EFFECTS OF DIFFERENT CUTTING TECHNIQUES ON CHANGE OF DIRECTION SPEED IN TEAM HANDBALL

Patrick Engel, Deborah Seipp, Stefanie Klatt, and Frowin Fasold

German Sport University Cologne, Institute of Exercise Training and Sport Informatics, Departement of Cognition in Team Sports, Cologne, Germany

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Abstract:

Change of direction (COD) actions play a crucial role in team handball performance. Achieving equal speed during specific cutting manoeuvres on the left and right side is believed to be advantageous for successful tactical behaviour. Although studies have investigated lateral disparities in movements towards and against the throwing arm, there is a lack of sport-specific evidence regarding the advantages and disadvantages of different cutting techniques in terms of direction and speed. This study aimed to explore the impact of technique on COD speed with the ball during team handball-specific cutting maneuvers. Change of direction speed was evaluated and compared under three conditions: (1) split-step technique, (2) side-step technique, and (3) individually preferred skill. A total of 19 male, active, injury-free team handball players (mean age 21.59 ± 2.60 years) with an average of 15.26 ± 4.33 years of team handball experience participated. *Post-hoc* video analysis was employed to calculate COD speed. No significant interaction between the direction of movement (towards or against the throwing arm) and technique was found (p=.09). However, a significant main effect of direction (p<.001) and technique (p=.013) was observed. Results indicated a higher COD speed when moving in the direction of the throwing arm. Additionally, a significant difference was found between individual skill and split-step technique (p=.01). Overall, the findings suggest that differences in COD speed, whether towards or against the throwing arm, are not attributable to movement technique.

Keywords: *agility, team sports, cutting manoeuvre*

Introduction

Team handball is characterized by a considerable frequency of change of direction (COD) actions (Karcher & Buchheit, 2014). On average, athletes engage in 13 offensive and 17 defensive COD movements per game (Póvoas, et al., 2012). Agility and COD skills play key roles in determining the success of individual actions, such as one-on-one situations, consequently influencing the overall match outcome (David, Komnik, Peters, Funken, & Potthast, 2017; Forster, Uthoff, Rumpf, & Cronin, 2022; Keiner, Kapsecker, Stefer, Kadlubowski, & Wirth, 2021; Nimphius, Callaghan, Bezodis, & Lockie, 2018; Wagner, Finkenzeller, Würth, & von Duvillard, 2014).

Agility, as defined by Haff, Triplett, National Strength and Conditioning Association (2016, p. 522) encompasses "[…] the skills and abilities needed to change direction, velocity, or mode in response to a stimulus". This performance factor is differentiated into two levels – a cognitive level and a motor level. The cognitive level comprises visual scanning, anticipation pattern recognition, and situational knowledge (Young & Farrow, 2006). The motor level pertains to the ability to change direction or speed (Haff, et al., 2016; Young & Farrow, 2006). Change of direction speed encompasses elements of technique, linear sprinting speed, and leg muscle quality (Young & Farrow, 2006). While both the motor and cognitive levels are performance-relevant, our study specifically focuses on the motor level of agility.

Numerous factors, such as the relationship between COD speed and maximum strength (Andersen, Lockie, & Dawes, 2018; Delaney, et al., 2015; Spiteri, et al., 2014), reactive strength (Castillo-Rodríguez, Fernández-García, Chinchilla-Minguet, & Carnero, 2012; Delaney, et al., 2015; Thomas, Comfort, Jones, & Dos'Santos, 2017), or linear sprinting ability (Horníková & Zemková, 2021) have been thoroughly examined in previous research. Additionally, investigations into handball-specific scenarios have revealed lateral differences in directional changes related to the throwing arm (Fasold, Braun, & Klatt, 2022). Notably, movements to the side of the throwing arm (right-handers to the right, left-handers to the left) demonstrate significantly higher speeds than movements against the throwing arm. Fasold et al. (2022) assume that the observed speed difference between sides may be attributed to variations in technique.

While Marshall et al. (2014) and Young and Farrow (2006) assert the existence of generalizable technique features for change of direction, such as: generating explosive force around the ankle, maintaining pelvic control during a single-legged support, and rotating the torso in the intended direction of movement, it is crucial to recognize the sport-specific nature of techniques. Generalizable technique characteristics alone are insufficient, as COD tests must be conducted in a sport-specific manner (Loturco, et al., 2022; Salaj & Markovic, 2011).

In team handball, various COD techniques are commonly observed in practice (Karcher & Buchheit, 2014). These techniques are frequently applied in both offensive and defensive situations, such as feinting with or without the ball, changing direction while dribbling, closing space defensively, or stepping out to challenge an opposing player. In basketball, similar patterns of directional change are observed, where agility and rapid movement adjustments are crucial for effective offensive drives and defensive positioning. Studies, such as the review by Sugiyama, Maeo, Kurihara, Kanehisa, and Isaka (2021), highlight that basketball players frequently perform changes in direction to maintain competitive performance during games. These maneuvers, like cutting, are comparable to the requirements in team handball. However, there is a lack of sport-specific evidence regarding the advantages and disadvantages of these techniques in terms of speed. Dos'Santos, McBurnie, Thomas, Comfort, and Jones (2019) summarized and discussed the most prevalent COD techniques in multidirectional sports, including the split-step, the side-step, and the crossover cut. The split-step involves a small preparatory jump followed by a push-off using the contralateral foot, enabling quick lateral movements. In contrast, the side-step consists of planting the outside foot and pivoting toward the desired direction (examples for both techniques in Fig. 1). Recent studies have focused on technique and training in handball, exploring areas such as plyometric and strength training or directional change performance. However, these studies did not directly address the influence of technique on performance outcomes during gameplay (Falch, Haugen, Kristiansen, & van den Tillaar, 2022; Gaamouri, et al., 2023; Noutsos, Meletakos, Kepesidou, & Bogdanis, 2024).

