trajectory*." Caldbeck & Dos Santos (2022) reported that approximately 85% of maximum speed sprints and manoeuvres in football are completed with some degree of curvature (e.g., curvilinear trajectory). However, in elite women's basketball, 31% of all sprints performed are curvilinear (Conte et al., 2015). Thus, both the frequency and radius of CS execution may differ between outdoor and indoor sports. For example, in soccer radii typically range from 3.5 m to 11 m (Brice et al., 2008), with angles of approximately 6.2º and, in some cases, even up to 30º (Fitzpatrick et al., 2019), whereas there is limited evidence about indoor team sports. Moreover, biomechanical differences between the inside and outside limbs indicate an asymmetric force-generating mode (Judson et al., 2020). CS requires specific neuromuscular (e.g., outside and inside limb muscle activation, strength, reactivity, and stiffness), kinematic and kinetic (e.g., body position, ground reaction force application, and joint angles), and spatiotemporal (e.g., contact time, stride length and frequency) adaptations, as it is a different physical skill from LS (Fílter et al., 2020a). In addition, previous studies have documented slightly faster CS performance with the left limb inside (Fílter et al., 2020b; Sašek et al., 2024). Overall, CS has a similar and, at the same time, a different movement pattern than LS, demonstrating a moderate to large association between components (Fílter-Ruger et al., 2022); thus, athletes generally execute CS slower than LS (Baena-Raya et al., 2023; Loturco et al., 2020). In recent years, the difference between CS and LS can be calculated as a curvilinear deficit (CSD), where a lower CSD reflects an athlete's ability to effectively adapt to biomechanical and postural demands without a reduction in sprint velocity (Loturco et al., 2020). Although athletes may perform CS more frequently than LS in game scenarios, there is limited evidence regarding whether CSD increases, stabilises, or decreases over longer distances, as well as about cases when an athlete executes CS faster or in equal time as LS. A faster CS performance could indicate an athlete's higher technical ability compared to isolated LS.

During game, athletes must effectively accelerate, decelerate, execute cuts, and repeatedly accelerate from different angles and positions of the body to minimise the risk of injuries (Nimphius et al., 2018). Bloomfield et al. (2007) emphasise that in a football game, an athlete performs more than 700 changes of direction, of which 300 are within 90°, forty-five from 90° to 180°, three from 180° to 270°, but only one from 270° to 360°. In contrast, Sweeting et al. (2017) report that the COD most frequently occur at angles between 45º and 90º. However, in basketball, athletes change direction every one to three seconds (Conte et al., 2015; Stojanović et al., 2018), executing over 300 COD manoeuvres during the game (Svilar & Jukić, 2018). Since the CODs are angle-dependent abilities, the different testing strategies provide coaches with precise tools to assess and monitor performance. For example, utilising tests that minimise the impact of acceleration on overall COD performance, such as the modified 505 test (e.g., 180º COD) (Ryan et al., 2022), practitioners can assess isolated strength-based COD performance. However, the 45º COD is characterised by a continuous running scenario similar to CS; therefore, it is defined as velocity-based COD (Bourgeois et al., 2017). In-game, athletes are required to perform COD effectively using both the right and left limbs as a plant foot; however, previous studies show that athletes tend to execute faster COD with one limb as a dominant limb (Arboix-Alió et al., 2021; Bishop et al., 2021). Furthermore, similar to CS, in COD tasks, practitioners can indicate the COD deficit (CODD), or the additional time required to make a COD compared to LS at an equivalent distance (Nimphius et al., 2013). Previous studies (Lazić et al., 2023; Pereira et al., 2018) report that athletes who show faster LS results often perform COD slower; therefore, CODD values are also higher. Although 180º and 45º COD have different biomechanical and neuromuscular demands, there is limited evidence about the association with CS and CSD. By identifying associations between multi-directional speed components and deficits, especially assessing the performance of the inside and outside (e.g., right and left) limbs, practitioners could gain useful information about possible lower limb dominance and mechanical differences and advantages in floorball (Loturco et al., 2020; Sašek et al., 2025).

