

Hitting the Brakes in Soccer: Individualised Thresholds for Assessing High-Intensity Decelerations during Matches

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ABSTRACT

There is currently a lack of understanding surrounding how to quantify high-intensity deceleration actions in soccer. Therefore, this study sought to compare the use of arbitrary (ARB) and individualised (IND) high-intensity deceleration thresholds when examining the most demanding passages of play (MDP) and full matches. Fourteen male soccer players (age = 19.44 ± 1.13 yrs.; mass = 79.14 ± 7.88 kg; height = 184.16 ± 5.00 cm) were monitored during competitive matches using global positioning systems (WIMU Pro, RealTrack System SL, Almeria, Spain). IND thresholds were determined as 75% of a subject's peak deceleration ability from match data. ARB values were set as $> 4\text{m/s}^2$ with the differences between these high-intensity deceleration thresholds analysed. ARB thresholds resulted in significantly ($p < 0.01$) larger distance and count metrics compared to IND during both MDP and full matches. These findings highlight the notable differences between ARB and IND high-intensity deceleration thresholds in matches. Thus, it is recommended a modified IND threshold approach is used when analysing the high-intensity deceleration demands of matches and MDP. Practitioners may be inclined to monitor high-intensity decelerations using IND thresholds, as is suggested when measuring other locomotor tasks during soccer training and matches.

Keywords: Change of Direction; Most Demanding Passages of Play; Global Positioning Systems; Load

Monitoring.

INTRODUCTION

Deceleration can be characterised as the ability to reduce whole-body momentum relative to the specific objective of the task, whilst skilfully attenuating the forces associated with braking (19). It has been well-documented that multidirectional sports are primarily aerobic in nature (3), yet it is the high-intensity anaerobic activities, such as deceleration, which can distinguish match outcomes and performance levels (27,36). For example, a recent study showed high-intensity ($\leq -3\text{m/s}^2$) decelerations preceded 40% of all goals scored in the 2018/19 English Premier League season (32). Additionally, previous research has reported when high-intensity decelerations ($\leq -3\text{m/s}^2$) were elevated in an English League Two team, match outcomes typically resulted in victory (41). However, ground reaction forces during high-intensity decelerations can reach as high as six times one's bodyweight (50), thus exposing the athlete to high mechanical loads which may increase injury risk (7,23,49). Indeed, findings from two systematic reviews suggest high-intensity decelerations are most likely to precede anterior cruciate ligament (ACL) ruptures (51) and contribute to 35% of all hamstring injuries (20). Moreover, recent research in male soccer players reported that 50% of ACL injuries occurred during pressing movements when the player is decelerating (12). Therefore, considering the

potential implications such as injury risk and team success in soccer resulting from decelerations, it is necessary to understand how to best measure this high-intensity action.

Traditionally, assessing deceleration in soccer has been determined using change of direction tests to derive an accurate peak deceleration value (21,36). For example, common tests used to assess deceleration ability in soccer include the 5-0-5, modified 5-0-5, T-test, and pro-agility shuttle (36). However, these tests have been critiqued due to limitations to adequately demonstrate discriminant validity because total time is typically assessed (36). Indeed, using total time to assess change of direction ability can be affected by an athletes' acceleration qualities which can mask their deceleration ability due to entry velocity, re-acceleration after the turn, and pacing strategies (24,36). Therefore, to ensure an accurate measurement of deceleration is obtained, it is preferable for instantaneous velocity values to be analysed during the movement task (24). As a result, several recent studies have used radar gun technology to accurately quantify peak deceleration in athletes (9,24). However, despite the usefulness of such an approach, issues exist such as equipment, transfer of testing environment, and time to complete (38). Therefore, in-situ approaches in which measurements are derived from global positioning systems (GPS) tracking may offer a more effective solution as it offers a non-invasive, invisible monitoring procedure for practitioners to help quantify the deceleration demands of match play (35). Indeed, in a recent survey of 72 practitioners who used GPS technology in team sports (soccer = 49), over 70% of respondents agreed that they found GPS metrics easy to analyse and report (10).