Our investigation focuses on the split- and the side-step as these techniques are commonly applied in team handball. Although the crossover cut is referenced for comparison, it was not directly included in our study. By analyzing these techniques, this study aims to provide actionable insights for the teaching and training of change-of-direction movements in handball (Dos'Santos, et al., 2019, p. 42). Trewartha, Munro, and Steele (2008) have showed that the split-step not only results in a greater lateral velocity during unplanned changes of direction but also involves a longer ground contact time compared to the side-step.

The findings align with the Bradshaw, Young, Russell, and Burge's (2011) study, wherein the side-step was proved to be faster than the split-step in pre-planned changes of direction among Australian Rules football players. This temporal discrepancy is manifested in a shorter total time attributed to a shorter initial ground contact and achieved through a swifter approach time. However, Bradshaw et al. (2011) demonstrated that defenders exhibited slower decision making when executing a split-step compared to a side-step. Notably, frequent decision errors are observed when reacting to the split-step, underscoring its effectiveness as an offensive agility technique and its challenging predictability. These findings are supported by Connor, Crowther, and Sinclair (2018), attributing the differences to the preceding jump with the double-leg landing. The double-leg landing impedes early anticipation of the movement direction. Summarizing these statements, the side-step appears to be faster than the split-step for planned directional changes. In conditions necessitating agility, the split-step appears

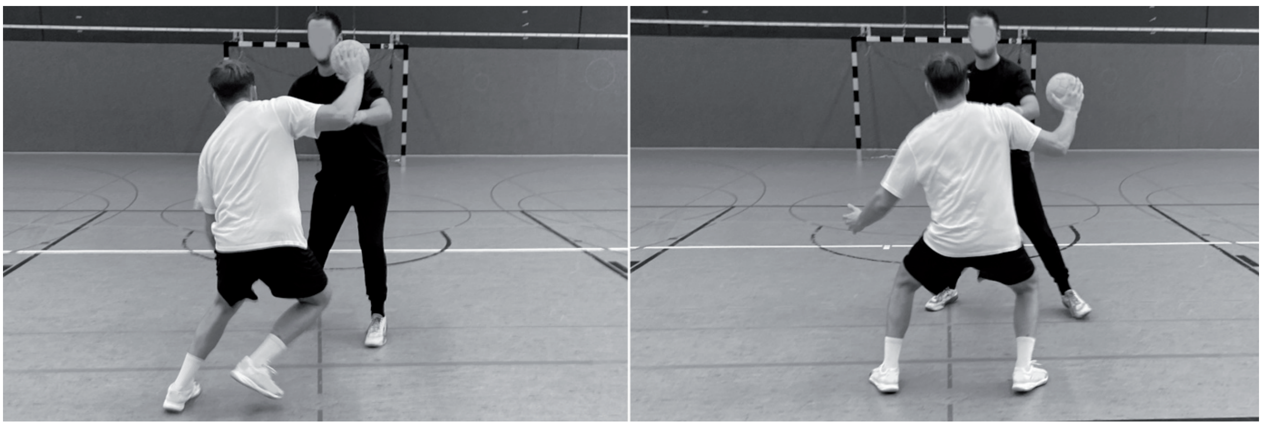

Figure 1. Illustration of handball-specific examples of the side-step (on the left) and the split-step (on the right) cutting techniques.

advantageous (Bradshaw, et al., 2011; Connor, et al., 2018). Despite these insights, team handball-specific studies on cutting maneuvers, with a focus on technique and movement speed, are notably absent.

Research in other sports, such as Australian Rules football, has explored diverse techniques for changing direction (Bradshaw, et al., 2011; Trewartha, et al., 2008). However, individual preferences for direction changes may exist in team handball. These individual techniques, which often combine elements of both the split-step and the side-step, form the individual skill. Hence, this study specifically focuses on the split-step and the side-step techniques (Fig. 1), along with an individual skill.

Based on the model developed by Young and Farrow (2006) and the results of Fasold et al. (2022), this paper specifically evaluates the motor level of agility, focusing on movement techniques and their impact on COD speed with the ball during team handball-specific cutting maneuvers. We hypothesize that (1) change of direction speed is influenced by different techniques, depending on the direction of movement. Furthermore, based on the results of prior studies (Bradshaw, et al., 2011; Connor, et al, 2018; Fasold, et al., 2022), we expect effects related to (2) techniques and (3) direction on speed.

Method

Participants

We conducted an *a priori* power analysis to calculate the appropriate sample size (using G*Power; Faul, Erdfelder, Buchner, & Lang, 2009). A total of eleven participants was required to detect a large effect size (η_p^2 = 0.47; Fasold, et al., 2022) with a significance level (α) of .05 and a statistical power of .95. To avoid false-positive results (Simmons, Nelson, & Simonsohn, 2011) and being robust against possible variances in the measurement, we calculated a sample size of N = 20 for the study.