Therefore, to investigate the multi-directional speed abilities of floorball players, the first study aim is to determine the performance of floorball players in CS, COD and LS, as well as CS and COD deficit values when distance length increases from both right and left limbs. This provides the opportunity to determine whether deficits increase, stabilise, or decrease over longer distances. However, the second aim of the study is to investigate the associations between CS and LS and velocity-based and strength-based COD performance variables, such as times and deficits. We hypothesised that deficits are higher as the distance increases, expecting that there is a significant association between CS and other multi-directional speed variables.

MATERIALS AND METHODS

Design and procedure

A cross-sectional study design was used to investigate floorball players' LS, CS, and COD, as well as deficits. Data were collected from two separate testing days (each lasting approximately 80 min). During the first visit, the anthropometric measurements (height, weight and body mass index) were obtained, as well as participants performed 20 m LS and CS tests. However, during the second visit, participants performed COD tests (180º and 45º Y-shape COD tests). All participants were in their regular competitive period during data collection. The test procedures took place in natural settings, e.g., on a floorball synthetic surface, at the participants' training base, during training time. Before the testing, in both visits, participants completed the same standard warm-up consisting of muscle activation, dynamic lower-limb stretching exercises, and sprint drills. Sprint and COD tests results were obtained using Microgate Witty (Microgate Srl, Bolzano, Italy) photocells to the nearest 0.01 seconds (Colino et al., 2019). The photocell pair was placed 1.5 m away, facing each other on marked points (Baena-Raya et al., 2023). Before each test, participants completed two submaximal trials at 60 to 80% of maximum intensity as familiarisation trials. The study received ethical approval (71-43/159) from the local ethics board and followed strict principles set in the World Medical Association Declaration of Helsinki.

Participants

The sample size was calculated using G*Power software (version 3.1.9.6, Kiel, Germany) for correlation analysis, based upon an effect size of 0.4 with a statistical power of 0.80 and an alpha error probability of .05, indicating that the minimal sample size is 34 floorball players. Therefore, forty eight male floorball players (age: 18.0 ± 3.7 years; body height: 180.8 ± 6.5 cm; body mass: 74.9 ± 8.6 kg; body mass index: 22.97 ± 2.3) participated in this study. All players were healthy and reported no musculoskeletal or neuromuscular injuries, health problems or pain syndromes in the past six months that could affect the results or the subjects' overall physical and psychological health. Participants were informed about the research protocol, benefits and risks. A written informed consent form was signed and obtained before tests.

Linear sprint tests

A 20 m sprint test was utilised to assess the floorball players' LS performance. All participants were instructed to stand in a two-point start position with the front limb 0.3 m behind the starting line and perform three maximal 20 m LS trials with two to three minutes of recovery between trials. Sprint distance was divided into four phases (0–5 m; 5–10 m; 10–15 m; 15–20 m), using five photocell pairs that collected split times. The best recorded 20 m sprint time, as well as trial split times were used for data analysis.

Curvilinear sprint test

The 20 m 3-point line arch test was used to assess CS performance. In basketball players, the test has demonstrated high reliability (CV, 5%; ICC ≥ 0.90). (Baena-Raya et al., 2023). According to International Basketball Federation (FIBA) regulations, the official curve radius for the 3-point line is 6.75 metres with an amplitude of 10.58° from the floor beneath the precise centre of the basket to the outside border of the arch. The test procedure took place in a multifunctional hall featuring a basketball court marked according to FIBA regulations, allowing the test to be used in other team sports, such as floorball. Using a tape measure, the 3-point line was precisely extended to match the 20 m length. In previous studies, such as by Baena-Raya et al. (2023), CS times were assessed from 0 to 18.7 m without split times, but Pleša et al. (2025) utilised a 20 m CS test. As a result, our study includes 20 m CS with split times, which provide a more precise assessment of an athlete's curvilinear sprint abilities, particularly since the first metres in team sports are crucial. The CS test was divided into phases (0–5 m, 5–10 m, 10–15 m, 15–20 m), using five photocell pairs that collected split times. All participants were instructed to stand in a two-point start position with the front limb 0.3 m behind the starting line and perform three maximal CS efforts with the right limb inside and three with the left limb inside, without crossing the line. During the testing process, an experienced research assistant monitored the participants' performance to ensure that the sprint was executed correctly. The best recorded 20 m CS trial from both sides, as well as trial split times were used for data analysis.

