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From Absolute to Individual Speed Thresholds in Football: An Empirical Analysis of Variability and Diagnostic Solutions for Implementation

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Abstract

Background: The classification of running intensities in football is often based on absolute thresholds that do not sufficiently account for individual differences in game speed and physical performance. Given the prevalence of injuries, the necessity of individualized speed thresholds is being examined.

Objective: This study investigates alternative methods for the individualization of speed thresholds, particularly considering individual physiological parameters such as maximal aerobic speed (MAS), maximal sprint speed (MSS), and anaerobic speed reserve (ASR). It includes an empirical analysis of various intensity zones at the absolute thresholds (19.8 km/h and 25.2 km/h) established for world-class players.

Methods: The analysis is based on official speed data from the FIFA World Cup 2022^{TM}, All data were extracted from official post-match reports. After applying filtering criteria (playing time >270 min, exclusion of goalkeepers), 196 players were included in the analysis. Players were categorized by position (Defenders (DF), Midfielders (MF), Forwards (FW)). Statistical analyses were conducted using non-parametric methods (Kruskal-Wallis test, Dunn's test with Bonferroni correction) in R (Version 4.4.2).

Results: Maximal speeds differed significantly across playing positions. Forwards (FW) recorded the highest values (Mean (M) = 33.23 km/h, Standard Deviation (SD) = 1.30 km/h) and showed a highly significant difference compared to midfielders (MF; M = 32.04 km/h, Z = 3.71, p = 0.0006). Additionally, a significant difference was found between MF and defenders (DF; M = 32.66 km/h; Z = 2.47; p = 0.0136). Individual intensity values at the absolute thresholds showed large variations, with a maximal difference of 60.91% at the 19.8 km/h threshold (mean deviation: 15.86%) and 77.52% at the 25.2 km/h threshold (mean deviation: 20.18%). The findings indicate that predefined speed zones (e.g., 19.8 km/h and 25.2 km/h) systematically distort individual load assessment, emphasizing the need for a more precise, player-specific classification.

Conclusion: Despite existing limitations, this study highlights the potential of shifting from absolute to individualized speed thresholds in football and provides practical approaches for their implementation. The results indicate that a differentiated consideration of individual physiological parameters allows for a more precise load assessment and represents an evidence-based alternative to current standard methods. Integrating internal and external load indicators into a standardized monitoring system could enable more targeted adjustments in training load management. The implementation of individualized speed thresholds may not only optimize load management but also contribute to the prevention of injury-related overload syndromes.

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1 Introduction

In modern football, precise performance diagnostics play an increasingly important role, particularly in training load management, match analysis, and injury prevention. The use of Global Positioning Systems (GPS) now enables the collection of detailed movement data from players. These data provide crucial information on running speeds, accelerations, and distances covered, allowing for an accurate analysis of the athletes' physical workload [3]. However, one of the central challenges in interpreting these data is selecting appropriate thresholds for classifying movement intensities.

In football practice and research, various approaches are used to define these thresholds. The most common methods differ between fixed absolute thresholds, individual thresholds based on percentage shares of maximal running speed, and physiologically derived thresholds, which are based on parameters such as Maximal Aerobic Speed (MAS), Maximal Sprint Speed (MSS), and Anaerobic Speed Reserve (ASR). Each of these approaches has specific advantages and disadvantages that must be considered in the context of training load management and match analysis.

1.1 Absolute Thresholds

Traditionally, absolute thresholds are used in football to classify different running intensities. These fixed thresholds define clear speed ranges that apply equally to all players—regardless of their individual performance capabilities. A widely used example is the definition of a sprint as any movement exceeding 25 km/h [55]. Similarly, high-speed running (HSR) is often categorized as running at speeds between 19.8 km/h and 25 km/h.

The advantage of this approach lies in its simplicity and the ability to make direct comparisons between players and teams. However, this methodology has significant drawbacks. Absolute thresholds do not account for individual differences in player performance. For instance, a central defender with a top speed of 28 km/h reaches the sprint threshold at 90% of their maximum speed, whereas a winger with a top speed of 34 km/h only enters the sprint zone at 73% of their maximum [15]. This discrepancy leads to a distorted representation of actual workload and can result in misinterpretations of performance data.

Moreover, there are no uniform standards for defining these thresholds. Different studies and organizations use varying limits for HSR and sprints, making it difficult to compare research findings and performance data [23]. This lack of standardization represents a key issue in the application of absolute thresholds in football. A common zone classification is shown in Table 1.

Zone	Zone name	km/h from	km/h to
1	Standing / No Movement	0.0	0.2
2	Walking / Low-Speed Running	0.2	7.2
3	Jogging / Moderate Running	7.2	14.4
4	High-Intensity Running	14.4	19.8
5	High-Speed Running (HSR)	19.8	25.2
6	Sprinting	> 25.2	

Table 1: Example of a Speed Zone Classification Based on Absolute Thresholds in Practice

1.2 Individually Fixed Speed Thresholds

To counteract the disadvantages of absolute thresholds, individualized thresholds have been developed based on the specific performance data of players. This method uses percentage shares of each player's maximal running speed (top speed) to define different intensity zones. For example, sprinting is often defined as movement reaching 85–90% of an individual's maximal speed, while HSR is positioned between 60–80% of the personal top speed [34].

This approach allows for a more precise assessment of the actual workload experienced by players and helps to avoid over- or underloading. Particularly in training load management, it has been shown that individualized thresholds provide a more accurate basis for planning and controlling training intensity (Rampinini et al., 2015). Another advantage lies in improved injury prevention, as workloads can be better adjusted to players' capacities.

However, this method also presents challenges. Determining an individual's top speed requires specific testing or must be assessed during matches, which can complicate data comparability. Additionally, a player's top speed is not always a reliable indicator of their physiological performance, as it is strongly influenced by factors such as technique, sprint mechanics, and playing position [31].

Problematic Issue: Differences Between Diagnosed and Match-Achieved Top Speed A significant issue in using individualized thresholds based on percentage shares of top speed is the discrepancy between the top speed measured in training or specific diagnostics and the actual top speed achieved in matches. This discrepancy poses a major challenge in accurately determining individualized thresholds and can lead to misinterpretations of workload data.

1. Different Testing Conditions: In diagnostic tests (e.g., 30–40-meter sprints), players have the opportunity to optimally prepare for the sprint, often leading to a higher measured top speed. In contrast, match situations are unpredictable and involve factors such as opponents, tactical requirements, or irregular movement patterns, often preventing players from reaching their diagnosed top speed in competition [11]. A study by Freeman [31] theorizes that many players rarely reach their diagnosed top speed in competition and that variations in maximum speed assessments throughout the training week must be accounted for due to training load.

2. Influence of Match Situations: The type of match situation also influences the attainable top speed. Sprints in matches often start from various speeds (e.g., after dribbling or changing direction) rather than from a stationary position, as in diagnostics. Additionally, the distances available for maximal sprints in matches are often limited. These factors result in players rarely reaching their diagnosed top speed in competition [24].

3. Risk of Over- or Underestimation: If individualized thresholds are based solely on diagnosed top speed, there is a risk that actual match workload is either underestimated or overestimated. A player who reaches a top speed of 34 km/h in training but only sprints at a maximum of 32 km/h in matches may be classified as experiencing lower workload in match analysis, even if they are performing at their limit. Conversely, a player who surpasses their diagnosed top speed in competition (e.g., due to adrenaline or match situations with more open space) may be incorrectly classified as overloaded.

