Adapting the percentage intensity method to assess accelerations and decelerations in football training: moving beyond absolute and arbitrary thresholds

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Note: this is a preprint version. This paper has been submitted in Sports Biomechanics journal.

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Please cite as: Silva, H., Nakamura, F.Y., Serpiello, F.R., Ribeiro, J., Roriz, P., Marcelino, R. (2023). Adapting the percentage intensity method to assess accelerations and decelerations in football training: moving beyond absolute and arbitrary thresholds. *SportRχiv*.

All authors have read and approved this version of the manuscript.
This article was last modified on 11th February, 2023.

ABSTRACT

We present an adaptation of the percentage intensity approach to monitor accelerations and decelerations allowing players' individualization.

Forty-two players were monitored during four training weeks via GNSS devices. Raw velocity and time data were collected, allowing acceleration, deceleration, and starting speed calculations. Training maximal accelerations and decelerations were calculated for each starting speed interval, and intensities were established as very low (< 25% of the maximal effort), low (25-50%), moderate (50-75%) and high (> 75%). Linear regressions and Pearson correlation (*r*) analyzed the relationship between the maximal acceleration and deceleration according to starting speeds, and mean paired differences compared efforts magnitudes between starting speed intervals.

Most very-low intensity efforts started < 5 $km\cdot h^{-1}$ (79-86%). Correlation between maximal efforts and starting speeds were -0.97 (p<.001) and -0.94 (p<.01) respectively. Maximal acceleration decreased as starting speed increases (very large effect sizes), but deceleration is less starting speed dependent (unclear to large effect sizes) during training.

This adaptation allows individual accelerations and decelerations classification during real-life scenarios, which can lead to a more precise training prescription. Very low intensity could be excluded to consider only relevant efforts. Maximal acceleration should be collected for each starting speed interval because accelerations are starting speed dependents.

INTRODUCTION

During football training sessions and matches, practitioners monitor load to assess if players are meeting physical demands requirements and responding to the stimulus provided (1,2). Different tools can assess load, including heart rate and perception of effort (i.e., internal load), or variables obtained via global navigation satellite system (GNSS) (1), such as the distance covered, the efforts performed at a specific velocity, or acceleration and deceleration occurrences (i.e., external load).

The quantification of accelerations and decelerations has become widely popular and these variables are among the most used metrics in elite football (3). This comes as no surprise since high-intensity accelerations are typically associated with fatigue and exercise-induced muscle damage (4,5), with implications for post-match recovery (6).

When collecting these data, efforts count is the most-commonly used approach, followed by the distance covered accelerating or decelerating (7). Scientific literature-based values can be very practical to use but raise two important concerns: the justification of the chosen categories and the "one size fits all" approach. Different "round-figure" thresholds are used in the literature but, since there is no justification to choose a specific threshold, researchers usually adopt values in the past (8,9). Additionally, intensity classifications vary across studies, making comparisons difficult (10). For example, high-intensity accelerations ranged from 2-3 $m{\cdot}s^{-2}$, to > 2.5 $m{\cdot}s^{-2}$, > 3 $m{\cdot}s^{-2}$ and > 4 $m{\cdot}s^{-2}$ across studies (10). Additionally, those strategies disregard individual capacities. If "high-intensity" is defined arbitrarily, a high-intensity action for one player could be of low- or moderate-intensity for another (11). To address this issue, Abbot and colleagues (12) compared an absolute intensity method with a relative intensity method during training sessions and friendly matches, reporting higher distances covered in the absolute intensity method. This means that results are influenced by the chosen method to classify accelerations and decelerations.

