Ole Haldor Ensrud

New velocity zones gain insights into the high velocity demands of soccer

Master's thesis in MPAHE
Supervisor: Vetle Veierød
Co-supervisor: Ulrik Wisløff
May 2023

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NEW VELOCITY ZONES GAIN INSIGHTS INTO THE HIGH VELOCITY DEMANDS OF SOCCER

By: Ole Haldor Ensrud

Background

Elite male soccer players experiencing increased:

- High velocity match demands (1;2)
- Hamstring injuries (3)

However, traditional velocity zones may provide limited accuracy for coaches in optimizing training load, due to wide zone thresholds at high velocities (>19.8 km·h⁻¹).

Aim:

Compare the position-specific intensity distribution from weekly training load to match load, within **new more precise velocity zones**

Study design & participants:

Longitudinal Cohort study | 15 male players, 1 elite club, 78 ± 7kg, 183 ± 7 | GPS data collected in match & training

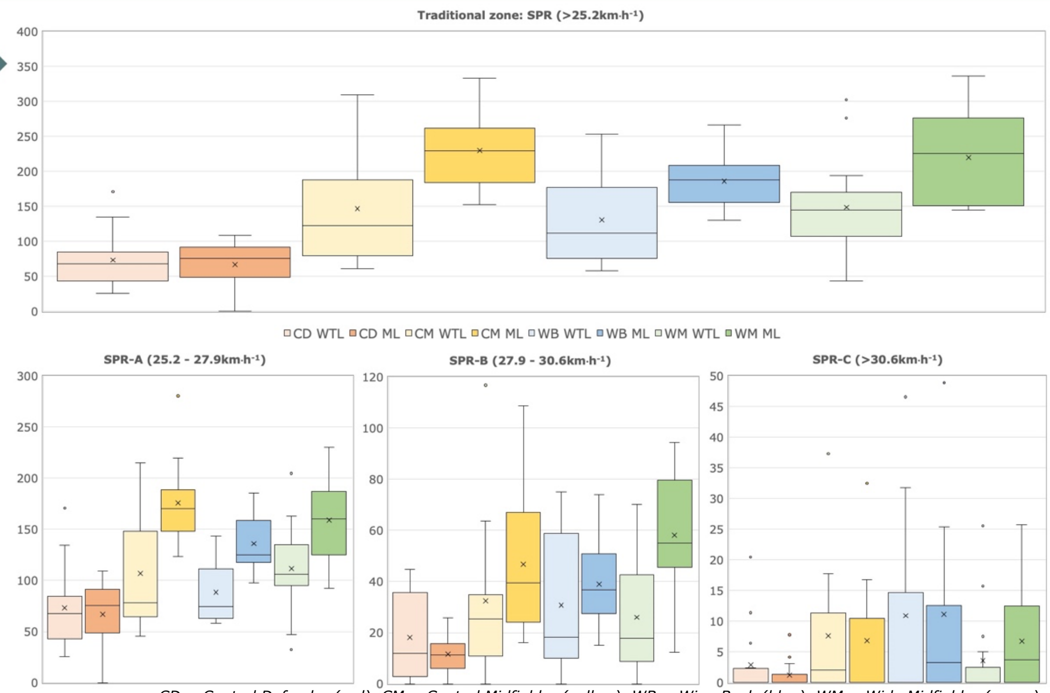
Traditional high-speed running (HSR, 19.8 - 25.2km·h⁻¹) and sprinting (SPR, >25.2km·h⁻¹) zones were divided into 5 **new zones** to quantify loads.

NEW ZONES	HSR-A	HSR-B	SPR-A	SPR-B	SPR-C
Velocity (km·h⁻¹)	19.8 - 22.5	22.5 - 25.2	25.2 - 27.9	27.9 - 30.6	> 30.6
WTL / Match demand	72%	59%	42%	34%	20%

WTL = Weekly training load distance. Match demand = Highest match load distance of the season.

1) WITH HIGHER VELOCITIES, AVERAGE PLAYERS ARE DECREASINGLY ABLE TO MEET MATCH DEMANDS IN TRAINING

2) NEW ACCURATE INFORMATION OF POSITION-SPECIFIC TRAINING & MATCH LOADS AT HIGH VELOCITIES



CD = Central Defender (red). CM = Central Midfielder (yellow). WB = Wing Back (blue). WM = Wide Midfielder (green). Light colors = Weekly training load. Dark colors = Match loads.

CONCLUSION

New velocity zones can enable more accurate planning of high velocity training, to prepare players according to match demands.

1) Bush et al. (2015). Evolution of match performance…
2) Lago-Penas et al. (2023). Evolution of physical and …
3) Ekstrand et al. (2016). Hamstring injuries have increased by 4% annually …
4) Rampinini et al. (2007). Varation in top level soccer match performance…

Abstract

Background: Accurately monitoring load is a crucial part of optimizing physical performance for elite soccer players. With the trend of increased match loads at high velocities, the traditionally used zones may deploy to wide velocity thresholds, to accurately monitor load at high velocities. Subsequently, the aim of this study was comparing external running load in matches to weekly training load, for different playing positions, within a new set of more precise velocity zones.

Methodology: Fifteen male soccer players (77.7 ± 6.8kg, 183.1 ± 6.6cm) playing for a Norwegian elite club, participated in this study. Global positioning system data were continuously collected during training and matches throughout the 2022 season. This study divided the traditional high-speed running (HSR, 19.8 - 25.2km·h^{-1}) zone into HSR-A (19.8-22.5km·h^{-1}) and HSR-B (22.7-25.2 km·h^{-1}). Moreover, the traditional sprinting (SPR, >25.2km·h^{-1}) zone was divided into SPR-A (25.2-27.9 km·h^{-1}), SPR-B (27.9-30.6 km·h^{-1}) and SPR-C (>30.6 km·h^{-1}). Load variables were distances and efforts within the velocity zones.

Results: This study showed that players have gradually decreasing training loads at higher velocities, with training distance gradually decreasing from HSR-A (72%) up to SPR-C (20%), when compared to the highest match load distance of the season. The average players HSR match distance (605 ± 64m) was distributed in the new zones HSR-A (67%) and HSR-B (33%). For the SPR match distance (154 ± 25), this was distributed in SPR-A (74%), SPR-B (22%) and SPR-C (4%), with a large portion of SPR load being within SPR-A zone. Further, comparisons between training and observed match loads, show that the average player covered respectively 10 and 28% less HSR ($p< .02$) and SPR ($p< .00$) distances in training. Efforts in training were similar at HSR ($p< .38$) and 25% less at SPR ($p< .01$) compared to matches.

Conclusion: Implementing new velocity zones can enable more accurate planning of high velocity training in soccer, to prepare players according to match demands.

***Keywords**:* External Load – High velocity – Sprinting – Position-specific – Soccer

Sammendrag

Bakgrunn: Nøyaktige belastningsmålinger er en avgjørende faktor for å kunne optimalisere prestasjonsevne for fotballspillere. Med økende kampkravene på høye hastigheter, er de tradisjonelt brukte hastighetssonene mulig for vide til å nøyaktig beskrive belastning på høye hastigheter godt nok. Muligens begrenser dette presisjonen til å forstå kampkrav, og til å optimalisere treningen deretter. Derfor har denne studien som mål å sammenlikne posisjonspesifikke forskjeller fra kamp- til treningsbelastning i et nytt sett av mer presise hastighetssoner.