1.3 Individual Speed Thresholds

An advanced approach to determining individualized thresholds is based on physiological parameters such as Maximal Aerobic Speed (MAS), Maximal Sprinting Speed (MSS), and the derived Anaerobic Speed Reserve (ASR). This method offers the advantage of accounting for both the aerobic and anaerobic capacities of players, thus enabling a more comprehensive assessment of physical performance [50].

Maximal Aerobic Speed MAS describes the lowest speed at which a player reaches their maximal oxygen uptake (VO2max). It provides insight into the athlete's aerobic capacity and serves as a basis for classifying intensive but predominantly aerobic workloads.

Maximal Sprinting Speed MSS represents the maximum velocity a player can achieve during a sprint. It primarily reflects anaerobic performance capacity.

Anaerobic Speed Reserve ASR is calculated as the difference between MSS and MAS and provides information about a player's anaerobic reserve. A high ASR indicates strong sprinting ability, whereas a low ASR suggests a greater reliance on aerobic metabolism.

These parameters allow for a differentiated classification of running intensities. For example, HSR can be defined as movement between MAS and a certain percentage of ASR, while sprints are considered as runs exceeding a predefined proportion of ASR [3].

1.3.1 Diagnostics

Determining Maximal Aerobic Speed (MAS) and Maximal Sprinting Speed (MSS) requires specific diagnostic procedures that must meet the quality criteria of objectivity, reliability, and validity to produce meaningful and comparable data. A recent systematic review by Thron [54] evaluates the validity and reliability of different methods for assessing these parameters, providing valuable insights into their practical applicability.

For the determination of MAS, the incremental treadmill test with direct oxygen uptake (VO2max) measurement is considered the gold standard. This method offers high construct validity, as it directly captures the physiological foundations of aerobic capacity. However, the review highlights that different protocols within the cardiopulmonary exercise test (CPET) can lead to slight variations in results. The criterion validity of these protocols varies, with effect sizes (Cohen's d) ranging from 0.83 to 2.8 and intraclass correlation coefficients (ICC) between 0.46 and 0.85. These values indicate that despite being recognized as the gold standard, differences in test definition and execution can lead to some measurement variability.

In practical sports applications, field tests such as the Vam-Eval Test or the Université de Montréal Track Test (UMTT) are frequently used to determine MAS. These tests are easier to administer and more cost-effective than laboratory assessments, but they exhibit lower criterion validity. According to Thron et al., the ICC values for these field tests range from 0.40 to 0.96, with a tendency to overestimate MAS compared to treadmill testing. This systematic overestimation must be taken into account when interpreting test results. Despite these limitations, field tests demonstrate acceptable reliability, with ICC values between 0.88 and 0.93, making them suitable for training applications.

The maximal sprint speed (MSS) is typically determined through sprint tests over distances of 30 to 40 meters. Laser systems are considered the gold standard, as they ensure high measurement accuracy and objectivity. The review report mentions excellent ICC values ranging from 0.93 to 0.98 and a coefficient of variation (CV) of less than 2.43%, indicating excellent reliability of this method. In addition to laser systems, light gates (timing gates) and radar measurements are also frequently used, which also demonstrate high validity and reliability.

As alternative measurement methods, GPS systems with a sampling rate of at least 10 Hz are used, especially in the context of team and endurance sports. These systems enable the capture of MSS during training or competitions, providing high ecological validity. However, their criterion validity varies significantly, with ICC values ranging from 0.14 to 0.97 and a CV of up to 9.77%. GPS systems also tend to slightly underestimate MSS, which should be considered when interpreting the data. The review highlights that the choice of measurement system has a significant impact on the results and, therefore, must always be considered when interpreting MSS values. This issue of value variation, particularly with respect to ASR, is described by Thor et al. in figure 1.

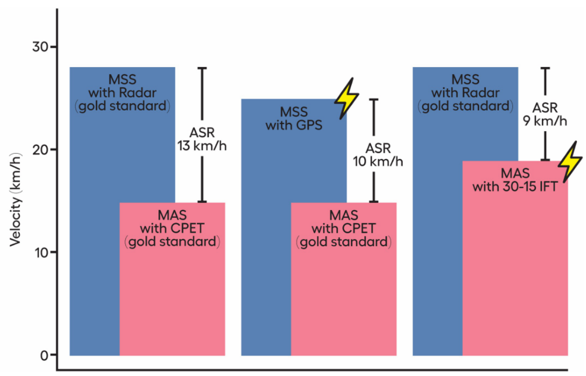

Figure 1: Different ASR Values When Using Various Testing Methods

A key finding of the systematic review is the observation that, for both MAS and MSS determination (see Figure 2), the choice of testing method can have a significant impact on measurement values. While laboratory assessments such as CPET for MAS and timing gate systems for MSS are considered the gold standard, practical field tests and GPS measurements offer greater applicability in everyday sports settings, albeit at the expense of validity and, in some cases, reliability.

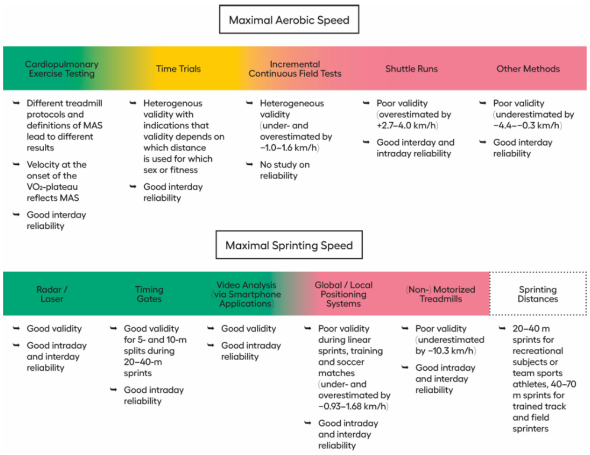

Figure 2: Overview of Testing Methods for Diagnosing MAS and MSS

Overall, the findings of Thron et al. emphasize the importance of carefully selecting testing methods while considering specific requirements and objectives. Adhering to the quality criteria of objectivity, reliability, and validity is essential to conducting precise and meaningful performance diagnostics and making well-founded training decisions.

1.4 Research Question

1.4.1 Problem Statement

The traditional classification of running intensities in football is usually based on fixed, predefined absolute speed thresholds (e.g., 19.8 km/h, 25.2 km/h). However, this standardization does not account for the individual variability of players, particularly concerning physiological parameters such as Maximal Aerobic Speed (MAS), Maximal Sprinting Speed (MSS), and Anaerobic Speed Reserve (ASR). Practical experience shows that the dispersion of these values is considerable, which calls into question the validity of fixed thresholds for load management.

1.4.2 Research Need

To enable a more precise load assessment, it is essential to empirically analyze the interindividual dispersion of speed thresholds. Additionally, practical diagnostic procedures must be identified to facilitate the efficient implementation of individualized thresholds. External factors such as financial resources, available time, and infrastructure must be considered to ensure realistic application across different performance levels in football.

1.4.3 Research Question

What is the extent of interindividual dispersion of speed thresholds at the absolute thresholds of 19.8 km/h and 25.2 km/h, and which practical diagnostic methods enable an efficient implementation of individualized thresholds while considering external influencing factors?

1.4.4 Hypotheses

- The interindividual dispersion at absolute speed thresholds is significantly high, leading to a distorted load assessment when using fixed absolute thresholds.

- Diagnostic procedures for individualizing speed thresholds differ in terms of their practical feasibility, with infrastructural, temporal, and financial factors playing a crucial role.

2 Methodology

2.1 Data Collection and Processing

The analysis of the practical part and all related data is based on official post-match reports from the FIFA World Cup™ Qatar 2022 [28]. Player speeds were recorded using an optical multi-camera tracking system. The TRACAB Gen5 system from ChyronHego utilized multiple high-resolution cameras operating at a frequency of 25 Hz to accurately track player movements during matches. The collected data was subsequently analyzed to determine the distances covered and the maximum speeds reached by players [17].