Additionally, Sonderegger and colleagues (13) highlighted the importance of the effort starting speed, proposing the acceleration intensity calculation as the percentage of the maximal observed acceleration and the maximal voluntary acceleration that could be achieved for each starting velocity [standing start; trotting (6.0 $km{\cdot}h^{-1}$), jogging (10.8 $km{\cdot}h^{-1}$), and running (15.0 $km{\cdot}h^{-1}$)]. Then, intensity was classified as high (acceleration >75% of the maximal), moderate (>50%), low (>25%), and very low (<25%). During matches, similar approaches have been used by different research groups to assess accelerations (11,12,14,15), with conflicting results. However, the cited papers used different starting speed thresholds (11,12,14,15) and did not use the four relative acceleration intensity intervals previously proposed (11,12,14,15). Of note, for this method, maximal acceleration was assessed during four acceleration tests, and assessing maximal acceleration as originally proposed could not be practical during the competitive season (14). Also of note, decelerations were disregarded in the original proposal (13), which is an important limitation due to the importance of these actions in football practices (16).

Therefore, with this study, we aim to provide a new method to classify accelerations and decelerations intensities during football training, by adapting the previous published individual percentage intensity method. We hypothesized that acceleration magnitudes would decrease with starting speed increases, and deceleration magnitudes would increase with starting speed increases.

METHODS

Procedures

Forty-two male professional football players from two Portuguese teams competing in the first division were monitored during one full mesocycle (4 weeks). Data were collected in the 2020/21 and 21/22 seasons (one team per season).

Sample

Coaching staff monitored and collected the daily training data from forty-two male professional players. To be included in this study, a minimum of 50% participation in training sessions was required. The average age, height and weight were 26.7 ± 4.2 years, 181.7 ± 6.3 cm, and 74.5 ± 6.0 kg. Due to the particularities of the position, goalkeepers were excluded from data collection. Sample characteristics are presented in Table 1. Since players monitoring was part of their professional routine, Ethics Committee clearance was not required (17), but written consent from the clubs was obtained.

Table 1. Sample characteristics as number of players, training files and average training sessions attendances (mean ± SD) per playing position.

	CD	FB	CM	WM	FW	Total
Players (*n*)	8	10	13	6	5	42
Training files (*n*)	148	192	264	110	98	812
Percentage of training sessions attendance (mean ± SD)	84.48 ± 12.25	89.08 ± 8.85	92.31 ± 7.37	84.58 ± 6.59	90.33 ± 10.26	88.71 ± 9.64

Note: CD=central defender; FB=fullback; CM=central midfielder; WM=wide midfielder; FW=forward.

Acceleration and deceleration assessment

The teams monitored their players using a 10-Hz global positioning system (Catapult Vector S7 and Vector X7 – one model per team – Catapult Sports, Melbourne, Australia) that encompassed a double constellation system (GNSS and GPS). Both models are FIFA certified (18) and the 10-Hz sampling rate has been validated to assess accelerations in team-sports (19). Devices were secured between the upper scapulae, at approximately the T3-4 junction and were activated 15 minutes before use, in accordance with the manufacturer's instructions.

Raw data of training sessions were retrieved from the proprietary software (OpenField Console, Catapult Sports, Melbourne, Australia) and the velocity ($m \cdot s^{-1}$) and time (ms) were used to calculate accelerations and decelerations ($m \cdot s^{-2}$). Training maximal accelerations and decelerations were retrieved as the maximal individual value when another effort was registered within 1 $m\cdot s^{-2}$ (for example, a maximal acceleration of 5.2 $m\cdot s^{-2}$ required another acceleration ≥ 4.2 $m\cdot s^{-2}$; the same procedure for decelerations). Training procedures were conducted as usual with no interference from the research team.

Thresholds and Intensities

Players' acceleration and deceleration efforts from training sessions were retrieved with the starting speed ($km\cdot h^{-1}$) and the effort magnitude ($m\cdot s^{-2}$). The starting speed was retrieved as the registered speed immediately before the speed increase (acceleration) or decrease (deceleration). Accelerations and decelerations were calculated as the change of speed divided by the change of time – as long as speed kept increasing or decreasing, one effort was counted. As so, no minimum effort duration was applied to ensure that all efforts were accounted (7).

