TRAIN THE ENGINE OR THE BRAKES? INFLUENCE OF MOMENTUM ON THE CHANGE OF DIRECTION DEFICIT

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ABSTRACT

Purpose: Currently, it is unclear which physical characteristics may underpin the change of direction deficit (COD-D). This investigation sought to determine if momentum, speed-, and jump-based measures may explain variance in COD-D. **Methods:** Seventeen males from a professional soccer academy (age: 16.76 ± 0.75 years; height: 1.80 ± 0.06 m; body mass: 72.38 ± 9.57 kg) performed 505 tests on both legs, a 40-m sprint and single leg countermovement and drop jumps. **Results:** Regression analyses did not reveal any significant predictors for COD-D on either leg. “Large” relationships were reported between COD-D and 505 time on both limbs ($r = 0.65$-0.69; $p < 0.01$) but COD-D was not associated with linear momentum, speed- or jump-based performances. When the cohort was median split by COD-D, effect sizes suggested that the sub-group with the smaller COD-D were 5% faster in the 505 test ($d = -1.24$; $p < 0.001$) but 4% slower over 0-10-m ($d = 0.79$; $p = 0.33$) and carried 11% less momentum ($d = -0.81$; $p = 0.17$). **Conclusion:** Individual variance in COD-D may not be explained by speed- and jump-based performance measures within academy soccer players. However, when grouping athletes by COD-D, faster athletes with greater momentum are likely to display a larger COD-D. It may therefore be prudent to recommend more eccentric-biased or technical focused COD training in such athletes and for coaches to view the change of direction action as a specific skill that may not be represented by performance time in a COD test.

INTRODUCTION

Change of direction speed (CODS) is an important component of performance in team-based invasion sports such as football.[1-3]. For this reason, understanding the determinants of change of direction (COD) ability is an important consideration for coaches. Young et al.[4] proposed linear speed and 'leg muscle qualities' – namely: strength, power and reactive strength – as the physical factors which may underpin CODS. Young et al.[4] also proposed the importance of technical factors (foot placement, stride adjustment and body position) in their deterministic model of CODS. Such factors have been well considered in recent review articles.[5,6] Subsequent investigations considering the importance of Young's physical components have supported the individual influence of linear speed,[7,8] strength,[9,10] power (typically represented by jumping performance),[11,12] and reactive strength[1,13] to overall CODS time, as well as a combination of these components.[14] However, less is known about the physical factors which may explain the COD deficit (COD-D).

The COD-D was first proposed by Nimphius et al.[15] as a measure that may better distinguish an athlete's COD ability versus simple time-to-completion in a CODS test. Specifically, the COD-D is calculated as the difference between CODS test time and the time taken to cover the same total distance in a linear sprint.[15,16] Whilst the literature has consistently reported a relationship between CODS and COD-D, these measures are not interchangeable.[8,15-18] For example, Nimphius et al.[16] demonstrated that CODS test time over- or underestimated COD ability when compared to COD-D in ~90% of athletes. This has subsequently led to investigations into whether the same physical qualities that may explain variance in CODS also explain variance in COD-D, and whether they are in fact independent physical qualities.

To date, research into this area has revealed mixed findings. Some investigations have reported that athletes with faster sprint times displayed a larger COD-D,[2,12,18-20] whilst others, even within the same research groups, have found to the contrary.[8,16,17] It is possible that sprint momentum, a function of velocity and body mass, may be more closely linked to COD-D as momentum may better represent the mechanical demands associated with the COD than velocity alone.[6] However, this has not been well examined. Group comparisons in rugby athletes have shown greater momentum and larger COD-Ds in males versus females[20] although greater momentum in forwards versus backs did not yield differences in COD-D.[19] Further research is therefore required to elucidate this relationship.

The relationship between COD-D and jumping performance would appear less disparate. Whilst several investigations have reported no relationship with bilateral jumping,[2,11,21] both bilateral[1] and unilateral[11,22] jumping performance has been associated with a smaller COD-D. Reactive strength has not been examined in the same detail as jump height. Whilst Thomas et al.[22] reported that reactive strength index modified in countermovement jump was associated with a smaller COD-D in a mixed-sex team-sport population, Emmonds et al.[1] observed that drop jump height, but not reactive strength index, was associated with a larger COD-D in female soccer players. It is possible that the discrepancy between stretch-shortening activity in the CMJ and DJ could explain these contrasting results; the slow stretch-shortening cycle inherent in the CMJ is likely to have demonstrated greater correspondence to the 180° turn in the 505-test than the fast cycle observed in the drop jump.[1] In addition, whilst it may appear counterintuitive for drop jump height to be associated with a larger COD-D, Emmonds et al.[1] observed drop jump height was associated with faster sprinting performance which, as previously outlined, may be anticipated to increase the COD-D. Moreover, Emmonds et al.[1] note that COD ability is more likely influenced by technical and motor control factors than by the physical qualities.

