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# Change-of-Direction Ability, Linear Sprint Speed, and Sprint Momentum in Elite Female Athletes: Differences Between Three Different Team Sports

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## Abstract

Freitas, TT, Pereira, LA, Alcaraz, PE, Comyns, TM, Azevedo, PHSM, and 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* 36(1): 262–267, 2022—The aim of this study was to compare the performance of elite female players from 3 different sports in linear sprint and change-of-direction (COD) tests and examine their efficiency for changing direction through the calculation of the COD deficit (i.e., the difference in velocity between a linear sprint and a COD task of equal distance). One hundred fifty-four elite players (rugby, $n = 40$, national team members; soccer, $n = 57$ and handball $n = 57$, first division players from the respective Brazilian National Championships) were assessed in the 20-m linear sprint and Zigzag COD tests. A one-way analysis of variance with a Tukey post hoc was used to detect between-sport differences. Female rugby sevens players achieved faster sprint velocities than handball (20-m: $6.21 \pm 0.24$ m·s$^{-1}$; $6.07 \pm 0.27$ m·s$^{-1}$, respectively; $p < 0.05$) and soccer players (5-m: $4.71 \pm 0.26$ m·s$^{-1}$ vs. $4.51 \pm 0.20$ m·s$^{-1}$; and 20-m: $6.08 \pm 0.19$ m·s$^{-1}$; $p < 0.05$) and exhibited the greatest COD deficits ($2.95 \pm 0.25$ m·s$^{-1}$; $2.69 \pm 0.19$ m·s$^{-1}$; $2.82 \pm 0.17$ m·s$^{-1}$, for rugby, handball, and soccer, respectively; $p < 0.05$). Handball players outperformed all other athletes in the Zigzag test ($3.38 \pm 0.15$ m·s$^{-1}$; $3.26 \pm 0.10$ m·s$^{-1}$; $3.26 \pm 0.10$ m·s$^{-1}$, for handball, rugby, and soccer, respectively; $p < 0.05$) but presented the lowest COD deficits ($p < 0.05$). Furthermore, soccer players displayed inferior sprint momentum when compared with the other sports ($p < 0.05$). Linear sprint and COD ability differ significantly among elite female athletes from different team sports, with handball players exhibiting a greater COD speed and efficiency to change direction, with respect to their maximum sprint velocity. The between-sport differences observed suggests that specific training and game demands may affect both sprint and COD performance.

**Key Words:** agility, directional changes, physical performance, women, velocity

## Introduction

Change-of-direction (COD) performance is particularly important in most team sports because during competitions, elite athletes frequently change movement velocity and direction as a means of avoiding contact with opposing players or obtaining positional advantages that may lead to a try or goal (2,19,30). Therefore, despite the unpredictable nature of "in-game" COD tasks (25,34), sport scientists have long been interested in the investigation of a multiplicity of preplanned COD tests. These assessments allow a better understanding of the physiological and mechanical basis underpinning this complex and multifaceted capability (e.g., kinetic and kinematic determinants of COD, specific biomechanical and technical aspects, or strength-power qualities of top performers) (4,9,16,27). Moreover, a deeper insight into the main set of COD-related skills in team sport athletes may be useful for training prescription purposes.

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Traditionally, COD ability has been evaluated through completion time in different multidirectional drills (3,7,23,33,34). Nonetheless, in recent years, with the purpose of assessing COD as a "separate skill," alternative approaches such as the "COD deficit calculation" (i.e., the difference in time or velocity between a linear sprint and a COD task of equal distance) have emerged (6,8,21,26,28). Interestingly, studies on team sport athletes have found that stronger, faster, and more powerful players tend to present higher COD deficits, indicating that they are less efficient at changing direction in relation to their maximum sprint velocity (13,21,28). Although this phenomenon seems to be commonplace among players from the same discipline (e.g., faster soccer players are less efficient than their slower peers) (13,21,28), a recent study (22) comparing the magnitude of COD deficits between male athletes from different team sports (soccer, rugby, futsal, and handball) revealed new and intriguing findings: (a) soccer players were the least efficient at changing direction, albeit not being faster during linear sprints and (b) futsal, handball, and rugby players exhibited similar levels of COD deficit; nevertheless, rugby players performed better in the Zigzag COD test. According to the authors, these findings might be due to, among other aspects, the different volume, frequency, and type of neuromuscular training performed by the players of different sports during their prospective development (i.e., training history) and professional careers (i.e., typical training routines) (22).

