Robert Rydningen

Quantification of Position-Specific In-Season Training Load Relative to Match Load in Professional Football

Master's thesis in Physical Activity and Health - Exercise Physiology

Supervisor: Ulrik Wisløff
Co-supervisor: Arnt Erik Tjønna

May 2021

Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Medicine and Health Sciences
Department of Neuromedicine and Movement Science

NTNU
Kunnskap for en bedre verden

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Infographic

Position-Specific Training Load in Professional Football

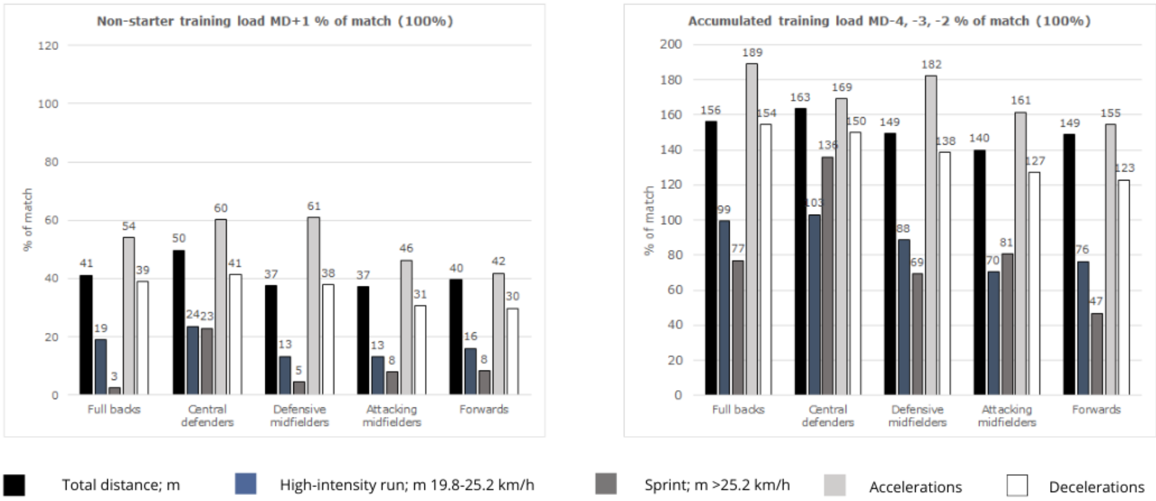
Aim: Quantify and compare external training and match load

Methods: Physical performance data of 19 male professional football players (25 ± 4 years, 185 ± 8 cm, 80 ± 9 kg) was collected from 15 home games, 9 training weeks, and 16 non-starter compensatory sessions

OBOS LIGAEN

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
MD+1	MD+2	MD-4	MD-3	MD-2	MD-1	Matchday
Training	Day off	Training	Training	Training	Day off	Match

Results



Conclusion

- Lack of specificity in training
- Training does not replicate sprint demands of match
- Non-starters underloaded in high-velocity movements

Practical Takeaways

Increase sprint distance in training by performing

- Game-based drills on large fields
- Running-based exercises
- Non-starters need additional loading

Robert Rydningen
Student MSc Physical Activity and Health - Exercise Physiology

NTNU | Norwegian University of Science and Technology

Abstract
Purpose: This study aimed to quantify and compare the total and peak (most intense 5 minutes) load of 1) the structured microcycle, and 2) the compensatory non-starter session to match demands per playing position.

Methods: Nineteen male professional football players participated in the study. Physical performance in fifteen home games, nine full training weeks, and sixteen compensatory non-starter sessions were measured with the same global navigation satellite system and analyzed through linear mixed models. Players were split into full backs (FB), central defenders (CD), defensive midfielders (DM), attacking midfielders (AM), and forwards (FW).

Results: High-intensity running (HIR; 70-103%) and sprint (47-136%) showed the lowest cumulative training load relative to match, while accelerations (ACC; 155-189%), decelerations (DEC; 123-154%), and total distance (TD; 140-163%) overperformed match demands. The non-starter session displayed low relative load of ACC (42-61%) TD (37-50%), DEC (30-41%), HIR (13-24%) and sprint (3-23%), although not all differences reached significance. Regarding the most intense training week periods, only the most demanding positions covered less HIR (AM and FW) and sprint (FW). Peak ACC overperformed match demands for all positions except CD. Compensatory session peak showed low relative load of HIR (34-54%), sprint (8-50%), and TD (70-79%), and higher load of ACC (109-130%) and DEC (84-95%).

Conclusion: These results highlight a need for higher training specificity. In general, ACC and DEC showed greater cumulative and peak load relative to match than HIR and sprint. Non-starters risk being underloaded, especially in high-velocity movements.

Keywords: Physical performance, high-intensity running, sprint, playing position, non-starters

Sammendrag
Hensikt: Hensikten med denne studien var å kvantifisere og sammenligne total og høyeste (mest intense 5-minuttersperiode) belastning for 1) normal treningsuke, og 2) kompensasjonsøkten for ikke-starterne med kampkravet til ulike spillerposisjoner.

Metode: 19 profesjonelle fotballspillere deltok i studien. Fysisk prestasjon i 15 hjemmekamper, 9 treningsuker, og 16 økter for ikke-startere ble målt med samme GNSS-system og analysert gjennom lineære blandede modeller. Spillerne ble fordelt i følgende posisjoner: sidebacker (FB), midtstoppere (CD), defensive midtbanespillere (DM), offensive midtbanespillere (AM), og angripere (FW).

Resultater: Høyintensitetsløp (HIR; 70-103%) og sprint (47-136%) viste laveste kumulative treningsbelastning relativ til kamp, mens belastningen for akselerasjoner (ACC; 155-189%), retardasjoner (DEC; 123-154%), og total distanse (TD; 140-163%) overgikk kampkravene. Økten for ikke-starterne viste lav belastning for ACC (42-61%) TD (37-50%), DEC (30-41%), HIR (13-24%), og sprint (3-23%) selv om ikke alle forskjellene var signifikante. For de mest intense periodene i treningsuken, bare de mest krevende posisjonene viste signifikant lavere tall enn kamp for HIR (AM og FW) og sprint (FW). Høyeste belastning for ACC overgikk kampkravet for alle posisjoner utenom CD. Mest intense perioder i kompensasjonsøkten viste lav belastning av HIR (34-54%), sprint (8-50%), og TD (70-79%), men høyere for ACC (109-130%) og DEC (84-95%).