For the percentage intensity calculation, we adapted the Sonderegger et al. proposal (13), using the following equation to calculate percentage acceleration:

$$\text{Percentage acceleration} = \frac{\text{amax, action}}{\text{amax}} * 100$$

Where "amax, action" corresponds to the action acceleration or deceleration (each individual effort) according to the starting speed bandwidth interval (<5 $km\cdot h^{-1}$, 5-10 $km\cdot h^{-1}$, 10-15 $km\cdot h^{-1}$, 15-20 $km\cdot h^{-1}$, 20-25 $km\cdot h^{-1}$, 25-30 $km\cdot h^{-1}$ and > 30 $km\cdot h^{-1}$); and "amax" corresponds to the maximal acceleration or deceleration achieved during training for each starting speed bandwidth interval (< 5 $km\cdot h^{-1}$, 5-10 $km\cdot h^{-1}$, 10-15 $km\cdot h^{-1}$, 15-20 km·h-1, 20-25 $km\cdot h^{-1}$, 25-30 $km\cdot h^{-1}$ and > 30 $km\cdot h^{-1}$).

Accelerations and decelerations intensities were categorized as high (>75%), moderate (25-50%), low (25-50%), and very low (<25%).

Statistical analysis

Descriptive statistics were conducted to analyze efforts intensities and starting speeds. Accelerations and decelerations occurrences were analyzed as a percentage of all occurrences. Linear regressions and Pearson correlation (*r*) were calculated to analyze the relationship between the maximal acceleration and decelerations and starting speeds, using jamovi (20,21). Mean paired differences compared accelerations and decelerations magnitudes between subsequent starting speed intervals, in jamovi with the ESCI package (20,21). Cohen's (*d*) effect sizes were established as trivial (<0.2), small (0.2<0.6), moderate (0.6<1.2), large (1.2<2.0), very large (2.0<4.0) and huge (>4.0) with 90% confidence intervals (22). If the CI crossed zero, an unclear effect size was established (23).

Results

Most of very low intensity accelerations and decelerations started from < 5 $km \cdot h^{-1}$ (86% and 79% respectively). Similarly, most of low and moderate intensity accelerations started from < 5 $km \cdot h^{-1}$ (79% and 68% respectively), while most of low and moderate intensity decelerations started between 5-15 $km \cdot h^{-1}$ (66% and 61% respectively). High-intensity accelerations started mainly < 10 $km \cdot h^{-1}$ (70%), while high-intensity decelerations varied from starting speeds of 15-20 $km \cdot h^{-1}$ (19%), 5-10 $km \cdot h^{-1}$ (19%), and 10-15 $km \cdot h^{-1}$ (31%). This is represented in Figure 1.

Means ±SD of maximal and average accelerations and decelerations per starting speed interval are presented in Table 2.

Correlation between maximal accelerations and decelerations were -0.97 (p<.001) and -0.94 (p<.01) respectively. Linear regressions and respective equations are presented in Figure 2.

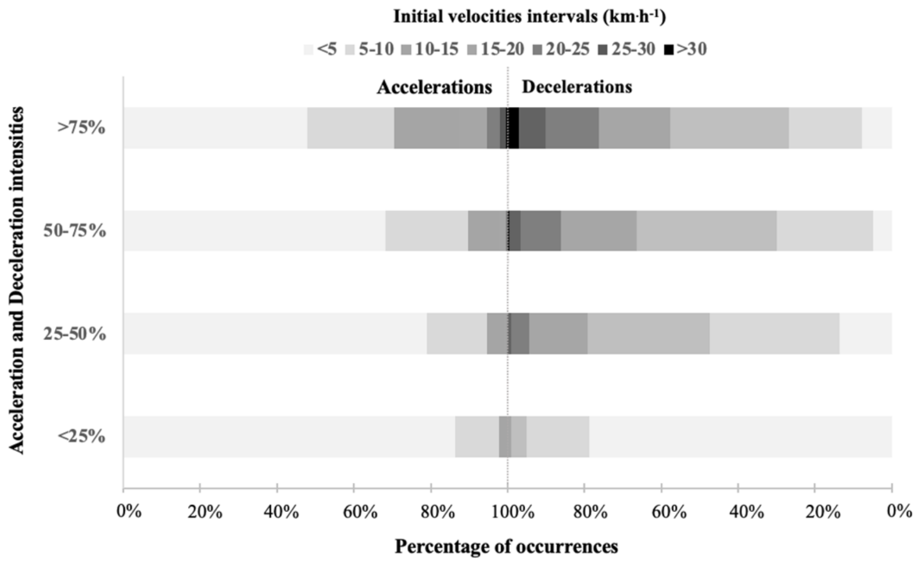

Figure 1. Comparison of mean percentage of accelerations and decelerations occurrences per training session separated per intensity interval, and according to starting speed.