All players who accumulated at least 270 minutes of playing time during the tournament (equivalent to approximately three matches) were included in the analysis (Mean (M) = 376.5 min, Standard Deviation (SD) = 111.94 min). This filtering ensured that only players with sufficient playing time were considered for a valid analysis. After data cleaning, a total of 196 datasets remained for further processing. In these publicly available datasets, players were also broadly categorized by position into defenders (DEF), midfielders (MF), and forwards (FW).

For all statistical analyses, the program R (Version 4.4.2) was used. The dataset included the top speed values (in km/h) and the individual percentage intensity at the absolute thresholds (19.8 km/h and 25.2 km/h) for World Cup participants. Players were categorized according to their playing positions: defenders (DF), midfielders (MF), and forwards (FW). The positions were coded as categorical variables in the predefined order DF, MF, and FW.

2.2 Data Preparation and Analysis

As part of the descriptive statistics, the mean, standard deviation, confidence intervals, minimum, and maximum values were calculated for each position and for the percentage intensities at the selected absolute thresholds. These metrics allowed for an initial assessment of central tendencies and the distribution of top speed values by position.

Subsequently, it was examined whether the assumptions for parametric testing were met. The normal distribution of residuals from a one-way ANOVA model was tested using the Shapiro-Wilk test. The test indicated that the residuals significantly deviated from a normal distribution ($p < 0.05$), which ruled out the use of parametric methods. Additionally, the homogeneity of variances was assessed using Levene's test. Due to the violation of the normality assumption, further analysis was conducted using non-parametric methods. To test for differences in top speed between positions, the Kruskal-Wallis test was applied. This test serves as the non-parametric counterpart to one-way ANOVA and allows for comparisons between more than two independent groups without assuming normality. The Kruskal-Wallis test indicated significant differences between the three positions ($p < 0.05$). To identify which groups differed significantly, pairwise comparisons were conducted using the Dunn test. A Bonferroni correction was applied to minimize the risk of Type I errors due to multiple comparisons. The results of these calculations revealed significant differences between the positional groups.

The results were visualized using various graphical representations to illustrate the distribution and central tendencies of the data. A half-violin plot was created to display the density distribution of top speed values per position. In this plot, boxplots were integrated to illustrate the median, quartiles, and outliers. Individual data points were plotted within the density curves to highlight the dispersion of the measurements. Additionally, a violin plot was generated to depict the distribution of intensities (%) at the speeds of 19.8 km/h and 25.2 km/h. The density curves in this plot illustrate the distribution of intensity values within the two speed ranges.

By combining these visualization techniques, both the central tendencies and the data dispersion were effectively highlighted.

All analyses and visualizations were conducted using the following packages: dplyr (for data preprocessing), ggplot2 (for graphical representation), ggdist (for half-eye plots), car (for the Levene test), FSA (for the Dunn test), and rstatix (for the Kruskal-Wallis test and pairwise comparisons with Bonferroni correction). By integrating robust non-parametric methods with visually effective graphics, well-founded conclusions could be drawn regarding the differences in top speed between the various playing positions.

3 Results

The following section provides a descriptive analysis of the ranges of maximal sprinting speeds, the different intensities at which players reach the chosen absolute thresholds of 19.8 km/h and 25.2 km/h, and examines positional differences for statistical significance.

3.1 Maximal Sprinting Speed

As described in the methodology section, the cleaned dataset included 196 players (Mean (M) = 32.58 km/h; Standard Deviation (SD) = 1.54 km/h; 95% Confidence Interval (CI95) = 32.36, 32.80 km/h). The minimum (Min) recorded speed was 27.7 km/h, while the maximum (Max) was 35.6 km/h, as shown in Table 2.

Table 2: Descriptive Statistics of the Maximal Speed for the Entire Dataset

n	Mean (SD)	SE	CI (95%)	Min	Max
196	32.58 (1.54)	0.11	[32.36, 32.80]	27.7	35.6

As shown in Table 3, midfielders (MF) exhibit the lowest average speed at 32.04 km/h (SD = 1.46 km/h; Min = 27.7 km/h; Max = 34.4 km/h). Both defenders (DF) and forwards (FW) show higher average maximal sprint speeds, with 32.66 km/h (SD = 1.59 km/h; Min = 28.7 km/h; Max = 35.4 km/h) and 33.23 km/h (SD = 1.30 km/h; Min = 30.1 km/h; Max = 35.6 km/h), respectively.

Table 3: Descriptive Statistics of Maximal Speed by Position

Position	n	Mean (SD)	SE	CI (95%)	Min	Max
DF	93	32.66 (1.59)	0.16	[32.33, 32.99]	28.7	35.4
MF	62	32.04 (1.46)	0.19	[31.67, 32.41]	27.7	34.4
FW	41	33.23 (1.30)	0.20	[32.82, 33.64]	30.1	35.6

Figure 3 illustrates the distribution of maximal sprinting speed (top speed) for the three player positions: defender, midfielder, and forward. The representation is done using a half-violin plot, which visualizes both the density distribution of the values and their central tendencies. The width of the violin plot indicates the density of observations – the wider the area, the more players exhibit that value. The highest density values for all positions are observed around the respective mean, while extreme high or low values occur less frequently.

Additionally, a boxplot was overlaid to represent the median, quartiles, and dispersion of the data points. The overlaid boxplot shows the central tendency and the spread of the data. The median for each group (DF = 32.7 km/h; MF = 32.2 km/h; FW = 33.4 km/h) lies within the densest part of the distribution. The boxes represent the interquartile ranges (25% (DF = 31.6 km/h; MF = 31.3 km/h; FW = 32.3 km/h) to 75% (DF = 33.8 km/h; MF = 33.0 km/h; FW = 34.1 km/h)), while the whiskers depict the remaining spread of the data. Individual points outside the whiskers indicate potential outliers.

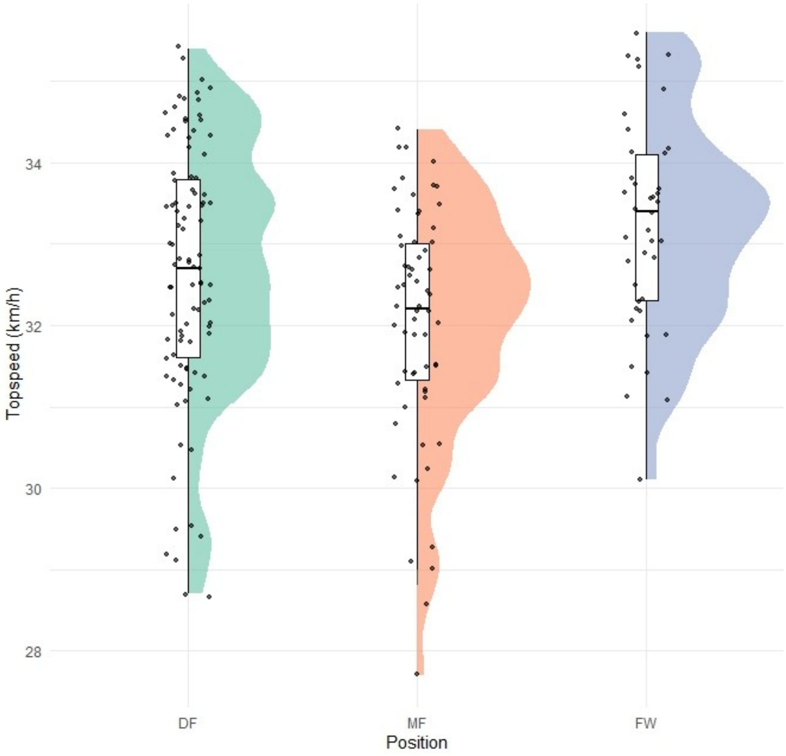

Figure 3: Representation of Different Maximal Speeds by Position

Statistical analyses using the Kruskal-Wallis test (Table 4) revealed a significant difference between positions (χ^2 = 14.318, p = 0.0008). Post-hoc comparisons following the Bonferroni correction, shown in Table 5, indicated that maximal speeds were highly significantly different between forwards (M = 33.23 km/h; SD = 1.30 km/h) and midfielders (M = 32.04 km/h; SD = 1.46 km/h) (Z = 3.71; p = 0.0006) and significantly different between defenders (M = 32.66 km/h; SD = 1.59 km/h) and midfielders (Z = 2.47; p = 0.0136) ($p < 0.05$), while no significant difference was found between defenders and forwards (Z = -1.82; p = 0.2048).

