Original Investigation

Change of direction and deceleration deficits in National team female rugby sevens players: interrelationships and associations with speed-related performance

Running head: COD ability in female sevens players

Abstract

Purpose: To investigate the relationships between a series of direct and indirect measures of linear and multidirectional speed performance in elite female rugby sevens players. **Methods:** Nineteen players from the Brazilian National team performed 40-m linear sprint and 505 change of direction (COD) tests on the same day. Based on the linear sprint and COD test performances, the COD deficit (CODD) and deceleration deficit (DD) were also obtained. A Pearson product moment correlation analysis was used to determine the relationships between linear sprint and COD-derived variables. **Results:** Linear sprint and 505 COD velocities were not significantly associated ($P > 0.05$). Large to very large significant associations (r values ranging from 0.54 to 0.78; $P < 0.05$) were detected between linear sprint velocity for the different distances tested (10-, 15-, 30-, and 40-m) and CODD. The COD velocity presented a very large inverse significant correlation with CODD and DD (r = -0.77 and -0.79 respectively; $P < 0.05$). A large and significant correlation was identified between CODD and DD (r = 0.79; $P < 0.05$). **Conclusions:** Significant associations were observed between linear sprint and CODD suggesting that faster players are less efficient at changing direction. No relationship was found between sprint velocity and DD, highlighting the independent nature of linear sprints and deceleration capabilities. A comprehensive and detailed analysis of multidirectional speed performance should consider not only linear sprint and COD performances but also complementary COD-derived variables, such as the CODD and DD.

Key words: athletic performance; team-sports; sprint speed; agility; sprint momentum.

Introduction

Rugby sevens is an intermittent high-intensity sport in which high-speed running, and linear and multidirectional sprinting efforts are key determinants of performance[1,2] since these actions frequently precede decisive game actions (e.g., tries and line breaks). Competition data indicate that during a match (i.e., which consists of two 7-minute halves), players cover from ~1000-m to 2500-m, with ~130-m to 190-m corresponding to velocities $> 18.0\ km \cdot h^{-1}$.[1] Moreover, the multidirectional nature of the game is evidenced by the considerable number of accelerations, decelerations, and changes of direction (COD) executed during match-play.[1] This is the reason why researchers have long been interested in studying and defining the main determinants of the ability to effectively accelerate, decelerate, and execute cutting and turning maneuvers in multiple directions in this team-sport.[3-5]

Traditionally, COD performance has been assessed either by completion time[5-7] or average velocity[4,8] as these measures represent how fast an athlete can get from one point to another. However, additional metrics such as the COD deficit (CODD) and the deceleration deficit (DD) have more recently been shown to provide meaningful and complementary information for coaches.[9-11] The CODD corresponds to the absolute (i.e., in time or velocity)[12,13] or relative (i.e., in percentage)[14] difference between a pure linear sprint and a COD test of equal distance and has been used to indicate how "efficient" an athlete is at changing direction with respect to his or her linear sprint ability (i.e., the lower the CODD, the greater the efficiency). The DD consists of the difference between the time taken to accelerate and come to a complete stop when changing direction in relation to linear sprint performance.[10] This variable has been described as an isolated construct related to the ability to rapidly decelerate and can be used to identify athletes whose COD performance might be limited by their deceleration capability.[10] In light of this, and given the importance of high-intensity acceleration[8] and deceleration[15,16] efforts in multidirectional team-sports, comprehensive COD assessments should include not only test completion time, but also other COD-derived measurements, such as the CODD and DD.

