# Change of Direction Frequency Off the Ball: New Perspectives in Elite Youth Soccer

*Running Head:*

Frequency of Change of Directions in Elite Youth Soccer

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**ABSTRACT**

The aim of this study was to investigate the frequency of change of directions (COD) and examine the influences of position, leg dominance and anthropometrics on COD in elite youth soccer match play. Twenty-four elite male English Premier League (EPL) academy players (19.0 ± 1.9 years) were individually recorded during ten competitive U18s and U23s matches. Video footage of individual players was analysed using a manual notation system to record COD frequency, direction, estimated angle and recovery time. The influences of position, anthropometrics and leg dominance were accounted for. Elite youth soccer players performed on average 305 ± 50 CODs with on average 19.2 ± 3.9 seconds of recovery. Frequency of CODs were independent of position, leg dominance, anthropometry and occurred equally between left and right direction and forwards and backwards direction. CODs were mostly ≤90° (77%) and there were significantly less CODs in the 2$^{nd}$ half (-29, *ES* = 1.23, *P*<0.001). The average and peak within match demands within 15 and five-minute periods were 49 and 62 CODs, and 16 and 25 CODs respectively. This study is the first to illustrate COD frequencies of elite youth soccer match play, providing practitioners guidance to prepare soccer players for competitive match demands.

*Key words:* change of direction, soccer, English Premier League, match demands, agility

## INTRODUCTION

Agility and change of direction (COD) has been highlighted as an important physical factor for successful sporting performance in team sports with the premise to evade opponents pressure or tackles, and to limit space for opponents' movements (Young, Dawson, et al., 2015). The importance of these movements in soccer has been highlighted in their ability to discriminate between levels of soccer players and have predictive value for career progression (Forsman et al., 2016; Gonaus & Müller, 2012; Höner et al., 2017; Mirkov et al., 2010; Reilly et al., 2000; Sarmento et al., 2018; Williams et al., 2020). These movements have also been associated with the onset of fatigue during soccer matches (Silva et al., 2018) as well as increased injury risk, in particular the anterior cruciate ligament (Dos'Santos et al., 2021; Waldén et al., 2015). To develop specific training, strength and conditioning, rehabilitation and return to play protocols as well as evaluative assessments for soccer, comprehensive observation and quantification of COD demands are warranted.

Only a small number of studies have directly investigated frequencies of multi-directional movement demands of soccer (Baptista et al., 2018; Bloomfield et al., 2007; Granero-Gil et al., 2020; Nedelec et al., 2014; O'Donoghue & Robinson, 2009; Robinson, O'Donoghue, & Nielson, 2011; Robinson, O'Donoghue, & Wooster, 2011). Evaluations of these studies show there is no consensus on how to measure COD frequency, as there is no agreement on how to identify a COD event. Whilst technological developments have allowed for automated identification systems, these different technologies have utilised a range of different variables to identify what should be, the same COD event, with no inter-system reliability established. For example, camera, radio tracking, gyroscope and Global Positioning System (GPS) technologies have assessed turns, four different types of path changes and nine different types of CODs, culminating in a range of results from 39 turns to 470 CODs (Baptista et al., 2018; Granero-Gil et al., 2020). These different approaches have led to a range of COD definitions and inclusion/exclusion COD identification criteria. The range of frequencies from automated systems, suggests this indirect approach of assessing CODs through the use of data because of its availability may not best describe CODs, perhaps due to the complexities of these movements. A recent review (Alanen et al., 2021) stated inertial measurement units have not been validated against unplanned CODs in real life settings, and even in pre-planned, laboratory controlled settings, overestimate forces, accelerations and mechanical load in COD movements. Overall, these methodological issues with automated systems have unsurprisingly resulted in inconsistent COD frequency findings, and therefore made the available data unusable for practitioners. Traditionally, manual notational analysis has been used to provide an alternative to automated systems. Manual notation recognises more instances of CODs than automated techniques (O’Donoghue & Robinson, 2009), perhaps because what constitutes a COD can be better made visually than hard coded into an algorithm. Manual notation has been identified to have good intra-tester (k = 0.79-0.92) (Bloomfield et al., 2004) and inter-tester (k = 0.56-0.79) (Bloomfield et al., 2007) reliability.

Overall, mean frequency of CODs in soccer games, range from 11.9 (‘hard changes in direction’) (Nedelec et al., 2014) to >700 (‘turns and swerves’) (Bloomfield et al., 2007). Furthermore, understanding COD frequencies beyond the total sum, to include the acute within-match demands, are vital for practitioners to provide the correct relative training stimulus to prepare players for optimal performance and mitigate injury risk (Delaney et al., 2018).

Player position, limb dominance and anthropometrics have been investigated to determine their influence on COD frequency. Like COD frequency, these studies have used different automated systems, technologies, definitions and identification criteria. There is no consensus on the influence of position with both defenders and midfielders reported to complete the most and least CODs (Baptista et al., 2018; Bloomfield et al., 2007; Robinson, O’Donoghue, & Nielson, 2011; Robinson, O’Donoghue, & Wooster, 2011). Shorter, lighter players have been observed to change direction more frequently (Granero-Gil et al., 2020; Robinson, O’Donoghue, & Nielson, 2011) with conflicting evidence found between which limb completes the most COD (dominant vs non-dominant) (Granero-Gil et al., 2020; Robinson, O’Donoghue, & Nielson, 2011; Robinson, O’Donoghue, &

Wooster, 2011). As these data have the ability to impact recruitment strategies, training prescription, testing protocols and rehabilitation, further investigation is warranted that is not dictated by technological availability. Furthermore, all research thus far on COD frequencies has been observed in professional soccer matches. In line with agility having high discriminatory power in talent identification systems, a deeper understanding could provide valuable information to enhance and evaluate athleticism and aid in the talent development process (Williams et al., 2020).

In light of this, the aim of this study was to assess the frequency of CODs in elite youth soccer match play using a clear COD definition and reliable identification methodology, over 90, 45, 15 and five-minute periods and establish the recovery times between CODs. A secondary aim was to investigate player position, leg dominance and anthropometrics as these could influence COD frequency.

## METHODS

### Study Design

As automated systems may currently be unable to provide a comprehensive COD frequency analysis, a new notational analysis approach informed by previous research (Robinson & O'Donoghue 2008) was developed to more clearly define and identify CODs. Due to no COD tests thus far being developed based on observational analysis of soccer match play (Chaouachi et al., 2012), this study specifically concentrated on CODs without individual possession of the ball.