Table 2. Mean ± SD of maximal and average accelerations and decelerations for each bandwidth interval starting speed.

	Maximal		Average	
Starting Speed Interval ($km{\cdot}h^{-1}$)	Acceleration ($m{\cdot}s^{-2}$)	Deceleration ($m{\cdot}s^{-2}$)	Acceleration ($m{\cdot}s^{-2}$)	Deceleration ($m{\cdot}s^{-2}$)
<5	4.52 ± 0.66	6.08 ± 2.93	0.36 ± 0.46	0.23 ± 0.26
5-10	3.11 ± 0.31	5.44 ± 3.34	0.29 ± 0.41	0.43 ± 0.54
10-15	2.10 ± 0.28	4.64 ± 0.66	0.29 ± 0.35	0.89 ± 0.78
15-20	1.43 ± 0.25	5.00 ± 0.96	0.31 ± 0.31	1.36 ± 0.88
20-25	0.80 ± 0.24	4.41 ± 0.79	0.24 ± 0.22	1.61 ± 0.92
25-30	0.45 ± 0.26	3.56 ± 0.72	0.23 ± 0.22	1.72 ± 0.88
>30	0.14 ± 0.07	2.24 ± 0.66	0.14 ± 0.06	1.63 ± 0.65

As starting speed increased, differences in maximal accelerations decrease with very large effect sizes. The only exception was when comparing 20-25 $km{\cdot}h^{-1}$ with 25-30 $km{\cdot}h^{-1}$

starting speed intervals (large effect size). Maximal decelerations decrease between starting speed intervals, except between <5 km·h^{-1} and 5-10 km·h^{-1} (unclear), and between 10-15 km·h^{-1} and 15-20 km·h^{-1} (maximal decelerations increased with a small effect size). These differences are represented in Figure 3.