Decelerations are currently quantified using arbitrary (ARB) thresholds akin to acceleration (22). For example, commonly used thresholds to quantify high-intensity acceleration and deceleration activities in soccer are 3 m/s² (40). An issue with ARB thresholds is the lack of ability to account for an individual's physical capacity (1). Indeed, previous research in soccer reported high-speed running distances to be ~111% greater when using individual (IND) compared to ARB thresholds (47). Therefore, to increase the accuracy of measuring high-intensity activities, IND thresholds are recommended (18). By implementing an individualised approach, intensity thresholds are determined that are specific for each player. The importance of such an approach was recently recognised by authors who used linear regression

analysis to classify high-intensity acceleration thresholds in male soccer players (46). Their findings proposed that high-intensity accelerations should be quantified using 75% of one's maximal acceleration ability with 3 m/s² representing only 50% of maximal voluntary acceleration. This may have important implications for quantifying deceleration efforts when considering several studies have reported peak deceleration values during soccer matches to be above -6 m/s² (28,45). Therefore, a percentage method approach might help to determine relative intensity of decelerations in soccer.

The most demanding passages of play (MDP) are defined as the most intense or chaotic periods of a match relative to time (31). By evaluating MDP alongside full matches, practitioners can prescribe training volumes and intensities that mirror the intermittent nature of multidirectional sport (52). Limited research has examined high-intensity deceleration demands during MDP. However, high-intensity (≤ -3 m/s²) deceleration distances covered during a 1-minute MDP are nearly 80% higher than the average distance observed across a whole match (42). This finding highlights the need for further research on high-intensity deceleration demands to inform training decisions and optimise player exposures (52). However, limited work exists on the deceleration demands during MDP, and commonly used thresholds may underestimate or overestimate actual decelerations. This gap in knowledge may leave athletes unprepared for the demands of competition, thereby limiting performance or increasing injury risk. As a result, further understanding on how to quantify high-intensity decelerations in soccer will support the day-to-day practices of coaches. Therefore, the aim of this study was to investigate differences between absolute and individualised high-intensity deceleration thresholds across MDP and full matches in soccer. We hypothesised that significant differences would emerge between ARB and IND high-intensity deceleration demands in both MDP and full matches.

METHODS

Experimental Approach to the Problem

The investigation was a longitudinal cross-sectional design, which did not include a control group and involved retrospectively analysing match data to quantify deceleration intensities. High-

intensity deceleration exposures during MDP and full matches were assessed using GPS over 11 competitive matches of the 2023/24 English soccer season. The distance (meters) and number of exposures (count) for ARB and IND thresholds were recorded and analysed.

Subjects

A priori sample size estimate was conducted prior to data collection to determine the minimum sample size required using G*Power (University of Düsseldorf, Dusseldorf, Germany). A minimum of nine subjects were required based on a within factors analysis using a moderate effect size ($d = 0.60$) from previous studies (5,8), a power of 90%, and an alpha value of 0.01. Subsequently, 14 male soccer players (age = 19.44 ± 1.13 yrs.; mass = 79.14 ± 7.88 kg; height = 184.16 ± 5.00 cm, central defenders: $n = 3$, wide defenders: $n = 3$, central midfielders: $n = 4$, wide midfielders: $n = 3$, forwards: $n = 1$) volunteered to participate. Subjects participated in university and club competitions which can require up to 1-3 matches per week. Additionally, subjects trained 2-3 times per week consisting of gym, recovery, and technical/tactical sessions. Similar to previous research, the following inclusion criteria was implemented for the analysis (3,34,44): i) played in at least 80% of matches during the season ii) completed at least 75% of a full match (~65 minutes) iii) did not suffer an injury within 3 months of data collection. Anthropometric data, including height (Leicester stadiometer, SECA, UK) and weight (SECA Electronic Scales 813, SECA, UK), was collected for all subjects. Prior to data collection beginning, all subjects provided informed consent and health history questionnaire information, and all testing procedures were approved by the Ethics Committee of the institution.