Modified 505 test (180º COD)

The modified 505 m test was used to assess the participant's isolated COD speed, which is commonly observed in practice as a strength-based test. The athlete's 180º cut strategy has been significantly observed in team sports, such as soccer (Kadlubowsk et al., 2019), basketball (Baena-Raya et al., 2023; Spiteri et al., 2019), and floorball (Leppänen et al., 2021). Stojanović et al. (2019) reported that the test showed high reliability (ICC = 0.82; CV% < 5.1%) to assess the isolated COD speed performance that is unaffected by acceleration ability or anaerobic capacity. All participants were instructed to stand in a two-point start position 0.3 m from the starting line (first photocell pair). Then accelerate 5 m to a COD line, place either the right or left lower limb on the line, depending on the attempt, turn 180° on either the right or left lower limb, and sprint back 5 m through the finish. The experienced research assistant ensured that the participant's turning limb was on the line (Baena-Raya et al., 2023; Taylor et al., 2019). If the participant turned before the line or used an incorrect turning limb, the trial was not considered successful. Each participant performed three COD trials on each limb, with a two to three min recovery between each trial. The best 180º COD trial for each limb were used for data analysis.

Y-shape 45° change of direction test (45º COD)
To assess the velocity-based change of direction, the Y-shaped test was used (Fiorilli et al., 2017). Several studies have shown that the Y-shape test is reliable and valid for measuring athletes planned COD and reactive agility (Horníková & Zemkov, 2022; Oliver & Meyers, 2009). During test preparation, the COD line was measured 5 meters from the start line. However, the finish line was measured 5 meters from the COD line to the right and left sides at a 45º angle. Using a goniometer, it was determined that the 45º angle is exactly in the middle of the COD and finish lines. Time gates were placed at each marked point. Each participant was instructed to stand in a two-point start position 0.3 m from the starting line, and after receiving approval, perform a 5 m maximal effort acceleration, change direction at a 45º angle as quickly as possible, placing either the right or left lower limb on the COD line depending on the attempt, and sprint 5 m through the finish. The experienced research assistant ensured that the participant's turning limb was on the line. If the participant turned before the line or used an incorrect turning limb, the trial was not considered successful. Each participant performed three attempts on each limb, with a two to three minute recovery between each trial. The best 45º COD trial for each limb, as well as trials split times, were used for data analysis.

Statistical analysis
Data were compiled in Microsoft Excel 2025 and analysed in IBM SPSS (Statistical Package for the Social Sciences) Statistics 29 (version: 29.0.0.0 (241)). All descriptive data were presented as means ± standard deviations, range (min and max), 95% lower–upper confidence intervals and a difference between limbs. The Shapiro-Wilk test was utilised to determine the normality of the data. A paired-sample t-test was performed to determine differences between right and left limbs in CS, 45º COD, and 180º COD test variables. The Pearson correlation coefficient (r) was utilised for parametric data, and the Spearman rank correlation coefficient (ρ) for non-parametric data. Correlations are classified 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 perfect (1). The significance level for all statistical tests was set to .05 (Hopkins et al., 2009). CSD and CODD were calculated as the time difference between CS or COD and LS (Loturco et al., 2020; Nimphius et al., 2013).