In this study, male, active, injury-free team handball players were examined (N = 20). One participant left the experiment due to reported ankle pain after the warm-up. Thus, three left-handed and 16 right-handed players participated in the study (height in m: 1.86(*M*) ± 0.08(*SD*), body weight in kg: 82.84 ± 9.82, age in years: 21.59 ± 2.60, team handball experience in years: 15.26 ± 4.33). Inclusion criteria for the study were age ≥ 18, gender (male), no known injuries to the cruciate, medial, and lateral ligaments within the last 18 months and injuries to the ankle joint within the last three months. Participants were required to frequently change direction during training and gameplay to be included in the study. Goalkeepers, who do not frequently perform comparable changes of direction like the field players, were not included in the study. The test group ultimately consisted of eleven back players, seven wing players, and one line player. Two participants reported their actual playing level by playing in the seventh league, three in the sixth, ten in the fifth, two in the third league, and one in the second league in Germany. The study was approved by the ethics committee of the German Sport University Cologne (nr. 018/2023) and was conducted in accordance with the Declaration of Helsinki of 1975 and its later revisions. Written informed consent was obtained from all participants prior to the investigation.

Design

In a 3 x 2 design, the influence of the within-subject factors *change of direction technique* (individual skill vs. side-step vs. split-step) and *direction* (towards the throwing arm vs. against the throwing arm) on the dependent variable *change of direction speed* were analysed.

Materials and procedure

The participants performed an individual warm-up and conducted three counter-movement-jumps followed by three broad jumps as a standardized activation. The warm-up was followed by a team handball-specific COD test. The team handball-specific COD test, developed by Fasold et al. (2022), was used and adapted to simplify test administration and to improve the validity of the results. The adapted test allowed us to differentiate the depth and width of the movements. Figure 2 and Table 1 show the test set-up. The participants started at the same, standardized starting point (the right-handers from the left, the left-handers from the right). After passing the ball to the player, the participants performed an arc-shaped run-up towards the defender. Approximately one meter in front of the defender, the participants received the ball and changed movement direction. During the execution of the techniques, defenders acted as static obstacles rather than active participants to ensure standardization across trials.

For the first measurement (individual skill), each participant performed three COD to each side (towards and against the throwing arm). The individual skill represents a unique combination of features from both the side-step and split-step techniques, mixed in varying degrees according to the athlete's personal style and preference. In contrast, the split-step and side-step techniques were explicitly planned and executed under controlled experimental conditions, with participants following precise instructions provided by the researchers. Subsequently, the participants were instructed to perform six changes of direction using the corresponding technique (split- or side-step), with three in the direction and three against the direction of the

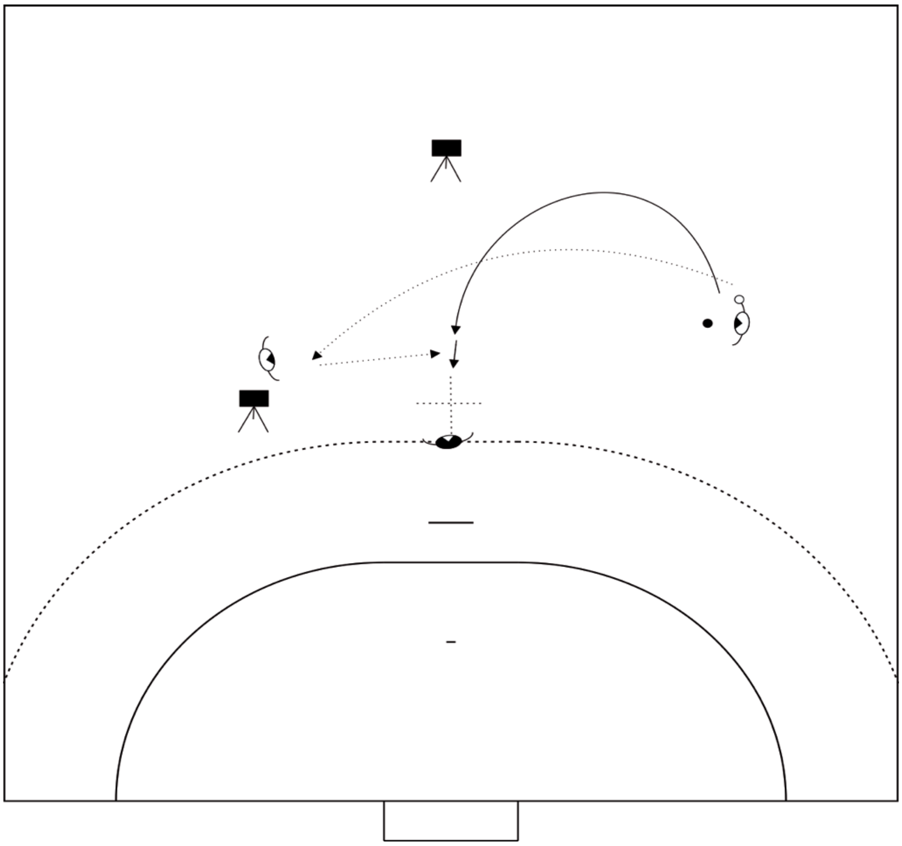

Figure 2. Structure and procedure of the change of direction test. The starting position is only marked for the right-handers; the left-handers started from the other side of the field from the corresponding position.

