Deceleration profiles of elite American soccer players obtained from change of direction tests with different approach speeds

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Headline

Soccer is a dynamic sport that requires rapid changes in direction, sudden stops, and quick transitions between high-intensity actions (8,12). High-intensity horizontal decelerations are a common aspect of match play and exhibit distinct biomechanical and physiological traits (11,13). Horizontal deceleration ability refers to an athlete's proficiency in effectively reducing whole-body momentum within specific task constraints and objectives, such as controlling braking force (10). This allows players to maintain control of the ball and position themselves optimally during play. Due to frequent engagement in horizontal decelerations, soccer players must possess resilient musculoskeletal systems to effectively manage braking forces and mitigate the potentially harmful effects of these intense actions (11).

Horizontal deceleration should be developed as a movement skill alongside enhancing a player's eccentric strength capacity and neuromuscular performance in off-field training (11). High-speed movements and abrupt decelerations place significant strain on the musculoskeletal system, particularly the lower extremities (9–11). Players who lack adequate deceleration mechanics are at a higher risk for injuries such as anterior cruciate ligament (ACL) tears, hamstring strains, and other lower-body injuries (2,10,11,14). Proper deceleration technique reduces the impact forces on joints and muscles, helping to prevent these common injuries (11). Consequently, deceleration training is not only essential for peak performance but also for ensuring player longevity and minimizing time lost to injury. Players who can decelerate quickly are better equipped to adapt to the unpredictable nature of the game, such as responding to an opponent's sudden change in direction or stopping to make a crucial shot, pass or tackle.

Therefore, given their importance for soccer performance and injury prevention, horizontal decelerations deserve greater attention in terms of assessment, training, and monitoring (11,13). One may wonder if the deceleration qualities are unique to the various tests and entry speed of a change of direction (COD). Also, from a practical perspective, it would be of interest to understand if the ability to decelerate was associated with peak speed and if there was a relationship between the various deceleration phases in COD tests with different approach speeds. For instance, practitioners may want to know that if you want to get better at decelerating at high speeds you must specifically work on decelerating from higher speeds.

Aim

The aim of this study was to compare the deceleration ability of elite American soccer players during COD tests with different approach speeds. This approach allows us to assess the variability and relationship of how players decelerate from various peak velocities to help us better understand areas of focus for training and return to play.

Methods

Participants in the study included elite level American first division soccer players (n = 20), brought together for a national training camp. All testing took place on a grass surface with players using their own soccer boots. Firstly, players went through a structured warm up which consisted of a sequence of general movements, followed by a brief pause, 2 minutes of self-guided stretching, and dynamic movements specifically designed to prepare for acceleration and changes of direction, culminating in three progressive build-ups to 20 meters, with a total warm-up duration of 10 minutes. Then, the players completed two trials of the 10-0-5 COD test with a left foot and then right foot turn. These procedures where then repeated for the 20-0-5 and 30-0-5 COD tests, with a 90-second recovery between trials. In brief, all these COD tests involve an initial acceleration, deceleration, 180° turn followed by a re-acceleration, with approach distance prior to the turn differing for each test. For example, 10-0-5, 20-0-5 and 30-0-5 involve a 10m, 20m, 30m approach, respectively, prior to performing a 180º turn and 5m re-acceleration. Therefore, with each increase in approach distance, the opportunity to obtain greater peak velocity (i.e., momentum) increases. Video was captured at 60 Hz using an iPhone 13 (Apple Inc., Cupertino, CA, United States) and uploaded to an advanced artificial intelligence and computer vision system (VueMotion, Sydney, Australia) to obtain detailed analysis of each players deceleration and COD performance. This VueMotion system has been reported to have high accuracy compared to a three-dimensional motion capture system when evaluating dynamic athletic movements (4). Metrics analysed included:

- Peak speed ($m \cdot s^{-1}$): The highest speed reached during each COD test. Note, that this is the maximum speed reached during the COD test and is not necessarily the maximum capacity of the player.

- Average deceleration (m·s^{-2}): Difference between maximum and minimum speed measured prior to COD divided by time-to-stop.
- Average early deceleration (m·s^{-2}); Difference between maximum speed and 50% of maximum speed prior to COD divided by early deceleration time.
- Average late deceleration (m·s^{-2}); Difference between 50% maximum speed and minimum speed prior to COD divided by late deceleration time.