Clarke et al.[10] analyzed the associations between linear sprint and 505 times, DD, and CODD in recreational players of different invasion sports (i.e., netball, hockey, rugby, and soccer), observing that: 1) 505 time was significantly correlated with 15-m sprint time, CODD, and DD (*r* values of ~0.75, ~0.75, and ~0.43, respectively); and 2) CODD was significantly related to DD (*r* ~0.60), which also reflects a moderate shared variance (i.e., 36%) between these two COD-derived measures.[10] Bishop et al.[9] used the CODD and DD to determine limb dominance and inter-limb asymmetries, confirming the independent nature of these metrics as only moderate levels of agreement were found between them (i.e., Kappa = 0.41 on left side and 0.48 on right side). Of note, Bishop et al.[9] evaluated a cohort of male rugby union players while Clarke et al.[10] reported pooled data from a mixed sample of male and female athletes. Hence, with the current knowledge, it is not possible to conclude whether the relationships between linear sprints, COD velocities, CODD, and DD are similar for both sexes. This is an important issue since several studies indicate that male and female team-sport players may exhibit specific differences in terms of speed-related performance.[3,17,18] For example, female soccer players have been reported to display less optimal braking strategies (compared to males) in drills with 180º turns (i.e., in female players, a greater proportion of braking took place during the final foot contact instead of the penultimate)[17] whereas male rugby sevens players have been shown to present higher levels of CODD and sprint momentum (i.e., a variable suggested to negatively affect COD ability)[3] when compared to their female counterparts. As such, the COD abilities of male and female players should be evaluated and interpreted separately in order to inform coaches on how to create tailored and effective training strategies for each specific group.

When reviewing the literature, it is clear that evidence is scarce regarding the association between speed-related variables (e.g., linear sprint and COD velocities, and sprint momentum) and COD-derived measurements such as the CODD and DD in female athletes. Specifically, only one study[4] tested the correlations between sprint momentum and CODD in this population; nonetheless, CODD was computed from the Zigzag (and not from the 505) test. In addition, to date, no research has examined and calculated the DD in female rugby sevens players. Therefore, the current study aimed to investigate the relationships between a series of direct and indirect measures of speed performance (i.e., linear sprint velocity, COD velocity, sprint momentum, CODD, and DD) in National team female rugby sevens players.

Methods

Subjects

Nineteen elite female rugby sevens players (age: 23.7 ± 3.5 years; body mass: 66.4 ± 7.5 kg; height: 1.68 ± 0.10 m) from the Brazilian National team participated in this study. Players were tested in the final phase of preparation for the World Rugby Sevens Series. No musculoskeletal injuries were reported at the time of testing in the preceding 4 weeks. The study was approved by the local Ethics Committee (registration number 4.355.629) and all subjects were informed of the inherent risks and benefits associated with study participation, before signing informed consent forms.

Study Design

This cross-sectional correlational study aimed to assess the relationships between linear and COD-related variables in female rugby sevens players. Due to the constant training and assessments in our sports facilities, all athletes were well familiarized with the testing procedures. Players performed physical assessments on the same day, in the following order: 40-m linear sprint (with split times in 10-, 15-, 30-, and 40-m) and 505 COD test. Prior to the tests, athletes performed standardized warm-up protocols including general (i.e., running at a moderate pace for 10-min followed by dynamic stretching for 3-min) and specific exercises (i.e., submaximal attempts for each test).

Methodology

Linear Sprint Velocity

Five pairs of photocells (Elite Speed System®; S2 Sports, São Paulo, Brazil) were positioned at the starting line and at the distances of 10-, 15-, 30-, and 40-m along the sprinting course. Players sprinted twice on an indoor sprint track, starting from a standing position 0.5-m behind the starting line. Sprint velocity was calculated as the distance travelled over a measured time interval. Sprint momentum ($kg \cdot m \cdot s^{-1}$) was obtained by multiplying the athlete's body mass by the respective velocity in the sprint test. A 5-min rest interval was allowed between the two attempts and the fastest time was considered for the analyses.

505 Change of Direction Velocity

Players started from a standing position with the front foot placed 0.5-m behind the first pair of photocells (Smart Speed System; Fusion Sport, Brisbane, Australia). The second pair of photocells was positioned at 10-m, and a contact mat (Smart Jump System; Fusion Sport, Brisbane, Australia) was set at the distance of 15-m from the starting line.