Konklusjon: Resultatene fremhever et behov for større spesifisitet i treningen for profesjonelle fotballspillere. Generelt viste ACC og DEC større total og høyeste belastning relativ til kamp enn HIR og sprint. Spillere med lite spilletid risikerer å bli underbelastet, spesielt i de høyeste hastighetssonene.

Nøkkelord: Fysisk prestasjon, høyintensitetsløp, sprint, spillerposisjon, ikke-startere

List of Abbreviations

ACC = Accelerations

AM = Attacking midfielder

CD = Central defender

DEC = Decelerations

DM = Defensive midfielder

FB = Full back

FW = Forward

GK = Goalkeeper

GNSS = Global navigation satellite system

HIR = High-intensity run

MD = Matchday

SSG = Small-sided games

1. Introduction

Association football (soccer) is a physically demanding sport characterized by intermittent high-intensity activities such as sprinting and powerful accelerations interspersed with periods of low-intensity movements like walking and standing (1, 2). Previous studies have pointed out the importance of high-velocity running capabilities for success at high-level football with players on higher levels covering greater distances at high speeds (3, 4). The physical requirements of the sport are ever evolving, evidenced by the 30-35 % increase in high-speed run and sprint distance in recent years in the English Premier League (5). Furthermore, the players' sprint ability has the potential to affect match outcome as linear sprint has been found to be the most frequent action before both scoring and providing assists in the German Bundesliga 1, suggesting a need for power and speed activities in training (6). Collectively, these findings indicate that elite football is characterized by the players' ability to perform repeated high-intensity actions, and that training should emphasize this.

The use of tracking technology has been widely adopted by high-level football clubs for objective quantification and managing of training load (7), allowing practitioners to better estimate the external load of players, potentially giving a more appropriate training stimulus both at the team and individual level within the collective periodization (8). As the playing positions display differences in physical requirements of match-play (2, 9, 10), there is a need for individualized position-specific training prescription. Hence, reporting training load relative to match demands can facilitate individual training prescription with the goal of preparing players for competition (11). When planning training, coaches should aim to maximize physiological adaptations while minimizing fatigue and risk of injuries, and although a dose-response relationship between external load and fitness variables in professional football players exists (12), the adverse effects of excessively high loads must be considered (13, 14).

While the characteristics of match-play in professional football has been thoroughly investigated, information about training load is still limited. Most research has focused on the load of separate training days during the microcycle (11, 15, 16), and football-specific conditioning as small sided-games (SSG) of various formats (17-20). Moreover, as matches serve as a strong physiological stimulus (11, 21, 22), coaches often schedule a compensatory session the day after the match for players with limited game time. Although some studies have investigated the load of non-starter sessions (11, 15), there is still a lack of knowledge about the additional training for this group of players, both in total and peak (most intense 5-min period per variable) load. Furthermore, the large differences in most demanding passages of play and average match demands suggest training only at the average game intensity will under-prepare players for extreme events and the worst-case scenario of match-play (23-25), and therefore it seems pivotal to train at or close to maximum game intensity.

Despite the importance for periodization purposes, studies on Dutch (11), Portuguese (26), and Norwegian (27) elite football teams have only recently investigated the accumulated training load in relation to match demands. The abovementioned studies, however, have some limitations with neglecting playing positions (11), and not considering the maximal intensity of training (11, 26) or the non-starter session (26, 27). Even though these studies reported similar trends, more studies, including teams on different performance standards, are needed to obtain more detailed knowledge about the positional training demands in professional football. Thus, the aim of the present study was to quantify and compare the total and peak external load of 1) the structured training week, and 2) the compensatory non-starter session to competitive match demands by playing positions. We hypothesize that accelerations (ACC), decelerations (DEC), and total distance (TD) will overperform the match demands during the training week, with high-intensity running (HIR) and sprint distance showing lower values compared to match. Secondly, we expect the non-starter session to present considerably lower HIR and SPR distances with less difference of ACC/DEC compared to match in both total and peak load.

2. Methods

2.1 Subjects

Nineteen male outfield players (mean ± SD: 25.3 ± 3.5 years, 185.5 ± 8.4 cm, and 80.2 ± 8.6 kg) from a professional Norwegian football team competing on the second highest level (OBOS-ligaen) participated in the study. The team systematically played in a 1-4-3-3 formation; therefore, players were split into the following five playing positions: full backs (FB; n=3), central defenders (CD; n=3), defensive midfielders (DM; n=2), attacking midfielders (AM; n=5), and forwards (FW; n=6). Goalkeepers were excluded from the sample. The study was approved by the Norwegian Centre for Research Data (NSD), and all subjects gave written informed consent for the inclusion of their data.

2.2 Design

An observational cohort study was conducted on this football team. Data from home matches and training sessions were collected during the 2020 season through the same FIFA approved (See *Appendix A*) stationary global navigation satellite system (GNSS) (ZXY Sport Tracking, Trondheim, Norway) installed at the home stadium. As the team in the study qualified for the play-off for promotion to the top division, sixteen home games were played, but due to technical issues with the tracking system one game was excluded. Consequently, data from fifteen competitive home games (excluding warm-up) were analyzed. For the match observation to be included in the final analysis players had to play at least 60 minutes and play in the same position throughout the game. The inclusion criteria were based on previous research (11, 27, 28). All included match observations were recalculated to the average full-game duration of the home games (95.80 minutes).

