EXAMINING THE IMPACT OF APPROACH AND EXIT PHASE STRATEGIES ON CHANGE OF DIRECTION PERFORMANCE: A NOVEL METHODOLOGY

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This study used new insole pressure technology to examine how movement strategies during approach and exit phases affect change of direction (COD) times. Participants (n=26) wore NURVV smart insoles and performed 90˚ cuts off each leg (dominant [Dom] and non-dominant [ND]). Ground contact time (GCT), cadence, centre of pressure, and return to linear sprinting metrics were analysed for four steps about the cut-step. Faster cadence and a more forefoot strike pattern predicted 58% of the variance in Dom side COD ability. ND COD ability was predicted by a faster cadence immediately post-cut and a quicker GCT two steps before the cut-step (66% of variance explained). These findings emphasize the approach phase's crucial role in COD ability and stress the need to examine multiple steps around the cut-step for a complete understanding of COD mechanisms.

KEYWORDS: COD deficit, insole pressure sensors, centre of pressure location, field sport athlete.

INTRODUCTION: Success in multidirectional sports can often be associated with effective change of direction (COD) ability (Nimphius et al., 2018). The importance of COD ability to overall sporting performance has led to numerous studies investigating the biomechanical characteristics or movement strategy associated with enhanced COD ability. However, the previous investigations have almost exclusively focused on the turn phase of the COD movement, outlining biomechanical variables during the cut-step which are associated with enhanced COD ability (Dos'Santos et al., 2017). This is despite suggestions that the steps preceding and following the cut-step will be critical to overall COD ability (Dos' Santos et al., 2018). This is particularly relevant for greater COD angles (i.e., 90-180˚ cuts) which require a larger deviation from normal linear sprinting technique, and hence a larger change in movement strategy from linear sprinting, to successfully perform the skill.
A challenge to conducting an in-depth biomechanical analysis of the steps both preceding and following the cut-step in a COD task has been the limitation in the capture volume of biomechanical assessment tools. This limited capture volume has restricted researchers from exploring multiple steps about the cut-step. However, the development of new technologies, such as smart insole pressure sensors, may provide a unique solution to such limitations, allowing for spatiotemporal variables to be collected for the entire movement strategy about a COD task. The purpose of this study is to delineate the key spatiotemporal variables, as measured by smart insoles, in the approach and exit phases of a COD task, with the objective of identifying the best predictors of COD ability.

METHODS: Twenty-six amateur team sport athletes (age = 26 ± 5.58 years, height = 1.80 ± 0.09 m, mass = 83.12 ± 18.72 kg) were recruited for this study. All participants provided written and informed consent. Ethical approval was granted by the institutional ethics committee. Participants were required to attend a single testing session which required them to complete three 10 m sprints and a total of six 90˚ COD tests, three trials on the left foot and three trials on the right foot. A three-minute rest period was provided between each trial. The 90˚ COD tests required participants to accelerate from a stationary start for 5 m, before performing a 90˚

cut to either the left or the right depending on the trial, and then accelerate for 5 m. The 10 m sprint required participants to perform a linear acceleration from a stationary start. The 10 m sprint was included to allow for the calculation of the change of direction deficit (Nimphius et al., 2018). The change of direction deficit is reported to be a more isolated measure of COD ability (Nimphius et al., 2018). Timing gates (Brower Timing Systems LLC, UT, USA) were used to calculate the time to complete each trial of the linear sprint and COD tests. The fastest trial for the 10 m sprint and for both the left and right COD tests was utilised for analysis. The faster of the trials for either the left or right foot was labelled the dominant side, with the slower labelled the non-dominant side for data analysis.

Participants completed each trial with calibrated smart insoles and inertial measurement unit tracker (NURVV Ltd, London, UK). The NURVV smart insoles and tracker have previously been found to be a reliable and valid measure of step, spatiotemporal variables (Lopes and Trewartha, 2021). The insole data was collected concurrently with video camera data recording at 240 Hz (iPhone 10, Apple Inc, Cupertino, CA, US), to allow the determination of the cut-step during COD testing, and consequently the preceding and following steps.