Table 1. Positioning of the starting points, cameras, and the defender and face-off player from Figure 2

	Distance from the goal-line (in meters)	Distance from the side-line (in meters)
Starting points	12	3
Defenders	9	10
Face-off player	11	7.50
Position camera 1 (back-view)	14	10
Position camera 2 (sideview)	10	7.50

throwing arm. Afterwards, six changes of direction were conducted with the alternate technique. The split-step and side-step techniques were balanced based on the participant's number. Within each technique, the direction towards the throwing arm and against the throwing arm was also balanced by the participant's number.

Before the first trial, participants were given instructions to perform CODs as close to the game-like as possible. Between each repetition, the participants had a break of 30 seconds to rest. This rest time roughly corresponds to the time between two game situations in a team handball match (Karcher & Buchheit, 2014). Two cameras were used to measure the depth (sideview) and width (back-view) of the directional movement changes (positions can be seen in Tab. 1). A GoPro Hero 8 (model number C3331352520026) was used to capture the sideview (camera 2). The back-view (camera 1) was captured using a Sony dsc-rx100 m4. The recording frequency was 120Hz.

Data analysis

The video analysis software Kinovea (version 0.9.5-x64) was used to evaluate the videos, as Kinovea enables a two-dimensional determination of the speed. According to Balsalobre-Fernández, Tejero-González, Del Campo-Vecino, and Bavaresco (2014) and Pueo, Penichet-Tomas, and Jimenez-Olmedo (2020), Kinovea can be classified as a valid tool for testing distances and is also valid for measuring time, such as the determination of jump height via flight time. The analysis was conducted by an experienced rater skilled in 2D video analysis and individual skill training in team handball. The reliability of the procedure was checked by the second rater with the same experience. Both raters were two experts (with a coaching license) with many years of experience in sport science and team handball coaching. Interrater reliability was assessed using the Spearman rank correlation coefficient, as the data did not follow a normal distribution. The analysis revealed a high agreement between the two raters ($\rho = .896$, $p < .001$), indicating consistent evaluation of COD speed.

The movement depth recorded by camera 2 and the lateral movements captured by camera 1 were evaluated separately. For this purpose, the basketball free throw area (part of the standardized sports hall, where the study was conducted) was used as calibration zone for both videos in Kinovea to adjust for depth distortions and camera positioning. The synchronization of the video recordings from the two cameras was achieved using a light signal. This signal served as a common reference point to align the recordings accurately. Camera 1 (backview) was used to measure the COD time and how far the step of the COD was set to the side. In the recordings, the first complete touchdown of the foot was defined as the starting point. The end point was defined as the complete foot touchdown of the direction-changing step. The measurement was taken between the medial point of the foot (determined by the investigator) that initiated the change of direction (for the movement to the right the left foot, for the movement to the left the right foot) and the medial point of the foot from the subsequent foot strike. If the participants used a cross-step, the distance from the first contact with the right foot to the second contact with the right foot was measured for the right-handers (for the left-handers it was the left foot). The distance of the movement depth was recorded via camera 2 (sideview). The distance measurement was taken from the heel of the direction change-initiating step to the subsequent foot strike's heel. The time was taken from the camera 1 measurement. If the wrong technique (split- instead of side-step or side- instead of split-step) was performed or a technical error was made, the attempt was excluded (2.9% attempts had to be excluded).

The data collected via Kinovea were entered into an Excel spreadsheet to calculate the COD speed. For this purpose, the distance of the direction-changing step in depth and in width (in meters) and the time required (in seconds) was measured. The Pythagorean theorem

$$\sqrt{(\text{distance width}^2) + (\text{distance depth}^2)} = \text{change of direction distance}$$

was used to calculate the total distance of the change of direction. Using the time and the total distance, the speed for the total change of direction was calculated as the dependent variable in $m{\cdot}s^{-1}$.

Statistical analysis

A multifactorial analysis of variance with repeated measures was run to analyse the effect of the within-subject factors on the dependent variable in a 3 x 2 design. The average COD speed of the respective technique and the direction of movement were calculated from the three attempts in every condition of the participants to increase the robustness against outliers. If one attempt was missing (due to technical errors), the mean speed was calculated out of the other two attempts. A Shapiro-Wilk test ($p < .001$) and a Mauchly test ($p = .023$) were performed to check distribution and sphericity of the data. The violation of normality can be disregarded due to the sample size (Knief & Forstmeier, 2021). If sphericity violations were observed in the model ($p < .05$), the Greenhouse-Geisser correction was applied.

Results

Table 2 shows the descriptive statistics of the COD speed in the three technique conditions divided by the directions of the movement. The repeated measures MANOVA revealed a non-significant interaction between the effects of technique and movement direction, $F(1.47, 26.49) = 2.83$, $p = .09$, $\eta_p^2 = .14$. The analysis revealed a significant main effect for the movement direction (towards the throwing arm 4.40 ± 0.90 $m{\cdot}s^{-1}$ vs. against the throwing arm 3.64 ± 0.66 $m{\cdot}s^{-1}$) on the COD speed, $F(1, 18.00) = 29.68$, $p < .001$, $\eta_p^2 = .62$. In addition, a significant effect of technique was shown (individual skill 4.21 ± 0.85 $m{\cdot}s^{-1}$, 95%-*CI* [3.82, 4.59]; split-step 3.99 ± 0.72 $m{\cdot}s^{-1}$, 95%-*CI* [3.42, 4.33]; side-step 3.87 ± 1.01 $m{\cdot}s^{-1}$, 95%-*CI* [3.66, 4.31]; $F(1.43, 25.67) = 4.88$, $p = .013$. $\eta_p^2 = .22$). A *post-hoc* comparison using the t-test with Bonferroni correction indicated a significant difference ($p = .01$) between the individual skill and the split-step ($M_{Diff} = .22$, *95%-CI* [.39, .45]). No significant differences between the individual skill and the side-step ($M_{Diff} = .33$, *95%-CI* [-.01, .67], $p = .057$) and between the split-step and the side-step ($M_{Dif} = -.11$, *95%-CI* [-.42, .20], $p = 1.0$) were found. Table 2 provides a detailed breakdown of the data for additional insight.