Metode: 15 mannlige fotballspillere (77.7 ± 6.8 kg, 183.1 ± 6.6 cm) som spiller for en norsk eliteklubb, deltok i denne studien. GPS-data ble samlet inn fra trening og kamper i løpet av 2022. Denne studien delte den tradisjonelle høyhastighetssonen (HSR, 19.8 - 25.2km·t^{-1}) i HSR-A (19.8-22.5km·t^{-1}) og HSR-B (22.7-25.2 km·t^{-1}). Videre, ble den tradisjonelle sonen spurting (SPR, >25.2km·t^{-1}) delt inn i SPR-A (25.2-27.9 km·t^{-1}), SPR-B (27.9-30.6 km·t^{-1}) og SPR-C (>30.6 km·t^{-1}). De målte variablene var distanse og antall innsatser i hastighetssonene.

Resultat: Denne studien viste at spillere har gradvis mindre treningsbelastning med økende hastigheter, med ukentlig treningsbelastning gradvis synkende fra HSR-A (72%) til SPR-C (20%), sammenliknet med høyeste kampbelastning. Den gjennomsnittlige kampdistansen på HSR sone (605 ± 64m) ble fordelt i de nye HSR-A (67%) og HSR-B (33%). For kampdistanse på SPR sone (154 ± 25), ble dette inndelt i henholdsvis SPR-A (74%), SPR-B (22%) og SPR-C (4%), med større vekting på lavere hastigheter. Ved å sammenlikne trening med observert kampbelastning, viste dette at gjennomsnittspilleren løper respektivt 10 og 28% mindre HSR ($p< .02$) og SPR ($p< .00$) distanse i ukentlig treningsbelastning. Antall HSR innsatser i trening var liknende ($p< .38$) med kamp, mens SPR innstaser var 25% mindre ($p< .01$) i trening sammenliknet med kampbelastning.

Konklusjon: Det å implementere nye hastighetssoner kan bidra til mer nøyaktig planlegging av høyhastighetsstrening, som kan bidra til å trene mot kampbelastning.

Nøkkelord: Ekstern belastning – høyhastighet – spurting – posisjonsspesifikk - fotball

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I would like to express my appreciation towards NTNU and, especially, my supervisor Vetle Veierød. Vetle guided me patiently throughout the project, I learned a lot from his expertise and we had many enjoyable discussions together. Further, I would like to express thanks to Professor Ulrik Wisløff, who helped with constructive feedback on the project. Lastly, the soccer team deserves a thanks, for allowing me to analyze and use their data, for making me feel welcome and for the hospitality offeredthroughout the study period.

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List of Abbreviations

GPS	Global Positioning System
SPR	Sprinting
HSR	High-speed running
CD	Central Defender
CF	Central Forward
CM	Central Midfielder
DM	Defensive Midfielder
WB	Wing Back
WM	Wide Midfielder

List of Definitions

Match load	Load accumulated within match time
Matchday-4	4 days prior to matchday
Matchday-3	3 days prior to matchday
Matchday-2	2 days prior to matchday
Matchday-1	1 day prior to matchday
Matchday+1	The day after matchday
Weekly training load	Accumulated load from Matchday-4 to Matchday-1
Training to match-ratio	Weekly training load divided by match load.
Match load max	Highest individual match distance through season
High-speed running	19.8 – 25. 2km·h^{-1}
High-speed running-A	19.8 – 22.5km·h^{-1}
High-speed running-B	22.5 – 25.2km·h^{-1}
Sprinting	> 25.2km·h^{-1}
Sprinting-A	25.2 – 27.9km·h^{-1}
Sprinting-B	27.9 – 30.6km·h^{-1}
Sprinting-C	> 30.6km·h^{-1}

1 Background

Soccer is a simple game in its essence, where the idea is to score more goals than the opponent. Nevertheless, many factors must be mastered for a team to perform at elite level. The game of soccer involves a combination of intermittent aerobic activity and high-intensity sprint efforts (Bangsbo et al., 2006). Match demands vary dependent on opponents' fitness level, playing position and match tactics (Chmura et al., 2018; Malone et al., 2015; Rampinini et al., 2007). Further, technical and tactical abilities alone cannot produce consistent top level performance without sufficient soccer specific strength and endurance capacities (Stolen et al., 2005). In addition, competing at the highest physical level throughout a long season, set requirements to optimize training load that secures progression while ensuring a low injury rate (Jaspers et al., 2017).

Despite considerable amount of knowledge available on elite soccer performance in today´s literature, it is crucial to recognize that match demands for elite soccer players is constantly evolving. For instance, average sprinting (SPR, >25.2 $km \cdot h^{-1}$) distances in English Premier League increased by 30-50% from the 2006/2007 season to 2012/2013, whilst total distance only increased by 2% (Bush et al., 2017; Bush et al., 2015). A similar study from the Spanish first division (La Liga) showed that male players ran 3.2 % shorter distance in 2020 compared with that in 2012 season (Lago-Penas et al., 2023), whereas high-speed running (HSR, 19.8 – 25.2 $km \cdot h^{-1}$) distance increased by a range from 8.0 to 9.5% for all playing positions, except for Wide Midfielders (WM). Despite this, WM still increased HSR efforts with 9.2% and Wingbacks (WB) as much as 14.6% (Lago-Penas et al., 2023), highlighting the variety and evolving sprint demands by position. Consequently, with the higher sprinting demands, loads on primary muscles activated have increased (Bush et al., 2017; Bush et al., 2015; Ekstrand et al., 2016; Lago-Penas et al., 2023). Research on 36 English Premier League clubs show that hamstring strain injuries have increased 4% annually from 2001 to 2014 (Ekstrand et al., 2016). The higher injury rate may be explained by the kinetic energy formula (Friedrichs, 1978), showing that the kinetic energy the musculature must absorb increases proportionally to an increase of mass or velocity squared ($Energy = \frac{1}{2} \cdot mass \cdot velocity^2$). Also explained by the injury pattern of the most common soccer injury, hamstring strains (Ekstrand et al., 2011), which typically occurs at high velocities or during deceleration (Gronwald et al., 2022; Howard et al., 2018).

As can be seen above, there is a need for new insights on a regular basis. This will help in training planning, enabling appropriate training loads, and equip players with skills and capacities needed to cope with match demands in elite soccer.

Current state of training load monitoring

Due to methodological challenges of determining training load´s impact on match performance, there is no theoretical evidence suggesting how to optimize training periodization (Kelly et al., 2020). The increasingly higher velocity demands and injury frequency (Ekstrand et al., 2011; Ekstrand et al., 2016; Verstappen et al., 2021) for elite male soccer players, makes managing training load crucial to optimize physical performance. Moreower, the initial step of managing an optimal training load management regime, involves preparing players based on the neuromuscular match demands, followed by monitoring the training regime´s impact on players performance and physical capacities (Djaoui et al., 2017). A well-managed training monitoring regime includes both external and internal load variables (Djaoui et al., 2017), which respectively monitor the activity and the physical response to the activity (Akenhead & Nassis, 2016; Bourdon et al., 2017; Djaoui et al., 2017; Halson, 2014). In line with this, most elite soccer teams use global Positioning System (GPS) technology and heart rate monitors to quantify weekly or daily load (Akenhead & Nassis, 2016).
GPS variables are often quantified within either arbitrary velocity zones, measured within a specific velocity range (see Table 1.1), or individualized velocity zones, tailored for each individual top speed (Akenhead & Nassis, 2016; Rago et al., 2020). Nevertheless, research show that using arbitrary zones, which is based on actual velocities, show similar sensitivity in predicting player demands as individualized zones (Rago et al., 2020). Also, individualized zones are not a measure on physical quality, as they may underestimate the external loads of players with higher top-speeds. In addition, arbitrary zones can monitor seasonal fluctuation in external load and enables comparability between different playing positions (Rago et al., 2020).