All data collected was processed using custom Python scripts. The dependent variable of COD deficit was calculated using the formula outlined by Nimphius et al. (2018). From the identification of the cut-step, 4 steps preceding and following the cut-step were identified and labelled for analysis. At each step, several variables were investigated; ground contact time (GCT: time of each step in milliseconds), cadence (time between initial contacts of the step and the step preceding it in milliseconds), initial centre of pressure (COP) position (average COP anterior-posterior coordinate ['Y'] over the first 10 frames of the step in millimetres), and when (if at all) sprinting technique returned to straight line sprinting technique (first step post cut where 70% of the COP trace was within an ellipse determined by straight sprint trials; Figure 1).

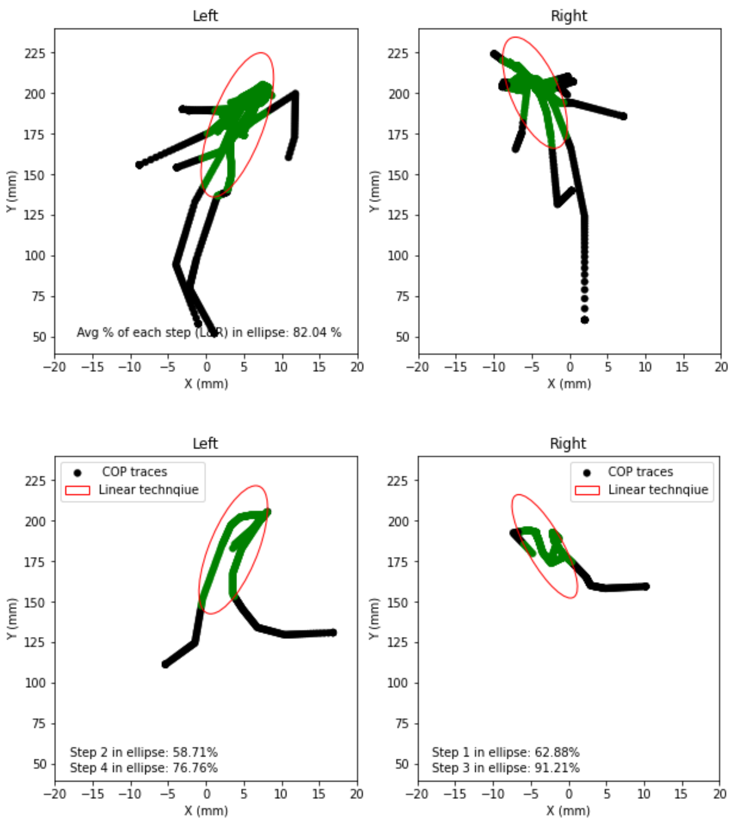

Figure 1: ***Top row:*** **Overlayed left and right foot centre of pressure coordinates during straight-line sprinting trials.** ***Bottom row:*** **Change of direction trial post cut step centre of pressure (COP) coordinates and linear sprint ellipse (red) overlayed demonstrating the percentage of coordinates comparable to straight line running. Green colour indicates COP trace inside the linear sprint ellipse.**

All statistical analysis was performed in Statistical packages for the social sciences version 26 (SPSS Inc., Chicago, IL, USA). Normality of each variable was determined by visual analysis of Q-Q plots. Due to the novel nature of the measure, the mean and standard deviation of the number of steps to return to linear sprinting COP following the cut-step was determined for both the dominant and non-dominant cuts. The effects of spatiotemporal kinematics upon COD ability were addressed by using a forward stepwise linear regression. Variables were included in the regression equation if $p < 0.05$. The variance inflation factor (VIF) was used to assess multicollinearity, where VIF = 1 indicated no correlation, 1 < VIC < 5 indicated moderate correlation, and VIF > 5 indicated high correlation between variables. In the instances of multicollinearity, the elimination approach to the model re-specification method was utilised.

RESULTS: All data was found to be normally distributed. Participants returned to linear sprinting COP following the cut-step, after 1.15 ± 1.19 and 1.77 ± 1.37 steps, for the dominant and non-dominant cuts, respectively. The results of the regression models for both the dominant and non-dominant COD ability can be seen in Table 1. The model containing three variable was found to be the best at predicting COD ability for the dominant turn, explaining 58% of the variance in COD performance. COD ability for the non-dominant turn was best predicted with a model containing two variables, explaining 66% of variance in COD performance.