### Participants

Twenty-four elite youth soccer players (19.0 ± 1.9 years, 179.9 ± 7.0 cm and 71.9 ± 6.4 kg) registered to an English Premier League club were used in the study. Twenty-three had represented their respective national team at youth level with five players having also represented their senior national team. The sample of players included five centre backs, five full backs, five centre midfielders, four wingers, and five centre forwards.

**Procedures**

Individual player footage was filmed across 10 games using digital video cameras (Canon XM2, Amstelveen, Netherlands) mounted on stationary tripods (Libec, Arizona, USA). All games were competitive games and occurred in the U18s/U23s Youth League, U18s FA Youth Cup and the Premier League International Cup. The matches were not consecutive fixtures and spanned from the beginning to the end of the season. The average duration of a game was 96.5 ± 1.4 min. All players remained in the same position, were injury free and played more than 90 minutes. All players completed the full match except one centre forward, who was substituted 4.4 minutes prior to the end of the game having completed 91.4 minutes of game time. Height was measured using a fixed Harpenden stadiometer (Holtain Ltd., UK) to the nearest 0.1cm, and body mass was measured using a weighing scale (Seca 875, Seca, Germany) to the nearest 0.1kg. Anthropometrics were measured by an ISAK level two practitioner in accordance to ISAK guidelines (Norton, 2018). Gatekeeper consent was granted by the football club and the study was approved by the university ethics committee (approval reference number 20/SPS/048).

**Notational Analysis**

All video footage was analysed using performance analysis software (Sportscode Gamebreaker Plus 10.3.36, Sportscode, NSW, Australia).

*Change of Direction Identification process*

A flow chart decision-tree was created to identify and characterise a COD. During match observation the flow chart decision tree was used when a change of movement direction was observed (Figure

1). A COD was defined as a path change caused by an identifiable plant of a leg that led to the change in path travelled. This was based on the description of a 'path change' (change in path travelled relative to the path previously travelled by the player (Robinson & O'Donoghue, 2008). Unlike Robinson & O'Donoghue (2008), there was no requirement of a '*moderate-high intensity movement before & after event*'. However, on the premise that CODs are used for evasion tactics or to reduce space and limit attacking movements (Nimphius et al., 2018; Young, Miller, et al., 2015) CODs with walking immediately post were not included.

*COD characteristics*

COD angles were visually estimated from the entry and exit paths pre and post COD and coded into three different angle categories (≤90, >90-≤180, >180 degrees, figure 2a) and five different direction categories (left, right, forwards, backwards, no direction, figure 2a and b). CODs were also divided into five and 15-minute periods. CODs that occurred outside of the 45 and 90 minute threshold (within injury time), were recorded but not included in the last five or 15-minute periods. The dominant leg of each player was determined from publicly available media sources of soccer player information, 15 players were right footed, and nine players were left footed.

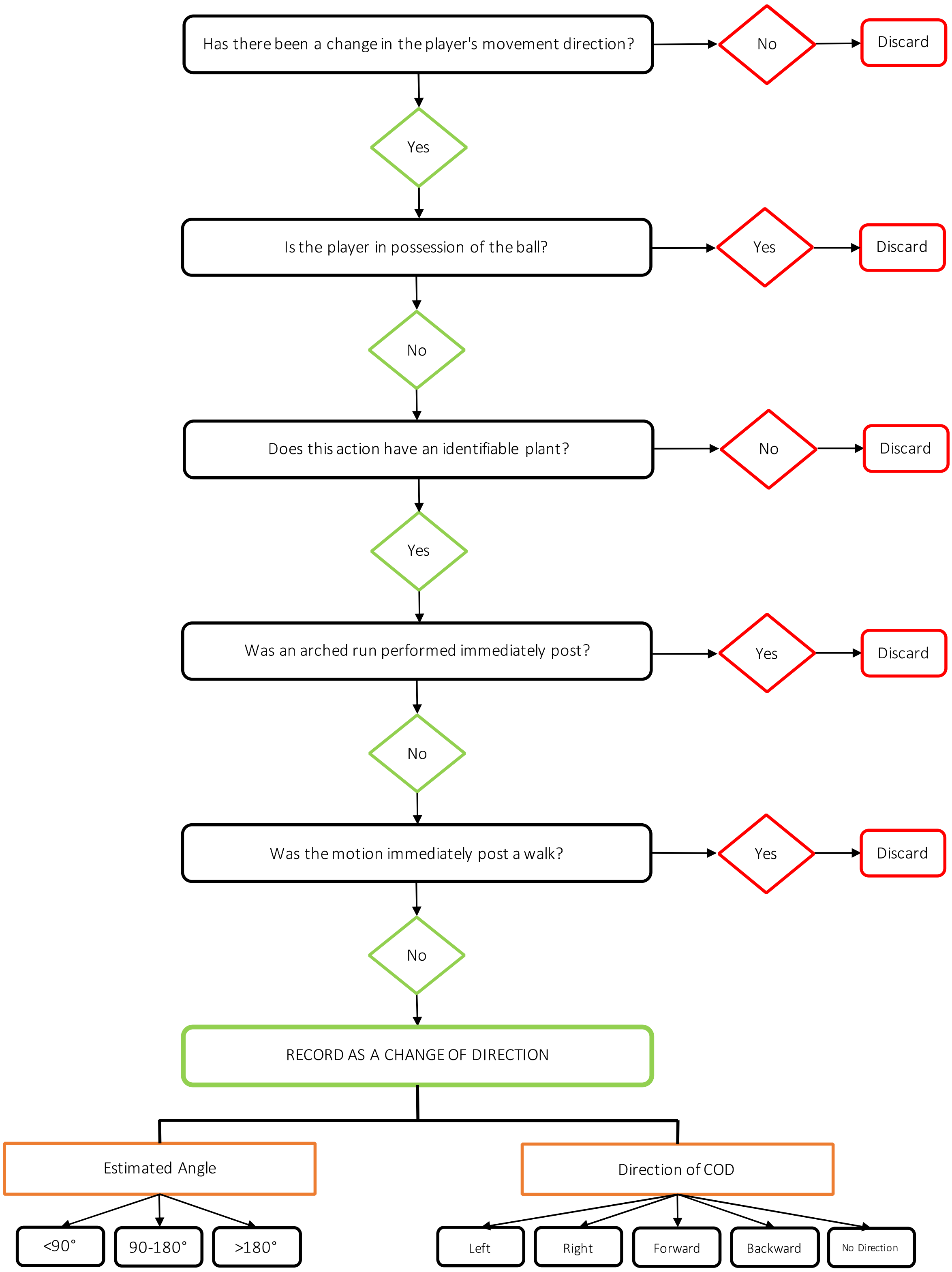


Figure 1. The flow chart used to identify and categorise a change of direction.