Training sessions were characterized by the number of days before or after matchday (MD) (i.e., MD- or +). For instance, MD-4 refers to the session four days before the next game. The cumulative and peak load for the training week was calculated only from the most standardized microcycles. The typical microcycle included six full days between games with a recovery/compensatory session, or a day off MD+1, two days off (MD+2 and MD-1), and three main training sessions (MD-4, MD-3, MD-2). In addition, microcycles with seven and eight full days between games were included if they followed the same main session structure as the typical week with either additional days off or the inclusion of a voluntary session. Thus, nine separate microcycles were analyzed to manifest the accumulated and peak in-season training load of the professional football players. Due to the outbreak of COVID-19, the season was shortened, leading to an increased number of weeks with multiple matches and fewer typical weeks. Three of the included microcycles contained a voluntary low-intensity session on either MD-5 or MD-6, and these sessions were excluded from all analyses. Only the three main training sessions (MD-4, MD-3, MD-2) during the week were included, referring to sessions where the whole team trained together. For the inclusion of the microcycle the player had to participate in all sessions. Players doing individual sessions due to injury or not participating in one or more sessions were excluded from that individual training week.

The day after the match, unless given a day off, non-starters performed a compensatory session. Players that did not finish the session were excluded. In total, sixteen compensatory sessions were analyzed, including the ones in non-typical microcycles. The total and peak load of the compensatory session MD+1 was analyzed separately from the main sessions.

Table 1 shows the number of included match observations, training weeks, and compensatory sessions per position. Training data from players without match observation was excluded. All training sessions, both main and non-starter, consisted of a combination of warm-up drills, technical and tactical exercises, small-sided games (SSG) with or without goals, and running drills. Every match and training session was played on the same outdoor artificial grass pitch (105 m x 68 m).

Table 1: Number of included observations across session types and playing positions.

Session	FB	CD	DM	AM	FW	Total files
Match	24 (n=3)	27 (n=3)	14 (n=2)	18 (n=5)	34 (n=6)	117 (n=19)
Microcycle	22 (n=3)	16 (n=3)	13 (n=2)	24 (n=5)	42 (n=6)	117 (n=19)
MD+1	15 (n=3)	5 (n=1)	9 (n=2)	27 (n=4)	35 (n=5)	91 (n=15)

Data are presented as number of observations with number of players in brackets.
Microcycle represents the main training sessions in standardized training weeks while MD+1 is the non-starter compensatory session the day after the game. FB=full back, CD= central defender, DM=defensive midfielder, AM=attacking midfielder, FW=forward.

2.3 Data Collection and Analysis

During training and match, all players wore a vest with a portable 10 Hz GNSS tracking unit (ZXY GEO transponder, 63 g, 90 mm x 45 mm x 15 mm) placed in a specially designed pocket between the shoulder blades, which collected physical performance data. To avoid inter-unit variability each player wore the same tag each training and match (29). The external load variables included total distance TD (m), HIR (m 19.8-25.2 $km \cdot h^{-1}$), sprint (m >25.2 $km \cdot h^{-1}$), ACC (>2 $m \cdot s^{-2}$), and DEC (<-2 $m \cdot s^{-2}$). Velocity thresholds were chosen in accordance with previous research (2, 10, 15, 27, 28). The four criteria for ACC/DEC in the ZXY Tracking System are 1) the acceleration reaches the minimum acceleration of 1 $m \cdot s^{-2}$, marking the start of the event, 2) the acceleration must reach the threshold of 2 $m \cdot s^{-2}$, 3) the acceleration must remain above this threshold for at least half a second, and 4) the acceleration drops below the minimum limit, marking the end of the event.

Moreover, peak periods state the 5 minutes with the highest value of each variable, which has previously been used to describe the most intense periods in training and matches (25, 28, 30, 31), and was individualized per variable and per player. Similar to Dalen et al. (28) we used a rolling 5-min window to obtain the true peak value. This was calculated in every match and training session, including MD+1. The training week peak refers to the highest 5-min value per variable and player in any of the three main session within each microcycle. The inclusion criteria described above were adopted for the peak 5-min periods, thus the same matches, sessions, and microcycles were included for analysis of the peaks as for the total external load.

Four players had no compensatory session observation, and as a result, fifteen players were included in the MD+1 sample. The cumulative training load was calculated by summing all sessions in each individual week. To account for different number of observations per player in match and training, aggregated means for each physical performance variable and session type were calculated for all individual players before being pooled into playing positions prior to the analyses.

2.4 Statistical Analyses

All statistical analyses were performed in SPSS (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp). All data are presented as mean ± standard deviation (SD), unless otherwise stated. Differences between accumulated and peak training and match load were analyzed through a linear mixed model. Subject ID was defined as random factor, with position and session type as fixed effects. The same procedure was performed comparing the absolute and peak load of MD+1 to match demands. The level of significance was set to $p<0.05$.

To find the estimated match value (100%) for the comparison of accumulated and peak training and MD+1 load to match, the average of the aggregated means was calculated per variable, playing position, and session type.

3. Results

3.1 Total external training load

The total external load of match, training week, and non-starter session is presented in *Table 2.* During the training week, AM and FW performed 30% ($p=0.001$) and 24% ($p=0.002$) less HIR than in match. Only FW showed significant differences between training and match regarding sprint, with 53% ($p=0.001$) less distance covered during the microcycle. No further differences were found comparing cumulative HIR and sprint distance in training to match demands for the remaining playing positions ($p>0.05$). All positions performed 55-89% more ACC ($p<0.001$), 23-54% more DEC ($p<0.05$), and covered 40-63% greater TD ($p<0.001$) throughout the training week than match. *Figure 1* represents the accumulated training load as a percentage of match (100%). Match demands were largely overperformed in training for ACC (155-189%), DEC (123-154%), and TD (140-163%), while varying loads relative to match demands were observed for HIR (70-103%) and sprint (47-136%) distance.