Athletes were instructed to sprint to the contact mat, placing either their right or left foot on the line (drawn in the middle of the mat), perform a 180º turn, and then sprint through the finishing line (10-m photocells) (Figure 1). The 505 COD test considered the time from the 10-m gate to the 15-m contact mat and back to the 10-m gate (for a total distance of 10-m) and was completed for either left or right sides. The 505 COD velocity was calculated as the distance travelled over a measured time interval. Two attempts were performed for each side and the best attempt was retained for analysis.

Change of Direction and Deceleration Deficits Calculation

The CODD was calculated based on the percentage difference between 10-m linear sprint and 505 COD velocities.[14] To determine the DD, during each 505 COD test trial, the time from the starting line to the contact mat (placed at 15-m) was recorded to calculate deceleration time. The DD was calculated as the difference between the fastest 15-m linear sprint and 15-m deceleration times (+ 50% ground contact time).[9-11]

***** INSERT FIGURE 1 HERE *****

Statistical Analyses

Data are presented as mean and standard deviation. Normality of data was confirmed via the Shapiro-Wilk test. Absolute and relative reliability were calculated for each metric, using the coefficient of variation and the intraclass correlation coefficient, respectively. A Pearson product moment test was performed to determine the relationships between linear and COD sprint-derived variables, which were qualitatively interpreted as follows: < 0.09 - trivial; 0.10-0.29 - small; 0.30-0.49 - moderate; 0.50-0.69

- large; 0.70-0.89 - very large and > 0.90 - nearly perfect.[19] Significance level was set at $P < 0.05$. All statistical analyses were performed using the Jamovi statistical software (version 2.2.5; Jamovi Project—Patreon, San Francisco, CA).

Results

Table 1 depicts the descriptive data (mean and standard deviation) for the different variables analyzed. Table 2 shows the reliability coefficients for the different performance measures. Table 3 depicts the correlation coefficients between linear sprint and COD-derived variables. Large to very large significant relationships were noticed between linear sprint velocity for the different distances tested and CODD (r values ranging from 0.54 and 0.78; $P < 0.05$). The COD velocity presented a very large inverse significant correlation with CODD and DD ($r = -0.77$ and -0.79 respectively; $P < 0.05$). Finally, a large and significant correlation was noticed between CODD and DD ($r = 0.79$; $P < 0.05$).

***** INSERT TABLE 1 HERE *****

***** INSERT TABLE 2 HERE *****

***** INSERT TABLE 3 HERE *****

Discussion

The present study examined, for the first time, the associations between linear sprint velocity, sprint momentum, 505 COD velocity, and two field-based COD-derived measurements (i.e., CODD and DD) in elite female rugby sevens players. The main findings were that: 1) sprint velocity was not correlated with COD velocity and DD; however, strong associations were found between sprint velocity and CODD; 2) sprint momentum was not correlated with CODD and DD; 3) large inverse relationships were detected between COD velocity and both COD-derived variables; and 4) CODD and DD were largely associated, which reinforces the notion that more efficient players at changing direction display superior reacceleration and deceleration capabilities.

Linear sprint and 505 COD velocities were not significantly related which suggests that, in this specialized sample, athletes with superior sprint capabilities were not necessarily faster when executing maneuvers with 180° turns, such as the 505 test. These results contrast with previous research that found moderate-to-strong associations between short-sprint and 505 COD times.[11,12,18] However, in line with the current findings, Delaney et al.[20] also reported no association between 10-m sprint and dominant side 505 times in elite rugby players. The authors hypothesized that this could be due to the limited similarities that exist between the acceleration phase of a pure linear sprint and the approach run of the 505 test since, in the latter, players are required to rapidly decelerate their center of mass[20] before turning and reaccelerating in the opposite direction. To some extent, the data presented herein reinforces this view, as no meaningful associations were identified between linear sprint performance and DD, highlighting the specificity and independence of these physical capabilities and the importance of, in high-performance training settings, assessing both separately.[10]