RESULTS

The Shapiro-Wilk test of normality revealed that all performance variables were normally distributed ($p < .05$), except for the 180º CODD from both limbs ($p > .05$). Table 1 presents the mean results for performance total and split times for the LS, CS, and COD tests, along with minimal and maximal times and the 95% confidence intervals. On average, athletes demonstrated faster sprint times in LS compared to CS; however, some athletes achieved faster times in the first 5 m of 45º COD and CS compared to the first 5 m of LS. In addition, athletes demonstrated faster times in CS with the left limb positioned inside. However, 180º COD performance revealed an opposite trend, with athletes achieving faster times when changing direction with the right limb. Significant differences between limbs were observed in CS (5, 10 and 15 m) and 180º COD 10 m times ($p < .05$), while no differences were found in any 45º COD variables ($p > .05$).

Table 1. Descriptive analysis (Mean ± SD), range (min–max), 95% confidence intervals (CI) and limb differences of the curvilinear sprint, change of direction and linear sprint tests performance variables.

Variables	Mean ± SD	Range (Min–Max)	95% lower – upper CI	*p*-value
LS 5 m (s)	1.04 ± 0.06	0.95 – 1.18	1.02 to 1.06	<.001
LS 10 m (s)	1.76 ± 0.08	1.63 – 1.94	1.74 to 1.79	
LS 15 m (s)	2.43 ± 0.11	2.23 – 2.69	2.04 to 2.47	
LS 20 m (s)	3.04 ± 0.13	2.84 – 3.35	3.00 to 3.08	
CS R 5 m (s)	1.07 ± 0.06	0.97 – 1.19	1.05 to 1.09	.003
CS L 5 m (s)	1.05 ± 0.06	0.94 – 1.19	1.03 to 1.07	
CS R 10 m (s)	1.83 ± 0.07	1.71 – 1.97	1.81 to 1.86	.019
CS L 10 m (s)	1.81 ± 0.09	1.66 – 2.00	1.78 to 1.83	
CS R 15 m (s)	2.57 ± 0.12	2.36 – 2.88	2.54 to 2.61	.002
CS L 15 m (s)	2.53 ± 0.13	2.34 – 2.88	2.49 to 2.56	
CS R 20 m (s)	3.24 ± 0.13	3.02 – 3.55	3.21 to 3.28	.878
CS L 20 m (s)	3.24 ± 0.14	2.95 – 3.54	3.20 to 3.29	
180º COD R 10 m (s)	2.50 ± 0.15	2.28 – 2.88	2.46 to 2.55	.002
180º COD L 10 m (s)	2.55 ± 0.14	2.31 – 2.89	2.51 to 2.60	
45º COD R 5 m (s)	1.06 ± 0.08	0.92 – 1.27	1.04 to 1.08	.495
45º COD L 5 m (s)	1.06 ± 0.07	0.93 – 1.24	1.03 to 1.08	
45º COD R 10 m (s)	1.80 ± 0.11	1.64 – 2.07	1.77 to 1.83	.192
45º COD L 10 m (s)	1.79 ± 0.10	1.64 – 2.10	1.76 to 1.82	

Note. LS: linear sprint; CS: curvilinear sprint; COD: change of direction; R: right limb; L: left limb.

Although the mean CSD and CODD values are positive (e.g., athletes perform LS faster), in some cases athletes have shown faster results in CS and 45º COD tasks (Table 2). Overall, as the distance length increases, the deficit value also increases, indicating task specific demands. Significant differences between limbs were observed in CSD (5, 10 and 15 m) and 180º CODD 10 m times ($p < .05$), while no differences were found in any 45º CODD variables ($p > .05$).

Table 2. Descriptive analysis (Mean ± SD), range (min–max), 95% confidence intervals (CI) and limb differences of the curvilinear sprint and change of direction deficits.