In the compensatory session, FB, AM, and FW presented 97% ($p=0.011$), 77% ($p=0.048$), and 92% ($p<0.001$) lower sprint distance compared to match-play, respectively. No significant differences were found in sprint for CD ($p=0.488$) or DM ($p=0.582$). All playing positions covered 76-87% less HIR distance ($p<0.05$), 50-63% less TD ($p<0.001$), and performed 59-70% fewer DEC ($p<0.01$) in the non-starter compensatory session compared to match. Every position, except CD, performed 39-58% less ACC ($p<0.05$) in the non-starter session than in match, although a tendency towards significance was observed for CD with 40% lower ACC count MD+1 ($p=0.06$). The load of the MD+1 session relative to match demands (100%) is presented in *Figure 2*. ACC most closely replicated the match demands (42-61%), followed by TD (37-50%) and DEC (30-41%). HIR (13-24%) and sprint (3-23%) displayed the lowest load compared to match.

Table 2: Descriptives (mean ± SD) for total external load of variables across playing positions and session types. Microcycle represents the sum of the main training sessions in standardized training weeks while MD+1 is the non-starter compensatory session the day after the game.

	Session	TD (m)	HIR (m)	SPR (m)	ACC (count)	DEC (count)
FB	Match	12,253.6 ± 544.4	678.0 ± 154.3	176.0 ± 38.2	85.6 ± 21.3	89.1 ± 15.4
	Microcycle	19,110.7 ± 676.3 *	672.8 ± 116.0	135.7 ± 14.4	161.9 ± 26.9 *	137.6 ± 19.3 *
	MD+1	5,046.6 ± 559.5 *	128.8 ± 47.3 *	4.5 ± 4.3 *	46.2 ± 9.1 *	34.6 ± 9.5 *
CD	Match	11,045.8 ± 110.6	434.3 ± 37.4	75.1 ± 38.2	82.1 ± 7.2	70.3 ± 3.2
	Microcycle	18,043.5 ± 1106.7 *	448.0 ± 206.6	102.2 ± 110.7	138.8 ± 14.7 *	105.4 ± 14.0 *
	MD+1 **	5,497.4 *	102.8 *	17.2	49.4	29.0 *
DM	Match	12,551.0 ± 360.6	459.3 ± 134.4	41.6 ± 36.5	75.4 ± 14.6	71.7 ± 14.3
	Microcycle	18,747.1 ± 2020.7*	406.3 ± 77.0	28.9 ± 3.7	137.3 ± 7.8 *	99.3 ± 18.5 *
	MD+1	4,703.4 ± 413.6 *	61 ± 27.5 *	1.9 ± 2.7	45.9 ± 6.5 *	27.2 ± 8.2 *
AM	Match	13,135.6 ± 278.5	879.8 ± 156.6	114.6 ± 55.3	98.6 ± 21.8	101.6 ± 19.0
	Microcycle	18,382.1 ± 1662.1*	619.3 ± 215.2 *	92.6 ± 37.1	159.2 ± 34.8 *	129.3 ± 30.1 *
	MD+1	4,872.1 ± 380.0 *	116.2 ± 17.6 *	9.2 ± 3.8 *	45.7 ± 3.9 *	31.2 ± 5.3 *
FW	Match	12,179.5 ± 898.1	851.3 ± 216.7	272.2 ± 163.6	102.5 ± 23.9	102.0 ± 20.6
	Microcycle	18,115.4 ± 1752.0*	651.2 ± 289.3 *	128.0 ± 88.2 *	158.4 ± 39.2 *	125.3 ± 31.5 *
	MD+1	4,822.5 ± 494.8 *	136.1 ± 146.1 *	22.8 ± 33.5 *	42.9 ± 12.8 *	30.4 ± 12.9 *

*TD, HIR, and SPR are presented in meters, and ACC and DEC are presented as number of ACC/DEC. * Statistically significant difference from match ($p<0.05$). ** Single observation, SD not defined. FB=full back, CD= central defender, DM=defensive midfielder, AM=attacking midfielder, FW=forward, TD=total distance, HIR=high-intensity run (19.8-25.2 $km \cdot h^{-1}$), SPR=sprint (>25.2 $km \cdot h^{-1}$), ACC=accelerations (>2 $m \cdot s^{-2}$), DEC=decelerations (<-2 $m \cdot s^{-2}$).*