Table 1.1: Arbitrary velocity zones in soccer, ProZone® (Rampinini et al., 2007).

I Walking, jogging	II Low-speed running	III Moderate-speed running	IV High-speed running (HSR)	V Sprinting (SPR)
0-7.2 km·h^{-1} 0-2.0 m·s^{-1}	7.2-14.4 km·h^{-1} 2.0-4.0 m·s^{-1}	14.4-19.8 km·h^{-1} 4.0-5.5 m·s^{-1}	19.8-25.2 km·h^{-1} 5.5-7.0 m·s^{-1}	> 25.2 km·h^{-1} >7.0 m·s^{-1}

With increased match and training demands due to soccer players running more at higher velocities, it seems natural to suggests that a primary focus in elite soccer should be to have more focus on load-periodization based upon high-velocity activities. Today, research and best practice mostly monitor high velocity loads distributed within the HSR and SPR zone of the Prozone velocity zone classification (Rampinini et al., 2007) (Table 1.1). However, both HSR (19.8-25.2 km·h^{-1}) and SPR (>25.2 km·h^{-1}) zone includes wide ranges of velocities. Since movement velocity impacts the degree of muscle activation (Brughelli et al., 2008; Coratella et al., 2018; Howard et al., 2018; Stolen et al., 2005), a sprint effort at 26 km·h^{-1} may require different neuromuscular demands to one at 30 km·h^{-1}. Hence, I suggests these zones may limit the representation of actual loads, especially when considering the trend of increased match demands and injury frequency for elite male soccer players (Ekstrand et al., 2016; Gronwald et al., 2022). Therefore, researching narrower and more accurate arbitrary velocity zones may be beneficial to optimize monitoring and control of load, potentially, leading to improved physical performance.

Comparing match and training load

One approach to monitoring external loads by playing position, is comparing match demands against accumulated training loads prior to match, more commonly described as match load and weekly training load. The literature suggests more training days prior to matchday, greatly elevates the training to match ratio (TMr) of multiple load variables for elite male soccer players (Clemente et al., 2019; Stevens et al., 2017). However, a challenge with previous studies comparing training to match load (Clemente et al., 2019; Stevens et al., 2017) is the different external load variables measured. Rather than classifying data within the Prozone velocity zone classification (Rampinini et al., 2007), an Eredivisie study defined HSR load as all distance above 19.8 km·h^{-1} (Stevens et al., 2017), including SPR values. Conversely, another study defined SPR load as distance (m) producing high power above 20W·kg $^{-1}$ (Clemente et al., 2019). Further, the inclusion criteria´s in the Eredivisie study, included all training weeks without considering match or training days participation, by categorizing training data based on days prior to matchday (Stevens et al., 2017). In contrast, Clemente et al. (2019) only included players participating in all training days within a microcycle. Thus, a primary challenge of comparing training and match data, is to use appropriate inclusion criterions.

Studies comparing training to match load by playing position, have documented that match load varies considerably according to playing position (Malone et al., 2015; Ingebrigtsen et al., 2015). One study from an English Premier League club found that HSR distance and efforts were lowest for Central Defenders (CD), while WB reached the highest values for both HSR distance, efforts and SPR distance (Akenhead et al., 2016). However, few studies (Modric et al., 2020) have investigated whether there are position-specific differences from match to training load. One study concluded (Modric et al., 2020) that certain playing positions could benefit from more tailored training according to position-specific match demands. It was suggested that CD could benefit from more acceleration training, while central forwards (CF) could benefit from longer distance sprint efforts (Modric et al., 2020). Nevertheless, it is important to highlight that this study only studied one soccer team in Croatia, which is also not considered a top league. Rather, the findings of Modric et al. (2020) can highlight the importance of monitoring match and training loads for each position, to accurately prescribe and control the training load of each player according to position-specific match demands.

No study have investigated position-specific load distribution within narrower velocity zone than the Prozone® classification (Rampinini et al., 2007). This may be especially relevant for elite male soccer players of today, given the trend of increased high velocity match demands (Bush et al., 2017; Bush et al., 2015; Ekstrand et al., 2016; Lago-Penas et al., 2023) and injury rate (Ekstrand et al., 2011; Gronwald et al., 2022). In summary, the wide velocity zone ranges deployed in Prozone® (Table 1.1) may provide coaches with limited knowledge of how to accurately control training load to meet match demands.

1.1 Research problem

The aim of this study was to compare external running load in matches to weekly training load, for different playing positions, within a new set of velocity zones. I hypothesized that new velocity zones may enable more accurate load monitoring than traditional zones, especially for players with higher top-speeds.

2 Methodology

This study was done with initiative from the soccer club to determine whether new velocity zones for external running load could enable improved monitoring and control of physical performance. This study exclusively investigated one-match microcycles with 4 training days prior to match. Importantly, for one-match microcycles, the coaching staff aimed for each player, during the 4-day training period prior to match, to obtain an equivalent sprinting distance as they experienced during the match with the highest distance (ML_{MAX}). The objective of this, was preparing players according to the most challenging match demands.

2.1 Participants

Fifteen male players (23.3 ± 3.7y, 77.7 ± 6.8kg, height 183.1 ± 6.6cm, VO_{2max} 64.7 ± 3.9 $mL \cdot kg^{-1} \cdot min^{-1}$) from a professional soccer club in the Norwegian elite league participated in this study. The team competed in two different competitions during data collection of this study (Norwegian Elite League and the Norwegian Football Cup), playing mostly a 3-5-2 formation. The players were classified into 6 positions: CD, central forward (CF), CM, defensive midfielders (DM), WB, and WM. This research was conducted in accordance with applicable law, NTNU guidelines and the ethical principles outlined in the Norwegian National Committees for research ethics and the Declaration of Helsinki. Subsequently, the author obtained written consent from subjects and the organization involved prior to collecting and analyzing data. To ensure privacy and confidentiality for the subjects, the author anonymized individual player names before analyses and publication. Also, to ensure beneficence for the soccer club and players, the author aided the soccer club in physical testing and shared potentially relevant information gathered during the research.

2.2 Design

This longitudinal cohort study collected data from training sessions and official matches during the 2022 season. To address the aim of this study, the results were divided into three chapters based on different methods used. Chapter 3.1 includes average distance and efforts expended in traditional zones, along with correlations between weekly training load and match load. Chapter 3.2 encompassed new velocity zone distribution of similar external load variables as Chapter 3.1. Chapter 3.3 presented position-specific differences with new and traditional velocity zones for velocities above 25.2 km·h^{-1}. The reason for not illustrating HSR velocities, were relatively similar differences between training and match within HSR-A and -B zones, in contrast to the SPR zones. In addition, the boxplots only included positions with the most sufficient sample sizes available (≥16 samples), namely CD, CM, WB, and WM.

