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Effects of Arm Dominance and Decision Demands on Change of Direction Performance in Handball Players

by
Frowin Fasold[1], Alexander Braun[1], Stefanie Klatt[1]

This field study investigated the effect of unilateral dominance (handedness of players) on the change of direction speed in a specific cutting manoeuvre with a ball (in the direction of the throwing arm vs. against the direction of the throwing arm) in team handball. In addition, the effect of a cutting manoeuvre in response to an immediate stimulus compared to one planned in advance on the movement speed was analysed. Forty participants (22 male, 18 female, M_{age} 23 years) performed change of direction actions to the left and the right side (the direction of the throwing arm vs. against the direction of the throwing arm) under planned and reactive (light as visual stimuli) conditions. Change of direction speed was measured post-hoc by video-analyses. The results showed two effects. First, the decision demand in reaction to a visual stimulus reduced the speed in the change of direction compared to the planned action. Second, participants performed their action faster in the direction of the throwing arm than against it. The results replicate the effects of decision demands of previous studies and regardless of the reaction to the stimuli being unspecific, further studies could investigate if specific training can reduce the speed loss due to decision demands. The lateral speed differences of cutting manoeuvres of handball players have been analysed for the first time in this study. This effect could have several causes (e.g., coordination, power, motivation) which should be investigated in future studies in more detail.

Key words: *team handball, agility, team sports, cutting manoeuvre.*

Introduction

There are diverse physiological, psychological, and cognitive skills which are necessary to fulfil the demands of a complex team sport. In this regard, some of the major skills required are the ability to accelerate, decelerate, and to change one's direction swiftly and efficiently (e.g., David et al., 2018; Taylor et al., 2017). Such unilateral high-intensity movements have a crucial impact on the outcome of competitions (e.g., Nimphius et al., 2018). In team handball, fast change of direction movements are one of the most frequently observed individual actions during a game (Karcher and Buchheit, 2014; Pereira et al., 2018). Some previous studies have focused on such change of direction movements in handball (Massuça et al., 2014; Pereira et al., 2018; Wagner et al., 2019). However, it is unclear how the unilateral dominance in handball, i.e., use of mainly one arm for throwing and passing (Weber and Wegener, 2019), influences the ability of players to change the direction. We conducted a field study to investigate if there are any differences in speed during an orthogonal change of direction action between left and right independent of the arm dominance. With this assumption, we examined whether this is influenced by the reaction to a visual stimulus.

Change of direction is simply defined as the ability to alter the direction, speed, and the type of a movement. When such change of direction is due to a reaction to a specific stimulus, it is termed as *agility* (Haff and Tripplet, 2016). This distinction between a simple change of direction and agility is crucial, particularly in the context of team sports, because in team sports,

[1] - *Institute of Exercise Training and Sport Informatics, German Sport University Cologne, Cologne, Germany*

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agility is the foremost requirement for players (Young et al., 2021). In general, every change of direction is due to tactical reasons and is affected by cognitive variables (e.g., perception, anticipation, decision making). Young and Farrow (2006) described agility in their deterministic model as a multifactorial ability which is based on cognitive factors (visual scanning, anticipation, pattern recognition, knowledge) and the basic change of direction speed (technique aspects, sprinting speed, muscle qualities).

Change of direction is mainly accompanied by high force impact and thus, injuries are common (e.g., rupture of the anterior cruciate ligament, David et al., 2017). Therefore, a large body of research has focused on injury prevention while changing direction in cutting manoeuvres in the past (David et al., 2017; Kadlec and Gröger, 2020; Nimphius et al., 2018; Taylor et al., 2017). While there is some general research on health considerations, particularly in performance sports, it lacks in specificities. The evaluation of agility or simply the change of direction speed should be done under precise conditions because of the movement dimensions (e.g., forward, backward, lateral) which differ according to the sport being analysed (Sekulic et al., 2014). For instance, in rugby the change of direction is mainly done in y-shape-courses, while in handball, basketball or tennis, more stop-and-go movements occur. These stop-and-go movements often occur at zero velocity in the deceleration phase in which athletes stop completely (Sekulic et al., 2014). If we assume that these differences are only at the motoric level, it becomes clear that the different specific cognitive requirements of different sports influence agility. A study by Nimphius et al. (2018) further elaborates that the results of testing the agility or the ability to change direction are influenced by a variety of test dimensions like the length of the test, the number of direction changes or the run-up direction.