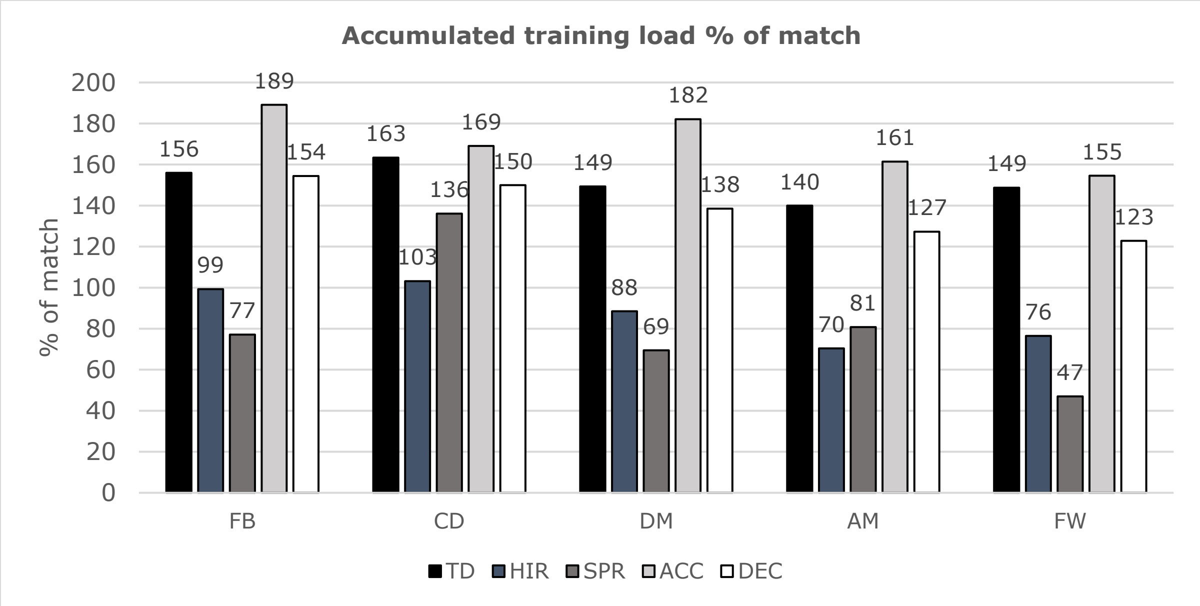


Figure 1: Accumulated training load per position and variable presented as a percentage of match demands (100%).
FB=full back, CD= central defender, DM=defensive midfielder, AM=attacking midfielder, FW=forward, TD=total distance, HIR=high-intensity run (19.8-25.2 km·h^{-1}), SPR=sprint (>25.2 km·h^{-1}), ACC=accelerations (>2 m·s^{-2}), DEC=decelerations (<-2 m·s^{-2}).

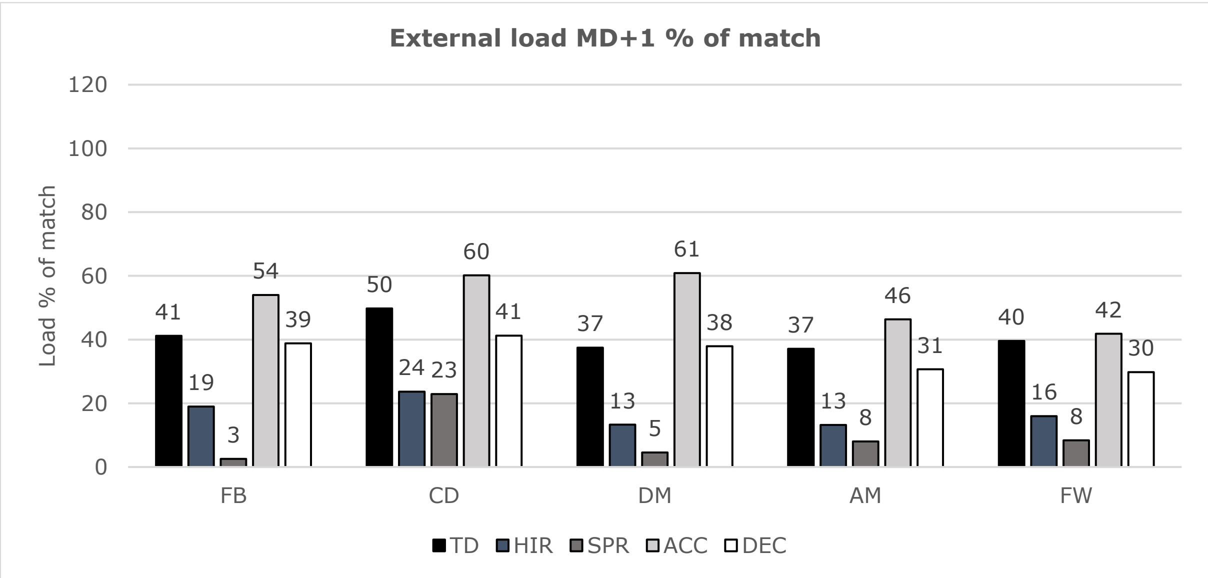


Figure 2: Total external load of non-starter session MD+1 per position and variable presented as a percentage of match demands (100%).
FB=full back, CD= central defender, DM=defensive midfielder, AM=attacking midfielder, FW=forward, TD=total distance, HIR=high-intensity run (19.8-25.2 km·h^{-1}), SPR=sprint (>25.2 km·h^{-1}), ACC=accelerations (>2 m·s^{-2}), DEC=decelerations (<-2 m·s^{-2}).

3.2 Peak 5-min periods

Table 3 shows the external load of physical variables during the most demanding 5-min periods per playing position across session types. AM and FW covered 23% (p=0.017) and 22% (p=0.008) less HIR distance during the most intense periods during the training week than in match play with no difference for the remaining positions (p>0.05). Peak sprint was only significantly different from match for FW, with 34% (p=0.002) lower values in training. All positions, except CD, performed 17-29% (p<0.05) more ACC in the most demanding passages of play in training than in match with no significant difference occurring for CD (p=0.261). The number of DEC in the peak 5-min periods during training week were significantly higher than peak match only for FB (p=0.013) and AM (p=0.003). No differences in DEC were found between peak training and match for CD, DM, and FW (p>0.05). DM, AM, and FW covered 9% (p=0.003), 7% (p=0.001), and 8% (p<0.001) less TD respectively, in the most demanding phases in training compared to match. No such difference occurred for FB nor CD, although tending towards lower values in training (p=0.077 and p=0.064, respectively). The most demanding 5-min periods for each variable throughout the training week are presented as a percentage of peak match demands (100%) in *Figure 2*. Similar to the accumulated load, peak ACC (109-129%) and DEC (101-117%) in training seem to overload the peak match periods. TD (91-96%), HIR (77-98%) and sprint (66-105%) display varying loads relative to match.

Regarding peak demands MD+1, HIR distance was 59-66% (p<0.05) lower than match for all positions except CD (p=0.123). FB, AM, and FW showed 92% (p<0.001), 77% (p=0.002), and 71% (p<0.001) less sprint distance in peak 5-min MD+1 compared to peak match. CD (p=0.106) and DM (p=0.65) showed no difference although DM tended towards significance. The number of ACC for FB, CD, DM, and AM were 24% (p=0.012), 30% (p=0.049), 26% (p=0.036), and 18% (p=0.014) higher during the most intense 5-min periods in MD+1 than peak match. No significant difference occurred for FW (p=0.140). For DEC, FW performed 15% (p=0.018) less DEC in peak 5-min MD+1 than peak match, with no difference for other positions (p>0.05). All playing positions covered 21-30% (p<0.001) less TD in peak MD+1 compared to peak match. *Figure 4* shows the most demanding 5-min periods in the non-starter session relative to peak 5-min match demands (100%). Peak ACC (109-130%) overperformed match demands in MD+1, while sprint (8-50%) and HIR (34-54%) displayed the lowest load in relation to peak match. TD (70-79%) and DEC (84-95%) slightly underperformed the peak match demands.