Variables	Mean ± SD	Range (Min–Max)	95% lower – upper CI	*p*-value
CSD R 5 m (s)	0.04 ± 0.05	-0.03 – 0.14	0.03 to 0.06	.003
CSD L 5 m (s)	0.02 ± 0.03	-0.04 – 0.11	0.01 to 0.03	
CSD R 10 m (s)	0.08 ± 0.06	-0.01 – 0.21	0.06 to 0.10	.019
CSD L 10 m (s)	0.05 ± 0.06	-0.04 – 0.22	0.04 to 0.07	
CSD R 15 m (s)	0.15 ± 0.09	-0.01 – 0.39	0.12 to 0.17	.002
CSD L 15 m (s)	0.10 ± 0.08	-0.03 – 0.34	0.08 to 0.13	
CSD R 20 m (s)	0.21 ± 0.09	0.00 – 0.44	0.18 to 0.24	.878
CSD L 20 m (s)	0.21 ± 0.10	0.00 – 0.52	0.18 to 0.24	
180º CODD R 10 m (s)	0.75 ± 0.11	0.58 – 1.13	0.72 to 0.78	.002
180º CODD L 10 m (s)	0.79 ± 0.12	0.55 – 1.15	0.76 to 0.83	
45º CODD R 5 m (s)	0.03 ± 0.04	-0.04 – 0.20	0.02 to 0.04	.495
45º CODD L 5 m (s)	0.03 ± 0.05	-0.04 – 0.16	0.01 to 0.04	
45º CODD R 10 m (s)	0.05 ± 0.05	-0.02 – 0.19	0.03 to 0.06	.192
45º CODD L 10 m (s)	0.04 ± 0.05	-0.03 – 0.19	0.02 to 0.05	

Note: CSD: curvilinear sprint deficit; CODD: change of direction deficit; R: right limb; L:left limb.

As statistical differences were observed between limbs, a correlation analysis was performed between all performance variables of each limb, including LS. Therefore, CS and CSD correlations with 45º COD, 45º CODD, 180º COD, 180º CODD and LS variables for the right limb are shown in Table 3, and for the left limb in Table 4. The significant positive correlations were observed between right and left limbs CS times and 45º COD times (r = 0.55 to 0.81, $p < .01$), 180º COD time (r = 0.34, $p < .05$ to 0.61, $p < .01$) and LS times (r = 0.60 to 0.82, $p < .01$). Right limb 20 m CS time showed positive moderate correlation with 5 m 45º CODD (r = 0.30, $p < .05$) and 10 m 45º CODD (r = 0.38, $p < .01$), as well as 180º CODD (r = 0.42, $p < .01$) (Table 3). However, left limbs 20 m CS time showed a significant correlation only with 180º CODD (r = 0.31, $p < .05$) (Table 4).

There were negative moderate correlations between 10 m CSD and 45º COD times, 180º COD time and LS times (r = -0.30, $p < .05$ to -0.50, $p < .01$), whereas left limb 5 m CSD showed only a positive moderate correlation with 45º CODD (r = 0.31 to 0.33, $p < .05$) and negative with LS 5 m time (r = -0.32, $p < .05$). However, right limbs 20 m CSD was a moderate negative correlation with 180º COD 10 m time (r = -0.34, $p < .05$) and LS 20 m time (r = -0.38, $p < .01$), as well as 5 m CSD with LS 5 m time (r = -0.37, $p < .01$) and 15 m CSD and 15 m LS time (r = -0.31, $p < .05$).

Table 3. Correlation coefficients between curvilinear sprint and change of direction and linear sprint performance variables for the right limb.

		CS performance times				CS deficits			
		5 m	10 m	15 m	20 m	5 m	10 m	15 m	20 m
45º COD	5 m	0.55**	0.70**	0.72**	0.72**	-0.31*	-0.35*	-0.10	-0.17
	10 m	0.61**	0.70**	0.74**	0.79**	-0.26	-0.36*	-0.09	-0.13
	CODD 5 m	0.06	0.20	0.26	0.30*	-0.03	-0.06	-0.04	0.04
	CODD 10 m	0.20	0.20	0.30*	0.38**	0.07	0.08	0.15	0.25
180º COD	10 m	0.36*	0.34*	0.45**	0.46**	-0.21	-0.46**	-0.10	-0.34*
	CODD 10 m	-0.01s	-0.10s	0.02s	0.42s**	0.06s	-0.24s	0.05s	-0.20s
LS	5 m	0.68**	0.73**	0.75**	0.75**	-0.37**	-0.39**	-0.11	-0.26
	10 m	0.63**	0.74**	0.73**	0.74**	-0.35*	-0.50**	-0.21	-0.30*
	15 m	0.60**	0.64**	0.73**	0.81**	-0.33*	-0.42**	-0.31*	-0.32*
	20 m	0.64**	0.74**	0.75**	0.74**	-0.30*	-0.41**	-0.21	-0.38**