Previous research has described general position-specific demands in handball (Büchel et al., 2019; Manchado et al., 2013; Taylor et al., 2017), without considering individual technical-tactical skills. While agility is necessary in all phases of the game (defence, offense, transition, goalkeeping), high speed and tactical effective change of direction behaviours like cutting manoeuvres with the ball, particularly in attack, seem to be advantageous against the opponent. Despite the overall importance of successful change of direction on the outcome of the game (Nimphius et al., 2018), Pereira et al. (2018) have indicated that with regard to handball, this crucial topic remains unexplored with the role of functional unilateral dominance in handball conspicuously missing.

In practice, it seems useful for an attacking player to be unpredictable for the defender. This means that having the same abilities (speed) in all movement vectors (in handball in particular from left to right and right to left) is an asset for offensive players. However, we assume that due to the tactical demands, the handedness of players influences the change of direction speed. Therefore, cutting manoeuvres with the final movement in the direction of the throwing arm are made faster than manoeuvres with the final movement direction against the throwing arm.

Accordingly, we conducted a field study to, firstly, investigate the impact of the throwing arm dominance on the change of direction speed in two different movement vectors (right, left). Secondly, we investigated the impact of the reaction to a visual stimulus on the change of direction speed by comparing a simple change of direction with an agility task. We assumed that an additional cognitive demand (perceiving a visual direction stimulus) in a simple change of direction task (cutting manoeuvre with the ball after a run up on the left or the right back position) leads to a loss in the speed of the change of direction. This assumption was based on several existing results (Spasic et al., 2015). The aim of evaluating this again was to validate the previously-used experimental paradigms, and to evaluate if the assumed effect of the hand dominance of players can be found in planned and unplanned situations.

Methods

Participants

An effect size was calculated based on the reported results of previous research examining the mean speed differences between an agility and a change of direction task (Spasic et al., 2015) for male and female participants (d = 2.32). Using G*Power (Faul et al., 2009) a sample size of just ten participants was proposed to achieve a power of .99. To avoid false-positive results (Simmons et al., 2011) and following the guidelines of Central Office for Research Ethics Committees (2007), we expected, that this sample size was first, not representative, and second, not robust against the effect of the covariate gender. Thus, we calculated a sample size of $N = 40$ for the study.

Twenty-two males and 18 females participated voluntarily in this study (mean age 22.60, *SD* = 2.05). The average handball playing experience of all participants was 13.97 years (*SD* = 3.52). Players who were injured in the past 15 months, which could impair the results, were excluded from the study. The study was approved by the German Sport University Cologne ethics committee (nr. 010/2021) and was carried out according to the declaration of Helsinki of 1975 and its later revisions. Written informed consent was obtained from each participant before testing.

Design

Due to the expected gender specific differences (cf. Karcher and Buchheit, 2014; Manchado et al., 2013), we assumed higher movement speed by male participants. Because the evaluation of gender difference was not the main aim of our study, we integrated the factor *gender* as just a covariate in the experimental design. Thus, the effect of the inner-subject-factors *direction* (direction of the throwing hand vs. against the throwing hand) and *decision* (planned vs. unplanned action) and the between-subject-factor *gender* (male vs. female) as covariate on the dependent variable *change of direction speed* were evaluated.

Materials and Procedures

To simplify the understanding of the experimental procedure, we present a common cutting manoeuvre in team handball in Figure 1. The attacker on the right back position starts with the run-up in the open space between two defenders. The direct opponent closes this space with a lateral movement to stay in the optimal defence position (between the attacker and the goal). After receiving the ball, the attacker now conducts a fast-cutting manoeuvre (in this example a change of direction movement to the right) against the movement direction of the defender to get an advantage (open space to the goal) (Figure 1).