Table 3: Descriptive statistics (mean ± SD) of physical load of variables in 5-min peak periods in different session types. Microcycle represents the peak periods of the main training sessions in standardized training weeks while MD+1 is the non-starter compensatory session the day after the game.

	Session	TD (m)	HIR (m)	SPR (m)	ACC (count)	DEC (count)
FB	Match	784.8 ± 32.8	117.5 ± 13.6	46.3 ± 7.5	9.3 ± 2.0	9.5 ± 1.4
	Microcycle	752.5 ± 55.0	114.2 ± 13.2	44.8 ± 6.3	11.4 ± 1.0 *	11.1 ± 1.1 *
	MD+1	616.9 ± 43.0 *	47.7 ± 17.7 *	3.9 ± 3.2 *	11.5 ± 1.8 *	9.0 ± 2.7
CD	Match	718.0 ± 13.5	92.5 ± 10.0	32.1 ± 5.6	8.8 ± 0.6	8.2 ± 0.5
	Microcycle	684.0 ± 17.9	85.4 ± 37.5	33.7 ± 22.5	9.6 ± 0.5	8.6 ± 0.4
	MD+1 **	576.0 *	50.2	16.1	11.4 *	7.8
DM	Match	812.1 ± 9.8	78.8 ± 22.7	17.7 ± 11.4	8.6 ± 0.9	7.9 ± 0.9
	Microcycle	739.1 ± 19.2 *	76.9 ± 13.1	16.7 ± 1.8	11.1 ± 1.5 *	8.5 ± 1.8
	MD+1	567.7 ± 62.9 *	26.4 ± 0.2 *	1.9 ± 2.7	10.8 ± 1.0 *	7.3 ± 1.7
AM	Match	847.1 ± 25.4	124.8 ± 25.5	30.8 ± 8.4	9.5 ± 1.3	9.8 ± 1.6
	Microcycle	789.7 ± 30.0 *	96.5 ± 29.4 *	29.3 ± 6.8	12.0 ± 1.7 *	11.4 ± 1.2 *
	MD+1	619.6 ± 18.7 *	45.0 ± 5.3 *	7.2 ± 1.6 *	11.2 ± 0.6 *	8.2 ± 0.5
FW	Match	778.9 ± 54.9	134.9 ± 38.7	56.3 ± 23.5	10.0 ± 1.5	10.1 ± 1.3
	Microcycle	715.7 ± 53.9 *	105.0 ± 35.7 *	37.2 ± 15.4 *	11.7 ± 2.4 *	10.2 ± 1.5
	MD+1	616.9 ± 46.8 *	52.6 ± 40.4 *	16.3 ± 21.1 *	10.9 ± 2.8	8.6 ± 2.6 *

*TD, HIR, and SPR are presented in meters, and ACC and DEC are presented as number of ACC/DEC. * Statistically significant difference from match ($p<0.05$). ** Single observation, SD not defined. FB=full back, CD=central defender, DM=defensive midfielder, AM=attacking midfielder, FW=forward, TD=total distance, HIR=high-intensity run (19.8-25.2 $km \cdot h^{-1}$), SPR=sprint (>25.2 $km \cdot h^{-1}$), ACC=accelerations (>2 $m \cdot s^{-2}$), DEC=decelerations (>-2 $m \cdot s^{-2}$).*

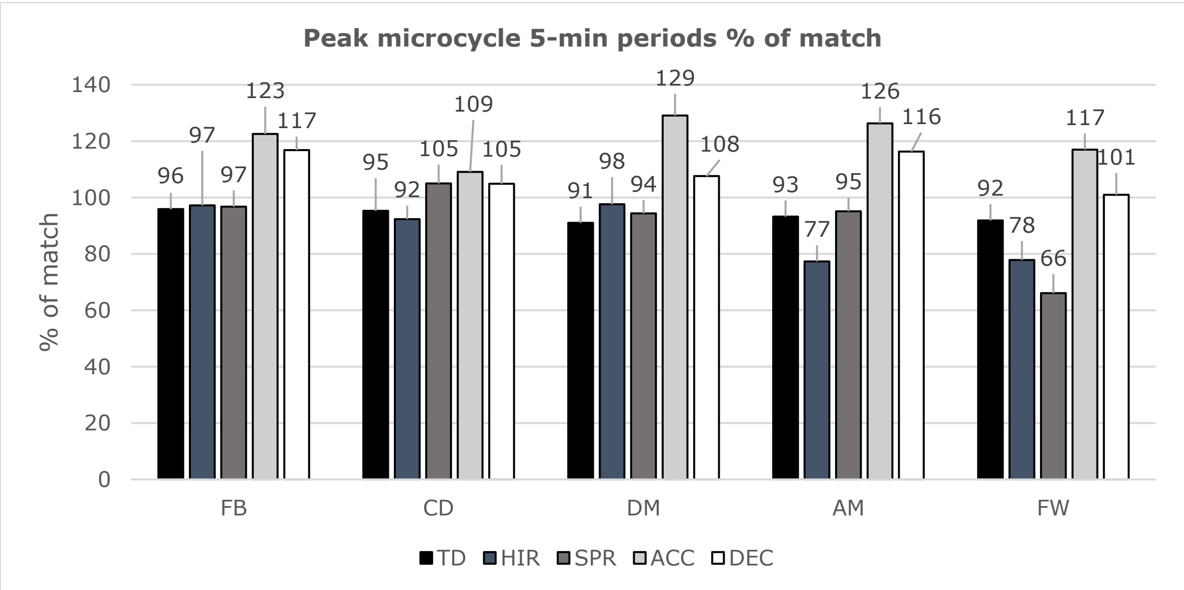


Figure 3: Peak 5-min periods in training week presented as percentage of peak 5-min match periods per position and variable.
FB=full back, CD= central defender, DM=defensive midfielder, AM=attacking midfielder, FW=forward, TD=total distance, HIR=high-intensity run (19.8-25.2 $km \cdot h^{-1}$), SPR=sprint (>25.2 $km \cdot h^{-1}$), ACC=accelerations (>2 $m \cdot s^{-2}$), DEC=decelerations (<-2 $m \cdot s^{-2}$).