**Intra-Observer Reliability**

The intra-observer reliability of identifying CODs was examined by observing five games (one for each player position) on two separate occasions, using the explained identification process. A Bland & Altman analysis was conducted to identify the level of agreement between the two observations. The mean difference between the observations was 1, and all second observations were within levels of agreement (-23.16 – 25.16). The intra-observer reliability of the direction of COD and estimated angle were completed by observing one half of a game on two separate occasions. This encompassed a total of 132 CODs. The level of agreement between the first and second observations was calculated using Cohen's kappa statistics (McHugh, 2012). Kappa coefficients for intra-observer reliability were reported to have strong and moderate levels of agreement for direction of COD and estimated angle ($k$ = 0.896, $k$ = 0.758) respectively (McHugh, 2012). Inter-observer reliability was not considered as only one person completed the analysis.

**Statistics**

All statistical analyses were completed using statistical software (Jamovi v. 1.2.20.0). All data were checked for normality using the Shapiro-Wilk normality test ($P$>0.05) (Mohd Razali & Bee Wah, 2011). Differences between the first and second half frequencies, recovery times and between dominant and non-dominant limbs were determined using paired sample *t*-tests. Differences within positions for 45-minute data and leg dominance were also determined using paired sample t-tests. Differences between, five and 15-minute periods within a match, estimated angles, and direction of COD were determined using one-way analysis of variance (ANOVA) with repeated measures including Tukey's *post-hoc* tests. Differences between positions for direction of COD, estimated angle and per half were also determined using one-way ANOVA with repeated measures including Tukey's *post-hoc* tests. A Kruskal Wallis H test with a Durbin-Conover correction was used for not normally distributed data. Alpha was set at $P$<0.05. Pearson's r was used to determine the strength and direction of correlations between COD frequency, height and body mass. Despite some deviations from normality, all data are expressed as mean ± SD for consistency.

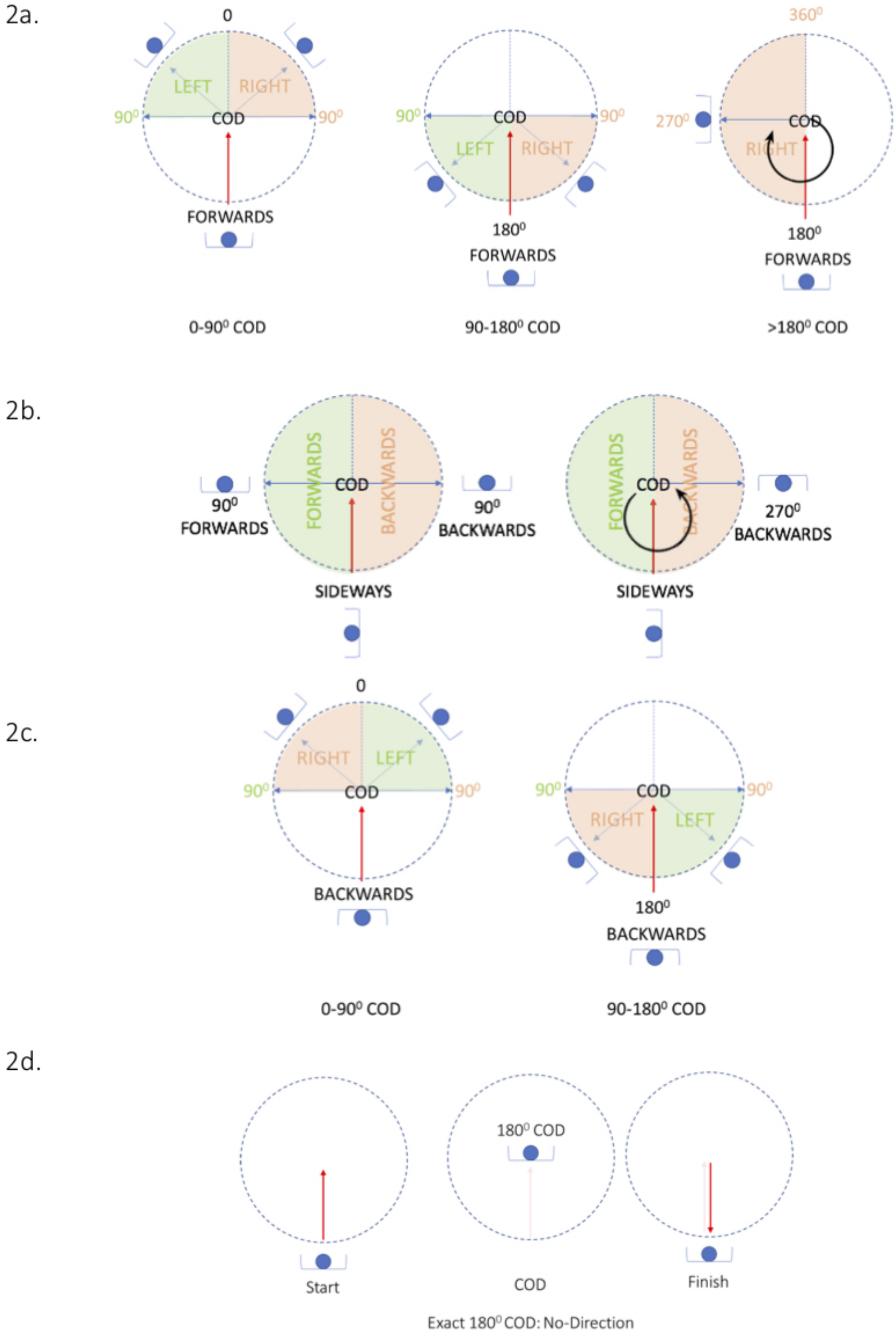


**Figure 2**. Illustrations of different CODs showing estimated angles based upon the entry and exit paths. The direction of a COD was categorised as left or right when a player was moving forward or backward prior to COD (figure 2a and 2c). When a player was moving sideways pre-COD, direction of COD was defined as forwards or backwards (figure 2b), based on the original line of direction. If the pre and post path of movement was the same (exactly 180°) the direction was labelled as no direction (figure 2d).

**RESULTS**

**Frequency of CODs**

The twenty-four players in this study completed a total of 7399 CODs, with a mean of 304.6 ± 50.3 CODs per game. There was no significant effect of position on the total absolute or relative frequency of CODs (table 1), but in the first half centre midfielders performed significantly more absolute CODs than wingers ($P<0.05$). There was a significant decrease in absolute and relative frequency of CODs from 1st half to 2nd half for the average of all twenty-four players ($P<0.001$). Within positions, centre midfielders, centre backs, full backs and centre forwards all performed significantly less absolute and relative CODs in the 2nd Half ($P<0.05$, midfielders $P<0.001$).