In light of this recent evidence suggesting that aspects associated with the ability to change direction may differ among male players from different sports (22), it is imperative to investigate these characteristics in female populations. Previous studies have reported that male and female athletes display dissimilar lower-body kinematics, vertical ground reaction forces, and impulse variables during tasks that involve rapid directional changes (32). In addition, differences in sprinting mechanical profiles have been observed across sports in elite female athletes (15). For these reasons, further research on the COD ability of women from different sport disciplines may help coaches to develop more efficient and tailored training strategies, according to the specific needs of professional female athletes. In this context, it is of particular interest to investigate modalities in which match-activity profiles differ, but sprinting and high-intensity COD maneuvers are frequently performed and often precede decisive game situations (e.g., goal scoring), such as soccer (2,10), rugby (30), and handball (19). This study aimed to compare the performance obtained by elite female rugby, soccer, and handball players in linear and COD speed tests. Moreover, to examine their efficiency at changing direction, we calculated and compared the COD deficit and sprint momentum (i.e., the product of body mass and sprint velocity) of the subjects.

## Methods

### *Experimental Approach to the Problem*

This cross-sectional study compared the differences in linear sprint velocity, COD speed, and COD deficit between female team sport athletes. The 20-m linear sprint test and Zigzag COD speed test were performed on the same day. Athletes arrived at the high-performance training center before the first training session of the week after at least 36 hours of rest. Subjects were required to be in a fasting state for at least 2 hours, avoiding caffeine and alcohol consumption for 24 hours before the procedures. All athletes were well familiarized with testing procedures because of their constant and regular assessments in our facilities (i.e., previously performed in distinct periods over the past 2–3 seasons) and were assessed during the competitive period of the season (first and third), according to the specific competition schedule of each sport. Before the tests, players performed the standardized warm-up protocols, including general (i.e., running at a moderate pace for 10 minutes, followed by active lower-limb stretching for 3 minutes) and specific exercises (i.e., submaximal attempts at each tested exercise), as previously described (21,22,28). Between each test, a 10-minute interval was provided to explain the procedures, allow adequate recovery, and adjust the equipment.

### *Subjects*

In total, a convenience sample of 154 elite female athletes from 3 different team sports (age range: 18–36) participated in this study (57 soccer players: age: 23.6 ± 3.5 years; body mass: 60.3 ± 7.2 kg; height: 167.5 ± 6.9 cm; 57 handball players: age: 25.7 ± 4.8 years; body mass: 69.3 ± 7.1 kg; height: 174.8 ± 5.2 cm; and 40 rugby sevens players: age: 22.4 ± 3.7 years; body mass: 65.5 ± 7.0 kg; height: 165.2 ± 0.5 cm; Age is presented as mean ± *SD*). Soccer players played in the first division of the Brazilian National Championship, and 8 players were members of the Brazilian National soccer team. Female handball players participated in the first division of the Brazilian National Championships, comprising 24 athletes of the Brazilian National Team. Rugby players were members of the Brazilian National Team that had just qualified for the 2020 Olympic Games. Only injury-free players who had not sustained any severe

**Table 1**
**Models of training organization for the team sport players during different training phases.***

| | Pre-season | | Competitive season | |
|---|---|---|---|---|
| Handball | | | | |
| Training strategy | Resistance training | Plyometrics | Resistance training | Plyometrics |
| Exercise type | Traditional | VJ-HJ | Traditional and ballistic | VJ-HJ |
| Intensity | 70–90% 1RM | Maximum | 30–50% 1RM | Maximum |
| Frequency | 3–4 sessions·wk$^{-1}$ | | 2–3 sessions·wk$^{-1}$ | |
| Sport-specific training | 5–6 sessions·wk$^{-1}$—∼4 friendly matches | | 4–5 sessions·wk$^{-1}$—∼20 official matches/season | |
| | Focus on technical-tactical training, offensive and defensive situations, and game-based drills | | | |