To investigate the dependent variable (change of direction speed) in such a cutting manoeuvre and to follow the experimental design, the following experimental conditions were created (setup is described in detail in Figure 2). Participants were unrestricted in choosing a ball with which they felt comfortable. They were told to perform a cutting manoeuvre as fast as possible. The run-up was marked by plates and an air body was used as a defending player.

Participants started after an individual warm up on the starting position (the centre of the starting position being 1.85 m away from the side-line, and 11.20 m away from the goal line) (Figure 2). They then passed the ball to the transitory player (positioned on the opposite goal post, 10 m distance to the goal line). Subsequently they ran, within the space marked by plates (1.35 m distance between the plates), a curved run-up, designed like a typical run-up in several game actions. The last plates of the run-up area were placed 7.80 m away from the side-line (centre between the two plates) and 10.70 m away from the goal line. The centre of the gym mat was placed at 5.50 m distance from the side-line and 11.80 m away from the goal line.

In the receiving zone, players received the ball from the passing player in front of the air body (8 m away from the side line, 9 m away from the goal line). The air body was meant to simulate a defending opponent. After receiving the ball, participants executed a change of direction (cutting manoeuvre) representing a 1:1 action (without contact), followed by a throw on the goal by a jump shot (Figure 2). This change of direction was planned (as instructed by the experimenter) in or against the direction of the throwing arm as one experimental condition (without decision/no reaction to a visual stimuli).

In another experimental condition (unplanned with decision/reaction to a stimuli), the movement direction was dependent on a light signal (BlazePods™ reaction lights; red = in the direction of the throwing arm, blue = against the direction of the throwing arm). A raised gym mat was used to prevent participants from getting an early view of the pod light (the light was supposed to be visible shortly before receiving the ball). The pod was placed in the middle of the left goal post (Figure 2). Due to this *decision* condition, participants were instructed with the cover story that the frequency of the *direction* was random to avoid the possibility that participants could plan their change of direction in every trial under these conditions.

Every participant repeated the cutting manoeuvres three times under all experimental conditions (*direction*: direction throwing hand vs. against throwing hand x *decision:* unplanned vs. planned action). Thus, every participant participated in twelve trials with 40 s rest intervals between the trials. The order of the conditions was counterbalanced by the independent variables and the number of subjects. If participants were left-handed (n = 5) the procedure was mirrored on the left side of the field.

Measure of change of direction speed

Based on the structure and functions of the validated and reliable measures, which were used to test jumping performances or throwing speed (Gallardo-Fuentes et al., 2016; Raeder et al., 2015), we developed a simple specific measure of the horizontal movement speed in change of directions in handball. A video camera was placed behind the experimental setup to record participants' actions (recording rate of 100 Hz) (Figure 2). Tape stripes 10 cm apart were placed on the floor on a line parallel to the goal line (9 m away from the goal line) to measure the change of direction distance of the cutting manoeuvre, in front of the air body (Figure 2). The stripes were big enough to be visible on the video, but small enough not to impair the movement of participants.

To calculate the change of direction speed, the distance from the first initial foot contact to the landing of the foot after executing the lateral space gain was determined through video recordings. The distance was measured using the distance of the line with the tape stripes. If participants placed their foot at the same height as a tape stripe, the farthest distance was documented. The time of this space gain was calculated by the frames of the video. Subsequently, the distance covered in meters was divided by the time (calculated by the number of frames) required to cover this distance in seconds, resulting in the calculation of the change of direction speed in m/s. For every participant under every condition, the mean of the three trials (m/s) was used in further analysis to reduce the risk of bias initiated by different run up speeds, variable passing and catching or shifts in the frame/distance analysis.

Statistical Analysis

A total of 9.2% of the trial data was missing. The missing data indicated wrong decisions, meaning the light showed one direction, but the participant moved to the opposite side. Some of the data were also marked as missing due to technical errors in catching the ball or losing the ball altogether. In situations where one set of trial data was reported missing, we calculated the mean based on the available data.