Discussion and conclusions

The aim of the current study was to examine differences in COD speed across various movement techniques in team handball-specific cuttings. Based on previous studies, an interaction between technique and direction of movement, a difference in speed between movements towards and against the throwing arm, and a difference in speed between the split-step and side-step techniques were assumed prior to the conduction of this study. The results did not confirm the first assumption, as no interac-

Table 2. Mean, standard deviation, and 95% confidence interval of the change of direction speed in the three technique conditions divided by the directions of movement

		Technique					
		Individual skill*		Side-step		Split-step*	
		Of the throwing arm [m·s^{-1}]†	Against the throwing arm [m·s^{-1}]†	Of the throwing arm [m·s^{-1}]†	Against the throwing arm [m·s^{-1}]†	Of the throwing arm [m·s^{-1}]†	Against the throwing arm [m·s^{-1}]†
M		4.51	3.90	4.38	3.37	4.32	3.65
SD		0.96	0.60	0.97	0.80	0.78	0.48
CI	*UL*	4.95	4.17	4.81	3.73	4.67	3.87
	LL	4.08	3.62	3.94	3.01	3.97	3.44

Note. M – mean, SD – standard deviation, LL – lower limit, UL – upper limit, * – shows a significant effect between the techniques ($p < .05$), † – shows a significant effect between the directions of movement of the arm and against the arm ($p < .001$).

tion between technique and direction of movement was observed. However, higher speed values were obtained for all techniques when performed towards the throwing arm**.** Thus, there is not technique that reduces the velocity difference between moving towards and against the throwing arm. These results contradict the findings of Fasold et al. (2022), who proposed technical reasons to explain the lateral speed differences. The discrepancy with Fasold et al.'s results (2022) may be attributed to differences in testing conditions and the specific test setup used in our study, which focused on handball-specific scenarios. It is important to note that Fasold et al. (2022) did not analyze movement techniques, which highlights the distinctive foci and methodological approaches between the two studies.

Due to the lack of interaction between technique and direction of movement, it cannot be approved that technique reduces the speed difference, although Connor et al. (2018) suggested a higher tactical flexibility with the split-step technique. This tactical flexibility is thought to arise from equal speeds of COD movements, whether towards or against the throwing arm. However, this connection could not be determined in the current study based on the parameter of speed.

In their studies Bradshaw et al. (2011) and Connor et al. (2018) propose that, in Australian Rules football and rugby players, the side-step proves to be the swifter cutting technique for COD movements, whereas the split-step is deemed more advantageous for agility movements. However, our study failed to replicate the observation that the side-step is the faster COD technique. This discrepancy arises from the inherent sport-specific nature of skills, such as chance of direction techniques, making their transferability to other sports challenging (Nimphius, et al., 2018).

The execution of a side-step against the throwing arm consistently led to a reduction in speed, irrespective of the moving technique. According to Arboix-Alió et al. (2021) this limits tactical flexibility as the defender anticipates that changes of direction against the throwing arm with a side-step are slower and thus easier to defend. According to Table 2, only the side-step against the throwing arm shows a clear negative deviation from the other conditions. Therefore, we do not particularly recommend prioritizing this technique. Another reason to avoid the side-step against the throwing arm is the higher number of technical errors (e.g., step violations) compared to the other techniques in our study. However, given the marginal differences between the techniques, all of them can be applied to both sides. These findings imply that all techniques are relevant for practical training. For movements against the arm, emphasizing the split-step is advisable. Since no technique demonstrated a clear advantage, it is suggested to individualize technique training and determine the most suitable technique for each player, aligning with practices in team sports such as goalkeeping in soccer (Otte, Millar, & Klatt, 2019). The findings of this study can be applied to tactical situations in handball. The split-step technique is particularly effective for one-on-one confrontations when directly facing a defender, as its unpredictability and agility can create opportunities to bypass the opponent. Conversely, the side-step proves most effective in situations where the player attacks open space, especially when the defender is already moving laterally. This tactical application aligns with scenarios where exploiting gaps in defensive positioning is critical.

In accordance with the findings of Fasold et al. (2022), the current study confirms that CODs towards the throwing arm are significantly faster than the directional changes against the throwing arm, thus proving the effect's robustness. However, no cause has yet been found that fully elucidates the speed differences between the directions of movement. As team handball is a sport that is unilateral in nature (Janicijevic, et al., 2023), lateral differences may develop over time due to training.