Table 1: Regression equations for change of direction ability using forward stepwise linear regression

Number of Parametres	Technique Parametre(s)	Coefficient	*p* - value	Percentage explained	VIF
Dominant					
1	TBICM2	0.576	<0.01	33%	1.00
2	TBICM2 TBICM4	0.425 0.404	0.03 0.03	47%	1.16 1.16
3	TBICM2 TBICM4 COPYM4	0.507 0.376 -0.334	0.01 0.03 0.04	58%	1.22 1.17 1.05
Non-dominant					
1	TBICP1	0.714	<0.01	51%	1.00
2	TBICP1 GCTM2	0.686 0.392	<0.01 0.01	66%	1.01 1.01

Abbreviations: variance inflation factor (VIF); time between initial contacts (TBIC); centre of pressure Y-coordinate (COPY); ground contact time (GCT); minus two (M2) steps before the cut-step; minus four (M4) steps before the cut-step; one step post (P1) the cut-step.

DISCUSSION: This study investigates the relationship between COD ability and spatiotemporal variables about the cut-step, using new smart insole technology. The results reinforced that the movement strategy adopted several steps prior to the cut-step are influential to overall COD ability and should look to be understood when performing COD movements. The results may also demonstrate that new smart insole technology is a viable means of providing additional and new information, outside the standard capture volume of typical biomechanical assessment tools, for an athlete’s movement strategy when performing COD tasks.

Three variables explained 58% of the variance in COD ability for 90˚ cut on the dominant turn. The results indicated that enhanced COD ability was associated with a shorter time between steps (faster cadence), and more anterior initial foot contact four steps prior to the cut-step. The faster cadence supports previous recommendation of a reduction in step length and increase in step frequency prior to a large COD movement, as to allow for a greater maintenance of speed prior to the cut (Dos' Santos et al., 2017). The more anterior initial foot

contact could also be associated with this movement strategy. Firstly, it is important to note, that a 'more anterior' initial contact does not explicitly mean a forefoot ground contact, just that a more anteriorly positioned COP on the foot was adopted at ground contact. The more anterior COP four steps prior to the cut-step may represent a delayed braking strategy prior to the cut, allowing faster athletes to carry a higher speed for longer prior to the COD. These results do highlight the importance of the strategy adopted by athlete's several steps prior to a large COD movement, supporting the need for future research to assess the biomechanics of COD ability beyond that of the cut and penultimate steps.
The study results outline that enhanced COD ability when performing a 90˚ cut on the non-dominant side is associated with a shorter time between ground contacts immediately following the cut-step, and a quicker GCT, two steps prior to the cut-step. Interestingly, the variables best able to predict COD ability for the non-dominant side, do not correspond with that of the dominant side. This difference is similar to that of previous research which also reported that athlete's will adopt different movement strategies when performing COD movements between their dominant and non-dominant sides (Dos'Santos et al., 2019). Hence, it is important for practitioners to note that the movement strategy adopted by an athlete when performing a COD task will vary between their dominant and non-dominant sides and ensure the screening of both limbs to enhance training prescription for improved COD ability.
The current study investigated many variables about the cut-step to best predict COD ability when performing a 90˚ turn. Most variables were excluded from the regression equation, leaving 42% and 38% of unexplained variance in COD ability for the dominant and non-dominant sides, respectively. These results do highlight the complex nature of COD ability, and the need for several factors, such as physical capacity, joint kinematics, and ground reaction forces to be included in investigation of COD ability to provide a more complete understanding. Nonetheless, the current study does still provide valuable insights into COD performance and presents a new method of assessing COD ability relative to linear sprinting, which could impact future research pertaining to COD.

CONCLUSION: This study investigated the spatiotemporal variables which best predicted COD ability when performing a 90˚ cut for both the dominant and non-dominant sides. The results reinforced that recreational athletes who are best able to maintain speed prior to the cut step, while still maintaining an appropriate sequencing of movements, will produce an enhanced COD performance. A strategy of minimising the time between ground contacts and maintaining a more anterior initial ground contact several steps prior to the cut step was suggested to be the most effective means of maintaining speed prior to the cut step for the dominant side. This was not the case for the non-dominant side, where a different movement solution was seen to be optimal. The results of the study highlight the importance of the steps preceding the actual cut-step in optimising COD ability. Practitioners need to ensure that they are effectively assessing both limbs' steps prior to the cut-step to enhance COD ability, as movements adopted during the cut-step are suggested to be a by-product of the preceding movement strategy adopted by the athlete.

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