*Note: LS: linear sprint; CS: curvilinear sprint; COD: change of direction; CSD: curvilinear sprint deficit; CODD: change of direction deficit, * p < .05, ** p < .01, s Spearman rho (ρ) correlation coefficient.*

Table 4. Correlation coefficients between curvilinear sprint and change of direction and linear sprint performance variables for the left limb.

		CS performance times				CS deficits			
		5 m	10 m	15 m	20 m	5 m	10 m	15 m	20 m
45º COD	5 m	0.73**	0.67**	0.65**	0.64**	-0.06	-0.06	0.02	-0.05
	10 m	0.81**	0.76**	0.72**	0.72**	0.01	-0.06	-0.01	-0.06
	CODD 5 m	0.09	0.11	0.08	0.08	0.31*	0.21	0.14	0.12
	CODD 10 m	0.23	0.16	0.14	0.19	0.33*	0.28	0.16	0.17
180º COD	10 m	0.56**	0.58**	0.53**	0.61**	0.06	0.07	0.13	0.06
	CODD 10 m	0.15s	0.18s	0.19s	0.31s*	0.21s	0.11s	0.13s	0.15 s
LS	5 m	0.82**	0.73**	0.73**	0.71**	-0.32*	-0.24	-0.08	-0.15
	10 m	0.82**	0.79**	0.76**	0.73**	-0.21	-0.25	-0.11	-0.19
	15 m	0.72**	0.77**	0.80**	0.75**	-0.26	-0.19	-0.15	-0.17
	20 m	0.78**	0.76**	0.78**	0.74**	-0.20	-0.22	-0.11	-0.26

*Note: LS: linear sprint; CS: curvilinear sprint; COD: change of direction; CSD: curvilinear sprint deficit; CODD: change of direction deficit, * p < .05, ** p < .01, s Spearman rho (ρ) correlation coefficient.*

DISCUSSION

The present study aimed to determine floorball players' performance in CS, COD and LS, as well as CS and COD deficit values when distance length increases, and to investigate the associations between CS performance and LS and velocity-based and strength-based COD variables. The main study findings were: (a) on average, floorball players performed 10 m CS and 45º COD slower than 10 m LS, showing greater CSD and 45º CODD as the distance length increased; however, in some cases, athletes performed slightly faster CS and 45º COD, indicating technical ability over isolated LS performance; (b) there are significant statistical differences between the right and left limb performance times in CSD (5 m, 10 m and 15 m) and 180º CODD; (c) CS times showed moderate to very large correlation with 45º COD, 180º COD and LS times; however, moderate correlations were determined between left limb 5 m CSD and 45º CODD 5 m and 10 m. Although athletes performed CS faster when the left limb was inside, only the right limb CSD had a statistically significant negative correlation with the multi-directional speed component times. Our hypothesis was confirmed, indicating that as CS and COD distances increased, deficit values also increased. The present study is the first to reveal cases where an athlete performs CS and 45º COD slightly faster, especially in the first 5 m (Table 1). These findings provide useful information to practitioners, indicating significant associations between CS and 45º COD and both components as a technical skill in floorball.