Procedures

Match data was collected from 11 official matches including cup and regular season fixtures (January – March 2024). The team adopted a 4-3-3 formation which approached matches with a combination of possession-based and direct-play tactics. All matches were played on grass surfaces, whereas training was conducted on artificial grass surfaces. To accurately assess high-intensity deceleration exposures during full matches and MDP, subjects wore a tightly fitted vest containing an 18Hz Wireless Inertial Measurement Unit (WIMU) Pro (RealTrack System SL, Almeria, Spain) GPS unit located between the scapulae. The use of WIMU Pro

devices have been cleared by FIFA for use in official matches (FIFA - WIMU Pro). The inter- and intra-unit reliability (CV = 4.3 – 14.3%; ICC = $\geq 90\%$; SWC = 7.6 – 8.3%) of the WIMU Pro system has been shown to be good to excellent in quantifying the high intensity demands of soccer (6,19,39). Each device was assigned to a specific player for the season to mitigate potential inter-unit variability. All WIMU Pro units were turned on before the matches according to the manufacturer's instructions. Only data with appropriate satellite signal (≥ 14 satellites) and horizontal precision of dilution (≤ 2) (30), were included in the dataset. All data was analysed post-match with both high-intensity deceleration thresholds (IND and ARB) applied on the WIMU SPro software (RealTrack, Almeria, Spain), before being exported and stored in a code-encrypted Microsoft Excel spreadsheet.

Classification of High-Intensity Deceleration Thresholds

Prior to data collection beginning for the 11 official matches, players peak deceleration values were recorded during a total of six sessions which involved pre-season friendlies and training practices (i.e., in-situ). The total number of sessions was chosen to provide a more stable measure of players peak values since an increased number of matches results in lower variation (13) whilst also taking into account logistical constraints (e.g., player availability). The in-situ method was chosen based upon pilot testing which investigated the usefulness of a linear acceleration to deceleration (ADA) assessment like that of Harper et al. (2022). However, our results demonstrated poor between-session reliability for both distances of 20m (Mean = -5.80 m/s²; $g = 0.43$; ICC = 0.48; CV = 11.7%) and 30m (Mean = -5.60 m/s² $g = 0.09$; ICC = 0.63; CV = 20.8%). Moreover, the ADA assessment resulted in lower peak deceleration values than those achieved during the in-situ testing (See Microsoft Excel Sheet provided in the supplementary material). This finding is also supported by previous literature, which found unanticipated deceleration exposures to elicit superior braking impulses and therefore higher peak decelerations compared to isolated, preplanned tests (15,50), such as the ADA test. Therefore, for this investigation, players peak deceleration ability was derived from an in-situ monitoring approach and thresholds were implemented accordingly.

Data Analysis

The highest peak deceleration value recorded during

the familiarisation period was used to determine the IND thresholds (Table 1) for data collection in this study. All peak deceleration values were extracted from the WIMU SPro system before data collection commenced. WIMU Pro defines deceleration as the rate at which one's velocity decreases during a specific time interval (**WIMU PRO - Deceleration**). For most subjects, the ARB high-intensity threshold remained less than 50% of their peak deceleration ability (Table 1). Hence why ARB (-4 m/s²) and IND (75%) thresholds were used in this investigation to assess high-intensity deceleration demands. Moreover, the use of the -4 m/s² threshold to quantify high-intensity decelerations has been used by other soccer research too (45). When assessing the high-intensity deceleration during MDP, a 4-minute rolling average window was included in SPro using ARB (-4 m/s²) and IND (75%) thresholds. Not only are shorter time windows strongly associated with match outcomes (43), but they also help prepare athletes for the high-intensity physical demands of a match (11). Moreover, a 4-minute time window has been suggested by Fanchini et al., as an "optimal" training window (17). High-intensity deceleration distance (m) and count (n) metrics were chosen for MDP and full matches. Considering the literature which assesses the physical demands of multidirectional sport, distance or count metrics are usually chosen (53). Therefore, their inclusion within this study will add to current literature and allow for a comparative analysis with other studies investigating the mechanical demands of soccer.