**Table 1.** Frequency of absolute and relative (COD.min$^{-1}$) CODs across a full match, 1st Half and 2nd Half performed by players of different positions. Data are means ± SD

| Variables | All (n=24) | Centre Back (n=5) | Full Back (n=5) | Centre Midfield (n=5) | Winger (n=4) | Centre Forward (n=5) |
|---|---|---|---|---|---|---|
| Full Match | 304.6±50.3 | 299.0±56.8 | 340.0±48.0 | 336.0±55.2 | 249.0±63.5 | 304.0±34.2 |
| 1st Half | 169.0±35.9 | 157.0±27.4 | 186.0±34.3 | 197.0±24.3^ | 132.0±43.0^ | 165.0±23.2 |
| 2nd Half | 140.0±23.7** | 143.0±29.0* | 154.0±15.1* | 139.0±31.7** | 120.0±22.0 | 140±11.2* |
| Full Match.min$^{-1}$ | 3.2±0.6 | 3.1±0.6 | 3.5±0.5 | 3.5±0.6 | 2.6±0.6 | 3.2±0.4 |
| 1st Half.min$^{-1}$ | 3.6±0.8 | 3.3±0.6 | 4.0±0.8 | 4.1±0.5 | 2.8±0.9 | 3.6±0.6 |
| 2nd Half.min$^{-1}$ | 2.8±0.5** | 2.9±0.6* | 3.1±0.2* | 2.8±0.7** | 2.4±0.4 | 2.9±0.3* |

Significant difference between halves *($P<0.05$) **($P<0.001$) ^significant difference between positions ($P<0.05$)

**Frequency of CODs with a five and 15-minute period**

*15-minute periods*

The most frequent period of CODs occurred in 0-15 minutes, which was significantly more compared to all other 15-minute periods (both absolute and relative) ($P<0.05$) (table 2). CODs occurred significantly less in 75-90 minutes compared to all 1st half 15-minute periods (both absolute and relative) ($P<0.05$). The average frequency of absolute and relative CODs in 15-minute periods was significantly higher in the $1^{st}$ half (53.9 ± 6.5, 3.6 ± 1.0) compared to the $2^{nd}$ half (44.0 ± 4.1, 2.9 ± 0.7) (*P*<0.05). There was an average of 9.4 and 12.7 CODs during injury time in the $1^{st}$ and $2^{nd}$ half respectively.

**Table 2**. Frequency of absolute and relative (COD.min$^{-1}$) CODs across 15-minute segments performed by players of different positions. Data are means ± SD

| Time (min) | All (n=4) | Centre Back (n=5) | Full Back (n=5) | Centre Midfield (n=5) | Winger (n=4) | Centre Forward (n=5) |
|---|---|---|---|---|---|---|
| 0-15 | 61.7±15.8[b,c,d,e,f] | 56.8±6.7 | 72.0±15.6[Θ] | 74.4±8.0[Δ] | 45.8±13.6[Δ,Σ] | 56.4±17.2 |
| 15-30 | 50.6±13.4[a,f] | 44.2±16.0 | 56.0±12.4 | 56.2±11.4 | 43.5±18.8 | 51.6±6.9 |
| 30-45 | 49.5±14.2[a,f] | 48.8±10.8 | 54.0±18.3 | 50.2±15.0* | 38.0±15.0 | 54.4±11.1 |
| 45-60 | 48.7±11.6[a] | 46.2±13.5 | 51.6±12.1 | 51.8±13.8 | 39.5±10.6 | 52.6±6.4 |
| 60-75 | 43.0±9.7[a] | 40.8±2.5 | 51.6±8.0 | 40.8±12.6** | 36.5±9.8 | 43.8±9.8 |
| 75-90 | 40.2±9.7[a,b,c] | 41.4±9.9 | 43.4±11.7* | 37.4±13.0** | 36.8±4.4 | 41.2±9.3 |
| 0-15.min$^{-1}$ | 4.1±1.1[b,c,d,e,f] | 3.8±0.4 | 4.8±1.0 | 5.0±0.5[Θ] | 2.9±1.0[Σ] | 3.8±1.1 |
| 15-30.min$^{-1}$ | 3.4±0.9[af] | 2.9±1.1 | 3.7±0.8 | 3.7±0.8 | 2.9±1.3 | 3.4±0.5 |
| 30-45.min$^{-1}$ | 3.3±0.9[a,f] | 3.3±0.7 | 3.6±1.2 | 3.3±1.0* | 2.6±1.0 | 3.6±0.7 |
| 45-60.min$^{-1}$ | 3.2±0.8[a] | 3.1±0.9 | 3.4±0.8 | 3.5±0.9* | 2.6±0.7 | 3.5±0.4 |
| 60-75.min$^{-1}$ | 2.9±0.6[a] | 2.7±0.2* | 3.4±0.5 | 2.7±0.8** | 2.5±0.7 | 2.9±0.7 |
| 75-90.min$^{-1}$ | 2.7±0.7[a,b,c] | 2.8±0.7* | 2.9±0.8* | 2.5±0.9** | 2.6±0.5 | 2.7±0.6 |

Significant difference (*P*<0.05) to [a] 0-15 min, [b] 15-30 min, [c] 30-45 min, [d] 45-60 min, [e] 60-75 min, [f] 75-90 min, [β] Centre Back, [Δ] Full Back, [Σ] Centre Midfield, [Θ] Winger, [Ω] Centre Forward, *0-15 min (*P*<0.05), **0-15min (*P*<0.001)

*Five-minute periods*

The peak five-minute period for absolute and relative CODs as an average for all players occurred in 0-5 minutes (25.3 ± 6.5, 5.1 ± 1.3) (figure 4), which was significantly more than all other five-minute periods (*P*<0.05) except 5-10 and 45-50 minutes. This was consistent for all players except wingers (peak five-minute period was 10-15 min). As an average, CODs occurred the least in the last five-minute period of the game (10.9 ± 3.6, 2.2 ± 0.9). The average CODs within a five-minute period was significantly higher in the 1st half compared to the 2nd (18.1 ± 3.7, 3.6 ± 1.4 vs 14.5 ± 3.0, 2.8 ± 1.3 *P*<0.05). There was a significant increase in the absolute frequency of CODs during the first five-minute period in the 2nd half compared to the rest of the 2nd half except 65-70 minutes (*P*<0.05). There was no significant decrease in the subsequent five-minute period after the peak five-minute period. There was an average of 6.2 and 10.3 CODs that occurred in injury time during the 1st and 2nd halves respectively. Wingers completed significantly less absolute CODs than full backs in 0-5min and 5-10min and less than centre midfielders in 0-5min (*P*<0.05). There were no significant positional differences between relative five-minute periods.