As already reported in the literature, faster players in linear sprinting actions tended to display larger CODD (*r* values ranging from 0.54 to 0.78), which indicates that they are less efficient at changing direction.[4,8,21,22] Previous research has indicated that a greater sprint momentum could be one of the key factors explaining this phenomenon.[7,21] For example, Freitas et al.[21] found large relationships between CODD in different multidirectional tests and sprint momentum in male rugby union players, most likely due to the higher braking forces that must be applied to overcome the greater inertia negatively affecting CODD.[3,21] Contradicting these observations, we did not observe significant correlations between sprint momentum, and CODD and DD. Nevertheless, it is important to mention that the participants in the present study presented a considerably lower body mass than that reported in Freitas et al.[21] (~65 kg vs ~85 kg). In this context, it seems that linear sprint velocity might be the main factor influencing CODD in lighter players whereas body mass (and momentum) is more decisive in heavier athletes, as already noted by Loturco et al.[11]. Of interest, the only study[4] that found sprint momentum to be related to CODD in female rugby sevens players utilized a different multidirectional speed test (i.e., the Zigzag, consisting of three ~90º-100º CODs) and, therefore, direct comparisons should be avoided, due to the well-established influence of COD angle and velocity on COD test performance (and its respective determinants).[23] From an applied perspective, for reasons to be further clarified, (lighter) female athletes appear to be less influenced by sprint momentum during aggressive COD maneuvers than their male counterparts. This also suggests that these players might possess a greater window of COD development, since physical skills that are theoretically more modifiable through training (i.e., linear sprint velocity and COD technique) appear to have a greater influence on multidirectional performance than anthropometric factors (e.g., body mass).

The strong negative correlations between 505 COD velocity and CODD and DD support that superior performances in this COD maneuver are highly determined by the athletes' capacity to decelerate quickly and abruptly and re-accelerate. Faster 180º directional changes have been linked to greater reductions in velocity during the antepenultimate and penultimate foot contacts in laboratory-based studies[24,25] but this is the first investigation to simultaneously analyze and search for correlations between the

CODD and DD in female rugby sevens players. The current findings strongly suggest that performance in the 505 test (and other COD maneuvers in which an aggressive deceleration is distributed over multiple steps) greatly depends on "how well" players are able to effectively reduce center of mass velocity and cope with the eccentric forces associated with these actions before re-accelerating in the opposite direction. Remarkably, in line with Clarke et al.[10], players more efficient at changing direction (i.e., lower CODD) displayed greater deceleration capabilities (i.e., lower DD), as evidenced by the large association detected between both COD-derived measurements (r = 0.79). This indicates that, in the cohort analyzed here, deceleration ability was an important limiting factor of performance in players displaying higher CODD. Therefore, despite their independent nature,[9,10] the CODD and DD seem to be closely related, and it can be expected that improving the ability to "hit the brakes" during sharp COD maneuvers will result in positive changes in CODD in elite female rugby sevens players. However, coaches should keep in mind that both COD-derived measures should be analyzed in conjunction with linear sprint and COD velocities, since peak velocities achieved before changing direction affect the distance over which athletes must decelerate,[26] which potentially affects the DD.

This study is limited by: 1) its cross-sectional design that does not allow establishment of causal relationships between the variables analyzed; and 2) the fact that deceleration ability was assessed with an indirect time-based measurement (i.e., DD) and not through actual changes in velocity over time using GPS or radar devices, as recommended in previous research.[27] Nevertheless, it is important to note that the DD calculation used here is a field-based method that can be easily employed by practitioners in the field.