Previous studies in team sports have documented significant differences in CS performance between the right and left limbs (e.g., curve sprint good and weak side) (Baena-Raya et al., 2023; Fílter et al., 2020a; Fílter et al., 2020b; Fílter et al., 2025; Loturco et al., 2020). Team sports are often referred to as "*asymmetrical*", as athletes frequently prefer to use one lower limb or side of the body in sport-specific movements (i.e., cutting, kicking, jumping, sprinting, and changing direction), leading to the development of neuromuscular asymmetry and side-specific adaptations (Fort-Vanmeerhaeghe et al., 2015; Maloney, 2019). For instance, longer contact time, stride length, and flight time, as well as lower stride frequency, vertical and propulsive forces, and higher braking forces, have been previously observed in the CS inside limb compared to the outside limb (Smith et al., 2006). In the present study, on average, athletes achieved faster 15 m CS times with the left limb positioned inside (2.53 ± 0.13 s) versus the right limb (2.57 ± 0.12 s). However, there are no significant differences in the CS time between the right and left limbs at 20 m. Since the floorball sprint profile is based on short accelerations, when distance length increases in CS, athletes may have difficulty resisting centripetal force, creating several mechanical adjustments in sprint pattern, which cause a decrease in velocity. The opposite scenario was observed in 180º COD, where floorball players performed faster COD when final foot contact (plant step) was with the right limb (2.50 ± 0.15 s) rather than with the left limb (2.55 ± 0.14 s). Similar results were reported by Cuthbert et al. (2019) using the 505 test (15 m + 5 m), where male team sport athletes performed faster COD with the right limb. However, authors utilised the COD test with a longer acceleration phase (e.g., athletes developed higher LS velocity); therefore, COD times were faster, and the CODD values were smaller, as opposed to the present study, which included isolated COD speed assessment. Overall, Fílter et al. (2021) report that most soccer players showed asymmetry in one direction during the COD test and in the other during the CS test, emphasising the different roles of each limb and supporting the present study's results. In fact, during CS, the inside limb plays a crucial role in forward propulsion, whereas the outside limb has a greater contribution in COD tasks (Fílter et al., 2020b). However, floorball players performed 45º COD similarly with both the right and left limbs (10 m: 1.80 ± 0.11 s and 1.79 ± 0.10 s, respectively). A possible explanation could be that the 45º COD involves a relatively small change of direction; therefore, the plant limb is not crucial as in 180º COD (Horníková & Zemková, 2022). These findings suggest that CS and COD are different physical qualities in terms of directional dominance that need to be developed and monitored separately to improve overall performance in floorball.

A large to very large correlation was observed between CS and LS performance times for both limbs ($r = 0.60$ to 0.82, $p < .01$), suggesting that athletes who showed faster LS times tend to sprint fast also in CS. However, a higher correlation coefficient was identified with left limb CS, possibly due to more efficient force generation, body positioning, joint stabilisation in the frontal plane and a higher ability to use linear velocity, indicating potential limb dominance. Loturco et al. (2020) also reported a large to very large correlation ($r = 0.52$ to 0.82) between CS and LS velocities, indicating that CS performance is influenced by LS ability. Furthermore, only a few previous studies have examined associations between CS and COD. For example, Freitas et al. (2020) identified a large correlation with COD from the Zigzag test ($r = 0.54$ to 0.60, $p < .05$), while Fílter et al. (2021) reported a moderate relationship between CS and the 90° COD test ($r = 0.33$ to 0.41, $p < .05$). However, the present study identifies a novel perspective on 45º COD and CS as velocity-based abilities that have similar biomechanical requirements; therefore, a moderate to very large correlation was indicated, especially for the left limb performance times ($r = 0.72$ to 0.81, $p < .01$). Additionally, the significant moderate correlations between CS and 180º COD times were also observed, ranging from $r = 0.34$ to 0.36 ($p < .05$) for the right limb and $r = 0.56$ to 0.58 ($p < .01$) for the left limb. Although CS cannot be classified as a COD, both components share common whole-body movement strategies and biomechanical features (i.e., body lateral inward lean and asymmetrical mediolateral ground reaction forces), particularly at narrower COD angles. These similarities can be a potential reason for the observed significant association with COD performance (Freitas et al., 2021; Kobal et al., 2021).