Finally, Chapter 3.4, compared the average weekly training load to toughest match load of the season, in both traditional and new velocity zones. This was done to compare which velocity zone classification providing the most value in monitoring load for a specific load management situation. During the 2022 season, the team mostly had one-match microcycles. The most common weekly pattern after match, consisted of recovery or compensation session the day after match (MD+1), followed by a rest day on MD+2. The team deployed a standardized periodization plan from 4 days (MD-4) leading up to matchday. However, multiple microcycles included matches in quick succession, also called two-match microcycles. To ensure comparable training weeks, the author defined weekly training load as the accumulated load from MD-4 to MD-1 (Table 2.1). Importantly, the team deployed a training load manipulation strategy, consisting of increasing or reducing field time based on individual sprint data or fitness status, resulting in individual differences in field time completed per microcycle.

Table 2.1: Standardized one-match microcycle plan in this study.

Training days prior to MD-5	Training days (standardized one-match microcycle plan)				Matchday	Rest / Compensation	Rest
>MD-5	MD-4	MD-3	MD-2	MD-1	MD	MD+1	MD+2
	WTL				ML		

Notes. Only colored cells were included in this study. MD-4 = 4 days prior to matchday. MD+1 = Day after matchday. WTL= Weekly training load. ML= Match load.

2.3 Data collection and analyzis

There was no intervention from the author in the design or execution of activities. To collect training and match data, the team deployed a global-positioning system (GPS) inside an upper body west with a 10Hz GNSS tracking unit (Catapult Vector S7, 48cm^3, 53g, 81·44·16mm, Figure 2.1). The Catapult Vector system has shown to produce reliable and consistent distance data for comparisons between playing positions (Crang et al., 2022). GPS data in this study were obtained from March 29, 2022, to November 13, 2022, more specifically, this study only extracted data tagged as in-session, which excluded periods of activity between first and second half of a match or between training exercises. Coaches tagging exercises accurately was crucial for quantifying activity accurately. Data was presented as mean ± standard deviation.

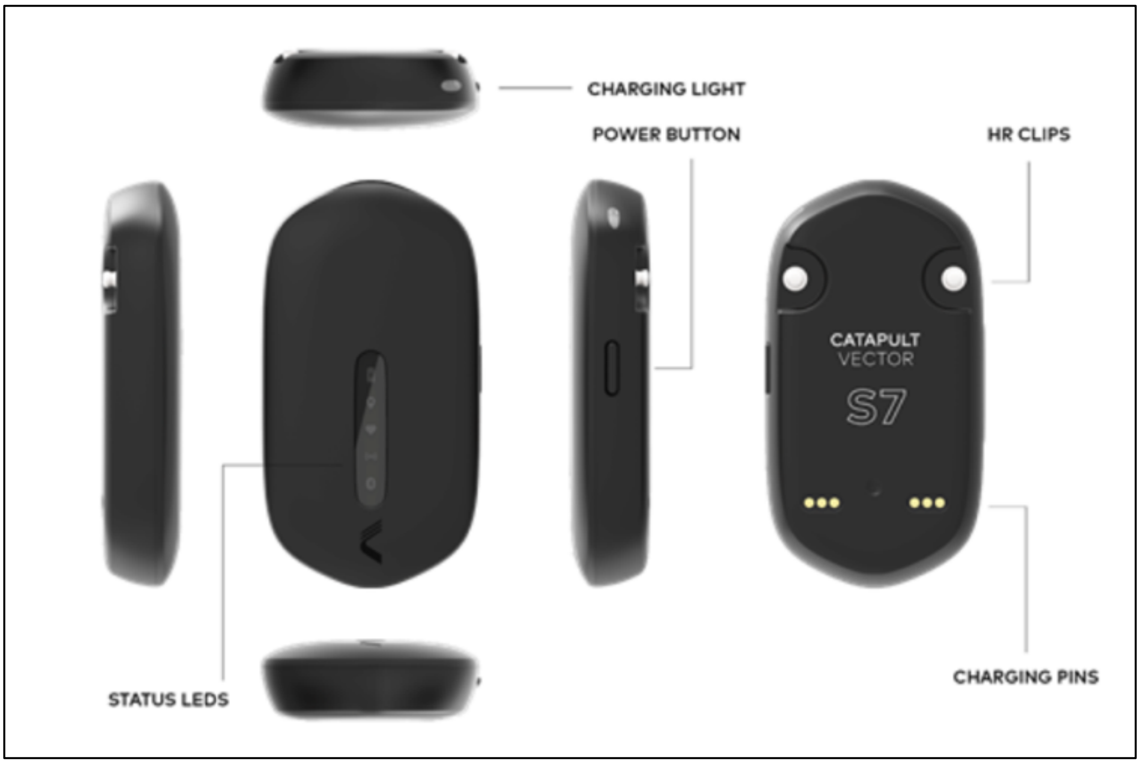

Figure 2.1: Catapult Vector S7. Notes: Tracking unit to collect GPS data during training and matches.

2.4 Inclusion and exclusion criteria

The sample size excluded individual, compensation, indoor or rehab sessions. Additionally, goalkeepers were excluded prior to analysis. The study timeline consisted of 30 microcycles of GPS data, with varying number of training days leading up to match day, and a diverse sample of players with wide-ranging participation in both training sessions and match minutes. To ensure the accuracy and consistency of the data, the author employed strict inclusion criteria, where players not passing all inclusion criteria, were excluded for analysis.

Since this study exclusively looked at one-match microcycles with 4 training days leading up to MD, **the first inclusion criteria** were to only include the 17 microcycles with 4 training days prior to MD. If the team had training sessions prior to MD-4, typically in a longer training period, the training sessions prior to MD-4 were not included. A potential weakness of this approach, is that the longer training period may be used for accumulating training load, resulting in easier training days than normal in the period analyzed, MD-4 to MD-1. On the other hand, only including microcycles with 4 training days has its strength in comparing similar training period durations against ML. **The second inclusion criteria** encompassed participation thresholds for match minutes and training participation within each of the 17 included microcycles. To ensure the accuracy and consistency of the ML measurements, the author opted to exclude players who were substituted before completing 80 minutes of match play for two reasons. Firstly, if lower-minute players were included, this data would need to be multiplied up to average match time of 96 minutes, to be comparable to other ML. The problem with this manipulation of data, is that multiplying lower-minute players might lead to elevated HSR and SPR data, due to ability to work at a higher intensity over a shorter time. Also, if the author multiply match loads up to an ideal scenario, the question becomes: Should the author also multiply training data as well? Instead, the author deployed strict inclusion criteria with a high threshold for match participation of above 80 minutes. Secondly, the author observed that a minimum of 90 minutes inclusion criteria would result in a reduction in sample size, particularly for lateral playing positions, which repeatedly where subbed of before final time. **For training participation**, there were no club reports for training participation. Instead, the author calculated the number of sessions a player registered from MD-4 to MD-1. A training exercise participation of above 80% were decided the most appropriate, both to exclude players who completed 3 or less training days and still include players who were partially absent from certain activities due to training load manipulation. Figure 2.2 summarizes the inclusion process of GPS data.