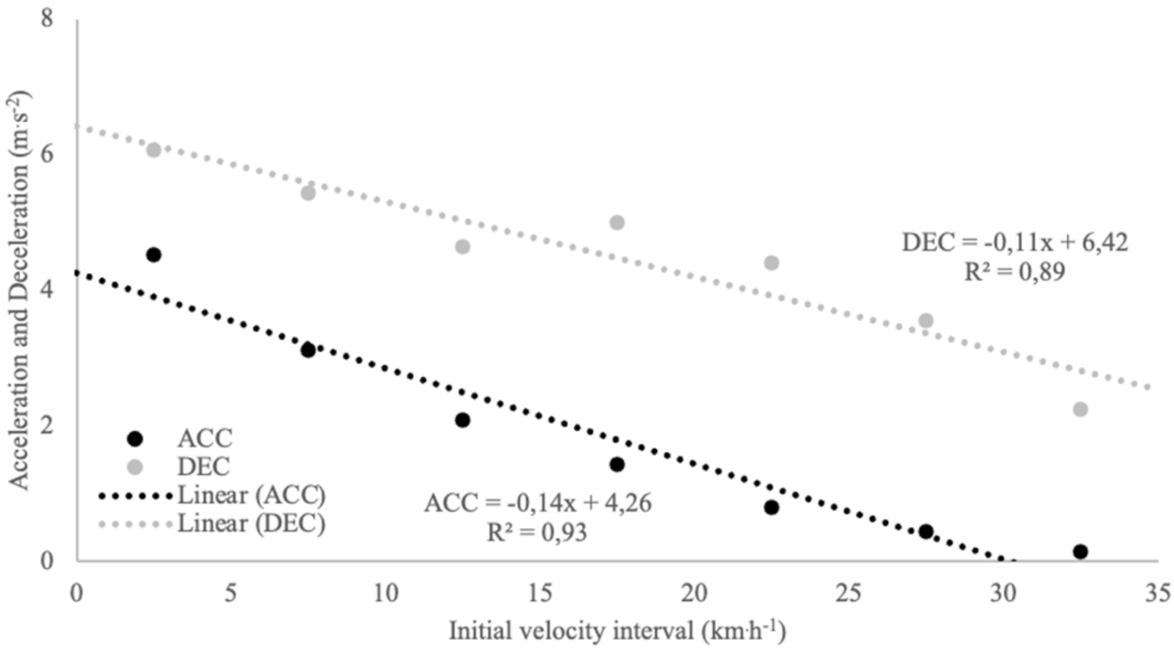

Figure 2. Linear regression of maximal accelerations (ACC) and decelerations (DEC) for each initial velocity bandwidth (< 5 km·h^{-1}, 5-10 km·h^{-1}, 10-15 km·h^{-1}, 15-20 km·h^{-1}, 20-25 km·h^{-1}, 25-30 km·h^{-1} and > 30 km·h^{-1}) for all players (n = 42).

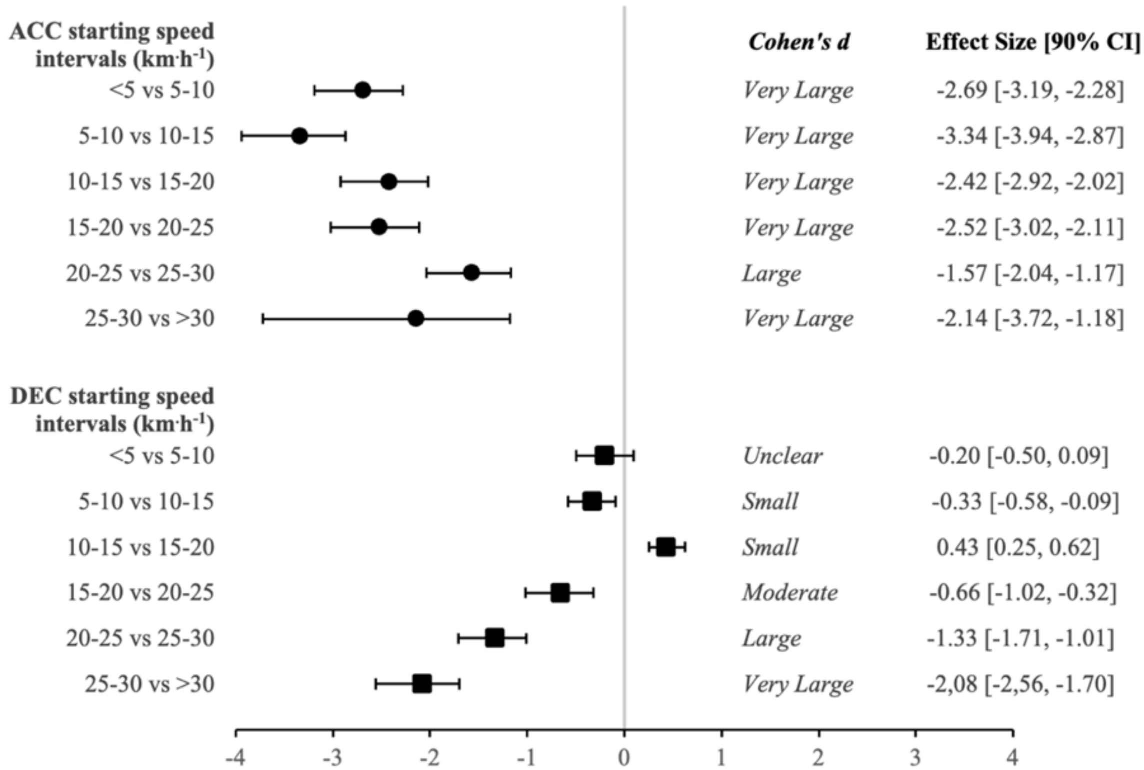

Figure 3. Differences between starting speed intervals (Cohen's d) for maximal accelerations (ACC) and decelerations (DEC).