The average of the left and right foot for each COD test was used for analysis. All correlations were interpreted using the scale from Hopkins (2002) as: trivial (r = 0.00–0.09), small (r = 0.10-29), moderate (r = 0.30-0.49), large (r = 0.50-0.69), very large (r = 0.70-0.89) and almost perfect (r = 0.90-0.99). Z-scores and total deceleration scores (TDS) were calculated based on recommendations adapted from the total score of athleticism (TSA) (16).

Results

Figure 1 illustrates the horizontal deceleration profiles obtained during the 10-0-5, 20-0-5 and 30-0-5 COD tests. Average deceleration was similar across each COD test (-5.36 ± 0.42 m·s^{-2}, -5.03 ± 0.22 m·s^{-2}, -5.34 ± 0.30 m·s^{-2} for 10, 20 and 30m approach, respectively). The early deceleration subphase had the lowest average deceleration magnitudes (-4.73 ± 0.49 m·s^{-2}, -4.20 ± 0.23 m·s^{-2}, -4.64 ± 0.42 m·s^{-2} for 10, 20 and 30m approach, respectively), with the highest average deceleration magnitudes observed in the late deceleration subphase (-6.70 ± 0.72 m·s^{-2}, -6.82 ± 0.57 m·s^{-2}, -6.65 ± 0.61 m·s^{-2} for 10, 20 and 30m approach, respectively).

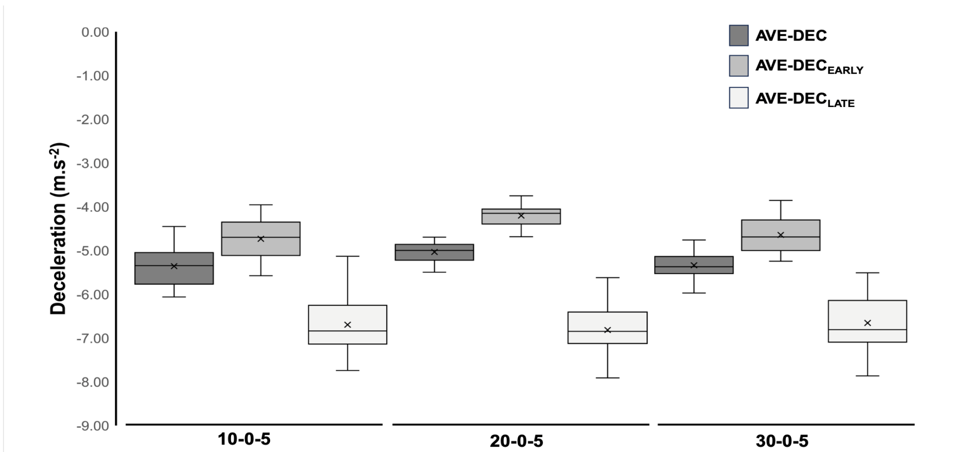

Fig. 1. Horizontal deceleration profiles obtained during 10-0-5, 20-0-5 and 30-0-5 change of direction tests. AVE-DEC = average deceleration

Table 1 illustrates the association between average deceleration (m·s^{-2}) and peak speed (m·s^{-1}) attained during each COD test. Average deceleration attained during 10-0-5 and 20-0-5 was not significantly associated (r = -0.30 and -0.43; respectively) with peak speed attained during the same COD tests. Only average deceleration attained during 30-0-5 COD test was significantly associated (r = -0.86; p < 0.001) with peak speed attained during the same COD test.

Table 1. Correlations between average deceleration (m·s^{-2}) and peak speed (m·s^{-1}) attained during each change of direction test.

	10-0-5 Peak Speed (m·s^{-1})	20-0-5 Peak Speed (m·s^{-1})	30-0-5 Peak speed (m·s^{-1})
10-0-5 Average Deceleration (m·s^{-2})	-0.30 (M)	0.04 (T)	-0.01 (T)
20-0-5 Average Deceleration (m·s^{-2})	-0.37 (M)	-0.43 (M)	-0.38 (M)
30-0-5 Average Deceleration (m·s^{-1})	-0.23 (S)	-0.35 (M)	-0.89 (VL)

T = trivial, S = small, M = moderate, VL = very large. Dark red = very large significant correlation.