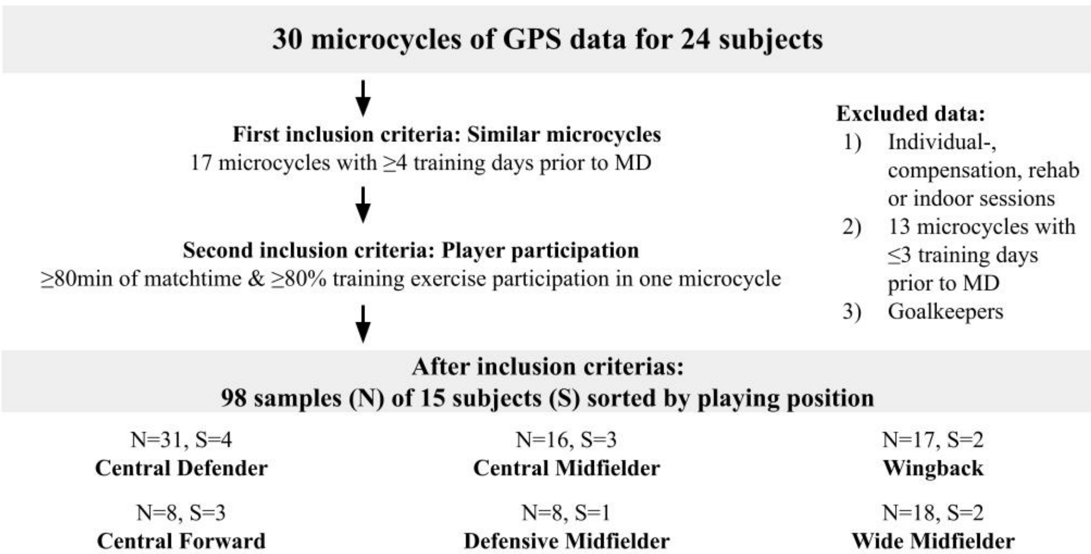

Figure 2.2: Inclusion of GPS data. Notes: One player changed position from WB to CD during season. In all analysis portraying data classified as playing position, this player was calculated as WB prior to the change, and CD after the change.

2.5 Developing new velocity zones

During the season, the team utilized the traditional velocity zones HSR and SPR provided by ProZone® (Rampinini et al., 2007) to monitor external loads. The new velocity zones for this study, were created by dividing HSR and SPR zone, into a total of 5 new velocity zones. These were created with intervals of 0.75 $m \cdot s^{-1}$ per zone (Table 2.3).

Table 2.2: Traditional and new velocity zones, both used in this study.

Traditional zones	**High-speed running (HSR)**		**Sprinting (SPR)**		
$km \cdot h^{-1}$	19.80 – 25.20		>25.20		
$m \cdot s^{-1}$	5.50 – 7.00		>7.00		
New zones	**HSR-A**	**HSR-B**	**SPR-A**	**SPR-B**	**SPR-C**
$km \cdot h^{-1}$	19.80 – 22.50	22.50 – 25.20	25.20 – 27.90	27.90 – 30.60	>30.60
$m \cdot s^{-1}$	5.50 – 6.25	6.25 – 7.00	7.00 – 7.75	7.75 – 8.50	>8.50

Notes: HSR = High-speed running. SPR = Sprinting. HSR-A and -B named after dividing HSR zone into two new velocity zones and SPR-A, -B and -C named for dividing SPR zone.

2.6 Statistical analysis

Data sorting and organization, including the creation of tables and figures, was carried out using Microsoft Excel 2022 version 16.68 for Mac. This was mostly done by manually tagging microcycles included and then sorting all data using pivot tables. The 28th version of IBM SPSS software (IBM Corp., Armonk, United States) was used to calculate mean, standard deviation and conducting correlation analyses. Correlations were computed between weekly training load and match load. As the datasets were found to be normally distributed, the Pearson´s correlation test was used along with a paired sample two-tailed t-test.
Based on the knowledge provided (Hopkins et al., 2009), combined with the sample size and the context of the study, the author deployed a 95% confidence interval (CI), resulting in an effect (P) up to .05 to indicate statistical significance. However, as Hopkins et al. (2009) states, this level of significance will be highly affected by sample size, since a large enough sample size can lead to even small effects giving statistical significance, and opposite with small sample sizes. Subsequently, CF (N=8) and DM (N=8) results were excluded from the box plots in Figure 3.1, and other results with these positions should be considered with caution.

3 Results

3.1 Traditional velocity zones load distribution

Using traditional velocity zones, the average player covered 10% less ($p<. 02$) HSR distances in weekly training load (545 ± 100m) compared to that observed in matches (605 ± 64m). SPR distances were 28% less ($p<. 00$) in weekly training load (111 ± 34m) compared to matches (154 ± 25). Regarding efforts, HSR efforts were similar ($p<. 80$) in training (72 ± 12) compared to matches (71 ± 7). In contrast, SPR efforts were 24% less ($p<. 00$) in weekly training load (9.6 ± 2.2) compared to observed efforts in matches (12.6 ± 1.8).

Traditional velocity zone distribution by position is shown in Table 3.1. Most playing positions had similar HSR distances in training and match. However, DM and WB covered respectively 22% ($p< .02$) and 21% ($p< .05$) less HSR distance during training compared to matches. At the SPR zone, multiple players did less distance in training compared to matches, with CF doing 51% less ($p< .01$), CM doing 32% less ($p< .01$) and WM doing 32% less ($p< .02$). Also, CF, CM and WM also did less SPR efforts ($p< .05$) for weekly training load.

Table 3.1: Distance (m) and efforts by position, distributed in traditional zones.

		High-speed running (HSR)			Sprinting (SPR)		
Playing position		WTL	ML	p	WTL	ML	p
Central Defender	Distance	354 ± 84	355 ± 62	.95	73 ± 40	67 ± 33	.65
	Efforts	49 ± 13	41 ± 7	.01*	6 ± 3	5 ± 3	.38
Central Forward	Distance	393 ± 109	481 ± 43	.13	68 ± 40	138 ± 44	.01*
	Efforts	51 ± 15	59 ± 5	.25	7 ± 4	12 ± 4	.01*
Central Midfielder	Distance	747 ± 275	798 ± 95	.50	146 ± 76	215 ± 71	.01*
	Efforts	95 ± 35	94 ± 12	.89	12 ± 6	16 ± 5	.05*
Defensive Midfielder	Distance	366 ± 117	468 ± 119	.02*	56 ± 46	88 ± 66	.23
	Efforts	46 ± 15	51 ± 13	.37	5 ± 3	7 ± 5	.30
Wing Back	Distance	596 ± 114	750 ± 129	.05*	130 ± 66	186 ± 42	.09
	Efforts	81 ± 15	85 ± 13	.61	11 ± 5	16 ± 2	.12
Wide Midfielder	Distance	672 ± 140	727 ± 93	.25	149 ± 67	220 ± 66	.02*
	Efforts	91 ± 18	90 ± 12	.91	13 ± 5	18 ± 6	.03*

Notes: Values are mean ± standard deviation. WTL=Weekly Training Load. ML=Match Load. P=Significance value comparing WTL to ML, using two-tailed t-test. *Significant difference (95% CI). HSR (19.8-25.2km·h^{-1}). SPR (>25.2km·h^{-1}).