Table 4: Results of the Kruskal-Wallis Test for Top Speed by Position

Test	**Chi-Quadrat**	**p-Value**
Kruskal-Wallis-Test	14.318	0.0008**

* p < 0.05, ** p < 0.01, *** p < 0.001 (Bonferroni-corrected)

Table 5: Results of Pairwise Comparisons Following the Kruskal-Wallis Test with Bonferroni Correction

Comparison	**Z-Wert**	**p-Wert (not corrected)**	**p-Value (Bonferroni)**
DF - FW	-1.82	0.0683	0.2048
DF - MF	2.47	0.0136	0.0407*
FW - MF	3.71	0.0002	0.0006**

* p < 0.05, ** p < 0.01, *** p < 0.001 (Bonferroni-corrected)

3.2 Individual Intensities at the Absolute Thresholds

This section of the paper describes the individual intensities at which players reach the absolute values of 19.8 km/h and 25.2 km/h.

For the descriptive analysis of the 19.8 km/h threshold, the average individual intensity value was 60.91% (SD = 2.98), with a 95% confidence interval between 60.49% and 61.33%, as shown in Table 6. The minimum measured intensity was 55.62%, while the highest value reached 71.48%, resulting in a maximum difference of 15.86%.

Table 6: Descriptive Statistics for the Different Intensities at the Absolute Threshold of 19.8 km/h

n	**Mean (SD)**	**SE**	**CI (95%)**	**Min**	**Max**
196	60.91 (2.98)	0.21	[60.49, 61.33]	55.62	71.48

As shown in Table 7, for the 25.2 km/h threshold, the individual average intensity value was 77.52% (SD = 3.79), with a 95% confidence interval between 76.99% and 78.06%. Individual variation was also evident, with a minimum intensity value of 70.79% and a maximum value of 90.97%, resulting in a maximum difference of 20.18%.

Table 7: Descriptive Statistics for the Different Intensities at the Absolute Threshold of 25.2 km/h

n	**Mean (SD)**	**SE**	**CI (95%)**	**Min**	**Max**
196	77.52 (3.79)	0.27	[76.99, 78.06]	70.79	90.97

The graphical representation in Figure 4 highlights these individual differences at the absolute thresholds through a violin plot, which shows the distribution of intensity values within the two threshold ranges. The width of the violin shape represents the density of data in the respective intensity ranges: broader sections indicate a higher concentration of values, while narrower sections reflect a lower data density. Additionally, individual data points are displayed in the visualization, representing the actual measurements and thus illustrating the individual variation within the groups.

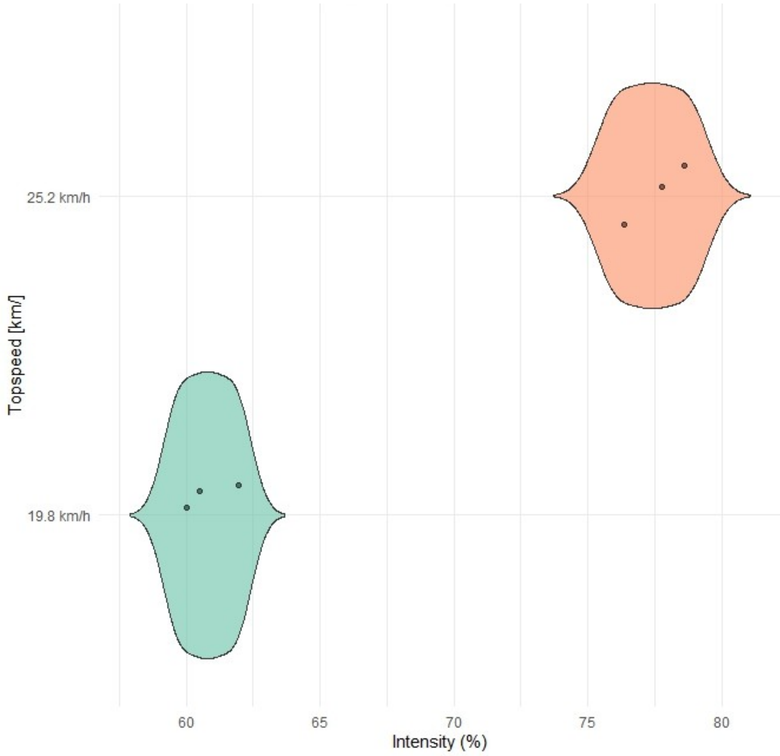

Figure 4: Dispersion of Individual Intensities at the Absolute Thresholds of 19.8 km/h and 25.2 km/h

While the values at 19.8 km/h are concentrated in a narrower range (M = 60.92%; SD = 2.98%), the variability at 25.2 km/h is more pronounced (M = 77.52%; SD = 3.79%). Both the minimum (55.62% and 70.79%) and maximum values (71.48% and 90.97%) show a wide range with regard to outliers.

4 Discussion

The following section discusses the empirical findings of this study and compares them with the prevailing literature. Subsequently, a model will be proposed, considering any potential limitations of the clubs, to create a practical guideline for the field in order to find ways for individualization.

4.1 Interpretation of Results

The analysis of maximal speeds at the FIFA World Cup 2022 reveals significant differences between player positions. While midfielders (MF) exhibited the lowest top speed values, forwards (FW) on average achieved the highest values, followed by defenders (DF). However, it should be noted that not all defenders achieve equally high sprint speeds. While full-backs often achieve comparable values to forwards, central defenders are generally slower because their primary duties are less focused on sprints, and they often prioritize tactical positioning. These position-specific differences in sprint performance are well-documented in football research and are closely linked to the tactical demands of the respective position [31]. However, it should be noted that not all defenders achieve equally high sprint speeds. While full-backs often achieve values similar to forwards, central defenders are typically slower due to their main responsibilities being less sprint-focused, often prioritizing tactical positioning. For example, forwards often have the opportunity to perform long linear sprints — such as during counter-attacks or when chasing through passes — while midfielders, due to the higher density of opponents and the need for more frequent direction changes, have less opportunity to reach their maximum speed [34].

Studies on load management in high-performance football confirm that defenders often achieve similar top speed values as forwards, but at a lower frequency [15]. This is because defenders typically reach their maximum speed in defensive situations — for example, when running back after a ball loss or during a sprint in a 1-on-1 duel — while forwards are more specifically trained to maximize their sprinting speeds [55]. A study by Haugen, Tønnessen, and Seiler [37] showed that players with offensive roles have significantly higher sprint volumes and greater variability in their top speed values, indicating that, alongside maximum speed, the repeatability of sprints plays a central role in position specificity. However, it is important to note that not all defenders achieve equally high sprint speeds. While full-backs often achieve comparable values to forwards, central defenders are generally slower due to their main tasks being less sprint-focused, often prioritizing tactical positioning.