As a limitation of our study we can ask ourselves whether the search for the fastest technique indeed represents the search for the most decisive technique. It is possible that in one-on-one situations in team handball, the maximum speed of COD may not be as important as the optimal speed at which cognitive and tactical components can be executed. Consequently, the investigation of the change direction ability without a cognitive component can be discussed. Young, Rayner, and Talpey (2021) highlight the lack of ecological validity of COD tests. While the current study employs a handball-specific movement, it does not simulate agility conditions typically observed in the game. This could be problematic, as knee loading under agility conditions can be higher than with pre-planned directional changes (Brown, Brughelli, & Hume, 2014). Pre-planned directional changes appear to differ not only in their cognitive but also in their physical aspects. Therefore, the translatability of pre-planned changes of direction to the game sport context appears to be limited.

One limitation of the current study is the use of a 30-second recovery interval between repetitions, which was selected to simulate the recovery times typically observed during match play in team handball. While this interval reflects practical competition conditions, it may not have allowed for complete phosphocreatine resynthesis in all participants. As a result, the repeated high-intensity efforts might have influenced the observed COD performance, particularly in later trials. However, the balanced order of trials across participants minimized the risk of systematic fatigue affecting the results. Nevertheless, it would also be valuable to investigate longer recovery intervals to assess whether complete recovery influences outcomes differently, providing a clearer distinction between the effects of fatigue and technique on performance.

The focus of this study was on average speed as a practical indicator of performance in directional changes. However, we acknowledge that accelerations, decelerations, and other kinematic variables may provide additional insights in feint techniques. Future research could incorporate such kinematic variables to provide a more detailed understanding of the biomechanics underlying directional changes. As highlighted by Robertson, Caldwell, Hamill, Kamen, and Whittlesey (2013), such analyses could offer valuable insights into movement strategies, complementing findings on average speed and further enriching our knowledge of performance in handball-specific scenarios. A potential extension of this work could further involve analyzing the behavior of the center of gravity during COD maneuvers. This additional focus would offer deeper kinematic insights and complement the current findings, as highlighted by Nimphius et al. (2018). Future studies could build on our results by incorporating center of gravity analysis to explore the interplay between movement strategies and biomechanical efficiency in greater detail.

The split-step action proves particularly relevant in one-on-one confrontations, as it leverages unpredictability and agility to overcome direct defensive pressure. In contrast, the side-step technique seems to be more effective in open-space situations, especially when defenders are already moving laterally. These position-specific tactical scenarios should be analyzed further to better understand their impact on team strategy and player effectiveness. Furthermore, future research could also evaluate the integration of actions like intended throws or passes to investigate the interplay between cutting maneuvers, COD speed, and tactical success. A focus on categorizing and ranking individual COD techniques could provide additional insights for training methodologies.

Additionally, expanding this study to include top professional handball players could help determine whether their advanced skill level, experience, and physical condition may lead to different outcomes. Such an approach could provide valuable insights into how performance techniques vary across different levels of play and enhance the applicability of findings to elite handball contexts.

Future research should focus on a detailed analysis of specific technique characteristics that result in successful changes of direction or one-on-one situations in the game. The first step here should be qualitative research that lists the individual characteristics of successful CODs. Subsequently, quantitative research is recommended to determine the extent to which the individual characteristics clarify the variance in one-on-one performance. In addition, psychological effects should also be investigated. Athletes' performance improves when they feel comfortable with their movements, as this increases their confidence in executing them effectively (Wulf & Lewthwaite, 2016).

In conclusion, no significant interaction between technique and direction of movement was found, while the side difference between directional changes towards and against the throwing arm remained as in the previous work by Fasold et al. (2022). In summary, all techniques can be trained in practice, considering that split-step movements are advantageous especially in terms of agility (predicting the direction of movement by the defender). Further research should focus on the ecological validity of COD tests, investigate psychological aspects, and collect technique characteristics that make one-on-one situations successful.

References

Andersen, E., Lockie, R., & Dawes, J. (2018). Relationship of absolute and relative lower-body strength to predictors of athletic performance in collegiate women soccer players. *Sports*, *6*(4), 106. https://doi.org/10.3390/sports6040106

Arboix-Alió, J., Bishop, C., Benet, A., Buscà, B., Aguilera-Castells, J., & Fort-Vanmeerhaeghe, A. (2021). Assessing the magnitude and direction of asymmetry in unilateral jump and change of direction speed tasks in youth female team-sport athletes. *Journal of Human Kinetics*, *79*, 15-27. https://doi.org/10.2478/hukin-2021-0061

Bradshaw, R.J., Young, W.B., Russell, A., & Burge, P. (2011). Comparison of offensive agility techniques in Australian Rules football. *Journal of Science and Medicine in Sport*, *14*(1), 65-69. https://doi.org/10.1016/j.jsams.2010.06.002

Balsalobre-Fernández, C., Tejero-González, C., Del Campo-Vecino, J., & Bavaresco, N. (2014). The concurrent validity and reliability of a low-cost, high-speed camera-based method for measuring the flight time of vertical jumps. *Journal of Strength and Conditioning Research*, *28*(2), 528-533. https://doi.org/10.1519/JSC.0b013e318299a52e

Brown, S.R., Brughelli, M., & Hume, P.A. (2014). Knee mechanics during planned and unplanned sidestepping: A systematic review and meta-analysis. *Sports Medicine*, *44*(11), 1573-1588. https://doi.org/10.1007/s40279-014-0225-3