Statistical Analysis

All data analyses were conducted using JASP statistical software (University of Amsterdam, Amsterdam, Netherlands). The Shapiro-Wilk test was used to assess the normality of the data. To compare ARB and IND thresholds, a paired samples t-test was applied for normally distributed data, while the Wilcoxon signed-rank test was used for non-normally distributed data (54). Statistical significance was set at $p < 0.05$. The coefficient of variation (CV% = SD/mean) was calculated for each threshold, categorized by session type (MDP or Match) and metric (distance or count). Effect sizes (ES) were computed using Hedges' g to determine the magnitude of between-group differences. Effect sizes were interpreted according to pre-defined ranges: <0.19 = trivial, $0.20-0.59$ = small, $0.60-1.19$ = moderate, $1.20-1.99$ = large, and $2.0-4.0$ = very large (26). Bootstrapped 95% confidence intervals, based on 1,000 resamples, were calculated for both CV% and effect size data. To visualize the dataset, raincloud plots were employed, illustrating both the overall distribution and individual observations (4).

RESULTS

Table 2 provides descriptive statistics for each measure (mean ± standard deviation, CV%) as well as comparisons between the IND and ARB thresholds. Paired samples t-tests were used for all comparisons except for IND MDP (m) vs ARB

Table 1. Maximum, minimum, and mean peak deceleration values observed from all matches with the corresponding individualised (IND) peak deceleration threshold calculated.

Subject	Max (m/s ²)	Min (m/s ²)	Mean (m/s ²)	IND (m/s ²)	ARB (m/s ²)	% ARB
Player 1	-9.08	-5.39	-6.76 ± 1.18	-6.81	-4.00	44.05%
Player 2	-9.16	-5.16	-6.89 ± 1.30	-6.87	-4.00	43.67%
Player 3	-8.81	-5.09	-6.47 ± 1.02	-6.61	-4.00	45.38%
Player 4	-8.73	-5.52	-6.75 ± 1.36	-6.55	-4.00	45.80%
Player 5	-8.88	-6.09	-7.45 ± 1.18	-6.66	-4.00	45.07%
Player 6	-8.80	-5.53	-6.45 ± 1.08	-6.60	-4.00	45.47%
Player 7	-8.34	-5.66	-6.91 ± 1.01	-6.26	-4.00	47.94%
Player 8	-8.74	-5.54	-7.14 ± 1.16	-6.56	-4.00	45.77%
Player 9	-8.06	-5.14	-6.44 ± 1.01	-6.05	-4.00	49.60%
Player 10	-7.79	-6.17	-6.75 ± 0.68	-5.84	-4.00	51.33%
Player 11	-9.04	-5.50	-7.00 ± 1.14	-6.78	-4.00	44.23%
Player 12	-9.34	-6.11	-7.61 ± 1.33	-7.01	-4.00	42.83%
Player 13	-9.42	-5.38	-6.88 ± 1.41	-7.07	-4.00	42.46%
Player 14	-9.47	-7.31	-8.32 ± 0.82	-7.10	-4.00	42.23%

Note. Max = maximum; Min = minimum; IND = individualised threshold calculated as 75% of peak deceleration from match data; ARB = arbitrary threshold; % ARB = Percent of arbitrary threshold relative to peak deceleration.

Table 2. Comparisons of Individualised and Arbitrary Deceleration Thresholds for Distance and Count Metrics.

Measure	Mean ± SD	CV%	Measure	Mean ± SD	CV%	p	Effect Size (g)
IND MDP (m)	1.64 ± 1.05	25.51 64.46 ^{79.80}	ARB MDP (m)	10.26 ± 10.25	17.57 99.82 ^{117.71}	0.006	0.93 1.15 ^{3.28}
IND MDP (n)	2.70 ± 2.03	51.18 75.28 ^{93.24}	ARB MDP (n)	19.78 ± 8.29	22.28 41.89 ^{58.50}	<0.001	1.90 2.75 ^{4.91}
IND Match (m)	20.56 ± 19.03	47.19 92.59 ^{118.92}	ARB Match (m)	149.84 ± 53.04	23.16 35.40 ^{44.29}	<0.001	2.46 3.15 ^{4.76}
IND Match (n)	7.99 ± 7.60	41.42 95.11 ^{118.67}	ARB Match (n)	28.14 ± 8.55	21.16 30.39 ^{36.21}	<0.001	1.50 2.42 ^{4.18}

IND = Individualised, ARB = Arbitrary, MDP = most demanding passage of play, CV% = Coefficient of variation percentage, m = meters, n = number, g = Hedges effect size. Numbers in superscript denote 95% bootstrapped confidence intervals.