The results regarding intensity at the absolute thresholds (19.8 km/h and 25.2 km/h) highlight the significant interindividual variability. The established thresholds for high-speed running (HSR) and sprints are frequently used in sports science research but are increasingly questioned [23]. The range within the intensity values (up to 20% difference) shows that a uniform threshold for all players is not appropriate, as individual performance and sprint economy vary greatly. A study by Malone et al. [42] emphasizes that players with higher maximum speeds not only enter defined high-speed zones less frequently but also have a greater potential for overestimating their load when fixed absolute values are used. This aligns with the current findings, which show that slower players reach a higher percentage of their maximum capacity relative to their top speed when exceeding the defined thresholds.

Furthermore, research indicates that the maximum speed measured in tests does not necessarily correspond to the maximum speed achieved in game situations. A systematic review by Barnes et al. [5] found that many players rarely reach their diagnosed sprint speed in competition, as situational factors such as available space, opponent pressure, and fatigue play a crucial role. This study does not only refer to sprints but also to other physical performance parameters that vary across different leagues. This is also confirmed by the findings of Freeman et al. [31], which show that many players achieve up to 5% higher maximum values in standardized sprint tests than in competition. The difference depends on the match situation: while wingers can occasionally use their full sprint capacity, central midfielders typically only reach 80–90% of their maximum running speed due to limited space.

Another challenge in classifying running speeds in football is the lack of standardization of thresholds, particularly when comparing different competitions and research studies [34]. Thresholds for high-speed running and sprints often vary between national leagues and international tournaments, complicating the comparability of data [42]. For example, differences in playing style philosophy, tactical demands, and player physical profiles can lead to certain leagues having higher or lower average running speed values. Studies have shown that players in the English Premier League, on average, perform a higher number of high-speed runs than in other European leagues [5], which affects the interpretation of the data.

These findings underscore the need for individualized thresholds for classifying running intensities. Models based on relative parameters such as maximal aerobic speed (MAS), anaerobic speed reserve (ASR), and maximal sprint speed (MSS) could allow for a more accurate assessment of physiological load [50]. Haugen et al. [37] point out that especially in professional football, an individualized approach to sprint analysis is necessary to obtain a more realistic picture of the actual performance requirements. Instead of using fixed absolute values, a system based on percentage shares of an individual's maximum speed could provide a more differentiated assessment of sprint load [42].

In summary, the results of this study show that fixed absolute thresholds in football are not sufficient to accurately depict individual sprint load. While midfielders, on average, have lower top speed values, forwards are more frequently able to reach high speeds. The significant variability in intensity values at absolute thresholds confirms the need for an individualized approach to running performance assessment to ensure realistic load management. The following sections of the discussion will develop models for the practical implementation of this individualization, considering both scientific insights and practical application cases.

4.2 Diagnostics Considering Various Limitations

The following section presents various testing methods as the basis for implementing individualized speed thresholds for practical work. The enumeration and development are carried out while considering various limitations that sports scientists face in everyday training.

Limitations in Practice In the daily training routines of nearly every club, limitations exist that require adjustments and deviations from the ideal test conditions. In this work, these factors are divided into three areas: "Money," "Time," and "Infrastructure," as shown in Figure 5. With this sequencing, conclusions for the appropriate choice of testing methods are drawn based on the currently prevailing literature.

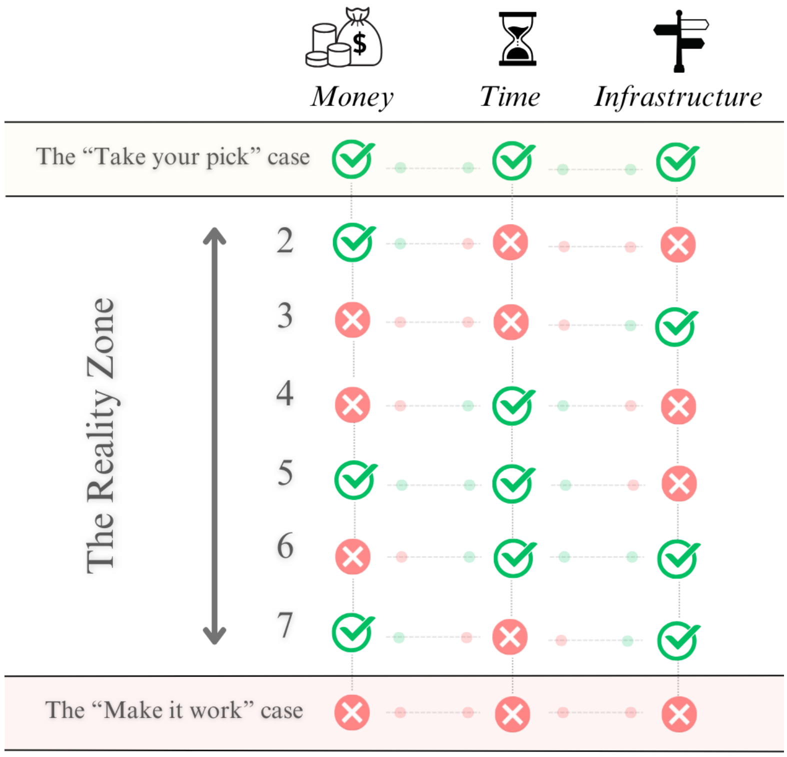

Figure 5: Representation of Prevailing Limitations in Training Practice by Categories

As shown in the figure above, both a best-case scenario (money, time, and infrastructure available) and a worst-case scenario (no category available) can be described. In most cases, compromises settle into the "Reality Zone" described by the author. In the following brief sections, the individual scenarios will be described using a Venn diagram visualization (see 6) along with the recommended MAS and MSS testing methods and their quality criteria.

For the inventory base of each club, this study assumes a football field with grass and a GPS monitoring system.

Money The term "money" encompasses all possibilities or purchases that are associated with significant costs. These include, among others, timing gate devices, radar guns, or access to laboratory equipment and their testing capabilities for CPET (Cardiopulmonary Exercise Testing).

Time In the "time" category, all possibilities that involve increased effort in testing and thus interfere with regular training activities are included. These include various field tests such as the 30-15 test, Yo-Yo IR1, and Shuttle Run, as well as CET (Continuous Endurance Tests), which are time- or distance-based.

Infrastructure Infrastructure is described as the ownership or free access to artificial turf fields, tracks, and indoor turf facilities.

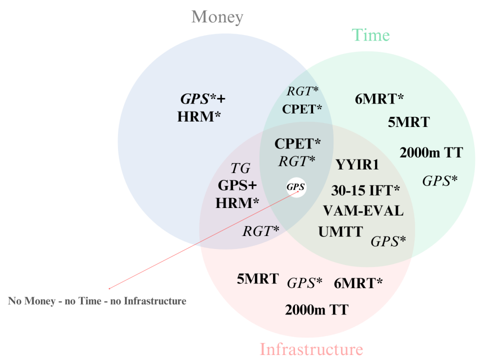

Figure 6: **Diagnostic Tool Based on the Prevailing Scenario within the Categories "Money," "Time," and "Infrastructure"** Bold = MAS Testing Methods, Italic = MSS Testing Methods; *indicates the gold standard in the respective category; Abbreviations: GPS = Global Positioning System, HRM = Heart Rate Monitoring, CPET = Cardiopulmonary Exercise Testing, Yo-Yo IR1 = Yo-Yo Intermittent Recovery Test Level 1, RGT = Radar Gun Testing, TG = Timing Gates, 5/6MRT = 5- or 6-minutes-Running Test, 2000m TT = 2000m Time Trial, UMTT = University of Montreal Track Test, 30-15 IFT = 30-15 Intermittent Fitness Test.