Castillo-Rodríguez, A., Fernández-García, J.C., Chinchilla-Minguet, J.L., & Carnero, E.Á. (2012). Relationship between muscular strength and sprints with changes of direction. *Journal of Strength and Conditioning Research*, *26*(3), 725-732. https://doi.org/10.1519/JSC.0b013e31822602db

Connor, J.D., Crowther, R.G., & Sinclair, W.H. (2018). Effect of different evasion maneuvers on anticipation and visual behavior in elite Rugby League players. *Motor Control*, *22*(1), 18-27. https://doi.org/10.1123/mc.2016-0034

David, S., Komnik, I., Peters, M., Funken, J., & Potthast, W. (2017). Identification and risk estimation of movement strategies during cutting maneuvers. *Journal of Science and Medicine in Sport*, *20*(12), 1075-1080. https://doi.org/10.1016/j.jsams.2017.05.011

Delaney, J.A., Scott, T.J., Ballard, D.A., Duthie, G.M., Hickmans, J.A., Lockie, R.G., & Dascombe, B.J. (2015). Contributing factors to change-of-direction ability in professional Rugby League players. *Journal of Strength and Conditioning Research*, *29*(10), 2688-2696. https://doi.org/10.1519/JSC.0000000000000960

Dos'Santos, T., McBurnie, A., Thomas, C., Comfort, P., & Jones, P.A. (2019). Biomechanical comparison of cutting techniques: A review and practical applications. *Strength and Conditioning Journal*, *41*(4), 40-54. https://doi.org/10.1519/SSC.0000000000000461

Falch, H.N., Haugen, M.E., Kristiansen, E.L., & van den Tillaar, R. (2022). Effect of strength vs. plyometric training upon change of direction performance in young female handball players. *International Journal of Environmental Research and Public Health*, *19*(11), 6946. https://doi.org/10.3390/ijerph19116946

Fasold, F., Braun, A., & Klatt, S. (2022). Effects of arm dominance and decision demands on change of direction performance in handball players. *Journal of Human Kinetics*, *85*(1), 127-135. https://doi.org/10.2478/hukin-2022-0116

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149-1160. https://doi.org/10.3758/BRM.41.4.1149

Forster, J.W.D., Uthoff, A.M., Rumpf, M.C., & Cronin, J.B. (2022). Training to improve pro-agility performance: A systematic review. *Journal of Human Kinetics*, *85*(1), 35-51. https://doi.org/10.2478/hukin-2022-0108

Gaamouri, N., Hammami, M., Cherni, Y., Oranchuk, D.J., Bragazzi, N., Knechtle, B., Chelly, M.S., & van den Tillaar, R. (2023). The effects of upper and lower limb elastic band training on the change of direction, jump, power, strength, and repeated sprint ability performance in adolescent female handball players. *Frontiers in Sports and Active Living, 5*, 1021757. https://doi.org/10.3389/fspor.2023.1021757

Haff, G., Triplett, N.T., & National Strength and Conditioning Association (Hrsg.). (2016). *Essentials of strength training and conditioning* (4th edition). Human Kinetics.

Horníková, H., & Zemková, E. (2021). Relationship between physical factors and change of direction speed in team sports. *Applied Sciences*, *11*(2), 655. https://doi.org/10.3390/app11020655

Janicijevic, D., Pérez-Castilla, A., Miras-Moreno, S., Ortega-Becerra, M., Morenas-Aguilar, M.D., Smajla, D., Sarabon, N., & García-Ramos, A. (2023). Effect of a high-intensity handball-specific fatigue protocol focused on the leg contralateral to the throwing arm on interlimb asymmetries. *Journal of Strength and Conditioning Research*, *37*(7), 1382-1389. https://doi.org/10.1519/JSC.0000000000004422

Karcher, C., & Buchheit, M. (2014). On-court demands of elite handball, with special reference to playing positions. *Sports Medicine*, *44*(6), 797-814. https://doi.org/10.1007/s40279-014-0164-z

Keiner, M., Kapsecker, A., Stefer, T., Kadlubowski, B., & Wirth, K. (2021). Differences in squat jump, linear sprint, and change-of-direction performance among youth soccer players according to competitive level. *Sports*, *9*(11), 149. https://doi.org/10.3390/sports9110149

Knief, U., & Forstmeier, W. (2021). Violating the normality assumption may be the lesser of two evils. *Behavior Research Methods*, *53*(6), 2576-2590. https://doi.org/10.3758/s13428-021-01587-5

Loturco, I., Pereira, L.A., Reis, V.P., Abad, C.C.C., Freitas, T.T., Azevedo, P.H.S.M., & Nimphius, S. (2022). Change of direction performance in elite players from different team sports. *Journal of Strength and Conditioning Research*, *36*(3), 862-866. https://doi.org/10.1519/JSC.0000000000003502

Marshall, B.M., Franklyn-Miller, A.D., King, E.A., Moran, K.A., Strike, S.C., & Falvey, É.C. (2014). Biomechanical factors associated with time to complete a change of direction cutting maneuver. *Journal of Strength and Conditioning Research*, *28*(10), 2845-2851. https://doi.org/10.1519/JSC.0000000000000463

Nimphius, S., Callaghan, S.J., Bezodis, N.E., & Lockie, R.G. (2018). Change of direction and agility tests: Challenging our current measures of performance. *Strength and Conditioning Journal*, *40*(1), 26-38. https://doi.org/10.1519/SSC.0000000000000309