Practical Applications

Faster female rugby sevens players in linear sprinting actions were not necessarily faster when performing the 505 test but displayed greater CODD. Furthermore, sprint momentum was not found to influence the efficiency to decelerate (as assessed by the DD) or change direction (i.e., assessed by the CODD), possibly due to anthropometric characteristics (i.e., low body mass). Altogether, the findings of the present study suggest that, to improve the ability of female rugby sevens players to perform 180º directional changes, training strategies should aim to improve COD technique (and reduce CODD) and optimize players' deceleration ability, instead of focusing on increasing linear sprint velocity. Coaches are encouraged to prescribe COD-based training programs that prepare their athletes to better cope with greater entry velocities and eccentric forces, utilizing, among other strategies, COD technique-oriented drills[28,29] and eccentric-accentuated exercises.[30,31]

Conclusions

Linear sprint and COD velocities were not correlated but significant associations were found between the former variable and CODD in elite female rugby sevens players. No relationship was found between sprint velocity and DD, highlighting the independent nature of linear sprint and deceleration capabilities. No meaningful relationships were detected between sprint momentum, CODD, and DD; conversely, CODD and DD were largely associated. A comprehensive examination of multidirectional speed performance should consider not only linear sprint and COD test velocities (or times) but also specific COD-derived measurements, such as the CODD and DD.

References

1. Ball S, Halaki M, Orr R. Movement Demands of Rugby Sevens in Men and Women: A Systematic Review and Meta-Analysis. *J Strength Cond Res*. 2019;33:3475-90.

2. Sella FS, McMaster DT, Beaven CM, Gill ND, Hebert-Losier K. Match Demands, Anthropometric Characteristics, and Physical Qualities of Female Rugby Sevens Athletes: A Systematic Review. *J Strength Cond Res*. 2019;33:3463-74.

3. Freitas TT, Alcaraz PE, Calleja-González J, Arruda AFS, Guerriero A, Kobal R, Reis VP, Pereira LA, Loturco I. Differences in Change of Direction Speed and Deficit Between Male and Female National Rugby Sevens Players. *J Strength Cond Res*. 2021;35:3170-6.

4. Freitas TT, Pereira LA, Alcaraz PE, Comyns TM, Azevedo P, Loturco I. Change-of-Direction Ability, Linear Sprint Speed, and Sprint Momentum in Elite Female Athletes: Differences Between Three Different Team Sports. *J Strength Cond Res*. 2022;36:262-7.

5. Loturco I, Pereira LA, Arruda AF, Reis VP, Robineau J, Couderc A, Guerriero A, Freitas TT. Differences in Physical Performance Between Olympic and Non-Olympic Female Rugby Sevens Players. *J Sports Med Phys Fitness*. 2021;61:1091-7.

6. Condello G, Minganti C, Lupo C, Benvenuti C, Pacini D, Tessitore A. Evaluation of Change-of-Direction Movements in Young Rugby Players. *Int J Sports Physiol Perform*. 2013;8:52-6.

7. Fernandes R, Bishop C, Turner AN, Chavda S, Maloney SJ. Train the Engine or the Brakes? Influence of Momentum on the Change of Direction Deficit. *Int J Sports Physiol Perform*. 2021;16:90-6.

8. Loturco I, L AP, T TF, P EA, Zanetti V, Bishop C, Jeffreys I. Maximum Acceleration Performance of Professional Soccer Players in Linear Sprints: Is There a Direct Connection with Change-Of-Direction Ability? *PLoS One*. 2019;14:e0216806.

9. Bishop C, Clarke R, Freitas TT, Arruda AFS, Guerriero A, Ramos MS, Pereira LA, Loturco I. Change-of-Direction Deficit vs. Deceleration Deficit: A Comparison of Limb Dominance and Inter-limb Asymmetry between Forwards and Backs in Elite Male Rugby Union Players. *J Sports Sci*. 2021;39:1088-95.

10. Clarke R, Read PJ, De Ste Croix MBA, Hughes JD. The Deceleration Deficit: A Novel Field-Based Method to Quantify Deceleration During Change of Direction Performance. *J Strength Cond Res*. 2022;36:2434-9.