In a 2 x 2 x 2 design, a single factor ANOVA with repeated measures was used to investigate the effect of the factors, *direction* (direction of the throwing hand vs. against the throwing hand), *decision* (planned vs. unplanned action), *and gender* (male vs. female) on the independent variable *change of direction speed.* The homogeneity of the covariance matrices was given according to the Box test (p > 0.001). The homogeneity of the error variances between the conditions was fulfilled (p > 0.05). As effect size, the partial η^2 was calculated.

Results

The three way interaction of the factors, *gender, direction* and *decision* shows no effect $F(1, 38) = 0.63$, $p = 0.43$, $\eta^2_{partial} = 0.01$. Furthermore, no statistically significant interaction effect of *gender* and *direction* $F(1, 38) = 0.30$, $p = 0.59$, $\eta^2_{partial} = 0.01$, *gender* and *decision* $F(1, 38) = 0.89$, $p = 0.35$, $\eta^2_{partial}$ = 0.02, and *direction* and *decision*, $F(1, 38) = 1.03$, p = 0.31, $\eta^2_{partial} = 0.02$, could be found. The missing interactions and the significant main effect of the covariate *gender*, $F(1, 38) = 7.66$, $p > 0.001$, $\eta^2_{partial}$ = 0.16, confirms that men performed faster under all conditions (Table 1).

The factor *decision* showed a significant main effect, $F(1, 38) = 7.92$, $p < 0.01$, $\eta^2_{partial} = 0.17$. In the planned action, participants reached a higher change of direction speed than in the unplanned action (Figure 3). Also, there was a significant main effect in the factor *direction*. The velocity to the throwing arm side was higher than against the throwing arm side, $F(1, 38) = 33.93$, p < 0.001, $\eta^2_{partial} = 0.47$ (Figure 3).

Discussion

The results of the current study confirm our assumption that a reaction to a visual stimulus (signal detection + decision) leads to a significant decrease in the change of direction speed. Primarily, we measured the direction differences between a cutting manoeuvre to the left and a cutting manoeuvre to the right, and found a significantly lower speed in movements against the direction of the throwing arm of participants (Figure 3).

The gender effect as a secondary result of our study was not surprising. The results of the faster changes of direction of male participants than female athletes could simply be explained by greater muscle mass of male compared to female participants (Karcher and Buchheit, 2014; Manchado et al., 2013). Interestingly, no interaction was found between the factor *gender* and the other experimental factors, thus, the effect of factor *direction* and *the decision* is also independent of the gender.

Table 1. *Means of the Change of Direction Speed in the Interaction of the Three Experimental Factors.*

	Planned action				Unplanned action			
	direction throwing arm		against throwing arm		direction throwing arm		against throwing arm	
	female*	male	female*	male	female*	male	female*	male
M	4.25	4.69	3.01	3.36	3.85	4.53	2.64	3.01
SD	0.88	0.69	0.87	0.88	0.80	0.81	0.74	1.00
CI	4.63, 3.88	5.03, 4.36	3.43, 2.59	3.74, 2.99	4.23, 3.46	4.88, 4.19	3.06, 2.21	3.39, 2.62

*Note. Mean change of direction speed in m/s with the standard deviation and the confidence interval (95%). * indicates the significant main effect (p < 0.001) between male and female participants.*