Figures 2-4 show the quadrant plot representing the average deceleration and peak speed attained during the 10-0-5, 20-0-5, and 30-0-5 COD test for each player. Table 2 displays the correlations between average deceleration and early and late deceleration sub-phases measured during the 10-0-5, 20-0-5 and 30-0-5 COD tests. A small correlation was observed between average deceleration attained during 10-0-5 COD test with that obtained during the 20-0-5 and 30-0-5 COD tests (r = 0.10-0.20). In contrast, a large significant correlation was observed between average deceleration attained during 20-0-5 and 30-0-5 COD tests (r = 0.55, p = <0.05). Early deceleration had very large significant correlations with average deceleration attained during 10-0-5 (r = 0.85; p < 0.001), 20-0-5 (r = 0.71; p < 0.001) and 30-0-5 (r = 0.77; p < 0.001) COD tests. However, correlations between the late deceleration subphase and average deceleration were smaller in magnitude (r = 0.25 – 0.54) across all COD tests.

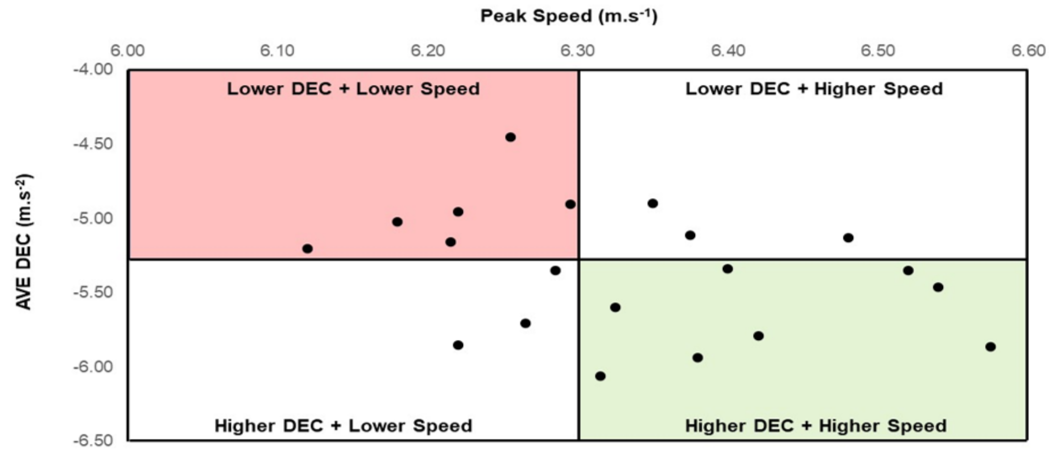

Fig. 2. Quadrant plot representing the average deceleration (AVEDEC – y-axis) and peak speed (x-axis) attained during the 10-0-5 test for each player

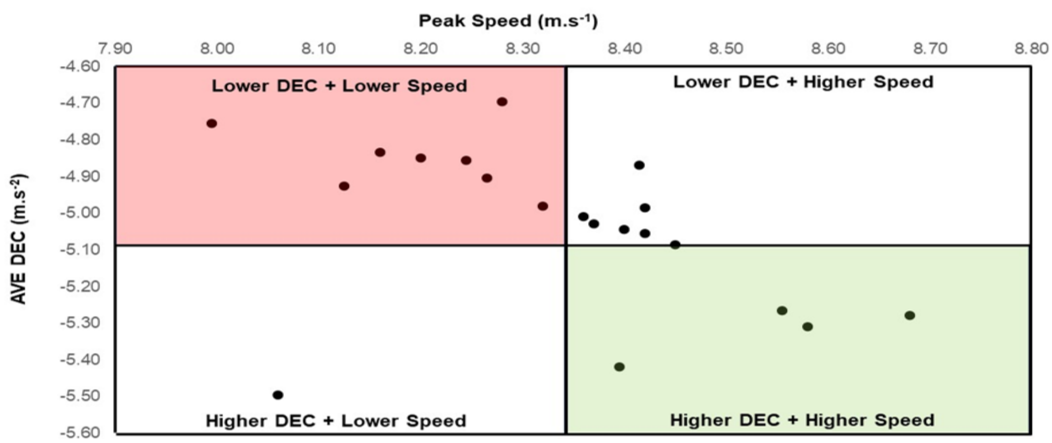

Fig. 3. Quadrant plot representing the average deceleration (AVE DEC – y-axis) and peak speed (x-axis) attained during the 20-0-5 test for each player