MDP (m). Statistically significant differences were observed for all comparisons with ARB resulting in greater distance and count measures. The magnitude of the differences favouring ARB were *very large* for IND MDP (n) vs ARB MDP (n), IND Match (m) vs ARB Match (m) and IND Match (n) vs ARB Match (n), whilst IND MDP (m) vs ARB MDP (m) was *moderate*.

DISCUSSION

The aims of this study were to examine the differences between ARB and IND high-intensity deceleration thresholds when considering MDP and full matches in soccer. This is the first study

to investigate applying ARB and IND thresholds when examining the high-intensity deceleration demands of MDP and full matches in soccer. As hypothesised, there were significant differences between IND and ARB high-intensity decelerations for MDP and full matches. Moderate to very large differences were observed, with the ARB threshold displaying greater distance and more high-intensity deceleration exposures than the IND threshold during both MDP and full matches. Therefore, the findings from the current study suggest that the use of ARB thresholds for quantifying high-intensity deceleration actions in soccer may not be appropriate due to overestimations and variability within heterogenous populations.

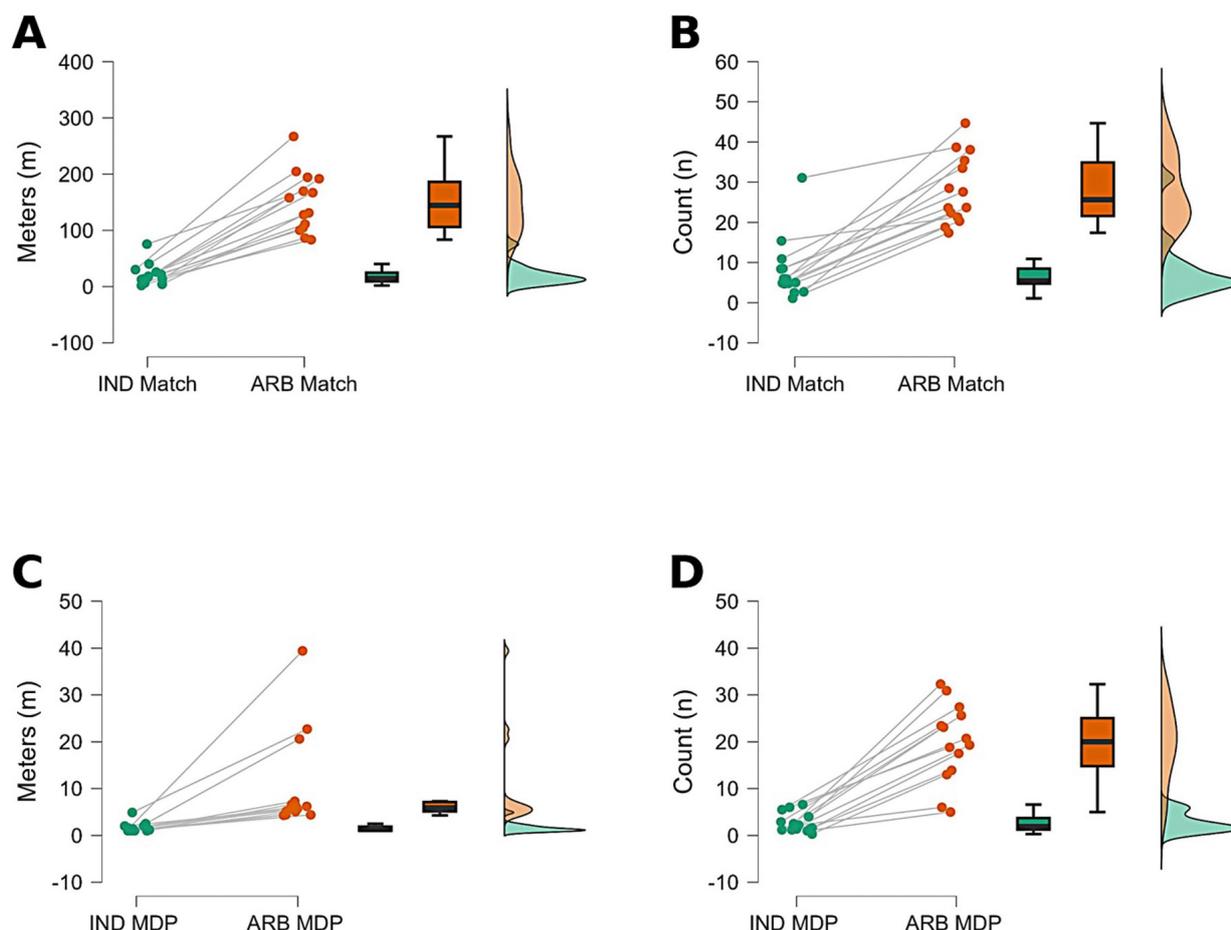


Figure 1. Raincloud plots of IND and ARB decelerations threshold for A = IND Match (m) vs ARB Match (m) distance, B = IND Match (n) vs ARB Match (n) count, C = IND MDP (m) vs ARB MDP (m) distance, D = IND MDP (n) vs ARB MDP (n) count.

Our results demonstrated significantly greater high-intensity decelerations for ARB compared to IND thresholds over full matches. This supports earlier evidence indicating that ARB thresholds can overestimate high-intensity actions in soccer. For example, Abbott et al. (1) reported significantly lower high-intensity accelerations when individualised to 75% of players maximal acceleration capacity compared to a global threshold. Subsequently, the *very large* differences we observed between IND and ARB thresholds suggests that practitioners should reconsider how high-intensity decelerations are quantified, especially given that GPS data from matches may guide training design (29). Indeed, coaches and performance staff use training data to assess physical outputs compared to what players do in a match (37). Consequently, employing standard ARB thresholds to track high-intensity deceleration