Another relevant finding was that floorball players both right and left limb CSD deficits gradually increased up to 15 m but stabilised at 20 m, suggesting a potential limb difference plateau over longer distances. The deficit correlation analysis indicates that the right limb 5 m or 10 m CSD values were negatively associated with 45º COD times (5 m and 10 m) and 180º COD 10 m time, indicating a possible movement strategy trade-off. Athletes who are able to perform fast CS (i.e., demonstrated lower CSD values) may lack efficiency in the COD tasks, especially with the right limb and the plant limb. One possible reason may be that in CS athletes perform cyclic and continuous sprint steps, whereas in COD the athlete often adjusts the steps prior to the plant phase to perform a cutting manoeuvre (Dos'Santos et al., 2018). Notably, no significant association was found between CSD and COD times with the left limb, suggesting limb-specific asymmetries and dominance. Furthermore, with all deficits, only 5 m CSD shows positive correlation with 45º CODD (both 5 m and 10 m) ($r = 0.31$ to 0.34, $p < .05$); thus, athletes who are less efficient in utilising LS abilities in the initial CS also tend to show greater inefficiency in 45º COD. These findings open new directions of research, where further studies are required that clarify a more detailed explanation of limb dominance, performance efficiency, and the association with CSD in different sports. It should be noted that in this study, there are cases where athletes performed CS or 45º COD slightly faster than LS (Table 1). In floorball, athletes perform CS or COD manoeuvres more often than isolated LS, thereby integrating these components into tactical situations of the game and improving them as a technical skill. This is especially observed in the first 5 m of both CS and 45º COD. To achieve maximum sprint speed in LS, the athlete must perform a gradual increase in step length and frequency, which requires high levels of coordination and horizontal ground reaction force generation. However, higher step frequency has been reported in team sports, where shorter first sprint steps and shorter flight time could be beneficial for efficient performance (Murphy et al., 2003; Sayers, 2000). Therefore, in some cases, the athlete performed the initial phase faster than LS. In semi-professional soccer players, Fílter et al. (2020b) observed a similar trend, where higher velocities were achieved in CS from the "*good*" side than in LS. As previously mentioned, performance technique and potential sport-specific characteristics (i.e., court surface, playing position and level) as well as radius length can significantly influence speed development. Therefore, understanding sport-specific characteristics enables practitioners to design tailored training interventions, thereby providing athletes with an advantage over their opponents.

The main limitation of this present study is the cross-sectional design, indicating only associations between multi-directional speed components and deficits. In addition, only representatives from one team sport and nation were included in this study. Overall, future studies should examine deficits at other COD angles, such as 90º or 135º, as well as utilise CS with different radii to identify both radius and angle biomechanical and neuromuscular requirements. To determine if performance times and deficits change (i.e., increase, stabilise or decrease) throughout a season or with the integration of specific training methods, longitudinal studies are needed to determine benchmarks for each cohort to identify poor and good performance.

CONCLUSIONS

In conclusion, this present study investigates the multi-directional speed performance in floorball players and associations between CS and LS and angle-dependent COD, identifying deficits and possible limb dominance. On average, floorball players tend to perform the initial phase of LS faster than CS and COD, but in some cases, athletes demonstrate faster results, especially in the first 5 m. As the CS time improves, athletes also perform LS and COD faster, highlighting the multi-directional speed competence of floorball players. Floorball players who demonstrate fast CS with the right limb inside tend to lack efficiency in the COD tasks with the same limb. However, athletes who tend to be less efficient at utilising LS abilities in the initial CS also show greater inefficiency in 45º COD, especially with the left limb. These findings suggest that CS and 45º COD are velocity-based abilities that have similar biomechanical requirements, as well as lower limb dominance in floorball. Therefore, practitioners and coaches can benefit from the integration of different multi-directional strategies effectively to develop faster CS in floorball players.

AUTHOR CONTRIBUTIONS

LV – study design, data curation, writing – original draft, review and editing; LP – conceptualization of the study, writing – review and editing; IA – study design, data curation, writing – review and editing.

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DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

DATA AVAILABILITY

Data will be available upon request to the corresponding author.

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