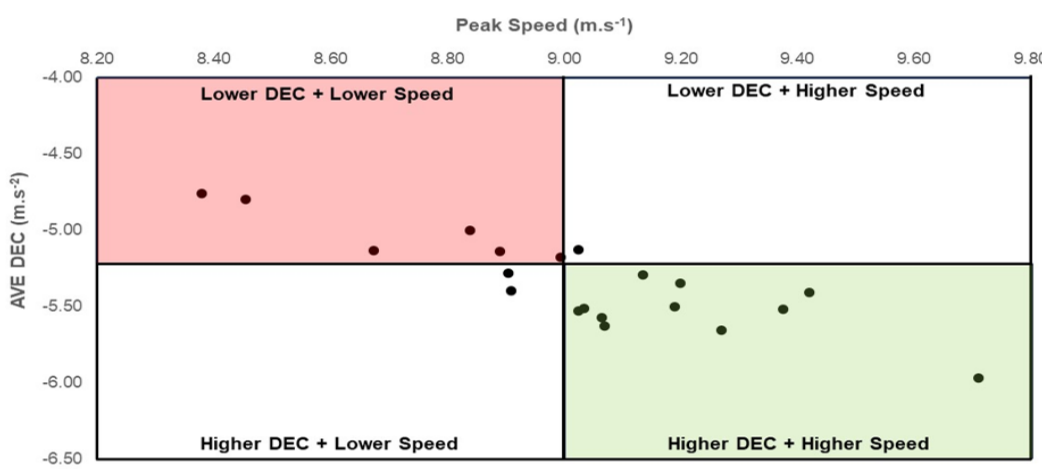

Fig. 4. Quadrant plot representing the average deceleration (AVE DEC – y-axis) and peak speed (x-axis) attained during the 30-0-5 test for each player

Table 2. Correlations between average deceleration ($m \cdot s^{-2}$) and early and late deceleration ($m \cdot s^{-2}$) sub-phases attained during each change of direction test.

		10-0-5			20-0-5			30-0-5		
		Ave DEC	Early DEC	Late DEC	Ave DEC	Early DEC	Late DEC	Ave DEC	Early DEC	Late DEC
10-0-5	Ave DEC	**1.00**								
	Early DEC	0.85 (VL)	**1.00**							
	Late DEC	0.53 (L)	0.02 (T)	**1.00**						
20-0-5	Ave DEC	0.22 (S)	0.26 (S)	-0.09 (T)	**1.00**					
	Early DEC	0.04 (T)	0.09 (T)	-0.15 (T)	0.71 (VL)	**1.00**				
	Late DEC	0.29 (S)	0.32 (M)	0.02 (T)	0.54 (L)	-0.20 (S)	**1.00**			
30-0-5	Ave DEC	0.10 (S)	-0.03 (T)	0.17 (S)	0.55 (L)	0.45 (M)	0.21 (S)	**1.00**		
	Early DEC	-0.02 (T)	0.06 (T)	-0.14 (S)	0.31 (M)	0.40 (M)	-0.01 (T)	0.77 (VL)	**1.00**	
	Late DEC	0.19 (S)	-0.07 (T)	0.41 (M)	0.33 (M)	0.03 (T)	0.36 (M)	0.25 (S)	-0.42 (M)	**1.00**

Ave = average, DEC = deceleration, T = trivial, S = small, M = moderate, L = large, VL = very large. Dark red = very large significant correlation. Light red = large significant correlation.

Figure 5 illustrates individual player total deceleration scores (TDS) calculated using sum of z-scores (16) attained from each player's average deceleration performance in 10-0-5, 20-0-5 and 30-0-5 COD test, which can be used to identify players who have well rounded deceleration performance qualities.

Figure 6 illustrates players with above and below average deceleration in the 10-0-5, 20-0-5 and 30-0-5 COD tests. Results illustrate that a player could have above average deceleration performance from lower approach speeds (i.e., 10-0-5) with below average deceleration performance from higher approach speeds (i.e., 30-0-5), and vice-versa.