efforts may result in players not being adequately physically prepared. For context, when using an ARB deceleration threshold of $\leq -3 \text{ m/s}^2$, the frequency of high-intensity actions in professional soccer has been reported to be ~ 60 in La Liga (28), ~ 70 in Ligue 1 (34), and ~ 90 in the Premier League (34). Thus, based upon IND thresholds, it is likely there are fewer occasions in a match that expose players to high-intensity deceleration efforts, implying that training must be adjusted accordingly.

During MDP, the IND threshold resulted in less high-intensity decelerations being recorded relative to the ARB threshold (Table 2). This may indicate fewer exposures are needed within the training week to help prepare players for the physical demands of a match. Although previous literature is yet to implement IND thresholds to monitor decelerations, research which has utilised similar high-intensity ARB thresholds have encountered similar results. Using a bandwidth of -3 to 5 m/s^2 to monitor high-intensity decelerations, a study involving national level second division football players reported the average number of exposures per session across a two-week training period was 10.27 exposures (48), slightly higher than the IND threshold value found in this study (Table 2). Therefore, although a lower number of high-intensity deceleration exposures, particularly from the IND threshold, are possibly performed during MDP than initially thought, it is important for practitioners to recognise individual differences and the upper and lower bandwidths across the squad. As per the findings of the IND threshold in Figure 1B and 1D, there is variation in the number of high-intensity decelerations where certain players are performing ~ 2 , and others performing ~ 6 decelerations during MDP, whilst

matches may have players performing ~ 2 , and other as high as ~ 30 decelerations. Due to this wide variation, from a training perspective, this could involve designing task-specific or constrained drills that expose players to similar volumes, intensities, and densities of high-intensity decelerations according to their match outputs. However, since there has been a lack of research investigating appropriate training dosages for high-intensity decelerations (33), practitioners are encouraged to evaluate the physical demands of decelerations within their team before incorporating specific training protocols.