**Table 3.** Frequency of absolute and relative (COD.min$^{-1}$) CODs during five-minute periods by players of different playing positions. Data are means ± SD

| Time (min) | All (n=4) | Centre Back (n=5) | Full Back (n=5) | Centre Midfield (n=5) | Winger (n=4) | Centre Forward (n=5) |
|---|---|---|---|---|---|---|
| 0-5 | 25.3±6.5[c,d,e,f,g,h,I,k,l,m,n,I,o,p,q,r] | 24.0±2.7[e,h,k,n,o,q,r] | 29.4±8.1[g,I,k,o,p,q,r,Θ] | 28.6±4.2[e,h,I,k,m,o,p,q,r,Θ] | 16.5±5.9[Δ,Σ] | 26.0±3.1[l,m,o,q,r] |
| 5-10 | 22.5±6.8[e,f,g,h,I,k,l,m,n,o,p,q,r] | 22.4±3.2[e,k,r] | 29.0±7.3[g,I,k,o,p,q,r,Θ] | 25.4±5.2[h,k,m,o,p,r] | 14.5±1.9[Δ] | 19.2±6.7 |
| 10-15 | 18.5±7.0[a,o,q,r] | 14.8±4.8 | 17.8±4.7 | 25.2±4.1[h,k,m,o,p,r] | 18.8±10.8 | 16.4±7.4 |
| 15-20 | 18.8±6.9[a,h,o,p,q,r] | 16.2±7.7 | 20.8±6.4 | 23.0±5.0[o,p,r] | 14.0±9.0 | 19.2±5.1 |
| 20-25 | 15.7±5.4[a,b] | 12.6±6.2[a,b] | 17.6±5.4 | 16.8±6.4[a] | 15.3±6.5 | 16.2±3.2 |
| 25-30 | 16.7±6.5[a,b,r] | 14.6±4.7 | 21.4±10.7 | 17.8±4.4 | 15.3±5.6 | 14.4±3.4 |
| 30-35 | 16.4±5.6[a,b,r] | 17.2±3.8 | 16.0±2.6[a,b] | 20.4±8.3 | 11.5±5.0 | 16.0±5.0 |
| 35-40 | 13.5±5.6[a,b,d] | 13.4±3.9[a] | 17.0±6.1 | 12.6±1.1[a,b,c] | 9.3±4.7 | 14.4±8.7 |
| 40-45 | 15.3±5.4[a,b] | 14.6±4.8 | 13.2±6.3[a,b] | 16.4±4.5[a] | 12.5±6.6 | 19.4±4.1 |
| 45-50 | 21.2±6.9[k,l,m,o,p,q,r] | 19.0±7.3 | 21.4±4.7 | 22.6±10.0[o,p,r] | 14.0±11.4 | 23.4±6.7[q] |
| 50-55 | 14.0±5.5[a,b,j] | 10.6±4.9[a,b] | 16.0±5.4[a,b] | 13.8±3.1[a,b,c] | 9.8±7.8 | 18.2±5.2 |
| 55-60 | 15.8±4.4[a,b,j] | 16.2±4.6 | 17.0±4.0 | 18.2±4.0 | 8.3±6.7 | 14.0±4.2[a] |
| 60-65 | 14.1±4.5[a,b,j] | 14.4±3.7 | 18.2±4.9 | 13.2±5.3[a,b,c] | 7.8±5.2 | 13.2±3.8[a] |
| 65-70 | 16.0±6.6[a,b] | 13.6±5.6[a] | 18.2±5.5 | 18.0±6.8 | 11.0±13.1 | 15.8±5.6 |
| 70-75 | 12.5±5.5[a,b,c,d,j] | 13.4±3.1[a] | 14.2±5.8[a,b] | 10.2±5.5[a,b,c,d,j] | 7.0±6.6 | 13.6±7.8[a] |
| 75-80 | 14.5±7.0[a,b,d,j] | 15.0±10.1 | 14.6±7.1[a,b] | 11.0±5.8[a,b,c,d,j] | 9.8±6.6 | 16.2±6.1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 80-85 | 11.9±3.8[a,b,c,d,j] | 13.2±2.2[a] | 13.63.6[a,b] | 14.2±4.0[a] | 7.5±5.8 | 8.4±3.0[a,j] |
| 85-90 | 10.3±4.2[a,b,c,d,f,g,j] | 11.8±2.6[a,b] | 10.6±4.5[a,b] | 10.8±5.7[a,b,c,d,j] | 7.0±5.0 | 13.2±4.0[a] |
| 0-5.$min^{-1}$ | 5.1±1.3[c,d,e,f,g,h,I,k,l,m,n,I,o,p,q,r] | 4.8±0.5[c,d,e,f,g,h,I,k,l,m,n,o,p,q,r] | 5.9±1.6[g,I,k,o,p,q,r] | 5.7±0.8[e,h,I,k,m,o,p,q,r] | 3.3±1.2 | 5.2±0.6[l,m,o,q,r] |
| 5-10.$min^{-1}$ | 4.5±1.4[e,f,g,h,I,k,l,m,n,o,p,q,r] | 4.5±0.6[e,f,g,h,I,k,l,m,n,o,p,q,r] | 5.8±1.5[g,I,k,o,p,q,r] | 5.1±1.0[h,k,m,o,p,r] | 2.9±0.4 | 3.8±1.3 |
| 10-15.$min^{-1}$ | 3.7±1.4[a,o,p,q,r] | 3.0±1.0[a,o,q,r] | 3.6±0.9 | 5.0±0.8[h,k,m,o,p,r] | 3.8±2.2 | 3.3±1.5 |
| 15-20.$min^{-1}$ | 3.8±1.4[a,h,o,p,q,r] | 3.2±1.5[a,h,o,p,q,r] | 4.2±1.3 | 4.6±1.0[o,p,r] | 2.8±1.8 | 3.8±1.0 |
| 20-25.$min^{-1}$ | 3.1±1.1[a,b] | 2.5±1.2[a,b] | 3.5±1.1 | 3.4±1.3[a] | 3.1±1.3 | 3.2±0.6 |
| 25-30.$min^{-1}$ | 3.4±1.3[a,b] | 2.9±0.9[a,b,r] | 4.3±2.1 | 3.6±0.9 | 3.1±1.1 | 2.9±0.7 |
| 30-35.$min^{-1}$ | 3.3±1.1[a,b,r] | 3.4±0.8[a,b,r] | 3.2±0.5[a,b] | 4.1±1.7 | 2.3±1.0 | 3.2±1.0 |
| 35-40.$min^{-1}$ | 2.7±1.1[a,b,d,j] | 2.7±0.8[a,b,d,j] | 3.4±1.2 | 2.5±0.3[a,b,c] | 1.9±0.9 | 2.9±1.7 |
| 40-45.$min^{-1}$ | 3.1±1.1[a,b] | 2.9±1.0[a,b,i] | 2.6±1.3[a,b] | 3.3±0.9[a] | 2.5±1.3 | 3.9±0.8 |
| 45-50.$min^{-1}$ | 4.1±1.6[h,k,l,o,p,q,r] | 3.8±1.5[k,l,m,o,p,q,r] | 4.3±0.9 | 4.5±2.0[o,p,r] | 2.8±2.3 | 4.7±1.3[q] |
| 50-55.$min^{-1}$ | 2.8±1.2[a,b,j] | 2.1±1.0[a,b,j] | 3.2±1.1[a,b] | 2.8±0.6[a,b,c] | 2.0±1.6 | 3.6±1.0 |
| 55-60.$min^{-1}$ | 3.0±1.1[a,b,j] | 3.2±0.9[a,b,j] | 3.4±0.8 | 3.6±0.8 | 1.7±1.3 | 2.8±0.9[a] |
| 60-65.$min^{-1}$ | 2.7±1.1[a,b] | 2.9±0.7[a,b,j] | 3.6±1.0 | 2.6±1.1[a,b,c] | 1.6±1.0 | 2.6±0.8[a] |
| 65-70.$min^{-1}$ | 3.1±1.5[a,b] | 2.7±1.1[a,b] | 3.6±1.1 | 3.6±1.4 | 2.2±2.6 | 3.2±1.1 |
| 70-75.$min^{-1}$ | 2.4±1.2[a,b,c,d,j] | 2.7±0.6[a,b,c,d,j] | 2.8±1.2[a,b] | 2.0±1.1[a,b,c,d,j] | 1.4±1.3 | 2.7±1.6[a] |
| 75-80.$min^{-1}$ | 2.7±1.4[a,b,c,d,j] | 3.0±2.0[a,b,d,j] | 2.9±1.4[a,b] | 2.2±1.2[a,b,c,d,j] | 2.0±1.3 | 3.2±1.2 |
| 80-85.$min^{-1}$ | 2.3±0.9[a,b,c,d,j] | 2.6±0.4[a,b,c,d,j] | 2.7±0.7[a,b] | 2.8±0.8[a] | 1.5±1.2 | 1.7±0.6[a] |
| 85-90.$min^{-1}$ | 2.2±0.9[a,b,c,d,g,j] | 2.4±0.5[a,b,c,d,f,g,j] | 2.1±0.9[a,b] | 2.2±1.1[a,b,c,d,j] | 1.4±1.0 | 2.6±0.8[a] |