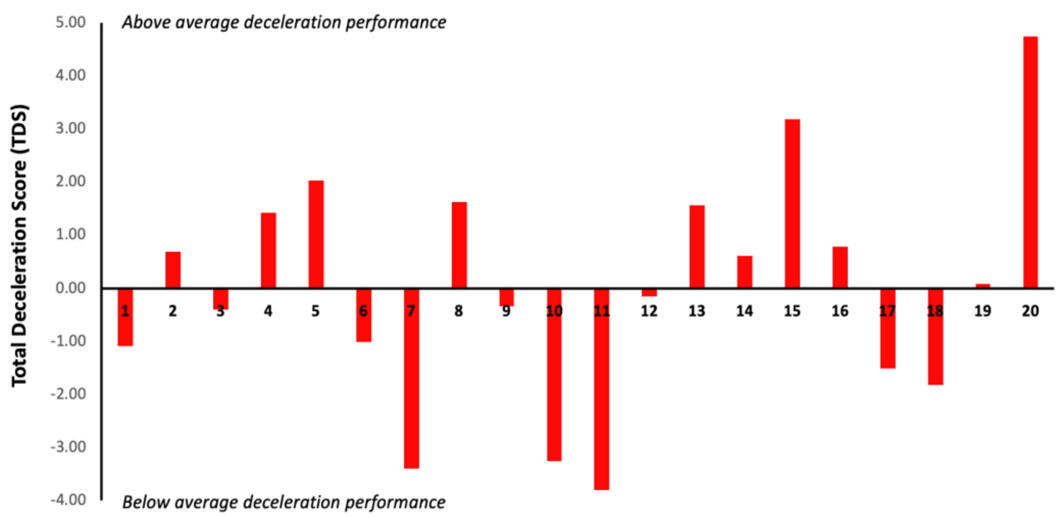

Fig. 5. Individual player total deceleration scores (TDS). Uses sum of z-scores attained from 10-0-5, 20-0-5 and 30-0-5 to illustrate an overall deceleration ability during change of direction tests with different approach velocities

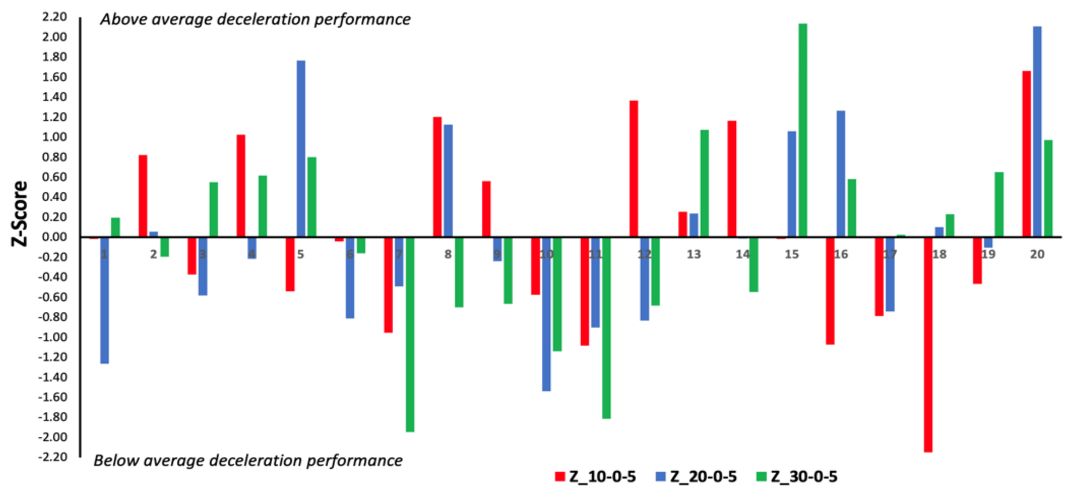

Fig. 6. **Z-scores illustrating players with above and below average deceleration in the 10-0-5 (red), 20-0-5 (blue) and 30-0-5 (green) COD tests**

Discussion and Conclusion

The aim of this study was to compare the deceleration ability of elite American soccer players during COD tests with different approach speeds (i.e., 10-0-5, 20-0-5 and 30-0-5). Our study found that deceleration magnitudes are lower in the early deceleration sub-phase and highest in the late deceleration sub-phase, with early deceleration strongly predicting overall deceleration performance (r = 0.71 to 0.85). Average deceleration was significantly correlated with peak speed in the 30-0-5 COD test (r = -0.89), but not in the shorter tests (10-0-5; r = -0.30 and 20-0-5; r = -0.43). Furthermore, there was only small correlations observed between average deceleration achieved in the 10-0-5 with that attained during the 20-0-5 (r = 0.22) and 30-0-5 (r = 0.10). There findings suggest distinct deceleration demands exist across different COD tests, emphasizing the need for individualized training. We recommend using evidence-based frameworks, like the “Braking Performance Framework”, to improve players’ horizontal deceleration abilities and reduce injury risks during match play (7).