| | Pre-season | | | Competitive season | | |
|---|---|---|---|---|---|---|
| Soccer | | | | | | |
| Training strategy | Resistance training | RST | Plyometrics | Resistance training | RST | Plyometrics |
| Exercise type | Traditional | Short sprints | VJ-HJ | Ballistic | Short sprints | VJ-HJ |
| Intensity | 60–80% 1RM | 10–15% BM | Maximum | 40–60% 1RM | 10–15% BM | Maximum |
| Frequency | 1–2 sessions·wk$^{-1}$ | | | 1–2 sessions·wk$^{-1}$ | | |
| Sport-specific training | 4–5 sessions·wk$^{-1}$—∼4 friendly matches | | | 3–4 sessions·wk$^{-1}$—∼40 official matches/season | | |
| | Focus on technical-tactical training, offensive and defensive situations, and small-sided games | | | | | |
| Rugby | | | | | | |
| Training strategy | Resistance training | RST | Plyometrics | Resistance training | RST | Plyometrics |
| Exercise type | Traditional | Short sprints | VJ-HJ | Traditional and ballistic | Short sprints | VJ-HJ |
| Intensity | 80–95% 1RM | 10–20% BM | Maximum | 30–50% 1RM | 10–20% BM | Maximum |
| Frequency | 3–5 sessions·wk$^{-1}$ | | | 3–4 sessions·wk$^{-1}$ | | |
| Sport-specific training | 3–4 sessions·wk$^{-1}$—1 preparatory tournament | | | 3–4 sessions·wk$^{-1}$—∼8 tournaments/season | | |
| | Focus on technical-tactical training, offensive and defensive situations, and game-based drills | | | | | |

*RM = repetition maximum; VJ = vertical jumps; HJ = horizontal jumps; BM = body mass; RST = resisted sprint training (performed with weighted sleds or weighted vests).

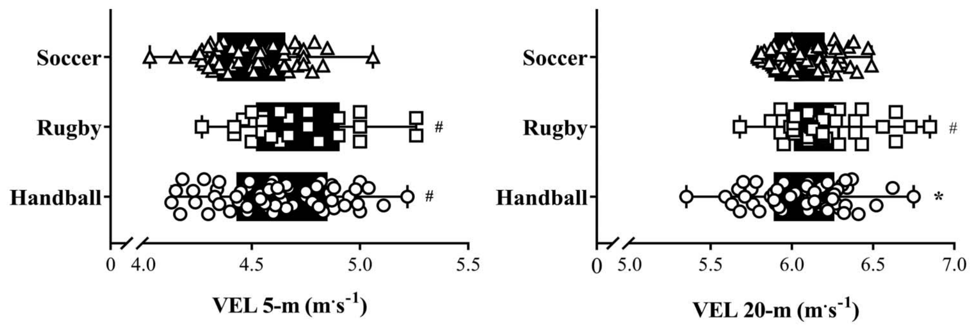


**Figure 1.** Comparison of the sprint velocity (VEL) in the different distances assessed among the 3 team sport disciplines. Symbols represent significant difference ($p < 0.05$) from: *rugby and #soccer.

injury in the 2 months before the assessments and did not present any problem that could limit their physical performance were considered for study participation. Two handball and 3 soccer goalkeepers performed the tests but were not included in the study. All players assessed had at least 8 years of high-level training experience, which included sport-specific drills, and speed and resistance training practices. The current typical training programs of the athletes participating in this study are presented in Table 1. The study was approved by the Bandeirante-Anhanguera University Ethics Committee, and written informed consent was obtained from all subjects.

### Procedures

*Linear Sprint Speed Tests.* Three pairs of photocells (Smart Speed; Fusion Sport, Brisbane, Australia) were positioned at the starting line and at the distances of 0, 5, and 20-m. Athletes sprinted twice, starting from a standing position 0.5 m behind the starting line. The sprint tests were performed on an indoor running track. Sprint velocity (VEL) was calculated as the distance traveled over a measured time interval. In addition, sprint momentum (kg·m·s$^{-1}$) was obtained by multiplying the athlete's body mass by the respective velocities achieved during linear sprints of 5 and 20-m. A 5-minute rest interval was allowed between the 2 attempts, and the fastest 20-m time was considered for subsequent analyses.

*Zigzag Change-of-Direction Speed Test.* The Zigzag COD test was performed on an indoor court and consisted of four 5-m sections (total 20-m of linear distance) marked with cones set at 100° angles (28) requiring the athletes to decelerate and accelerate as fast as possible around each cone. Two maximal attempts were performed with a 5-minute rest interval between attempts. Starting from a standing position with the front foot placed 0.5 m behind the first pair of timing gates (Smart Speed; Fusion Equipment) (i.e., starting line), athletes were instructed to complete the test as quickly as possible, until crossing the second pair of timing gates, placed 20-m from the starting line. The fastest time from the 2 attempts was retained for further analysis. To properly evaluate the efficiency of each athlete to use her linear speed during a COD task, an adapted COD deficit calculation was used, as previously described (26,28). Hence, the COD deficit was calculated as follows: *(20-m velocity − Zigzag test velocity).*