3.2 New velocity zones load distribution

Table 3.2: Distance (m) and efforts by position. distributed in new zones.

		HSR-A			HSR-B			SPR-A			SPR-B			SPR-C		
Playing position		WTL	ML	p	WTL	ML	p	WTL	ML	p	WTL	ML	p	WTL	ML	p
Central Defender	Distance	257 ± 57	253 ± 39	.74	97 ± 37	102 ± 29	.62	52 ± 28	54 ± 28	.83	18 ± 17	12 ± 8	.25	2.9 ± 5.6	1.2 ± 2.2	.35
	Efforts	36 ± 9	29 ± 5	.00*	13 ± 4	12 ± 3	.60	5 ± 2	4 ± 2	.39	1.3 ± 1.2	1 ± 0.7	.51	0.2 ± 0.5	0.1 ± 0.2	.51
Central Forward	Distance	282 ± 82	308 ± 93	.22	111 ± 42	152 ± 22	.09	55 ± 31	105 ± 35	.02*	13 ± 12	27 ± 10	.02*	0 ± 0	6.3 ± 6.7	.05*
	Efforts	36 ± 11	40 ± 3	.48	14 ± 5	19 ± 3	.08	5 ± 3	8 ± 2	.01*	1.5 ± 1.3	2.9 ± 1.6	.07	0 ± 0	0.5 ± 0.5	.04*
Central Midfielder	Distance	516 ± 185	533 ± 64	.37	231 ± 98	265 ± 39	.23	105 ± 55	165 ± 54	.01*	34 ± 31	44 ± 28	.26	7.0 ± 10.9	6.3 ± 9.7	.86
	Efforts	66 ± 24	63 ± 8	.59	29 ± 11	31 ± 5	.46	9 ± 5	12 ± 3	.07	2.3 ± 1.7	3.8 ± 1.9	.06	0.4 ± 0.7	0.5 ± 0.6	.06
Defensive Midfielder	Distance	254 ± 90	341 ± 88	.00*	112 ± 39	127 ± 42	.48	40 ± 21	59 ± 37	.20	11 ± 18	25 ± 30	.12	5.5 ± 10.7	3.3 ± 8.7	.71
	Efforts	33 ± 10	37 ± 9	.17	14 ± 5	14 ± 4	.99	4 ± 2	5 ± 3	.34	0.6 ± 0.9	1.6 ± 1.5	.07	0.4 ± 0.7	0.1 ± 0.3	.08
Wing Back	Distance	399 ± 73	506 ± 83	.02*	197 ± 60	244 ± 51	.25	102 ± 51	130 ± 27	.02*	33 ± 28	43 ± 22	.48	10.9 ± 17	12.2 ± 16.4	.89
	Efforts	56 ± 9	56 ± 8	.94	25 ± 7	29 ± 5	.23	9 ± 4	12 ± 2	.21	2.6 ± 2.2	3.9 ± 1.6	.20	0.5 ± 0.7	0.8 ± 1.0	.20
Wide Midfielder	Distance	464 ± 93	481 ± 68	.54	209 ± 61	246 ± 51	.15	111 ± 42	159 ± 43	.00*	34 ± 36	54 ± 28	.20	3.6 ± 7.3	6.8 ± 7.7	.36
	Efforts	64 ± 12	61 ± 7	.55	27 ± 6	29 ± 6	.52	10 ± 3	14 ± 4	.02*	2.6 ± 2.1	4.4 ± 2.1	.08	0.3 ± 0.6	0.5 ± 0.6	.20

Notes: Values are mean ± standard deviation. WTL=Weekly Training Load. ML=Match Load. P=Significance value comparing weekly training load to match load. using two-tailed t-test. *Significant difference (95% CI). HSR-A (19.8–22.5km·h^{-1}). HSR-B (22.5-25.2km·h^{-1}). SPR-A (25.2-27.9km·h^{-1}). SPR-B (27.9-30.6km·h^{-1}). SPR-C (>30.6km·h^{-1}).

The new velocity zones presented in Table 3.2, show the exponential decay of external load measures with higher velocities. Notably, a trend occurred with all players except for CD, recording mean values lower in weekly training load than in matches. Although, most of position-specific mean differences from training to match were not statistically significant within new velocity zones. Especially, for the highest velocity zone, SPR-C (>30.6km·h^{-1}), where players such as CD covered 240% (.35) higher mean values in weekly training load compared to matches, without leading to statistically significant differences.

Statistically significant differences from weekly training load to load measures observed in matches, occurred mostly at the SPR-A zone (25.2 – 27.9km·h^{-1}). More specifically, CF covered 48% less ($p < .02$), CM 36% less ($p < .01$), WB 22% less ($p < .02$) and WM 31% less ($p < .00$) distances in weekly training load compared to observed in matches. Besides, CF were the only player to record significant differences in the two upper zones, SPR-B (27.9 – 30.6km·h^{-1}) and SPR-C (>30.6km·h^{-1}). Further, CF covered respectively 52% ($p < .05$) and 100% lower ($p < .05$) distances at SPR-B and SPR-C. An interesting observation for CF, is that differences were not found at lower velocities, such as similar HSR-A (19.8 – 22.5km·h^{-1}) distances ($p < .22$) and efforts (< .48). Overall, this showed that CF had weekly training loads more like match loads at lower velocities, as opposite to the higher velocities.

3.3 Comparing traditional with new velocity zones

Comparisons between traditional SPR zone (> 25.2 km·h^{-1}) and the 3 new zones created to accurately describe activity higher than 25.2 km·h^{-1}, is presented with boxplots in Figure 3.1. The differences within the boxplots for training, show that for all velocity zones, players cover less distance in weekly training load compared to what was observed in matches. However, the SPR-C (>30.6 km·h^{-1}) zone show both CD, CM and WB had similar or higher distributions in weekly training load compared to matches.

Also, weekly training load had many outliers above the 75th percentile for SPR-C zone (>30.6 km·h^{-1}), showing that some training weeks included large increases in distance at the velocities above 30.6 km·h^{-1}.