Average deceleration magnitudes were lowest in the early deceleration sub-phase and highest in the late deceleration sub-phase (Figure 1). This may be better explained by the braking steps leading up to the final foot plant in a COD, which are crucial for slowing down the system’s center of mass, enabling propulsion into the new direction (11). This process not only enhances COD performance but also helps decrease multi-planar knee joint stress during the final foot plant (11). In intense COD movements, the limited time available for whole-body postural adjustments may lead to suboptimal frontal and transverse motion patterns, increasing the risk of harmful knee-joint loading (i.e., ACL injuries) during the last foot contact (11). This is further emphasised in the deceleration profiles across each COD test in the current study, where the highest deceleration magnitudes are observed in the late deceleration sub-phase (Figure 1). As such, training to enhance early deceleration performance may not only transfer to enhanced deceleration performance but may also have important implications for mitigating tissue damage and various lower extremity injuries in soccer players.

In addition, our results showed that average deceleration attained during 30-0-5 COD test was significantly correlated with peak speed attained during this test (r = -0.89), whilst no significant correlation was observed between average deceleration and peak speed during the shorter 10-0-5 and 20-0-5 COD tests (r = -0.30 and -0.43, respectively). These findings imply that at longer distances, the ability to decelerate effectively may be more influenced by the speed achieved prior to braking. In this regard, a previous study concluded that approach distance affected the deceleration required for velocity adjustments to complete the COD maneuver (5). Moreover, there was a stronger correlation between deceleration in the longer COD tests (i.e., 20-0-5 and 30-0-5) than between the 10-0-5 and longer 20-0-5 and 30-0-5 COD tests. This could be attributed to the different demands of decelerating from higher speeds in the longer tests or players’ deceleration capabilities. Therefore, when testing deceleration abilities, it is recommended to profile players across different approach speeds so that coaches and biomechanists can collaborate with players to identify the most effective deceleration training strategies to target individual needs (Figure 6), thus helping them condition their bodies to handle the loading demands associated with high-risk deceleration and COD movements (6). It is important to note, that use of motorised resistance devices (such as the 1080 sprint), whilst being an effective strategy to overload deceleration in different COD sub-phases could also influence the magnitudes of the correlations reported here in the current study. For example, Buchheit and Eriksrud (1) reported large correlations between maximum deceleration and peak speed attained during a 15-0-5 COD test, which is larger than those reported in the current study for the 10-0-5 and 20-0-5 COD tests.

In addition, this study observed that early deceleration phase had a very large significant correlation with the average deceleration achieved in all three COD tests (r = 0.71 to 0.85), meaning that how well an athlete decelerates early may be a strong predictor of their overall deceleration performance across these tests. Specifically, players’ ability to brake effectively at the beginning of a deceleration phase may have greater impact than their ability to decelerate later. In this context, a previous study concluded that the antepenultimate foot contact played a more crucial role in aiding deceleration than the penultimate foot contact for optimal 505 COD performance (3). This could suggest that training programs might prioritize improving early-phase deceleration to optimize overall performance in tasks that involve a COD.

Finally, the present findings suggest that, overall, some players were good decelerators in certain COD tests but not in others (Figure 6), further indicating that distinct deceleration demands exist for each test due to differences in peak speed and the specific qualities required to decelerate effectively. A player's ability to decelerate quickly and efficiently can be the difference between successfully executing a play or losing possession, making it a fundamental skill for elite performance. However, given the wide variety of deceleration profiles, individualized training strategies should be adopted. Unfortunately, limited focus has been given to training strategies specifically designed to enhance an athlete's horizontal deceleration ability. Performance practitioners should adopt approaches like the "Braking Performance Framework", which offers a range of evidence-based training methods that can be integrated with key physical, technical, and tactical components to optimize player's preparation for performing and tolerating repeated horizontal decelerations during match play (7).

This study presents several limitations that need to be acknowledged. For example, sample size is limited to the squad size of an elite soccer team. Also, differences between preferred and non-preferred legs were not considered and future studies could investigate how preferred legs impact the way players decelerate (15).

Key Findings

- Some players are good decelerators in certain tests but not in others, indicating that distinct deceleration demands exist for each test due to differences in peak velocity and the specific qualities required to decelerate effectively.
- Generating high deceleration during the early deceleration phase is key to achieving greater overall deceleration across all COD tests.
- A higher peak speed in shorter COD tests (i.e., 10-0-5/20-0-5) does not necessarily correlate with greater deceleration.
- The highest average deceleration values occur during the late deceleration phase across all COD tests. It is important to note that some players generate greater deceleration in the early phase compared to the late phase (represented by a deceleration ratio > 1; meaning different braking strategies and abilities are evident amongst players during COD tests).

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