Significant differences [a] 0-5 min, [b] 5-10 min, [c] 10-15 min, [d] 15-20min, [e] 20-25min, [f] 25-30min, [g] 30-35min, [h] 35-40min, [i] 40-45min, [j] 45-50m, [k] 50-55min, [l] 55-60min, [m] 60-65min, [n] 65-70min, [o] 70-75min, [p] 75-80min, [q] 80-85min, [r] 85-90min, [β] Centre Back, [Δ] Full Back, [Σ] Centre Midfield, [Θ] Winger, [Ω] Centre Forward (*P*<0.05)

**Recovery intervals between CODs**

Recovery time between CODs was 19.2 ± 3.9 s on average. Recovery times in the 2nd half were significantly longer than the 1st half (*P*<0.001) (table 4). Recovery times between CODs were significantly shorter in 0-15 minutes than all other 15-minute time periods, and significantly longer during 75-90-minute period than all other periods except 60-75-minute period (*P*<0.05). There was no positional influence on recovery times in any time category.

**Table 4.** Recovery times (seconds) between CODs performed by players of different playing position for 90mins, 1st and 2nd Halves, and 15-minute intervals. Data is means ± SD

| Variable | All (n=24) | Centre Back (n=5) | Full Back (n=5) | Centre Midfield (n=5) | Winger (n=4) | Centre Forward (n=5) |
|---|---|---|---|---|---|---|
| 90min | 19.2±3.9 | 20.1±3.9 | 17.1±2.3 | 17.5±2.6 | 23.6±5.5 | 18.6±2.4 |
| Minimum | 0.86±0.2 | 0.89±0.2 | 0.71±0.2 | 0.95±0.1 | 0.85±0.2 | 0.83±0.2 |
| Maximum | 208±60.9 | 187.8±33.5 | 218.0±22.0 | 198.2±30.2 | 204.0±18.9 | 217.8±130.5 |
| 1st Half | 17.6±5.1 | 18.74±3.5 | 15.5±3.1 | 14.5±1.6 | 23.5±9.2 | 16.9±2.3 |
| 2nd Half | 21.3±3.7** | 21.2±4.2 | 19.1±1.4 | 21.8±5.1 | 24.5±3.4 | 20.5±2.6 |
| 0-15 | 14.1±3.8[b,c,d,e,f] | 14.5±2.3 | 12.1±3.1 | 11.1±1.1 | 19.2±4.0 | 14.8±3.2 |
| 15-30 | 19.5±7.2[a,c,e,f] | 24.9±10.2 | 16.1±4.3 | 16.3±4.1 | 23.6±10.4 | 18.5±2.3 |
| 30-45 | 22.3±12.5[a,b,d,f] | 20.8±5.7 | 19.6±3.9 | 18.8±3.4 | 35.5±28.4 | 19.4±4.9 |
| 45-60 | 18.3±4.9[a,c,e,f] | 21.0±6.7 | 16.2±3.9 | 17.4±4.6 | 21.6±4.5 | 15.9±2.1 |
| 60-75 | 22.3±5.6[a,b,d] | 21.8±2.0 | 18.6±2.5 | 23.0±7.5 | 27.2±8.5 | 21.9±4.2 |
| 75-90 | 24.5±5.4[a,b,c,d] | 23.2±6.8 | 24.2±6.6 | 25.2±5.0 | 24.7±4.4 | 25.2±5.8 |

Significant difference to (*P*<0.05) [a] 0-15 min, [b] 15-30 min, [c] 30-45 min, [d] 45-60 min, [e] 60-75 min, [f] 75-90 min, * *P*<0.05, ***P*<0.001

**Direction of CODs**

There was no difference between left and right CODs but these were performed significantly more than no direction, forward and backward directions (*P*<0.001) (table 5). No direction was performed significantly less than all other categories (*P*<0.001). There was no influence of position on direction of COD.