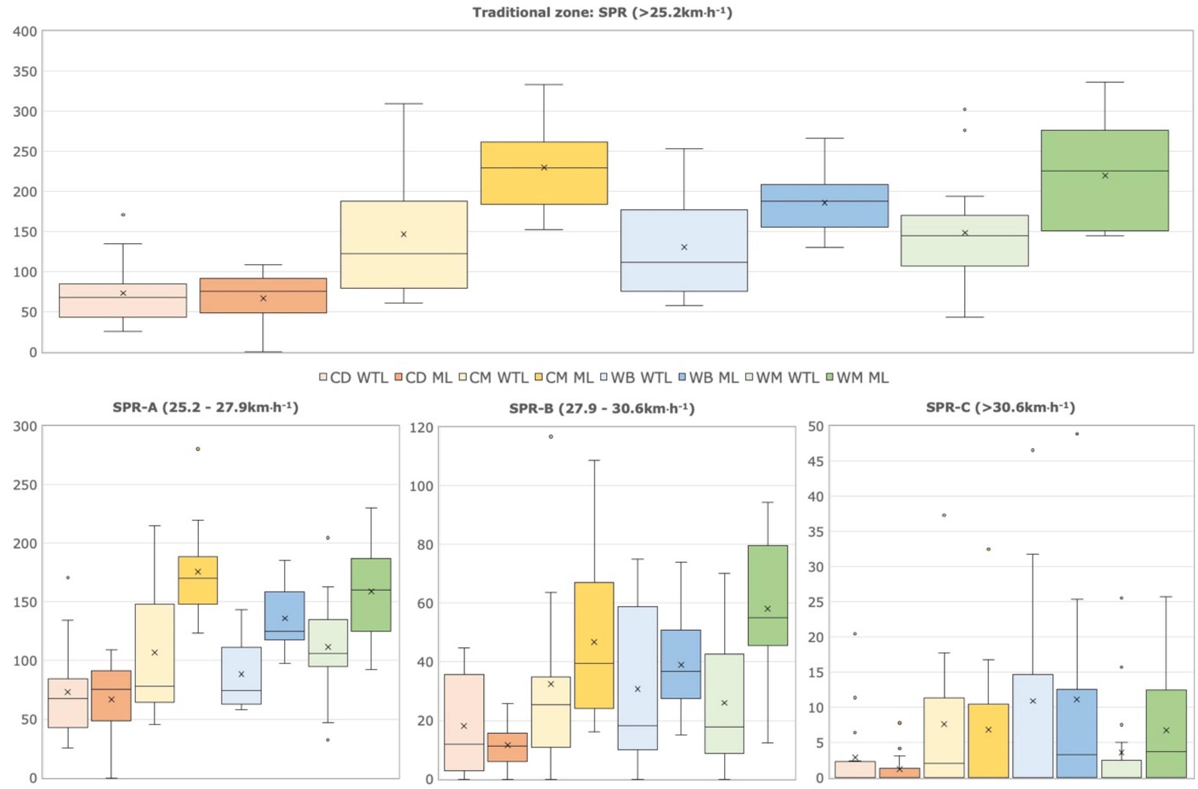

Figure 3.1: Box plots of Position-specific SPR distance distribution for WTL and ML. Notes: All values in meter. WTL= Weekly training load. ML= Match load. 2 box plots for each position, one for WTL (light color) and one for ML (darker color). The upper box plot show distribution within the traditional velocity zone SPR, while the 3 latter box plots show distribution within new SPR-A, -B and -C velocity zones. Median marked as "x" and median represented as line inside box. Boxes represents distribution within 25th to 75th percentile, while the line shows distribution above or below this threshold. Outliers presented as small circles.

3.4 Individual player velocity targets

Comparisons between the individual highest match load of the season (ML_{MAX}) and the average weekly training loads, were presented in Table 3.3. This enabled to test to what extent, players reached the club´s external load target for one-match microcycles, and whether new or traditional zones provided most value.

By deploying the traditional velocity zones, players reached less of the sprint goal with higher velocities, with HSR (43%) compared to the HSR (69%) zone. Similar findings were found with new zones; however, the differences were now magnified, with continuously decreasing percentage reaching sprint target at higher velocities; HSR-A (73%), HSR-B (59%), SPR-A (42%), SPR-B (34%) to SPR-C (20%).
Some positions, such as WB and WM, were closer to reaching sprint target with the traditional SPR zone (42-52%), than what was observed with the new SPR-B (29-36%) or SPR-C zone (2-20%).

Table 3.3: Individual player load compared to sprinting target.

Player	Samples	HSR-A		HSR-B		SPR-A		SPR-B		SPR-C		HSR		SPR	
		ML_{MAX}	$WTL_{\%}$	ML_{MAX}	$WTL_{\%}$	ML_{MAX}	$WTL_{\%}$	ML_{MAX}	$WTL_{\%}$	ML_{max}	$WTL_{\%}$	ML_{MAX}	$WTL_{\%}$	ML_{MAX}	$WTL_{\%}$
CD-1	13	343	78%	159	73%	115	43%	50	39%	9	8%	473	81%	158	44%
CD-2	3	80	77%	40	94%	0	-	0	-	0	-	120	82%	0	-
CD-3	6	367	67%	243	35%	92	41%	19	113%	0	-	611	54%	95	64%
CD-4	9	327	82%	182	55%	111	55%	27	54%	0	-	510	72%	130	61%
CF-1	1	275	92%	122	91%	92	37%	35	77%	4	0%	397	92%	131	47%
CF-2	3	389	75%	158	77%	98	56%	22	40%	10	0%	547	75%	119	53%
CF-3	4	353	78%	200	52%	147	38%	43	40%	20	0%	537	71%	187	39%
CM-1	8	600	104%	339	85%	280	46%	109	40%	17	69%	936	97%	333	55%
CM-2	7	642	51%	323	44%	158	36%	49	39%	33	3%	922	51%	229	33%
CM-3	1	369	72%	131	44%	66	24%	28	48%	0	-	500	64%	94	31%
DM-1	8	468	54%	188	59%	127	31%	99	11%	26	21%	632	58%	226	25%
WB-1[CD]	12	609	64%	324	58%	185	54%	76	36%	49	20%	912	63%	266	52%
WB-2	5	560	68%	318	60%	215	44%	80	33%	11	14%	878	65%	262	47%
WM-1	12	532	86%	345	61%	230	50%	94	29%	26	2%	844	79%	336	42%
WM-2	6	616	76%	272	74%	182	53%	133	30%	2	*	843	79%	301	48%
Team Average	**98**		**72%**		**59%**		**42%**		**34%**		**20%**		**69%**		**43%**

Notes: Values as distance in meters and percentage (%). ML_{MAX} = The highest match distance throughout the season. $WTL_{\%}$ = Average weekly training load divided by ML_{MAX}. Team Average calculated using average WTL for all players divided by average ML_{MAX} for all players. Position[CD]=This player changed to CD position during season. *Extreme outlier excluded (>500%). Notice that values are comparing weekly training load against ML, meaning that a $WTL_{\%}$ value of 20, suggests that ML_{MAX} is

4 Discussion

The main finding of this study was that players tend to cover less distance at higher velocities during weekly training load, compared to that observed during matches. The study's results provided new information regarding the physical match demands for different positions. Furthermore, the new velocity zones could be beneficial for coaches to accurately monitor if a training regime replicates match load demands, for each position.

Current state of training load monitoring

By deploying traditional velocity zones (Table 3.1), the average player ran 14% less HSR (19.8 – 25.2 $km \cdot h^{-1}$) distance in training compared to matches ($p < .01$), distributed over similar number of efforts ($p < .38$). This shows that the average distance per effort in training, were shorter than those in match. A possible explanation for this, may be that coaches manipulate field sizes in training to accommodate for more accelerations rather than top speed actions. However, this pattern was not observed at the SPR zone(>25.2 $km \cdot h^{-1}$), with players running 31% less distance ($p < .00$) and 25% less ($p < .00$) efforts in training compared to matches. Anyways, traditional zones showed that training loads are preparing players more according to match loads at lower velocities.