It is not clear which physical characteristics may underpin the COD-D. For this reason, the current study sought to determine if momentum, speed- and jump-based performance measures may explain variance in COD-D, within academy soccer players.

METHODS

Subjects

Seventeen male soccer players (mean ± standard deviation: age: 16.76 ± 0.75 years; height: 1.80 ± 0.06 m; body mass: 72.38 ± 9.57 kg) from a category 3 professional soccer academy provided informed consent to participate in the study. A minimum sample size of 13 was determined from *a priori* power analyses using G*Power (Version 3.1.9.4, Heinrich-Heine-Universität, Düsseldorf, Germany)[23] and based on an effect size of 0.6,[11,17] power of 0.8, and alpha level of 0.05. Participants were required to have been injury free for the last three months and instructed to refrain from maximal training for two days prior to testing. This study was approved by the relevant institutional review board.

Design

Across two sessions, separated by one hour, soccer players performed single leg countermovement (SLCMJ) and drop jump (SLDJ) tests followed by a 40-m sprint and CODS test (T-test). In the first session, players completed anthropometric assessments and both jump tests. Following a lunch break, players performed the sprint and CODS tests. All tests were completed by all players in this order with 3-min between tests in the same session. Participants regularly performed these tests as part of periodic physical assessments; thus, it was deemed that a familiarisation session was not required. Regression analyses were used to examine the extent to which variance in COD-D could be explained by the other measured variables

Methods

Warm Up

The same group warm-up (~8-min duration) was performed prior to both testing sessions, this consisted of jogging and a series of dynamic movements (i.e. mountain climbers, squats, lunges, etc.) led by the team's soccer coach. Participants then performed two familiarisation trials at 50% perceived effort for each assessment prior to testing.

Single Leg Countermovement Jump

Both jumping assessments were performed on an indoor gym surface and recorded using the MyJump 2 App (Version 4.0) for iOS (version 12.2; iPhone X, Apple Inc., USA). For the SLCMJ, participants performed jumps with hands on hips and to a self-determined countermovement depth. The non-jumping leg was held in a relaxed position, with the foot held in line with the medial malleolus of the jumping leg. Participants were instructed to 'jump as explosively and as high as possible' with height recorded for each jump. Participants performed three maximal attempts on each leg, alternating from left to right, with 30-sec between attempts. SLCMJ performance was determined as the highest recorded jump.

Single Leg Drop Jump

Participants performed SLDJs off a solid box raised at 0.18 m off the floor.[13] Participants were instructed to step off the box with the testing leg and to 'jump as high and as fast as possible' immediately upon landing. Reactive strength index (RSI) was calculated as jump height (cm) divided by contact time (ms).[24] All SLDJs were observed to ensure players did not step down or jump off the box to change the drop height. SLDJs were otherwise standardised in the same manner as the SLCMJs with three attempts performed on each leg. SLDJ performance was defined as the largest recorded RSI.

40-m Linear Sprint

Linear sprint testing over 40-m was conducted on an all-weather AstroTurf pitch and following procedures outlined by Nimphius et al.[16]. Timing gates (Brower Timing Systems; IR Emit, Draper, UT, USA) were positioned at 0-m, 10-m, 30-m and 40-m intervals (height: of 1.2 m, width: 1.5 m). Participants began 0.30 m behind the first timing gate and from a standing start. Three trials were completed with 3-min between trials. With the timing gates being placed at different intervals, this allowed for differentiation between acceleration (0-10-m) and maximum velocity (30-40-m) capacity. Sprint times for all intervals were recorded to the nearest 0.001 second and the fastest time/split was used to determine ‘performance’. Acceleration and maximum velocity momentum were calculated as the average velocity obtained over the 0-10-m and 30-40-m splits, respectively, multiplied by the athlete’s body mass.[25]