Noutsos, K.S., Meletakos, P.G., Kepesidou, M., & Bogdanis, G.C. (2024). Equal effects of low- and moderate-volume supplementary plyometric training on sprint, change of direction ability, and lower-limb power in preadolescent female handball players. *Journal of Functional Morphology and Kinesiology*, *9*(4), 204. https://doi.org/10.3390/jfmk9040204

Otte, F.W., Millar, S.-K., & Klatt, S. (2019). Skill training periodization in “Specialist” sports coaching—An introduction of the “PoST” framework for skill development. *Frontiers in Sports and Active Living*, *1*, 61. https://doi.org/10.3389/fspor.2019.00061

Póvoas, S.C.A., Seabra, A.F.T., Ascensão, A.A.M.R., Magalhães, J., Soares, J.M.C., & Rebelo, A.N.C. (2012). Physical and physiological demands of elite team handball. *Journal of Strength and Conditioning Research*, *26*(12), 3365-3375. https://doi.org/10.1519/JSC.0b013e318248aeee

Pueo, B., Penichet-Tomas, A., & Jimenez-Olmedo, J.M. (2020). Validity, reliability and usefulness of smartphone and Kinovea motion analysis software for direct measurement of vertical jump height. *Physiology and Behavior*, *227*, 113144. https://doi.org/10.1016/j.physbeh.2020.113144

Robertson, D.G.E., Caldwell, G.E., Hamill, J., Kamen, G., & Whittlesey, S.N. (2013). *Research methods in biomechanics* (2nd ed.). Human Kinetics.

Salaj, S., & Markovic, G. (2011). Specificity of jumping, sprinting, and quick change-of-direction motor abilities. *Journal of Strength and Conditioning Research*, *25*(5), 1249-1255. https://doi.org/10.1519/JSC.0b013e3181da77df

Simmons, J.P., Nelson, L.D., & Simonsohn, U. (2011). False-positive psychology: Undisclosed flexibility in data collection and analysis allows presenting anything as significant. *Psychological Science, 22*, 1359-1366.

Spiteri, T., Nimphius, S., Hart, N.H., Specos, C., Sheppard, J.M., & Newton, R.U. (2014). Contribution of strength characteristics to change of direction and agility performance in female basketball athletes. *Journal of Strength and Conditioning Research*, *28*(9), 2415-2423. https://doi.org/10.1519/JSC.0000000000000547

Sugiyama, T., Maeo, S., Kurihara, T., Kanehisa, H., & Isaka, T. (2021). Change of direction speed tests in basketball players: A brief review of test varieties and recent trends. *Frontiers in Sports and Active Living, 3*, 645350. https://doi.org/10.3389/fspor.2021.645350

Highlights:

Agility actions, including cutting manoeuvres with the ball, play a crucial role in team handball performance.
Although, a balanced bilaterality in agility actions seems to be beneficial for sports performance, team handball athletes exhibit an imbalance, with cuts in the direction of the throwing arm executed faster than those against it.
The results indicate that differences in technique cannot account for the observed lateral variations in change of direction speed during team handball-specific cutting manoeuvres.
Further research should explore alternative factors contributing to lateral differences in sport-specific agility movements.

Conflicts of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization, PE, FF, DS; methodology, PE, FF; validation, SK, FF; formal analysis, PE, FF, SK; investigation, PE, FF, DS; data curation, PE; writing—original draft preparation, PE, DS, FF; writing—review and editing, PE, DS, SK, FF; supervision, SK, FF.; project administration, PE, FF. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement

The study was carried out in accordance with the Helsinki Declaration of 1975. The study was approved from the lead institution’s ethics board.

Informed Consent Statement

Not applicable.

Data Availability Statement

The raw data sets used in this study will be available after publication under doi: 10.17605/OSF.IO/9EYB2

Thomas, C., Comfort, P., Jones, P.A., & Dos'Santos, T. (2017). A comparison of isometric midthigh-pull strength, vertical jump, sprint speed, and change-of-direction speed in Academy Netball players. *International Journal of Sports Physiology and Performance*, *12*(7), 916-921. https://doi.org/10.1123/ijspp.2016-0317

Trewartha, G., Munro, B., & Steele, J. (2008). *Can the split-step cutting technique reduce loading and maintain performance?* [Conference paper]. International Conference of Biomechanics in Sport, Tsubaka, Japan. https://ojs.ub.uni-konstanz.de/cpa/article/view/1870

Wagner, H., Finkenzeller, T., Würth, S., & von Duvillard, S.P. (2014). Individual and team performance in team-handball: A review. *Journal of Sports Science and Medicine*, *13*(4), 808-816.

Wulf, G., & Lewthwaite, R. (2016). Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. *Psychonomic Bulletin and Review*, *23*(5), 1382-1414. https://doi.org/10.3758/s13423-015-0999-9

Young, W., & Farrow, D. (2006). A review of agility: Practical applications for strength and conditioning. *Strength and Conditioning Journal 28*, *5*, 24-29.

Young, W., Rayner, R., & Talpey, S. (2021). It's time to change direction on agility research: A call to action. *Sports Medicine—Open*, *7*(1), 12. https://doi.org/10.1186/s40798-021-00304-y

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Correspondence to:
Frowin Fasold
Institute of Exercise Training and Sport Informatics
Section Cognition in Team Sports, German Sport University Cologne
Am Sportpark Muengersdorf 6, 50933 Cologne, Germany
E-mail: f.fasold@dshs-koeln.de