11. Loturco I, Pereira LA, Alvarez-Dacal F, Martinez-Maseda J, Freitas TT, Fernandez-Fernandez J. Predicting Change-Of-Direction Performance in Elite Young Badminton Players: A Multiple Regression Analysis on Acceleration-and Deceleration-Related Qualities. *Int J Sports Sci Coach*. 2022;17:583-9.

12. Nimphius S, Callaghan SJ, Spiteri T, Lockie RG. Change df Direction Deficit: A More Isolated Measure of Change of Direction Performance Than Total 505 Time. *J Strength Cond Res*. 2016;30:3024-32.

13. Pereira LA, Nimphius S, Kobal R, Kitamura K, Turisco LAL, Orsi RC, Cal Abad CC, Loturco I. Relationship Between Change of Direction, Speed, and Power in Male and Female National Olympic Team Handball Athletes. *J Strength Cond Res*. 2018;32:2987-94.

14. Freitas TT, Pereira LA, Alcaraz PE, Azevedo P, Bishop C, Loturco I. Percentage-Based Change of Direction Deficit: A New Approach to Standardize Time- and Velocity-Derived Calculations. *J Strength Cond Res*. 2022;36:3521-6.

15. Harper DJ, McBurnie AJ, Santos TD, Eriksrud O, Evans M, Cohen DD, Rhodes D, Carling C, Kiely J. Biomechanical and Neuromuscular Performance Requirements of Horizontal Deceleration: A Review with Implications for Random Intermittent Multi-Directional Sports. *Sports Med*. 2022;52:2321-54.

16. McBurnie AJ, Harper DJ, Jones PA, Dos'Santos T. Deceleration Training in Team Sports: Another Potential 'Vaccine' for Sports-Related Injury? *Sports Med*. 2022;52:1-12.

17. Thomas C, Dos'Santos T, Comfort P, Jones PA. Male and Female Soccer Players Exhibit Different Knee Joint Mechanics During Pre-Planned Change of Direction. *Sports Biomech*. 2020:1-14.

18. Zhang Q, Dellal A, Chamari K, Igonin PH, Martin C, Hautier C. The Influence of Short Sprint Performance, Acceleration, and Deceleration Mechanical Properties on Change of Direction Ability in Soccer Players-A Cross-Sectional Study. *Front Physiol*. 2022;13:1027811.

19. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive Statistics for Studies in Sports Medicine and Exercise Science. *Med Sci Sports Exerc*. 2009;41:3-13.

20. Delaney JA, Scott TJ, Ballard DA, Duthie GM, Hickmans JA, Lockie RG, Dascombe BJ. Contributing Factors to Change-of-Direction Ability in Professional Rugby League Players. *J Strength Cond Res*. 2015;29:2688-96.

21. Freitas TT, Alcaraz PE, Calleja-Gonzalez J, Arruda AFS, Guerriero A, Mercer VP, Pereira LA, Carpes FP, McGuigan MR, Loturco I. Influence of Physical and Technical Aspects on Change of Direction Performance of Rugby Players: An Exploratory Study. *Int J Environ Res Public Health*. 2021;18

22. Lockie RG, Dawes JJ, Jones MT. Relationships between Linear Speed and Lower-Body Power with Change-of-Direction Speed in National Collegiate Athletic Association Divisions I and II Women Soccer Athletes. *Sports (Basel)*. 2018;6

23. Dos'Santos T, Thomas C, Comfort P, Jones PA. The Effect of Angle and Velocity on Change of Direction Biomechanics: An Angle-Velocity Trade-Off. *Sports Med*. 2018;48:2235-53.

24. Dos'Santos T, McBurnie A, Thomas C, Comfort P, Jones PA. Biomechanical Determinants of the Modified and Traditional 505 Change of Direction Speed Test. *J Strength Cond Res*. 2020;34:1285-96.