### Statistical Analyses

All data are presented as mean ± standard deviation. Data normality was confirmed through the Shapiro-Wilk test. An a priori analysis of the required sample size in the 3 groups analyzed was conducted through the G*Power 3.1.9.2 software assuming an $\alpha$ of 0.05 and a minimum statistical power of 80%. The effect size (ES) used for defining the sample size was calculated based on a previous study, which tested identical variables in male athletes of the same team sports (22). The sample size required based on the established criteria was estimated to be 153 subjects. The referred software was also used to calculate the statistical power achieved for each assessed variable. The comparisons of linear sprint, sprint momentum, COD velocity, and COD deficit between the 3 sports were performed using a one-way analysis of variance. The Tukey post hoc test was used to detect differences. Effect sizes were calculated to estimate the magnitude of significant differences and interpreted using the following thresholds proposed for highly trained subjects: < 0.25, 0.25–0.50, 0.50–1, and >1 for trivial, small, moderate, and large, respectively (29). In addition, a Pearson product moment correlation was computed to determine the relationships between the variables assessed in each sport. The correlation coefficients were qualitatively

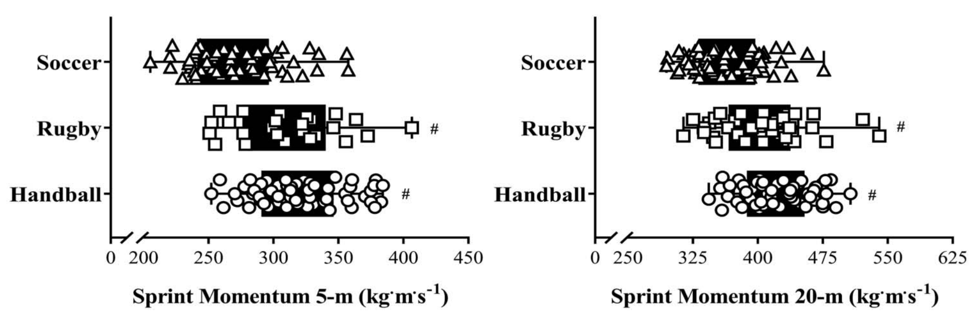


**Figure 2.** Comparison of the sprint momentum in the different distances assessed among the 3 team sport disciplines. #Symbol represents significant difference ($p < 0.05$) from soccer.

**Table 2**

**Correlation coefficients (*r*) between linear sprint, Zigzag change-of-direction (COD), COD deficit, and sprint momentum (SM) in the distinct team sports disciplines.**

| | Zigzag | COD deficit | SM 5-m | SM 20-m |
|---|---|---|---|---|
| Handball | | | | |
| VEL 5-m | 0.74* | 0.53* | 0.38* | 0.19 |
| VEL 20-m | 0.70* | 0.84* | 0.06 | 0.04 |
| Zigzag | | 0.19 | 0.17 | 0.07 |
| COD deficit | | | −0.04 | 0.00 |
| Rugby | | | | |
| VEL 5-m | 0.12 | 0.78* | 0.70* | 0.61* |
| VEL 20-m | 0.15 | 0.92* | 0.46* | 0.53* |
| Zigzag | | −0.26 | −0.16 | −0.26 |
| COD deficit | | | 0.50* | 0.63* |
| Soccer | | | | |
| VEL 5-m | 0.10 | 0.69* | 0.35* | 0.20 |
| VEL 20-m | 0.45* | 0.84* | −0.05 | −0.04 |
| Zigzag | | −0.10 | −0.42* | −0.39* |
| COD deficit | | | 0.20 | 0.18 |

*$p < 0.05$.

interpreted as follows: <0.09, trivial; 0.10–0.29, small; 0.30–0.49, moderate; 0.5–0.69, large; 0.70–0.89, very large; and >0.90 nearly perfect (17). The significance level was set at $p < 0.05$. All performance tests used in this article demonstrated high levels of reliability and consistency (i.e., intraclass correlation coefficients >0.90 and coefficients of variation <5%) when analyzing the total number of attempts performed by the athletes in each respective physical test.