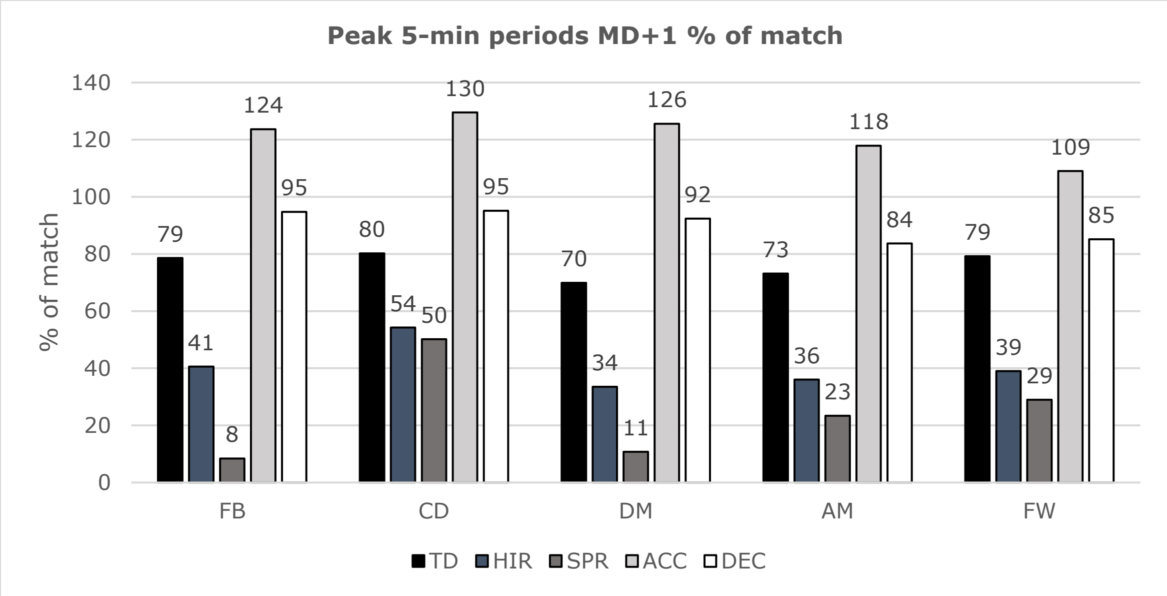


Figure 4: Physical load of peak 5-min periods for the compensatory non-starter session MD+1 presented as % of peak 5-min match demands per variable and position.
FB=full back, CD= central defender, DM=defensive midfielder, AM=attacking midfielder, FW=forward, TD=total distance, HIR=high-intensity run (19.8-25.2 km·h^{-1}), SPR=sprint (>25.2 km·h^{-1}), ACC=accelerations (>2 m·s^{-2}), DEC=decelerations (<-2 m·s^{-2}).

4. Discussion

The present study sought to objectively quantify position-specific physical demands of training compared to match demands of a professional football team. In line with the hypothesis, the accumulated training load of ACC, DEC, and TD overperformed the match demands for every position. Somewhat surprisingly, only two positions (AM and FW) covered significantly less HIR distance, and only FW presented a smaller amount of sprint distance during the training week compared to match, although a trend of lower (not significant) microcycle sprint values was observed for FB, DM, and AM. Even though not all differences reached the level of significance, total external load of the non-starter session was considerably lower compared to match for all variables and positions, with lowest load of HIR and sprint distance. Moreover, for the microcycle 5-min peaks AM and FW presented lower HIR distance, and only FW showing less sprint distance than in match, while the other positions managed to recreate the most intense periods for these velocity thresholds in training. Peak ACC and DEC match demands were overperformed for most positions in the most demanding passages of play in training week. The peak 5-min periods MD+1 overperformed ACC match demands for all positions except FW. Again, peak HIR and SPR distance showing the lowest load relative to match, with peak TD being lower than match for all positions. Peak DEC closely replicated match demands with only FW showing lower load in MD+1.

<u>Total external load</u>

The lower accumulated training load of HIR (70-103%) and sprint (47-136%), and higher load of ACC (155-189%), DEC (123-154%), and TD (140-163%) relative to match demands are to a certain degree in agreement with previous studies with a similar design. When investigating position-specific training load relative to match in a Norwegian elite team, Baptista and colleagues (27) reported a training load of 57-71%, 36-61%, 131-166%, 108-134%, of the match demands for HIR, sprint, ACC, and DEC, respectively, in a standardized training week with four sessions. Similar patterns of higher accumulated loads of ACC, DEC and TD, and lower loads of high-velocity running distance relative to match were observed in studies on Dutch (11) and Portuguese (26) elite teams. A study on an English Premier League team (16) reported high-speed running (m 20.88-24.12 km·h^{-1}), sprint (m >24.12 km·h^{-1}), and TD of 398 m, 87 m, and 19,939 m, respectively, throughout the training week with four sessions. This is somewhat in line with the results from the present study (HIR; 406.3 m-672.8 m, sprint; 28.9 m-135.7 m, and TD; 18,043.5-19,110.7 m), even though direct comparisons are difficult due to possible differences in tracking systems and speed thresholds. Interestingly, in our study only the playing positions with the highest HIR (AM and FW) and sprint (FW) demands of match-play covered significantly less distance in these velocity zones in training than match, and presented the lowest relative training load. Similarly, in the study by Baptista et al. (27), wing backs showed the lowest training load of HIR (57%) and sprint (36%) relative to match while covering the most high-velocity distance in games. Collectively, these results imply that exercises used in professional football teams tend to provoke ACC, DEC, and TD more than running at high speeds. The discrepancies observed between match and training sprint load for most positions, even though only FW reached the level of significance, indicate a lack of training specificity, most likely not providing an optimal stimulus for physiological adaptations (32).