Discussion

The main purpose of this study was to provide a new method to classify acceleration and deceleration intensities during football training, by adapting the individual percentage intensity method proposed by Sonderegger and colleagues (13) applied with sprint tests. We presented a practical method that allows practitioners and researchers to classify players' individual accelerations and decelerations efforts during training sessions and that could be potentially extended to competitive matches. Importantly, since we used maximal efforts as the highest values obtained during training sessions (per starting speed bandwidth interval), absolute players' capacities could differ if tested. However, field tests can only provide a glimpse of players' status, as players change their capacities across the season and constant testing is difficult to implement in elite contexts (24). Additionally, these tests are usually performed with a standing start which differs from what happens in competition and training practice. Nevertheless, previous research established the diminish capacity of accelerating as the starting speed increases (13), which relates with our findings. Regarding decelerations maximal capacities, one would expect that the higher magnitudes would be achieved when starting at higher speeds.

Indeed, when assessing maximal decelerations with a field test, players were instructed to sprint maximally for 20 meters before decelerating (25). However, according to our findings, players appear to protect themselves during training, minimizing deceleration forces especially when running at higher velocities. That is, considering the potential damage of decelerations (16), players can voluntarily avoid sudden stops during practice. When comparing maximal decelerations magnitudes, our values ranged from 6 to 3 $m \cdot s^{-2}$, while previous research reported maximal decelerations 8 $m \cdot s^{-2}$ after achieving ~26 $km \cdot h^{-1}$ (25). As so, during training, players could minimize explosive decelerations when sprinting, even though the capacity to do so exists, with the associated risks (16). Nevertheless, this "protection" defines the training maximal decelerations and respective intensities for each player.

Accelerations and decelerations intensities are frequently classified with arbitrary thresholds that lack individualization (8,10). Additionally, they also ignore the efforts starting speed. Two studies compared this arbitrary classification with an individualize classification. First, Abbot and colleagues (12) compared a global method (low intensity: 1-2 $m \cdot s^{-2}$; moderate intensity: 2-3 $m \cdot s^{-2}$; and high intensity: > 3 $m \cdot s^{-2}$) with an individualize method during training sessions and friendly matches (low intensity: 25-50%; moderate intensity: 50-75%; and high intensity: > 75%) and calculated the maximum acceleration with players' testing. Players were then divided in groups according to their acceleration capacity (low, medium, and high). The authors reported higher distances covered in the global method (medium group: moderate and high intensity accelerations; and high group: all intensities). Hence, how practitioners classify players accelerations and decelerations impacts the load reported. The second study (26) compared the percentage intensity method (13) with a speed-based method (measured the distance cover in different speed zones: standing, 0.0-0.7 $km \cdot h^{-1}$; walking, 0.7-7.2 $km \cdot h^{-1}$; jogging, 7.2-14.4 $km \cdot h^{-1}$; running, 14.4-19.8 $km \cdot h^{-1}$; high-speed running, 19.8-25.2 $km \cdot h^{-1}$; and sprinting, > 25.2 $km \cdot h^{-1}$) and with an absolute method (low intensity: 1-2 $m \cdot s^{-2}$; moderate intensity: 2-3 $m \cdot s^{-2}$; high intensity: > 3 $m \cdot s^{-2}$; and another high intensity interval: > 4 $m \cdot s^{-2}$). However, the absolute threshold method was also dependent from initial velocity and the statistical analyzes focused in the sample level. From the latter study, differences were reported between methods, but similarities can be found in this study such as the number of efforts in > 75% and > 4 $m \cdot s^{-2}$ (29.7 vs. 30.7) intervals with starting speeds of 0-1 $m \cdot s^{-1}$. Finally, the latter study used open ended thresholds (>3 $m \cdot s^{-2}$ and > 4 $m \cdot s^{-2}$), which leads to the inclusion of different thresholds in the same interval (27).