Importantly, the traditional zones could not tell whether the match demands of players were at 26 or 30$km \cdot h^{-1}$. This is important information, to accurately know how to prepare players for similar neuromuscular demands in training as in matches (Brughelli et al., 2008; Coratella et al., 2018; Howard et al., 2018; Stolen et al., 2005). Since preparing players according to match demands is the first step of managing an optimal training load regime (Djaoui et al., 2017), the author suggests accurately monitoring the match and training loads as crucial. In addition, the increased high-velocity match demands (Bush et al., 2015; Lago-Penas et al., 2023) and, the increased injury rate (Ekstrand et al., 2016), may suggest players' training load are not being optimally adjusted to the elevated match standards.

New information from new velocity zones

Firstly, Table 3.2 showed the exponential decay of load measures with higher velocities, unique for different playing positions. CF, trained more similarly to matches at low velocities, with similar HSR-A distances ($p < .22$) in training as observed in matches. However, differences increased at higher velocities. More specifically, CF covered 48% less distance in weekly training load within SPR-A ($p<.02$), 52% less in SPR-B ($p < .02$) and 100% less in SPR-C (0%, .05), when compared to matches. Notably, CF recorded no efforts at the highest velocity zone in training for the studied sample, although, matches demanded efforts at SPR-C (>30.6 km·h^{-1}).

Secondly, the boxplots in Figure 3.2 illustrated that weekly training loads included more outliers than match loads for all positions, especially at the SPR-C zone. This may suggest that coaches deploy a periodization strategy, with extra focus on sprints in some training weeks. A result of the varied training load, may be that most training weeks does not replicate similar loads as match demands, possibly even more so than first assumed looking at traditional velocity zones. This finding was supported with Table 3.3, comparing weekly training load to the hardest match load of the season. This comparison showed that average players are decreasingly able to replicate match demands in training at higher velocity zones. Exemplified with HSR-A being 72% of maximal match load, while for the highest velocity zone, SPR-C, players only reached 20% of maximal match load in training. Similarly, the traditional velocity zones also showed a decrease from HSR (69%) to SPR zone (43%), however, the traditional zone underestimated loads greater than SPR zone (>25.2 km·h^{-1}).

<u>Traditional vs new velocity zones</u>

Traditional velocity zones may underestimate external loads within HSR-B, SPR-B and SPR-C zone, due to respectively 67 and 74% of the HSR and SPR zones being distributed within HSR-A and SPR-A zones. This was especially noticeable for individual WB and WM players in Table 3.3, which reached between 2 and 36% of club´s sprinting goal within the SPR-B and SPR-C zone. In contrast, the traditional zones showed that WB and WM players reached 42 - 52% of ML_{MAX} of the same goal. In practice, if the coach deployed traditional zones and wanted a 1 training to match-ratio, the coach may suggest these players would need to double the distances within the SPR zone. However, if these loads where within 25.2 – 27.9 km·h^{-1}, there would be no increase in SPR-B and SPR-C distances at all. Since match demands were much higher, this shows that, in accordance with the hypothesis, current velocity zone does not portray accurate load measure for players with high top-speeds. On the other hand, the new velocity zones did not provide additional value for lower top-speed players, such as one CD not recording any SPR efforts during this study.

Implementing new velocity zones may come with additional drawbacks as well. Since a well-managed training monitoring regime involved both external and internal load variables (Akenhead & Nassis, 2016; Bourdon et al., 2017; Djaoui et al., 2017; Halson, 2014), introducing more load variables, may provide additional noise, but limited signal. After all, more information is not necessarily always better. On the other hand, the new velocity zone classification was developed with initiative from the soccer club. This suggests that traditional velocity zones did not provide enough accuracy in monitoring load for the respective club. Further, the potential need for more accurate zones at high velocities, may come as a response to the trend of higher match velocities in modern soccer (Bush et al., 2017; Bush et al., 2015; Ekstrand et al., 2016; Lago-Penas et al., 2023) and compounded increase of hamstring injuries (Ekstrand et al., 2011; Ekstrand et al., 2016). Due to hamstring injuries primarily occurring during top-speed or deceleration activities (Gronwald et al., 2022), the highest SPR-B and SPR-C zone may be especially valuable in providing insights for how to control load better.

Practical considerations

Due to the numerous factors impacting match demands (Chmura et al., 2018; Malone et al., 2015; Rampinini et al., 2007), it should be expected to find significant differences in external load measures between playing positions. Subsequently, results from this study does not suggest that players should aim to reach similar loads as other playing positions. The results of this study highlight the position-specific differences from training compared to match demands more accurately than previously done. The new information provided, by deploying narrower velocity zones, can improve coaches ability to understand the position-specific match demands, and potentially, understand whether training is optimized to prepare each player accordingly (Chmura et al., 2018; Ingebrigtsen et al., 2015; Malone et al., 2015). In line with previous studies (Modric et al., 2020), this study support that different playing position may benefit from training according to their match loads, to further equip players with the skills and capacities needed to cope with match demands. Coaches may achieve this to a greater extent with the new velocity zones in this study, given more precisely measure what match loads are. This can help coaches in planning training sessions to target skills and capacities needed in matches.

Importantly, there is no evidence supporting an optimal training load to prepare players for physical match demands in soccer (Kelly et al., 2020). This indicates that coaches should be careful to extrapolate differences from weekly training load to matches, considering that monitoring external loads were only the first step of managing an optimal training load regime (Djaoui et al., 2017). The second part, measuring the physical response with internal load variables (Akenhead & Nassis, 2016; Bourdon et al., 2017; Djaoui et al., 2017; Halson, 2014), may be especially important given the increasing injury trend for elite male soccer players (Ekstrand et al., 2011; Gronwald et al., 2022). The injury trend suggests that increasing training load at high velocities, up to match loads, may lead to further increase of injuries (Coratella et al., 2018; Ekstrand et al., 2011; Gronwald et al., 2022). Consequently, an elite soccer coach should complement the use of external load variables with internal load monitoring, in line with previous research (Akenhead & Nassis, 2016; Bourdon et al., 2017; Djaoui et al., 2017; Halson, 2014).

Methodological considerations

All results from correlation analysis using CI of 95%, must be considered with caution, due to potential type I or type II errors, effect sizes, or other factors, when drawing conclusions.
A primary challenge of this study was to establish appropriate inclusion criteria. Previous studies comparing external load measures (Clemente et al., 2019; Stevens et al., 2017), employed broad inclusion criteria, a practice the author found to restrict comparability and the precision of the specific objective and available data for this study. The stricter inclusion criteria used in this study, were considered to enable more accurate load measures of reality. On the other hand, stricter inclusion criteria´s reduced sample sizes, further, limiting statistical significance of correlations. Anyways, the inclusion criteria´s deployed in this study were done with a purpose, to avoid comparing players or training participating in variating number of training days and match minutes.

The club´s sprint goal, for each player to reach equivalent distances in the 4 days prior to matches as their highest match load of the year, shows the team wants to prepare players for two-match microcycles. If players reached this goal, a two-match microcycle would theoretically not demand additional loads than what players already were used to. How much coaches potentially should reduce training load for periods with matches in quick succession, both to optimize physical performance while keeping injury rate low, is unclear. Therefore, the author recommends future research to investigate load variables for microcycles with less than 4 training days prior to match, within new velocity zones. This is especially important for soccer clubs playing in multiple tournaments, trying to optimize training load within more congested match periods.

5 Conclusion

This study showed that implementing new velocity zones can enable more accurate planning of high velocity training in soccer, to prepare players according to match demands.

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