**Table 5**. Frequencies of CODs by direction performed by players of different playing positions. Data are means ± SD

| Direction | All (n=24) | Centre Back (n=5) | Full Back (n=5) | Centre Midfield (n=5) | Winger (n=4) | Centre Forward (n=5) |
|---|---|---|---|---|---|---|
| Left | 131.5±21.7[c,d,e] | 127.0±13.5 | 138.0±28.4 | 140.0±22.3 | 111.0±10.7 | 137.0±21.8 |
| Right | 133.8±31.2[c,d,e] | 127.0±28.9 | 148.0±23.2 | 150.0±37.6 | 106.0±32.8 | 133.0±24.1 |
| No Direction | 4.5±2.9[a,b,d,e] | 4.8±2.9 | 4.8±3.6 | 6.4±4.0 | 3.0±2.2 | 3.4±0.6 |
| Forwards | 20.0±9.0[a,b,c] | 16.8±9.4 | 25.4±9.1 | 16.6±3.7 | 19.8±9.2 | 21.2±12.5 |
| Backwards | 21.3±6.4[a,b,c] | 23.4±7.0 | 20.4±2.5 | 21.0±4.9 | 23.5±11.6 | 18.4±5.7 |

Significant differences [a] Left, [b] Right, [c] No Direction, [d] Forwards, [e] Backwards (*P*<0.001)

**Estimated COD Angle**

All players performed significantly more ≤90° CODs than >90-≤180° and >180° (*P*<0.001), and significantly less >180° than >90-≤180° (*P*<0.001) (table 6). The frequencies of CODs were significantly less in the 2$^{nd}$ half for all COD angle categories (≤90° and >90-≤180° *P*<0.001, >180° *P*<0.05). There was no significant difference between players for the full match, 1$^{st}$ half or 2$^{nd}$ half.

**Anthropometrics and Leg Dominance**

Low non-significant negative correlations were found between total COD frequency and height (r = -0.190) and body mass (r = -0.126). No significant difference was observed between COD frequency and leg dominance.

**Table 6.** Frequencies of CODs within estimated angle ranges for a full match and 1st and 2nd halves performed by players of different playing position. Data are means ± SD

| COD Angle (Degrees) | All (n=24) | Centre Back (n=5) | Full Back (n=5) | Centre Midfield (n=5) | Wing (n=4) | Centre Forward (n=5) |
|---|---|---|---|---|---|---|
| ≤90° Full Match | 238±45.1** | 230±47.2 | 264.0±37.0 | 262.0±39.3 | 191.0±49.8 | 232.0±27.3 |
| >90-≤180° Full Match | 53.1±15.8** | 55.0±8.7 | 56.8±13.2 | 53.8±25.9 | 42.3±9.8 | 55.4±16.9 |
| >180° Full Match | 16.2±5.9** | 14.6±6.5 | 15.6±4.2 | 18.8±7.2 | 14.0±5.8 | 17.4±6.7 |
| 1st Half ≤90° | 117.2±34.5 | 102.4±32.0 | 132.2±40.1 | 134.8±31.8 | 88.0±40.0 | 122.6±16.0 |
| 1st Half >90-≤180° | 41.0±27.3 | 49.8±32.0 | 44.6±32.6 | 44.4±38.4 | 33.3±20.8 | 31.4±9.3 |
| 1st Half >180° | 12.3±7.6 | 13.8±8.1 | 11.2±7.6 | 15.8±12.0 | 9.8±5.7 | 10.4±3.5 |
| 2nd Half ≤90° | 97.8±27.5** | 88.4±31.0 | 108.6±35.4 | 97.8±29.9* | 82.0±23.9 | 109.0±12.6 |
| 2nd Half >90-≤180° | 33.5±24.7** | 47.8±31.9 | 35.4±25.9 | 31.4±33.3 | 28.0±18.1 | 24.0±8.4 |
| 2nd Half >180° | 10.1±7.5* | 13.4±5.8 | 9.8±7.0 | 11.8±13.1 | 8.0±5.5 | 7.0±3.7 |

**significant difference ($P$<0.001) *significant difference ($P$<0.05)

**DISCUSSION**

This is the first study to investigate COD frequencies in elite youth soccer players. Elite youth soccer players on average changed direction 305 ± 50 times with an average of 19 ± 4 seconds recovery time between CODs. CODs occurred evenly across left and right directions and the majority of CODs were ≤90°. The average and peak within match demands within 15 and five-minute periods were 49 and 62 CODs, and 16 and 25 CODs respectively. There were no significant differences between positions for total COD frequency, estimated COD angle or direction of COD. There was no significant relationship between COD frequency and leg dominance or anthropometry. These data provide practitioners with valuable references to optimally condition, rehabilitate and test elite youth soccer players.

An average COD frequency of 305 fits within ranges previously reported by other multi-directional based studies of soccer match play. Comparisons to previous research are difficult due to the different methods, definitions and inclusion/exclusion criteria used to identify changes of direction. For research using similar definitions (Robinson, O'Donoghue, & Nielson, 2011; Robinson, O'Donoghue, & Wooster, 2011; Robinson & O'Donoghue, 2008), we report a higher frequency of CODs. It is unlikely that these differences are due to any differences between professional and youth populations as similarities of match demands between these populations have been established (Abbott et al., 2018; Russell et al., 2015). More likely, frequency differences are attributable to the differences between automated and notational systems and stipulations of direction, intensity and time in the previous studies. The shortest recovery time observed in this study of 0.39 seconds, demonstrates why limiting analysis to one COD per second (Robinson, O'Donoghue, & Nielson, 2011; Robinson, O'Donoghue, & Wooster, 2011) might not comprehensively represent COD frequency. Varying recovery times highlights the non-uniform nature of CODs and thus a need for understanding within-game requirements.

CODs were performed significantly less in the second half and fluctuated across 15 and five-minute periods, supporting previous research (Robinson, O'Donoghue, & Wooster, 2011). Reduced CODs in the 2nd half is in-line with numerous studies observing physical performance decrements for total distance, high-intensity running and sprinting (Bradley et al., 2009, 2010; Mohr et al., 2003, 2010). The significant differences seen between the initial and consecutive 15 and five-minute periods, confirm the frantic high tempo nature of those initial periods (Lovell et al., 2013; Oliva-Lozano, Fortes, et al., 2021; Oliva-Lozano, Martínez-Puertas, et al., 2021) and do not represent the match intensity holistically. There was no decrement observed immediately post a five-minute peak period, suggesting no temporary fatigue effect seen in other physical output variables (Bradley et al., 2009; Mohr et al., 2003). This is in agreement with a decreased physical cost of shallower CODs (reduced braking demands; Havens & Sigward, 2015b) as the majority of CODs in this study were ≤90°. The mean recovery between CODs of 19.2 seconds equates to a mean frequency of 3.13 CODs per minute. The most COD dense 15 and five-minute periods had COD frequencies of 4.1 and 5.1 CODs per minute, respectively. Despite criticisms of the first periods of a match not representing general match play (Carling et al., 2008; Lovell et al., 2013; Weston et al., 2011), players are still exposed to and expected to cope with, these heightened demands. More research into the repeated nature of CODs is warranted to further develop within-match demand knowledge to further facilitate the design of optimal conditioning and rehabilitation processes.