We found that most of the very low intensity (< 25%) efforts started from < 5 $km \cdot h^{-1}$ (Figure 1) which means that these efforts probably represent insignificant changes of velocity and would probably relate to efforts < 1 $m \cdot s^{-2}$, which are often disregarded when assessing efforts with fixed thresholds (10). However, an acceleration of < 1 $m \cdot s^{-2}$ could represent a high intensity effort if starting > 25 $km \cdot h^{-1}$, because acceleration capacity decreases as starting speed decreases (Figure 2) (13). By considering the starting speed, we can recommend practitioners to disregard this intensity interval (< 25%) because they probably represent a negligible mechanical load to the player and can carry movement "artifacts". Additionally, we also recommend merging the starting speed intervals of 25-30 $km \cdot h^{-1}$ and > 30 $km \cdot h^{-1}$ to > 25 $km \cdot h^{-1}$, because very few efforts occur in the highest interval, which can condition maximal values.

To calculate the maximal acceleration and deceleration, we must consider the differences between the two efforts: while both maximal efforts tend to decrease as the starting speed increases (Figure 2), the acceleration capacity is more starting speed dependent than the deceleration capacity – as seen with the average accelerations and decelerations for each starting speed bandwidth interval (Table 2), and when comparing the maximal efforts between subsequent starting speed intervals (Figure 3). As so, we recommend that assessing maximal accelerations for each starting speed interval, while assessing maximal decelerations as the maximal overall value, independent of the starting speed. This partially aligns with our hypothesis. That is, players achieve lower acceleration magnitudes at higher starting speeds, but higher decelerations magnitudes are achieved in different starting speeds. This is probably because players perform sudden stops from lower speeds, while slowly decelerate when at higher starting speeds, protecting themselves.

We assessed maximal accelerations and decelerations efforts during training sessions, instead of performing field tests. Although it can be questioned if the maximal efforts represent players' maximal capacities, we considered four microcycles to collect maximal efforts. As so, using only one match or one training session could mislead practitioners regarding maximal values. However, field tests can also mislead practitioners with players failing to replicate their field tests maximal speeds during matches (28,29). Other limitation relates to our sample consisting only of training sessions. Specifically, it would be interesting to assess if players "protect" themselves when decelerating during matches. However, we stress that this study aimed to adapt the original method proposed by Sonderegger et al. (12), so it can be considered a methodological study.

As so acceleration and deceleration monitoring should be individualized and not arbitrary, with intensity efforts representing a percentage of the maximal individual effort. Additionally, when assessing accelerations intensity, practitioners should assess the maximal acceleration for each starting speed bandwidth interval – as acceleration capacity diminishes as the starting speed increases; but when assessing decelerations intensity, practitioners should assess the maximal deceleration regardless of the starting speed – as deceleration capacity is less dependent on the effort starting speed. Finally, very-low intensity efforts (<25%) should be excluded from overall acceleration and deceleration demands, because these efforts potentially represent insignificant velocity changes, occurring mostly (~80%) from < 5 $km \cdot h^{-1}$ starting speeds.

Conclusion

We presented an adaptation of the percentage intensity approach, by assessing maximal accelerations and decelerations from training data. To assess maximal values, we recommend consider the maximal acceleration for each starting speed interval, and the overall maximal deceleration, independent of starting speed intervals. This is justified by the higher dependence of acceleration than deceleration to the starting speed during training sessions. Finally, considering low, moderate and high intensities would provide the fundamental information to practitioners, without excluding relevant efforts. This strategy can be used to replace the absolute thresholds method, with two major advantages: individualization of players' capacities/demands and ability to assess players according to their physical performance during real-life scenario such as training sessions.

Contributions

Contributed to conception and design: HS, FYN

Contributed to acquisition of data: JR, PR

Contributed to analysis and interpretation of data: HS, FYN, RM

Drafted and/or revised the article: HS, FYN, FS, RM

Approved the submitted version for publication: HS, FYN, FS, JR, PR, RM

Funding information

The author Rui Marcelino has received funding by national funds through FCT – Fundação para a Ciência e a Tecnologia, I.P., within the scope of the project "2021.02330.CEECIND".

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