505 Test

CODS was evaluated using the 505-test and followed procedures outlined by Nimphius et al.[16] Participants began 0.30 m behind a starting line and sprinted 15-m before performing a 180° turn and sprinting back 5-m. Timing gates were positioned 10-m beyond the starting line to record the time to complete the last 5-m of the initial sprint (i.e. following a 10-m approach) and the turn-and-sprint back 5-m. Three attempts were completed on each leg, alternating between left and right, with 3-min between attempts. If the participants did not meet the turning line, their attempt was discarded and repeated after a recovery period. Times were recorded to the nearest 0.001 second and the fastest time for each leg was used for to determine CODS performance. To determine the COD-D for each leg, participants’ fastest 10-m linear sprint time was subtracted from their fastest 505-test time turning on that respective limb.[15]

Statistical Analyses

Shapiro-Wilk tests were used to assess normality of each outcome variable. Within-session session reliability was determined using the standard error of measurement (SEM), coefficient of variation (CV), and intraclass correlation coefficient (ICC), and was calculated using a preformatted spreadsheet. “Good” absolute reliability was interpreted as a CV $< 10.0\%$.[26] ICCs were interpreted as poor = < 0.49, moderate = 0.50–0.74, good = 0.75–0.89, and excellent = > 0.90.[27]

Separate and independent multiple linear regression analyses were performed for COD-D and CODS on the left and right limbs. Variables entered into the model were 0-10- and 30-40-m split times, acceleration and max velocity momentum, and SLCMJ and SLDJ performances. Also, bivariate correlations between each variable and COD-D or CODS were examined using Pearson’s r. Correlations were interpreted as small = 0–0.3, moderate = 0.31–0.49, large = 0.50–0.69, very large = 0.70–0.89, and near perfect = 0.90–1.00.[28] Finally, the cohort was split using the COD-D to examine the magnitude of difference between ‘smaller’ and ‘larger’ COD-D groups (both n = 8) for each of the measured variables. Between-group differences were analysed using a one-way ANOVA and Cohen’s effect sizes.[29] Effect sizes were interpreted as trivial = 0–0.19, small = 0.20–0.59, moderate = 0.60–1.19, large = 1.20–1.99, and very large = 2.00–3.99.[28] All statistical procedures were conducted using the Statistical Package for the Social Sciences for Windows (v22.0; SPSS Inc., Chicago, IL, USA).

RESULTS

Descriptive statistics and reliability for all measured variables are reported in Table 1. The CVs for all performance tests indicated “good” reliability. The ICC for most of the performance tests were “good” or “excellent”. However, the ICC was “moderate” for the 30-40-m split and “poor” for both directions of the CODS test. All variables measured were deemed normally distributed (P > 0.05).

*** Table 1 Near Here ***

No regression model was predictive for COD-D or CODS on either limb. Significant and “large” relationships were reported between COD-D and CODS on both limbs (Table 2), however, the COD-D was not associated with performances in the other tests. Moreover, athletes were ranked differently when using COD-D versus CODS time. When the cohort was median split by COD-D (Table 3), the sub-group with the smaller COD-D were faster in the CODS test with a “large” effect size. However, “moderate” effect sizes suggested these players were slower over 0-10-m and carried greater acceleration momentum.

*** Tables 2-3 Near Here ***

*** Figure 1 Near Here ***

DISCUSSION

The aim of the current study was to determine if momentum-, speed- and jump-based measures explained variance in COD-D. Regression analyses revealed no predictors of the COD-D and no significant correlations were observed (aside from CODS). These findings would suggest that individual variance in COD-D cannot be explained by these performance measures alone. However, when splitting the group by COD-D, effect sizes indicated that the subgroup with the higher COD-D (indicating poorer COD ability) accelerated faster and carried more momentum over 10-m.

In the current study, athletes with a faster 505 test time (CODS) exhibited a lower COD-D; "large" and significant correlations were reported between CODS and COD-D on both the left ($r = 0.69$; $P = 0.002$) and right ($r = 0.65$; $P = 0.004$) limbs. Several other investigations have reported similar associations between COD-D and the 505 test, with correlations ranging from 0.48 to 0.74.[8.16-18] Investigations using other CODS tests (i.e. zig-zag,[2,12] 90° cut,[8] and pro-agility[15] assessments) have also documented similar findings. This implies that athletes who perform better in CODS tests are likely to display a lower COD-D. However, whilst CODS and COD-D may be associated, these measures are not synonymous. The COD-D provides practitioners with more information regarding an athlete's profile. For example, in the current study, two athletes in the top five performers on the CODS test were in the bottom five for COD-D (Figure 1). In such instances, it may be reasonable to suggest that these athletes prioritise eccentric-biased or technically focused COD training as opposed to linear speed/ballistic training; this will be considered in more detail later in this discussion.