## Results

The statistical power values estimated for VEL 5 and 20-m were 82 and 81%, respectively. The statistical power values for the remaining variables were all >99%. The body mass was significantly different among the athletes of the 3 distinct team sports tested, with handball players displaying the highest values and soccer players the lowest values ($p < 0.05$). Figure 1 shows the comparison of linear sprints among the female athletes. Handball and rugby players demonstrated higher VEL 5-m than soccer players (ES = 0.60 and 1.00, respectively; $p < 0.05$). Rugby players demonstrated higher VEL 20 m than handball (ES = 0.56; $p < 0.05$) and soccer players (ES = 0.68; $p < 0.05$).

Figure 2 depicts the comparison of sprint momentum among the female athletes. Handball and rugby players demonstrated greater sprint momentum in 5-m (ES = 1.37 and 1.13, respectively; $p < 0.05$) and 20-m (ES = 1.28 and 0.96, respectively; $p < 0.05$) than soccer players. No significant differences were observed between sprint momentum in 5 and 20-m between handball and rugby players (ES = 0.21 and 0.26, respectively; $p > 0.05$).

Figure 3 shows the comparison of Zigzag performance and COD deficit among the female athletes. Handball players demonstrated higher Zigzag velocity than rugby (ES = 1.19; $p < 0.05$) and soccer players (ES = 1.14; $p < 0.05$). Rugby players demonstrated a higher COD deficit than handball (ES = 1.03; $p < 0.05$) and soccer players (ES = 0.78; $p < 0.05$). Meanwhile, soccer players demonstrated a higher COD deficit than handball players (ES = 0.73; $p < 0.05$). Finally, Table 2 reports the correlation coefficients between linear sprint, Zigzag velocity, COD deficit, and sprint momentum in the distinct team sports female athletes. For handball players, large to very large significant ($p < 0.05$) correlations were found between linear sprint and Zigzag velocity and COD deficit. Regarding rugby, moderate to nearly perfect significant ($p < 0.05$) relationships were detected between linear sprint velocity, COD deficit, and sprint momentum. For soccer players, large to very large significant ($p < 0.05$) relationships were found between linear sprint and COD deficit.

## Discussion

The main findings of this study were (a) female rugby players achieved faster sprint velocities than soccer (i.e., 5 and 20-m) and handball players (i.e., 20-m); (b) despite being slower in linear sprint distances and in the COD speed test, soccer players did not display greater efficiency to change direction, relative to their maximum velocity; (c) elite handball players outperformed all other athletes in the Zigzag test and, surprisingly, displayed the lowest COD deficits. In addition, when compared with female rugby and soccer players, female handball players presented the greatest coefficients of correlation between linear sprint and COD velocity. Finally, very large to nearly perfect relationships were found between sprint velocity and COD deficit in the 3 sport disciplines, indicating that higher velocities are significantly associated to greater deficits irrespective of the group considered.

During official competitions and technical-tactical training sessions, elite rugby sevens players frequently achieve velocities above 90% of their maximum sprint velocity (5,31) and cover greater high-intensity running distances (with a lower number of directional changes) than handball players (19). To some extent, this might explain the significant differences found between these 2 respective team sports. The inclusion of resisted sprint training (RST) in rugby (but not in handball) players' training program is also an important aspect to consider. Resisted sprint training is

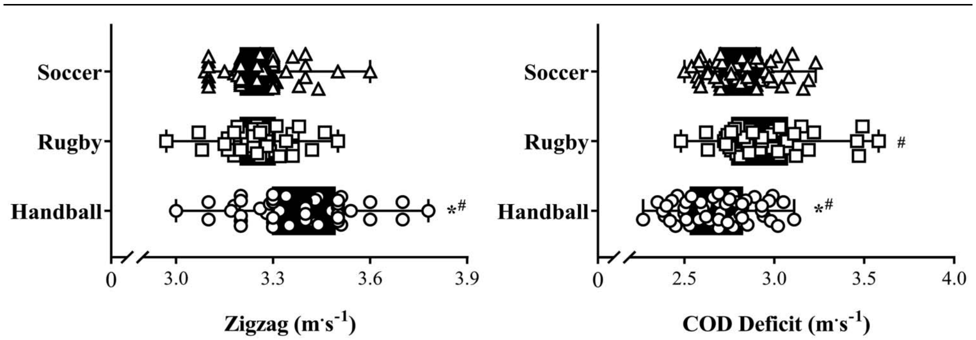


**Figure 3.** Comparison of the Zigzag change-of-direction (COD) test and COD deficit among the distinct team sport disciplines. Symbols represent significant difference ($p < 0.05$) from: *rugby and #soccer.

widely recognized as an effective sprint-specific stimulus and could be an important factor for increasing the sprint velocity (1,20). In addition, when compared with soccer and handball players, rugby players usually perform greater volumes of strength, power, and speed-related training (Table 1), which probably explains their superior performance in linear sprint tests (14,18,22).