The differences between ARB and IND high-intensity deceleration thresholds may have significant implications for player preparation. While the number of high-intensity decelerations may be lower than previously assumed during a soccer match, their intensity remains substantial. For instance, peak vertical ground reaction forces during deceleration can reach $6.3 \times \text{BW}$ and require high eccentric muscle forces (49). Moreover, deceleration is not confined to just the final step, with high vertical impact forces and horizontal braking forces occurring during the penultimate steps (14). Previous research has reported soccer players perform approximately 3-6 steps when changing of direction from short (4m) and long (20m) distances (16). Therefore, players may be exposed to a high volume of eccentric actions during soccer matches. Eccentric muscle actions are known to incur high levels of muscle damage and neuromuscular fatigue which subsequently requires an increased post-exercise recovery period (25). Therefore, when high-intensity decelerations are defined solely by a threshold above 3 m/s^2 , coaches may misinterpret data, believing players have undergone excessive high-intensity efforts when most decelerations are only marginally above this threshold. Alternatively, if players performed most of their deceleration efforts near their true IND threshold, coaches would also not be aware of this which could lead to training not being adjusted and inducing further fatigue.

An important finding is the distribution and variability of data when comparing arbitrary (ARB) and individualised (IND) deceleration thresholds. Except for total distance under the IND threshold, all coefficient of variation (CV%) values were lower with ARB thresholds (Table 2), indicating greater variability when using IND thresholds during full matches and MDP. These results suggest that high-intensity decelerations are inherently variable, regardless of the threshold used. However, ARB

thresholds tend to produce less variability within a heterogeneous group of university-level soccer athletes. While this may appear advantageous, it could lead to under- or overestimation of deceleration demands, depending on each athlete's peak deceleration capacity or their exposure during training or matches (36). Therefore, it is important for future research to consider population heterogeneity when analysing high-intensity deceleration. A more individualised approach allows for tailored recovery and training strategies, grounded in a clearer understanding of match demands for each player (2). Prior research has shown that inadequate preparation for match demands increases injury risk, particularly during decelerations (22,33). Thus, applying IND thresholds may better capture individual performance profiles and support more precise load management.

When interpreting the results of the present study, it is important to consider the following limitations. Firstly, it may have been useful to also assess low-(25%) and moderate-intensity (50%) deceleration thresholds (46), and compare these to the respective ARB low (e.g., $-1-2\text{m/s}^2$) and moderate ($-2-3\text{m/s}^2$) intensity thresholds. This would offer further insights into the volume and intensity of decelerations during MDP and full matches. Secondly, our results may have been adjusted if the peak deceleration value from each game was used to quantify distance and count metrics as opposed to using the maximum value from all the analysed games. However, due to the technical and tactical requirements of matches being influenced by the opposition, some games would naturally result in lower physical demands than others. Moreover, as can be seen in Table 1, even the minimum peak deceleration value recorded for all athletes across all games was substantially higher than the ARB threshold of -4m/s^2 we used in the current study and the -3m/s^2 threshold commonly reported in literature. Lastly, the validity of one's peak deceleration attained in-situ can be questioned. Although this approach may provide ecological validity for practitioners, without contextual video analysis to confirm each high-intensity deceleration, subsequent outputs may have a larger discrepancy between ARB and IND thresholds. Therefore, applying contextual evidence to peak deceleration actions during training and matches may help validate the application of deceleration thresholds in soccer and help assist in enhancing the specificity of deceleration training activities.

PRACTICAL APPLICATIONS

Due to the significant differences between ARB and IND high-intensity deceleration thresholds for both MDP and full matches found in the current study, it is suggested practitioners collect MDP and full match data (52) using individualised thresholds. Implementing the IND threshold to attain high-intensity deceleration activities from matches will enable a more effective load monitoring approach per player relative to the heterogeneous population of team sport athletes. Utilising percentages above and below MDP and referencing these demands relative to full matches is also recommended in accordance with recent literature (31). Thus, practitioners can use the outlined methods used in this study to provide greater insights into the mechanical training exposures required to best prepare their athletes for MDP and full matches.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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ETHICAL APPROVAL

Ethics for this study were approved in line with University's ethics procedure.

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