The rationale for employing the COD-D as an indication of COD ability is that performance within a CODS test can be influenced by linear speed.[15,16] In the current study, significant negative associations between acceleration performance (0-10 m time) and COD-D were not observed for the left ($r = -0.34$; $P = 0.18$) or right limbs ($r = -0.39$; $P = 0.13$). Whilst significant associations between acceleration performance and CODS were also not observed (both limbs: $r = 0.45$; $P = 0.07$), the relationship would, however, appear to trend in the opposite direction. Such findings tend to support the notion that the COD-D removes the confounding influence of linear speed on CODS.

The lack of a significant association between COD-D and acceleration performance is in line with the findings of several investigations. Whilst Cuthbert et al.[8] did observe a relationship between 10-m performance and COD-D (505-test) on the right limb ($r = -0.38$, $r^2 = 0.14$; $P < 0.05$), similar to the magnitude of relationship reported in the current study, no further correlations with COD-D were reported across three sprint tests (5-, 10-, and 20-m) and two CODS tests (505-test and 90°-cut) in collegiate team-sport athletes. Also considering COD-D in the 505-test, three investigations have not reported significant correlations with speed measures. Lockie et al.[11] did not observe relationships with 5-, 10-, and 20-m performance in 43 university students, nor did Nimphius et al.[16] using 10-, and 30-m sprint times in 17 first-grade cricketers or Dos'Santos et al.[17] using 10-m sprint time in a mixed-sex mixed-sport cohort. Within the pro-agility test, Nimphius et al.[15] observed no relationship between COD-D and 10-yd sprint time in American footballers. Finally, regression analyses performed by Emmonds et al.[1] were able to predict COD-D (505 test), but 10- and 20-m performance measures were not included within the model.

However, the current study did note a "moderate" difference ($d = 0.79$) in acceleration performance between athletes with a smaller versus larger COD-D; faster accelerating athletes exhibited a larger COD-D. Furthermore, in contrast to the previous findings described above, several investigations would also support such a negative association between acceleration on COD-D. Dos'Santos et al.[18] reported large correlations for COD-D (505-test) with 10-m time for both limbs ($r = -0.54, -0.63$; both $P < 0.01$) in youth netball athletes. Using the same tests, Lockie et al.[30] reported stronger associations in NCAA division I ($r = -0.88$; $P < 0.01$) and division II ($r = -0.77$; $P < 0.01$) female soccer players. Pereira et al.[12] also observed stronger correlations for COD-D (T-test) with 5-, 10-, and 20-m velocity ($r = 0.54, 0.80, 0.88$, respectively; all $P < 0.05$). Employing the zig zag test, Loturco et al.[2] reported nearly perfect correlations for COD-D with flying (i.e. a 5-m 'headstart') 10-, and 20-m sprint velocity ($r \approx 0.90$-0.95 – estimated from figures; $P < 0.05$) and a large correlation with flying 5-m velocity ($r \approx 0.58$; $P < 0.05$).

Further in support of the notion that faster athletes have a larger COD-D, Freitas et al.[19] median-split 24 national male rugby union players into two groups based upon 0-40-m velocity. Loturco et al.[7] similarly split 49 professional male soccer players based upon 0-5-m acceleration performance. Both investigations reported a larger COD-D in the faster group. Although not directly examining the influence of speed on COD-D, Freitas et al.[20] compared 18 male and 18 female national rugby union 7's players across sprint (40-m) and three CODS tests (pro-agility, L-drill and zig zag). Males were significantly faster than females and displayed larger COD-Ds across each of the CODS tests. It is not surprising that some investigations have reported that faster athletes display a larger COD-D. For a given body mass, a faster athlete carries greater momentum into the COD. The faster athlete must therefore exert a larger impulse to decelerate and, consequently, is likely to require longer ground contact times. As this decelerative component is not required during linear sprint testing, this explains why the faster athlete may display a larger COD-D.

In the current study, whilst no significant correlation between acceleration momentum and COD-D was observed ($r = 0.29$-0.35; $P = 0.17$-0.29), a "moderate" effect size ($d = -0.81$) suggested athletes with a lower COD-D carried less momentum. This is the first investigation to directly examine the relationship between momentum and COD-D. In their male-female comparison, Freitas et al.[20] did report that the faster males carried greater momentum. However, when comparing male rugby forwards versus backs, greater momentum in forwards did not yield differences in COD-D, likely because the forwards were significantly slower.[19] Further research is certainly required to elucidate this relationship, specifically in homogenous adult populations. As this study was conducted in male academy soccer players, an influence of maturation status cannot be discounted.