4.2.1 The "Take your pick" case

In this context, both money, time, and infrastructure are available, so the currently prevailing gold standards can be used. To determine the MAS, a CPET (Cardiopulmonary Exercise Testing) using a spirometer on a treadmill can be conducted, noting that different protocols may result in a wide range of values. Generally, step-based testing appears to be effective for team sports [54]. The MAScalc protocol can be mentioned here, which has very high validity (r = 0.92) and reliability (ICC = 0.94).

Regarding the measurement of MSS, the literature describes the radar gun (RGT) and laser measurement as the gold standard. The validity is between 0.93 - 0.98 [7][27] and 0.97 - 1.00 [29][30]. The reliabilities range from 0.83 - 0.99 [27] and 0.91 - 0.97 [29]. Since radar measurement is more suitable for high-speed sprints compared to laser measurement, it is preferred in this "Take your pick" scenario. As with all testing, a standardized surface or environment is a key factor in minimizing noise interference. In this setting, the test should be conducted on an indoor artificial turf field to exclude external weather conditions. Haugen & Buchheit [36] describe in their review that a +2.0 m/s tailwind makes athletes run 0.10 - 0.14 seconds faster over 100m sprints. If running into headwind, times can be up to 0.17 seconds slower. Testing can also take place on a track, but here the specific comparison with the conditions in the sport should be conducted and discussed. Gains et al. [33] compared 24 college football players and their sprint times on artificial and natural turf, finding no significant differences. Also, regarding different surfaces on tracks, Stafilidis & Arampatzis [53] found no significant differences in sprint times (p = 0.57).
With this knowledge, a standardized, weather-protected environment should be used.

4.2.2 The Reality Zone

This zone consists, as shown in Figure 5, of 6 different scenarios based on the previously described categories of money, time, and infrastructure. In the following, various practical situations will be discussed in more detail.

"We have money, but no time and infrastructure" If both time and infrastructure are lacking, but money is available, diagnostics should ideally be conducted during team training. The MAS can be estimated from internal monitoring (heart rate data) in combination with external GPS. This method offers the advantage that it does not require additional testing effort and instead uses the training and match load for MAS estimation. Modern high-frequency GPS systems (>10 Hz) and heart rate sensors allow continuous monitoring of individual physiological responses during regular training sessions and matches [18][6].

Individual adjustments of load thresholds are crucial, as standardized MAS values do not reflect the variable load profiles of team sports. Studies show that the combination of external GPS tracking and internal heart rate monitoring provides a valid and reliable method for continuous MAS adjustment [57][52].

Especially in Small-Sided Games, heart rate response can be used for indirect MAS determination, thereby capturing aerobic performance in a game-like setting without additional testing [1][44]. It has been shown that MAS values derived from Small-Sided Games align well with those from direct field and lab tests [38].

For testing MSS in this setting, the GPS method is also recommended. This method has the advantage of being usable in real game situations without the need for the athlete to be tested under standardized lab conditions. However, the accuracy of this method is strongly dependent on the sampling rate of the GPS system. GPS systems with a frequency of 10 Hz or higher show an acceptable correlation with laser and radar measurements ($r > 0.92$, $CV < 2.5\%$), while systems with a lower sampling rate (e.g., 5 Hz or less) are more error-prone and may show deviations of up to 10% compared to the gold standard methods (Radar Gun; Laser) [41]. Additionally, Sandford et al. [50] emphasize that GPS data are influenced not only by the sampling rate (recommended >10 Hz) but also by environmental factors such as satellite availability and signal interference. Furthermore, comparing GPS-based MSS data between players and training periods can be problematic, as differences in position tracking (e.g., movement patterns, sprint direction, field conditions) can systematically distort the values. These aspects should be considered when interpreting GPS measurements to avoid misinterpretations of actual sprint performance.

In general, measuring MSS with GPS systems in this context can offer a practical alternative to lab or field tests, especially in team sports with high movement dynamics.

"We have no money, no time but infrastructure" To determine maximal aerobic speed (MAS) under the condition that only infrastructure is available, but no financial resources and only limited time, time trials are a practical alternative to expensive lab tests. The 2000-meter time trial is considered one of the most reliable methods for determining MAS, as it shows a high correlation with direct VO2max measurements [20]. Studies show that the validity of the 2000-meter time trial compared to cardiopulmonary exercise tests is reported with $r = 0.85$ to 0.92, while the reliability ($ICC = 0.90$ to 0.94) ensures high repeatability of the results [32]. This method is particularly suitable for endurance athletes, but it can lead to an overestimation of MAS in team sports [48].

As an alternative, the 6-minute time trial is recommended, providing comparable results with a shorter test duration. The validity is between $r = 0.85$ to 0.90, similar to the 2000-meter test, while the reliability with an ICC of 0.94 to 0.96 is even slightly higher [47]. The 6-minute test is particularly advantageous for team sports as it requires less time and demands a consistent running speed. The 5-minute test also shows high values in validity and reliability, but the stability of the results is somewhat lower, so the 6-minute version is preferred [21].

For determining maximal sprint speed (MSS), GPS-based systems provide a practical alternative to radar and laser measurements. However, the accuracy of this method is highly dependent on the GPS system's sampling rate. GPS systems with a frequency of 10 Hz or higher show high validity ($r = 0.91$ to 0.95) and ICC values between 0.89 and 0.94, while systems with 5 Hz or less are less reliable and can have errors of up to 10% compared to the gold standard methods (Radar Gun, Laser) [39][4].

Studies on MSS determination via GPS show that 10-Hz VX Sport GPS devices correlate with radar measurements ($r > 0.92$), but slight fluctuations occur during abrupt speed changes [39]. A systematic review found that while GPS measurements are suitable for linear sprint tests, they are less precise for short, explosive sprint actions with direction changes [54].

In summary, the 6-minute time trial for MAS determination and MSS testing via GPS measurements with 10 Hz or more offer a practical method for determining these metrics when expensive laser devices are not available.

"We have no money and no infrastructure, but plenty of time" Due to the lack of infrastructure, solutions for MAS and MSS must be conducted on natural grass fields.

The 6-minute time trial offers, as indicated in the previous section, a simple and time-efficient way to determine maximal aerobic speed.

Another alternative is the 5-minute time trial, which shows similar values in validity and reliability, but due to the shorter test duration, it exhibits slightly higher variability [21]. This method is particularly advantageous when a quick test execution is necessary and a sufficiently valid assessment of maximal aerobic speed needs to be made.

The 2000-meter time trial, as previously described, is also an established test method. However, this method can slightly overestimate maximal aerobic speed in team sports, as it does not reflect the intermittent loads that occur in many team sports [48]. The measurement and delineation of the distance on the field must also be seen as a hurdle.

For MSS testing, the GPS method described in the previous section appears to be the most suitable.

"We have money and time, but no infrastructure" In this scenario, monetary resources and time for diagnostics are available, but infrastructure is the limiting factor. Planning must be done within the setting of a football field.

For determining MAS, a CPET test can be conducted again. Alternatively, this can also be derived using all time and distance runs as described previously. Another option is the approximation using heart rate monitoring and GPS data (see "We have money, but no time and infrastructure").