Regarding COD speed, previous investigations suggest that faster, stronger, and more powerful athletes tend to exhibit greater COD deficits, when considering players from the same sport discipline (13,21,28). However, a recent study (22) revealed interesting between-sport differences in the COD ability of elite male athletes. Loturco et al. (22) observed that rugby players were faster at completing the Zigzag test when compared with soccer, handball, and futsal players; nonetheless, they did not present significantly higher COD deficits, as could be expected based on previous literature (13,21,28). These findings differ from this study, where female rugby players were found to be the least efficient when changing direction (i.e., higher COD deficits). The limited time devoted to executing eccentric strength training, COD-specific and decelerative drills, and the greater volume of short straight sprints and concentric-based resistance training (Table 1) may partially explain the greater deficits observed in this population. Notably, the study of Loturco et al. (22) comprised a sample of rugby union players (and not sevens players). This is an important aspect to consider because rugby sevens is characterized by a lower number and frequency of tackles and scrums in comparison with fifteen-a-side rugby union (30) and thus, by fewer "aggressive" cuts and accelerations-decelerations. Still, caution is necessary when contrasting these results because direct comparisons between male and female athletes may lead to erroneous interpretations and conclusions (24).

Female soccer players displayed the lowest sprint momentum, but no differences were found between handball and rugby sevens players. Interestingly, this variable, previously suggested to be a potential key factor explaining why faster and heavier athletes are less efficient at changing direction (11,12), was significantly correlated with a COD deficit only in the rugby players (the ones with the highest deficits). Considering that these athletes displayed similar sprint momentum to the handball players but presented lower body mass, it is plausible to assume that sprint velocity per se is the most important factor explaining the differences in COD deficit magnitude between these 2 sport disciplines. Again, the specific RST (i.e., an acceleration-oriented stimulus) performed by the rugby (but not by the handball players) could have potentially influenced our findings (1,20). Nevertheless, more research is clearly warranted to determine the actual influence of velocity, body mass, and sprint momentum on the ability of female team sport athletes to efficiently change direction.

When examining the relationships between variables, handball players (who exhibited the highest COD speed but the lowest COD deficit among the studied sample) were the only athletes displaying very large associations between straight sprint and Zigzag velocity. As such, it seems that, to perform the COD test, female handball players used their linear velocity "positively" and to a greater extent when compared with the rugby players. To some degree, this is in line with previous results showing that (a) male rugby players were not more effective than handball players at changing direction (22) and (b) male rugby players faster in linear sprints presented greater magnitudes of COD deficit (when compared with their slower peers) (11). Moreover, and supporting recent research (28), the present results showed very large to nearly perfect correlations between sprint velocity and COD deficit, implying that these 2 variables are, indeed, related.

In summary, the ability to change direction differs significantly between elite female players from different team sports. Handball players presented faster COD velocities and lower COD deficits when compared with rugby sevens and soccer players. Moreover, rugby players were found to be the least efficient at changing direction, whereas soccer players presented the lowest velocities at the shortest distance (VEL 5-m). Coaches and sport scientists should consider these relevant and specific differences when designing specific COD training programs for professional female rugby, handball, or soccer athletes.

This study is naturally limited by its cross-sectional design; therefore, it is not possible to determine causal relationships from the data set. In addition, the specific training content performed by the athletes throughout the season was not controlled or prescribed within this study. However, the technical staff of the teams involved provided the general and regular characteristics of the training programs, which can be used as a framework to understand their usual training practices. Nevertheless, this is the first study to show these marked and particular differences and sport-specific relationships in a large sample composed of 154 professional female athletes from 3 different team sports. Further research is needed to examine the effects of different training interventions on the COD ability of these athletes.

## Practical Applications

The between-sport differences observed in this study indicate that the game demands and sport-specific training models may affect linear sprint and COD performance. As such, it seems that training regimens centered on strength-power and speed development may not be sufficient to ensure faster COD velocities and lower deficits if athletes are not regularly exposed to COD training strategies. To increase the ability to tolerate high entry velocities in COD maneuvers, complementary training approaches may be required, especially in female rugby sevens and soccer players. Also, given the importance of acceleration, deceleration, and directional changes in soccer, female soccer players would seemingly benefit from tailored training schemes, specifically focused on the development of COD-related qualities.

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