25. Jones PA, Thomas C, Dos'Santos T, McMahon JJ, Graham-Smith P. The Role of Eccentric Strength in 180 degrees Turns in Female Soccer Players. *Sports (Basel)*. 2017;5

26. Hader K, Mendez-Villanueva A, Palazzi D, Ahmaidi S, Buchheit M. Metabolic Power Requirement of Change of Direction Speed in Young Soccer Players: Not All Is What It Seems. *PLoS One*. 2016;11:e0149839.

27. Harper DJ, Morin JB, Carling C, Kiely J. Measuring Maximal Horizontal Deceleration Ability Using Radar Technology: Reliability and Sensitivity of Kinematic and Kinetic Variables. *Sports Biomech*. 2020:1-17.

28. Dos'Santos T, McBurnie A, Comfort P, Jones PA. The Effects of Six-Weeks Change of Direction Speed and Technique Modification Training on Cutting Performance and Movement Quality in Male Youth Soccer Players. *Sports (Basel)*. 2019;7

29. Dos'Santos T, Thomas C, Comfort P, Jones PA. Biomechanical Effects of a 6-Week Change of Direction Speed and Technique Modification Intervention:

Implications for Change of Direction Side step Performance. *J Strength Cond Res*. 2022;36:2780-91.

30. Chaabene H, Prieske O, Negra Y, Granacher U. Change of Direction Speed: Toward a Strength Training Approach with Accentuated Eccentric Muscle Actions. *Sports Med*. 2018;48:1773-9.

31. Tous-Fajardo J, Gonzalo-Skok O, Arjol-Serrano JL, Tesch P. Enhancing Change-of-Direction Speed in Soccer Players by Functional Inertial Eccentric Overload and Vibration Training. *Int J Sports Physiol Perform*. 2016;11:66-73.

Figure Caption

Figure 1. 505 change of direction test sequencing (in counterclockwise order, starting from the upper right corner) with the necessary apparatus for the measurement of the “deceleration deficit” (DD). A-C: Initial acceleration; D-E: Antepenultimate and penultimate foot contacts; F: Final foot contact; G-H: Re-acceleration.