For MSS testing, the Radar Gun should be used. The use of radar guns for measuring sprint speed on different surfaces has been studied in several studies. The results show that radar guns have high validity and reliability, regardless of whether measurements were taken on natural grass, artificial turf, or a track. Earnshaw et al. [25] analyzed the measurement accuracy of radar guns on synthetic athletic tracks, 3G artificial turf fields, and natural grass pitches. They found that the radar gun provided valid measurements on all tested surfaces, but slight differences in measurement accuracy were observed due to the surface structure. Runacres et al. [49] conducted a comparative analysis between sprint measurements on artificial turf and natural grass using radar guns and found no significant differences between surfaces. Haugen and Buchheit [36] examined the methodological accuracy of sprint tests on various surfaces and concluded that the radar gun provides high measurement accuracy regardless of the surface and is therefore still considered the gold standard for determining sprint speed. With these results, it can be concluded that the use of the radar gun also holds gold standard status on natural grass.

"We have no money, but time and infrastructure" The situation with limited financial resources but sufficient time potential and access to artificial turf fields or halls is probably the most common configuration. For MAS testing, various field tests can be used here, with both the Université de Montréal Track Test (UMTT) and the 30-15 IFT being the gold standards for reliability (0.92 - 0.96 and 0.91 - 0.95) [14][13] and validity (0.91 - 0.95 and 0.87 - 0.95) for VO2max. The 30-15 is closer to team sports due to its intermittent protocol. Other test types that can be used here are the VAM-EVAL (ICC = 0.89 - 0.95, r = 0.88 - 0.94 [8][2][22]) and the Yo-Yo Intermittent Recovery Test 1 (YYIR1) (ICC = 0.89 - 0.94, r = 0.85 - 0.91 [51][56][40]). The YYIR1 is designed for athletes with a moderate to high aerobic performance component. The intensity increase is slower, so players with good endurance can sustain it for longer periods. Therefore, the test is often used for youth players, recreational athletes, and athletes at moderate performance levels [51]. In contrast, the Yo-Yo Intermittent Recovery Test Level 2 (YYIR2) is designed for sports with a high anaerobic component, which disadvantages it in relation to the YYIR1. The starting speed is higher, the intervals are shorter, and the intensity increase is faster than in YYIR1. This leads to a greater demand on the anaerobic energy systems. The test is therefore particularly suitable for professional athletes who need to perform explosive sprints and high-intensity exertions [56].

For MSS determination, the use of the GPS system (>10Hz) is recommended again.

"We have money and infrastructure, but no time" This scenario can occur during sudden coaching and staff changes within the season. In order to make the best possible decisions in the absence of time, the MAS diagnostics will again use the previously described GPS with HRM access. Additionally, for isolated sprints, maximal sprints during training can be measured in-situ. In this case, the radar gun is the gold standard. In practice and in-situ diagnostics, light gate systems / timing gates (TG) have also proven effective. Studies show that the validity of MSS measurements with light gates compared to radar guns reaches values between r = 0.96 and r = 0.98, while reliability with ICC values between 0.93 and 0.98 is also rated as excellent [58].

In comparison, modern GPS systems with a sampling rate of at least 10 Hz show a high correlation with light gates, with validity values between r = 0.91 and 0.95. However, reliability is slightly lower with ICC values from 0.89 to 0.94, especially during abrupt accelerations and changes in direction [39]. A systematic review [24] found that GPS systems tend to slightly underestimate MSS values, with deviations of up to 4.2% compared to light gate measurements.

A specific study of rugby players found that 10-Hz GPS systems correlate with light gate measurements (r = 0.89 to 0.94) but show greater individual variation [41]. This suggests that while GPS is a practical alternative to light gates, it does not offer the same accuracy in assessing an athlete individually.

In conclusion, light gates remain the preferred method for MSS measurements compared to GPS systems, especially when the highest precision is required. However, it should be noted that both the setup, handling, and quality criteria for the gold standard radar gun also play a key role in this setting.

4.2.3 The "Make it work" case

In practical terms, this means that, in addition to the previously defined basics (GPS system and natural grass), neither money, time, nor infrastructure is available for diagnostics.

Determining maximal aerobic speed (MAS) can be done through GPS-based analysis during regular training and game loads. One option is to calculate the highest average running speed over a period of three to six minutes. This method has the advantage of not requiring a separate test and allows MAS values to be continuously updated. Studies show that the validity of this method compared to direct MAS tests is high ($r = 0.89$ to 0.93), while the reliability with ICC values between 0.88 and 0.92 ensures good repeatability of the values [19]. The practical implementation involves regularly evaluating GPS data from training and match loads. The highest average speeds over defined time windows are then compared with previous values to make individual adjustments in training management [6].

Another method for MAS estimation is the analysis of Small-Sided Games (SSG). In these small-sided games with fewer players, high running intensities are achieved, so the highest sustainable running speeds can be used to estimate individual MAS. The validity of this method ranges from $r = 0.85$ to 0.90 compared to classical MAS field tests, while the reliability with ICC values between 0.87 and 0.91 shows stable reproducibility [1]. Data processing involves analyzing the highest stable running speeds during intense 4v4 or 5v5 games. These values are then compared with earlier measurements to observe the development of aerobic capacity and, if necessary, make training adjustments [44].

For MSS testing, GPS values during games or training are recommended.

4.3 Implications for Practice and Research

The results of this study show that the use of individualized speed thresholds for classifying running intensities in football enables more precise load management than conventional absolute thresholds. By integrating MAS, ASR, and MSS, training processes can be better adapted to the individual physiological capacities of the players, which is important both in load management and consequently in injury prevention. A testing framework has been created for practical decision-making based on the diagnostic options previously described along with their quality criteria, as shown in Figure 7.

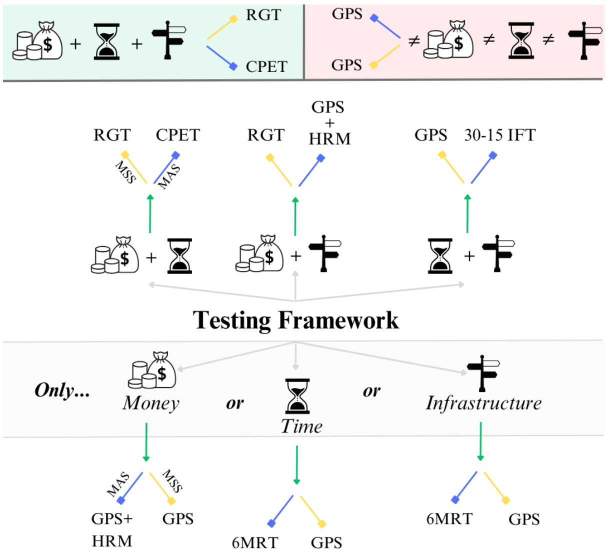

Figure 7: **Decision Tree for MAS and MSS Diagnostics Based on Prevailing Circumstances** GPS= Global Positioning System, HRM= Heart Rate Monitoring, RGT = Radar Gun Testing, CPET= Cardiopulmonary Exercise Testing, 6MRT= 6min Running Test, 30-15IFT= Intermittent Fitness Test

Based on the classification of speed zones according to absolute values (see Table 1), Table 8 presents a possible classification of these individual threshold ranges.

Zone	Zone name	Individual threshold from	Individual threshold to
1	Standing / No Movement	<10% MAS	10% MAS
2	Walking / Low-Speed Running	10% MAS	40% MAS%
3	Jogging / Moderate Running	40% MAS	80% MAS
4	High-Intensity Running	80% MAS	120% MAS
5	High-Speed Running (HSR)	120% MAS	90% MSS
6	Sprinting	>90 MSS%	

Table 8: Example of a Speed Zone Classification Based on Individual Thresholds Using MAS and MSS

Zone 1 - Standing / No Movement This zone includes phases where no or minimal movement occurs (<10% MAS). Energy expenditure remains at a very low level, as ATP resynthesis is almost entirely covered by the aerobic metabolism. This corresponds to recovery phases in a game, where players, for example, regenerate after intense sprints. Studies show that muscular activity remains low in this phase, which facilitates the rapid recovery of phosphocreatine (PCr) through aerobic ATP resynthesis [10][35].