Where athletes carry greater momentum into a COD, they must exert a larger braking impulse in order to overcome this. Whilst Young et al.[4] proposed the importance of strength to CODS ability, strength may be further considered in terms of specific sub-qualities relating to components of the COD action, namely: eccentric strength (braking phase), isometric strength (support phase) and concentric strength (propulsive phase).[31] Spiteri et al.[31] has previously shown that eccentric strength is more strongly associated with CODS performance than isometric or concentric strength, suggesting the critical importance of being able to withstand high braking forces. In line with the findings previously discussed, it is possible that faster athletes are more likely to more likely to exceed their eccentric strength capacity than slower athletes, although no direct strength measures were assessed in the current study. This could provide a rationale for interventions with faster athletes to focus on either eccentric-biased training modalities (to improve eccentric capacity) and/or specific COD technique training (to make better use of their current capacity). Methods such as isoinertial training could provide a means of overloading specific phases of COD actions,[32] thus potentially contributing to both eccentric overload and technical objectives, and have shown to elicit improvements in CODS.[33]

However, such interventions have not been fully evaluated against traditional resistance training or CODS training interventions and require further exploration.

The current study did not report relationships between unilateral jumping performance (both SLCMJ and SLDJ) and COD-D. Intuitively, it may be anticipated that jumping performance should be associated with COD-D as faster performances are related to the rapid production of force during the COD.[34,35] Nonetheless, this finding is in agreement with several previous investigations which have investigated bilateral jumping performance. Lockie et al.[21] reported no relationship between jump performance (CMJ and broad jump) and COD-D in either 8 female collegiate rugby players or 8 team-sport athletes. The same research group also observed no relationship between CMJ height and COD-D in female soccer players[30] and in a student population.[11] Such findings have also been replicated in academy soccer players.[2]

In contrast, other investigations have reported significant findings. Negative associations between bilateral CMJ height and COD-D (i.e. higher CMJ = lower COD-D) have been noted in female soccer players performing a 505-test,[1] the same test and similar population to the current study, whilst positive associations have been reported in international handball athletes using both zig-zag and T-tests.[12] Even within Emmonds et al.'s investigation,[1] findings are somewhat conflicting. CMJ height and drop jump RSI were associated with a smaller COD-D but DJ height was associated with a larger COD-D. To the author's knowledge, only two other studies have employed unilateral jumping tests and neither concur with the findings of the current study. Thomas et al.[22] observed a "small" negative correlation between unilateral CMJ height and COD-D (from 505-test) in the right limb ($r = -0.30$; $P < 0.05$), but not the left, in a mixed-cohort of male and female team-sport athletes. However, when male and female athletes were analysed separately, no significant associations were reported. Whilst Lockie et al.[11] did not report associations between bilateral jumping and COD-D within another mixed-sex cohort of recreational athletes, lateral hopping performance was "moderately" correlated with COD-D on both limbs ($r = -0.34 – -0.44$; $P < 0.05$). Future investigations may wish to consider the effect of jumping/hopping direction if seeking to explore relationships with COD-D.

PRACTICAL APPLICATIONS

If seeking to assess COD ability, using COD-D or CODS performance may yield similar interpretations but should not be used interchangeably. Furthermore, whilst the current study reports that individual variance in the COD-D was not explained by speed- and jump-based performance measures, effect sizes suggested that players with a smaller COD-D were slower in an acceleration task (0-10-m) and carried less momentum over this distance. It is possible to infer that faster players may need to perform more specialised eccentric-biased or COD technique training to improve CODS (i.e. train the brakes) as opposed to developing linear speed/power qualities (i.e. train the engine). For the coach, grouping athletes into potential CODS training interventions based upon acceleration or momentum should prove a viable strategy. Indeed, similar strategies based upon force-velocity profiling has proven successful.[36] However, the effectiveness of such a strategy in regard to CODS would need to be determined before clear recommendations should be stated.

CONCLUSIONS

The current study reports a significant association between COD-D and CODS (505-test) such that academy soccer players with a smaller COD-D performed better in a CODS task. However, this relationship was not perfect. A sub-group of players with a smaller COD-D were slower and carried less momentum in a linear 10-m sprint.

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