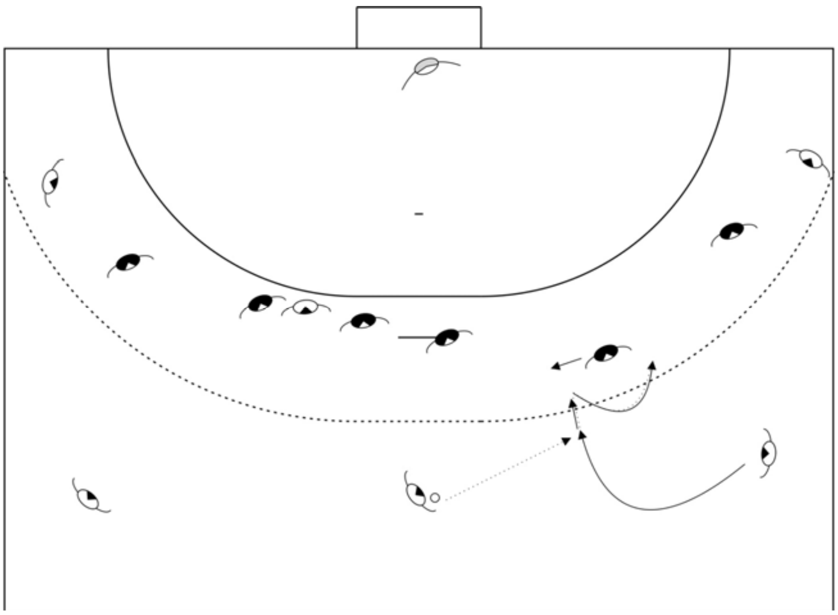

Figure 1. *An Illustration of a Common Cutting Manoeuvre in a Team Handball Game.*
Note. This illustration shows a typical 1-on-1 situation on the right back position in team handball where a cutting manoeuvre with the ball (change of direction) is used to defeat the defender. Players in black represent defenders, players in white attackers. The dotted lines show the trajectory of the ball, and the solid lines indicate the trajectory of players without the ball.

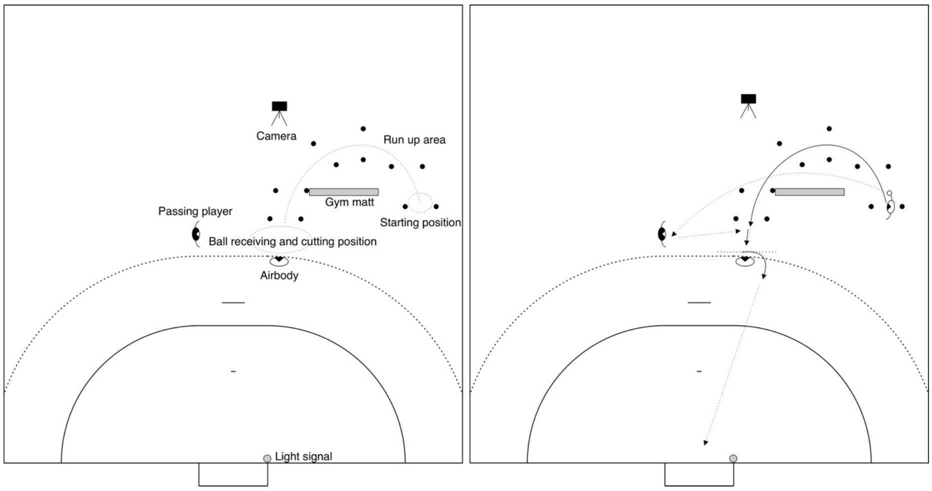

Figure 2. *Materials, Positions, and Test Procedures.*
Note. The materials and the positions are shown on the left side, the procedure of the test is shown on the right side of the figure.

Figure 3. *Main Effects of the Experimental Factors: Decision and Direction.*
*Note. Mean change of direction speed in m/s under the different experimental conditions. * indicates the significant main effect of the factor decision ($p < 0.01$), and † indicates the significant main effect of the factor direction ($p < 0.001$).*