Zone 2 - Walking / Low-Speed Running This zone includes speeds between 10–40% MAS and corresponds to low intensities with predominantly aerobic energy supply. Heart rate remains moderate, and the primary energy source is fat burning, while carbohydrate consumption remains low. This intensity range is typical for active recovery phases during a game or regenerative running sessions. According to the "crossover hypothesis," fat is primarily burned at loads below 45% VO2max, while carbohydrate consumption increases with intensity [12].

Zone 3 - Jogging / Moderate Running In the upper range of this zone (40–80% MAS), the transition phase between aerobic and anaerobic energy supply begins, where oxygen uptake increases continuously and is typically associated with submaximal endurance runs. With increasing intensity, the use of carbohydrates as an energy source increases. The MLSS (Maximal Lactate Steady State) is typically reached at 70–90% MAS, meaning the body can still efficiently break down lactate before accumulation begins [26].

Zone 4 - High Intensity Running From 80% MAS onwards, the transition to high-intensity exertion begins, where lactate production increases significantly and can lead to fatigue accumulation throughout the game. Oxygen debt increases as anaerobic metabolism takes over a greater role. In team sports, this zone is often reached during quick direction changes or intense tempo shifts. Studies show that neuromuscular fatigue increases sharply in this area, negatively affecting running economy [9].

It has also been shown that spending more time in this zone correlates with increased fatigue, resulting in players being able to perform less high-intensity running (HIR) in the second half [46]. A high load in this zone can therefore reduce performance in later phases of the game.

Zone 5 - High-Speed Running This zone includes loads between 120% MAS and 90% MSS, which cause a high neuromuscular load. In this range, type-II muscle fibers are heavily engaged. The body produces lactate through anaerobic glycolysis at a rate that can no longer be fully broken down [45][43].

Zone 6 - Sprinting The final zone includes running speeds above 90% MSS, where the body primarily uses the anaerobic alactic system (ATP-CP). This means that energy is provided without oxygen, which leads to maximal recruitment of muscles and high mechanical strain. Sprint training in this zone not only improves explosiveness but can also prevent injuries by increasing muscular endurance. A recent study by Buchheit [16] shows that regular sprint training at >90% MSS can lower the risk of injury.

4.3.1 Practical Examples of Individual Zone Design

Table 9 aims to provide a practical representation of how different MAS and MSS values affect the zone classification. Player 1, Player 2, and Player 3 have different MAS (18.5 km/h, 19.2 km/h, 20.0 km/h) and MSS (32.0 km/h, 34.5 km/h, 36.2 km/h) values. In this context, the individual zones are customized to estimate the approximately equal physiological stimuli as described earlier.

Table 9: Individual Speed Ranges based on MAS and MSS - Practical Example

Player	**Zone 1** Standing	**Zone 2** Walking	**Zone 3** Jogging	**Zone 4** High-Intensity	**Zone 5** High-Speed	**Zone 6** Sprinting
Player 1	<1.85 km/h	1.85 - 7.4 km/h	7.4 - 14.8 km/h	14.8 - 22.2 km/h	22.2 - 28.8 km/h	>28.8 km/h
Player 2	<1.92 km/h	1.92 - 7.68 km/h	7.68 - 15.36 km/h	15.36 - 23.04 km/h	23.04 - 31.05 km/h	>31.05 km/h
Player 3	<2.00 km/h	2.00 - 8.00 km/h	8.00 - 16.00 km/h	16.00 - 24.00 km/h	24.00 - 32.58 km/h	>32.58 km/h

When comparing the same players and their personal intensity values at common absolute thresholds (1), the increasing difference in the various exertions across the zones becomes apparent in Table 10. In Zone 1, a difference of 0.08% between the players is observed, which progressively increases up to 9% (Zone 6). Furthermore, the values for the sprint range, with 69.61% - 78.75%, are far from the previously described 90% of MSS.

Table 10: Comparison of Individual Intensity Levels Using Absolute Thresholds

Player	**Zone 1** Standing	**Zone 2** Walking	**Zone 3** Jogging	**Zone 4** High-Intensity	**Zone 5** High-Speed	**Zone 6** Sprinting
Player 1	0 – 1.08% MAS	1.08 – 38.92% MAS	38.92 – 77.84% MAS	77.84 – 107.03% MAS	107.03% MAS - 78.75% MSS	> 78.75% MSS
Player 2	0 – 1.04% MAS	1.04 – 37.50% MAS	37.50 – 75.00% MAS	75.00 – 103.13% MAS	103.13% MAS - 73.04% MSS	> 73.04% MSS
Player 3	0 – 1.00% MAS	1.00 – 36.00% MAS	36.00 – 72.00% MAS	72.00 – 99.00% MAS	99.00% MAS - 69.61% MSS	> 69.61% MSS

Practical Application In practice, there should be a shift from the currently rigid absolute threshold values. Both coaches and sports scientists should use this GPS tool and consider the individual performance capabilities of players in these highly intense muscular speed zones. Implementing individual thresholds allows for more differentiated load management, as players with different athletic profiles will no longer be discussed or evaluated in the same way by coaches and sports scientists.

To ensure effective individualization, regular data collection is essential. Modern GPS systems with a sampling rate of at least 10 Hz have proven to be a practical alternative to lab tests, although the measurement accuracy still depends on the quality of the systems used. To avoid systematic misjudgment of the maximal sprint speed (MSS) through GPS devices, alternative measurement methods such as radar guns or light gates should be used as reference measurements.

Another important practical element is considering the training and game situations in which maximal values are reached. Data analysis shows that diagnosed topspeed values from standardized sprint tests are often higher than those achieved in competition. Therefore, individual speed thresholds should not solely be derived from lab tests but should be regularly checked in the game and training context.

Future Research Directions For sports science research, the findings of this study highlight the need for further standardization of methods for determining MAS and MSS. Different studies currently use various protocols and measurement systems, which complicates comparability. A systematic validation of field tests compared to lab tests is necessary to further improve the practicality of these methods for team sports. Additionally, it would be desirable for in-situ testing methods to be further developed to ideally create methods where explicit diagnostics of individual thresholds would become a thing of the past.

Another promising research area is the investigation of individual threshold determination and its effects on load management and performance development over the long term. While short-term adjustments have already been shown to lead to improved load management, it remains unclear how the implementation of these methods affects a whole season or several seasons over time.

In conclusion, the results of this study should be seen as impulses and suggestions for practice and research in the field of athletic performance diagnostics. The individualization of speed thresholds based on physiological parameters provides a meaningful alternative to absolute limits and should become standard in future team settings, potentially developing a tool that could at least stagnate the rising injury rates in the future.

4.4 Limitations and Future Perspectives

Regarding the practical part of this study, the greatest limitation lies in the assumption that all 196 players who met the filter criteria reached their maximal speed during the tournament. In practice, it can be estimated that the variability of diagnosed values is lower, but individual intensity differences at the respective thresholds still prevail.

Furthermore, the categorization of players into defensive, midfield, and forward positions must be described as a distorting factor. On the one hand, due to the modern, flexible tactical formations, explicit positional labels only apply to a few positions, and on the other hand, differentiation within a position sector must also be made. For example, the defensive sector includes positions such as center-backs and full-backs, which have completely different load profiles. Moreover, high-speed values obtained through GPS systems need to be tracked and updated over a longer period. A minimal time span within a short event limits the conclusions that can be drawn.

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