In our results there was no influence of position on COD frequency, except between centre midfielders and wingers in the 1st half (cf. Baptista et al., 2018; Bloomfield et al., 2007; Granero-Gil et al., 2020; Robinson, O'Donoghue, & Nielson, 2011; Robinson, O'Donoghue, & Wooster, 2011). However, as full backs and centre midfielders completed very similar COD frequencies, a combination of defensive and offensive responsibilities could explain a higher multi-directional demand. The grouping of positions together, and different formations provide the biggest obstacle when comparing to previous research. This study used five positions in line with positional match demand investigations with contemporary 4-3-3 formations (Abbott et al., 2018; Bradley & Ade, 2018). It could be that the consideration of defenders as one group (Bloomfield et al., 2007; Granero-Gil et al., 2020) is influenced by the full backs performing more than centre backs. The small difference between some positions and large overlap of variance however could warrant further investigation beyond frequency to assess the characteristics of CODs between different positions.

This is the first investigation to characterise COD angles in elite youth soccer. In support of previous research, the majority (77%) of all CODs were identified as ≤90° (86%; Bloomfield et al*.,* (2007)). This difference is likely due to more CODs in this study being identified as >180° (16.2 vs 7.3; Bloomfield et al., (2007)), which is likely attributable to the differences in definitions between studies. Identifying COD angles in match play is important for practitioners to understand, as COD ability has been shown to be angle dependent (Buchheit et al., 2012; Hader et al., 2015; Young et al., 2001). The angle of a COD will impact on both the velocity and the technique required to change direction. An increased COD angle increases ground contact times, due to longer braking force application to reduce velocity (Havens & Sigward, 2015a, 2015b). A reduced velocity to perform a larger COD would insinuate a greater demand on acceleration post-COD (Hader et al., 2015) placing heightened importance of eccentric strength and force propulsion for enhanced COD capabilities. However, as 77% of CODs occurred ≤90°, practitioners may not need to focus solely on strength qualities to maximise COD performance, as high intensity accelerations and decelerations within CODs may not be frequent. Further investigations are required to establish what velocities are reached pre and post COD.

Players performed an equal number of left and right, and forward and backward CODs immaterial of position, which is in support of previous studies (Bloomfield et al., 2007; Robinson, O'Donoghue, & Nielson, 2011). Interestingly, no direction CODs, which resemble an exact 180° COD, only occurred approximately 1.5% out of all CODs. This undermines the use of COD tests using COD angles such as 180° to evaluate COD performance in soccer players. This study doesn't support previous research in finding an influence of leg dominance on direction of COD. A suggested increased speed generated from the dominant limb was proposed as an explanation for previous findings (Robinson, O'Donoghue, & Nielson, 2011; Robinson, O'Donoghue, & Wooster, 2011). However, these results were only found in 45-135° CODs, with speeds >4m.s$^{-1}$ either before or after the COD. A large proportion of right footed players (78%) in previous research has also been proposed as an explanation (Robinson, O'Donoghue, & Wooster, 2011), which was not evident in this study (63%).

In contradiction to previous research (Granero-Gil et al., 2020; Robinson, O'Donoghue, & Nielson, 2011) there was no significant relationship with COD frequency and anthropometrics, weakening the proposition that lighter, smaller players change direction more often. Despite different populations used (senior vs elite), significant differences in height and body mass between these populations are unlikely, due to players in this study likely to have achieved a large percentage of their estimated adult height (Parr et al., 2020), and non-significant differences in body mass being found between EPL players and youth players of a similar age to this study (18.4 ± 1.0 years) (Milsom et al., 2015). Our results suggest that despite taller players potentially being at a disadvantage when changing direction (Chaouachi et al., 2012), total COD frequency is not affected. This could be due to the majority of angles being ≤90°, and therefore requiring less lowering of centre of gravity (Sunagawa & Fukubayashi, 2015). This is particularly relevant for TID and development purposes as professional players have generally become taller and heavier in recent times (Nevill et al., 2019; Williams et al., 2020). However, further research beyond quantitative data is required to determine the *quality* of these movements during match play.

There are a number of practical recommendations for practitioners. Our data suggests that tests with angles >90° (especially 180°) despite having discriminant validity, may lack ecological validity for soccer (Nimphius et al., 2018). Additionally, less emphasis should be placed on higher angled CODs in pitch-based conditioning and return to play programs. However, due to the increased knee loading and subsequent risk of injury of larger COD angles (Dos'Santos et al., 2018) and their inevitability in soccer match play, practitioners are advised not to neglect conditioning players for these events. Total COD frequency, average and peak within-match frequencies and recovery times may provide practitioners an 'end-goal' when devising rehabilitation and return to play strategies as well as providing the correct relative training stimulus to prepare players for optimal performance and mitigation of injury risk. Due to the even distribution of direction of CODs, utilising unilateral strength and conditioning processes and evenly distributed pitch conditioning drills/exercises/programs and testing protocols that assess individual limbs, would be most appropriate.

There are a number of limitations to this study. A larger sample size could provide more confidence in establishing meaningful differences between positions. Formation and tactics could have biased our data due to all players playing for the same club, and therefore our results may not extend to teams deviating substantially away from these tactics and formations. Furthermore, excluding events in possession could have prevented a full quota of CODs, however, individual ball possession has been shown to be less than two minutes over the course of a game (Link & Hoernig, 2017). The number of CODs over a course of two minutes with an average of 19.2 seconds recovery between CODs would equate to 6.3 CODs, approximately only 2% of the total mean frequency seen in match play.

## CONCLUSION

In conclusion, this study used a clearly defined and reliable manual notational system, to identify CODs. Elite youth soccer players changed direction 305 times per match, with on average 19 seconds of recovery between CODs. Significantly less CODs occurred in the second half. The average and peak within match demands within 15 and five-minute periods were 49 and 62 CODs, and 16 and 25 CODs respectively. CODs were independent of position, leg dominance and anthropometry, and occurred equally between left and right, and forwards and backwards directions with 77% of these CODs occurring ≤90°. The present data provides practitioners with COD frequency references and COD qualities to contextualise and enhance training, as well as provide guidance for COD test selection. Further research is required to provide more insight on the characteristics of CODs during soccer match play.

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## DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors

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