Independent of this covariate, in our study, we could replicate the finding that additional cognitive requirements reduce the speed in the change of direction. With these findings, we verified the results of different experimental approaches (Nimphius et al., 2018; Spasic et al., 2015). Thus, our results are not novel, but are now validated in a new experimental setting. This could be due to the time limitation for spatial perceptions for positioning the body parts in the movement in a way that a deceleration with subsequent acceleration cannot be performed in a biomechanically optimal way. Also, the action of vision could affect the focus for movement execution. This could make movement execution more challenging based on the coordinative abilities. Additionally, it is possible that participants were uncertain about the correctness of their decision and therefore, unconsciously performed the action at a slower speed. This could result in a longer contact time during the stop-and-go phase of the movements or shorter distances during the change of direction due to lower force development. Nevertheless, we think that the speed differences between planned and unplanned cutting manoeuvres could be seen as a potential for the development of playing performances. We expect that the influence of additional cognitive demand, which is always a part of the game, cannot completely be removed, but players should be trained in a way that they could handle the visual and decision-making demands of the game to improve their performance in unplanned and open game situations. Several studies have indicated that agility abilities (change of direction in response to a stimulus) could be trained and developed (Paul et al., 2016). In particular, smallsided games seem to be effective to develop specific agility performances and are superior in just training change of directions without decision-making components (Paul et al., 2016). It should be further investigated in line with a cognitive-perceptual expertise approach (Williams and Ericsson, 2005) if experts could better handle the additional visual and decision demands than less experienced players.

The result of the higher change of direction speed on the side of the throwing arm could be based on several reasons. First, we expected a technical-coordinative aspect. Getting in an optimal throwing position which allows a rotation of the body-segments to get an optimal acceleration of the ball (Wagner et al., 2012), after the change of direction in the direction of the throwing arm is easier than in another one. If the cutting manoeuvre is performed against the direction of the throwing arm additional to the step combination (due to the rules a maximum of three steps are allowed) a (opposite) body rotation after the throwing movement is necessary to get in an optimal throwing position. We expected that this additional demand could lead to a slower execution of the preparation movement of the throw, the cutting manoeuvre. Furthermore, we expected that simple reasons of athleticism could affect the differences between the two movement directions. If the cutting manoeuvre in the direction of the throwing arm is easier, it is more likely to be used. Thus, we expected that frequency effects had an impact on the power development in a way that experienced handball athletes could have higher deceleration and acceleration abilities in the direction of their throwing arm. If cutting manoeuvres in one direction are more likely, we would expect that motivation could also influence the speed.

Thus, it would be useful for further research to examine if the determined pattern of results is affected by firstly, expertise, secondly, athleticism (e.g., power, coordination), and thirdly, motivation. Independent of the reason for the direction effect on movement speed, coaches could focus on technical or athletic exercises to develop balanced agility abilities. Athletes who could perform the specific cuttings in both directions with nearly similar speed, might be superior because they can act more unpredictably. Nevertheless, it has to be evaluated in further intervention studies if complete balancing of the vector depending movement speed is possible or restricted by the sport specific unliteral dominance (in team handball the handedness).

The main aim of this study was to test the change of direction movement in a specific situation with utilisation focused measures. Therefore, we suggest further adaptations of the experimental setting with a test environment being as realistic as possible (Nimphius et al., 2018). For example, the air body could be replaced by a (passive) defender, the direction stimuli could be modified (e.g., defender steps to the left or the right side), and speed measurement could be simplified via local positioning systems, a radar or light barriers.

Conclusions

Our study shows that in cutting manoeuvres, the movement to the direction of the throwing arm could be performed with higher speed than the movement in the direction against the throwing arm. This could be based on expertise, athleticism or motivation. The additional cognitive task (reaction to a stimuli) could affect the time needed for orienting and positioning the limbs and thus, could have lower velocities as a result. Against the general criticism on measuring the change of direction speed under unspecific conditions (Nimphius et al., 2018), our study represents results in specific spatially executed cutting manoeuvres. While our study lacks in specificity due to the visual-perceptual stimuli (signal detection of a light) and further research is needed, we expect that our experimental design can help coaches test and develop the potential of their athletes. In cutting manoeuvres, the fluid transition between deceleration and subsequent acceleration in the new direction should be trained at the cognitive and motoric levels. Especially, from a technical point of view, there still seems to be a potential for development in the movement in the direction against the throwing arm side.

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Corresponding author:

Frowin Fasold
Institute of Exercise Training and Sport Informatics,
German Sport University Cologne, Cologne, Germany.
Phone: +49 221 / 4982-4293,
E-mail address: f.fasold@dshs-koeln.de

Authors statement :
There is a shared first authorship (the authors Frowin Fasold and Alexander Braun contributed equally to the work).