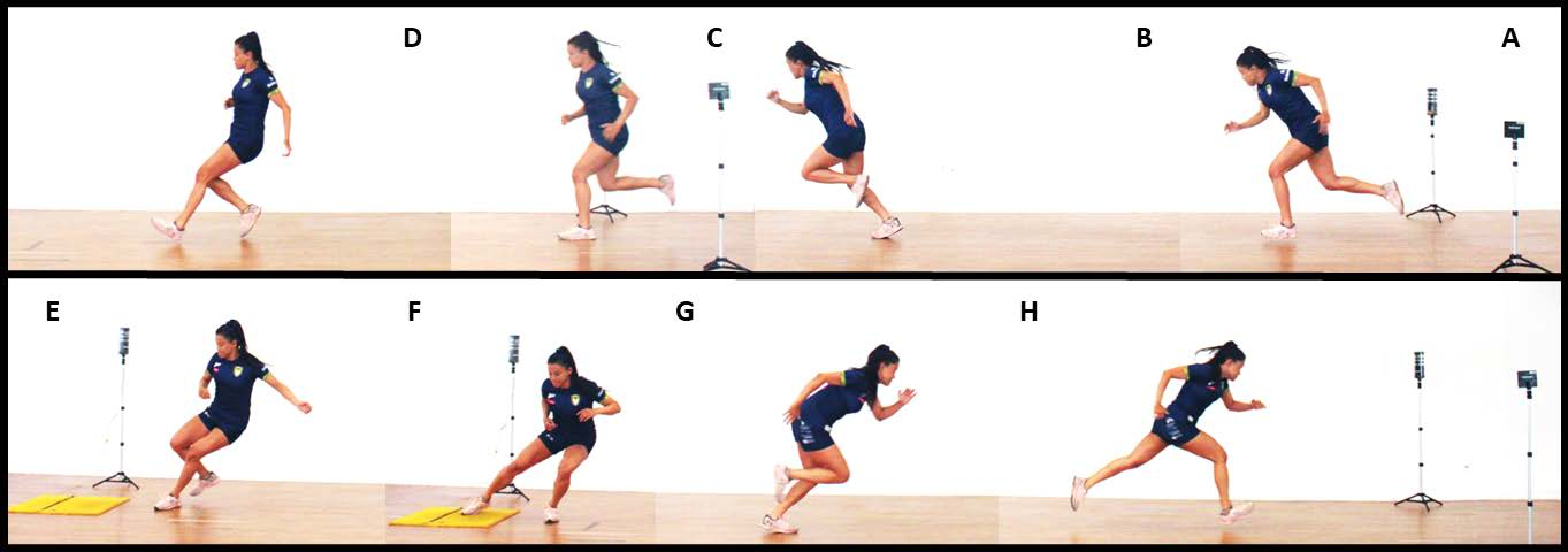
D
C
B
A
E
F
G
H

Table 1. Descriptive data of the different sprint- and change of direction-derived variables.

	Mean		SD
Velocity 10-m ($m \cdot s^{-1}$)	5.53	±	0.22
Velocity 15-m ($m \cdot s^{-1}$)	5.86	±	0.24
Velocity 30-m ($m \cdot s^{-1}$)	6.80	±	0.31
Velocity 40-m ($m \cdot s^{-1}$)	7.05	±	0.35
Sprint momentum 10-m ($kg \cdot m \cdot s^{-1}$)	367.1	±	42.4
Sprint momentum 15-m ($kg \cdot m \cdot s^{-1}$)	388.7	±	45.3
Sprint momentum 30-m ($kg \cdot m \cdot s^{-1}$)	450.2	±	47.5
Sprint momentum 40-m ($kg \cdot m \cdot s^{-1}$)	466.7	±	48.8
COD velocity ($m \cdot s^{-1}$)	4.82	±	0.19
COD deficit (%)	21.9	±	7.8
Deceleration deficit (s)	0.62	±	0.15

COD: change of direction; SD: standard deviation.

Table 2. Reliability coefficients for the different performance measures.

	CV (%)	**ICC**
Velocity 10-m ($m·s^{-1}$)	0.91	0.96
Velocity 15-m ($m·s^{-1}$)	0.72	0.97
Velocity 30-m ($m·s^{-1}$)	0.49	0.99
Velocity 40-m ($m·s^{-1}$)	0.48	0.99
COD velocity ($m·s^{-1}$)	1.70	0.91

CV: Coefficient of variation; ICC: Intraclass correlation coefficient.

Table 3. Correlation coefficients among the different sprint- and change of direction-derived variables.

	VEL 10-m ($m \cdot s^{-1}$)	VEL 15-m ($m \cdot s^{-1}$)	VEL 30-m ($m \cdot s^{-1}$)	VEL 40-m ($m \cdot s^{-1}$)	SM 10-m ($kg \cdot m \cdot s^{-1}$)	SM 15-m ($kg \cdot m \cdot s^{-1}$)	SM 30-m ($kg \cdot m \cdot s^{-1}$)	SM 40-m ($kg \cdot m \cdot s^{-1}$)	COD VEL ($m \cdot s^{-1}$)	CODD (%)
COD VEL ($m \cdot s^{-1}$)	0.02	-0.21	0.06	0.07	-0.27	-0.36	-0.28	-0.27		
CODD (%)	**0.56***	**0.78***	**0.54***	**0.54***	0.29	0.39	0.34	0.36	**-0.77***	
DD (s)	0.12	0.45	0.11	0.12	0.30	0.42	0.33	0.34	**-0.79***	**0.79***

COD: change of direction; CODD: COD deficit; DD: deceleration deficit; SM: sprint momentum; VEL: velocity; *$P < 0.05$.