As the main part of most training sessions for physical conditioning, both within the microcycle and for non-starters, the observed team almost exclusively used SSG with and without goals. This approach is frequently used by practitioners to develop physical, technical, and tactical capabilities and skills simultaneously (33). Ade et al. (19) reported greater HIR and sprint distances covered in running exercises compared to SSG, while the opposite was observed for ACC and DEC, in part explaining the high load of these variables. Both the absolute and relative pitch size are of importance for the physical actions during SSG (17, 34-36), with positional differences in the area per player needed to replicate high-velocity running match demands (34). Riboli et al. (34) reported that the area per player needed to reach match sprinting demands was largest for attackers, and this was very close to the relative pitch area in matches (~325m^2). Other authors reported a linear relationship between increases in relative pitch size and distance covered >21 km·h^{-1} (36), suggesting pitch dimensions in our study were not large enough, for FW in particular, to cover match-specific amounts of sprint distance in training, leading to the underload of this variable observed. Accordingly, while the small-sided games (SSG) and drills used in training for this team were sufficient for replicating HIR match demands for FB, CD, and DM, a larger surface area per player, or the addition of running-based exercises may be needed for the most demanding positions i.e., AM and FW and for players to reproduce sprint demands of match-play.

In the present study, we also compared the non-starter session to match demands (*Figure 2)*. The low amount relative to match of HIR (13-24%) and sprint (3-23%), and higher number of ACC (42-61%) and DEC (30-41%) observed in this study is somewhat comparable with observations from the non-starter session of a professional Spanish team (15) showing higher load of accelerations, and very low load of HIR and sprint, although they presented higher values for ACC and DEC (80-86% of match) compared to the present study. A study on a Dutch elite team (11) reported ~30% less running distance >19.8 km·h^{-1} for non-starters compared to starters in the full week with one match, and ~80% lower in weeks with two games, indicating a lack of fast-running activities in the compensatory sessions. As players with limited game time are at risk of being underloaded, especially in high-speed running (11, 22), and have demonstrated 40% lower intermittent running capacity (37), the additional session is of importance for maintaining physical capacity and reduce differences in performance and long-term adaptations for players with different starting status. In addition, the high-intensity activities of match-play serve as an important stimulus for the power development in football players (21). The reported load of ACC and DEC, and the SSG performed by the non-starters in this study could, due to the high neuromuscular demands of this exercise (18), have reduced some of the potentially greater development of the starters. However, sessions with low amount of HIR and sprint may not optimally develop the players sprint capabilities and ability to perform high-speed actions of importance for football performance at the highest level as muscle recruitment (38, 39) and performance enhancements (40) are highly specific to the exercise carried out. In light of this, high-velocity sprinting and acceleration ability must be considered separate qualities in professional football players, and should be trained accordingly (41).

For non-starters, Lacome et al. (17) suggested a session of SSG 4v4+goalkeeper (GK), 8v8+GK, and running-based interval training to make up for a 60 minute match. Due to the low number of players participating in the non-starter session it seems difficult to implement this strategy. For this reason, the conditioning and SSG for the non-starters were performed on relatively small pitches with few outfield players on each side (three to five). Several studies have reported reductions in high-velocity running distances with decreasing total and relative pitch size, and number of players on the pitch (18, 36, 42, 43). Rebelo et al. (18) reported lower demands of high-speed running, and higher demands of ACC/DEC in 4v4+GK compared to 8v8+GK, which is in line with the low amount of high-velocity distance observed in our study. A study comparing SSG 4v4+GK on small, medium, and large pitch, found higher amounts of HIR when playing on large pitch than on small and normal (20). These results may explain the load pattern observed and challenge practitioners to physically prepare non-starters for the demands of the match in a football-specific way.

Moreover, the low distances covered in the most demanding speed thresholds have implications for injury risk of football players. Almost one third of injuries in professional football are muscle injuries, with the majority affecting hamstrings (44). As only maximal-speed sprinting induces high hamstring activation (38), its role in an injury-preventive and conditioning program has been proposed. Although a relationship between excessively high sprint loads and elevated risk of soft-tissue injuries has been stated (13), a high chronic physical load with frequent exposures to near-maximal velocity running provide a protective effect against muscle injuries in elite team sport athletes (45). In support of this, a study on professional football players reported an under-exposure of distances covered >24 $km \cdot h^{-1}$ in the five matches prior to muscle injury compared to the uninjured players who presented greater high-velocity running distances (46). In addition, favorable injury-preventive adaptations in hamstring muscle architecture and improvements in sprint performance were found after sprint training in football players (47). These findings suggest that non-starters and underloaded players need additional loading and sprint activities to make up for the lack of game-time or minimal exposure to high-velocity movements in training. The approach for additional non-starter training by this team induced low load of HIR and sprint distance, possibly elevating injury risk in upcoming matches due to spikes in high-speed running load which is associated with muscle injuries (48). Future research should investigate different protocols for physical conditioning of non-starters and the effect on physical performance characteristics.

Peak 5-min periods

Our findings of AM and FW displaying significantly lower peak microcycle HIR distance and only FW covering less sprint distance compared to peak match demands, again show an underloading in the respective speed thresholds in training for the most demanding playing positions (*Figure 3*). Baptista et al. (27) reported similar results with wing backs covering the greatest HIR and sprint distances in peak match while also having the lowest relative peak training load (71% and 64%, respectively). Similar to the present study, peak ACC and DEC training load was in general greater than peak match load (27). When comparing 5-min peaks of training and match in a professional Spanish second level team, albeit without considering playing positions, Oliva-Lozano et al. (31) found that no session throughout the training week managed to recreate the most intense HIR and sprint periods of match. In this study however, FB, CD, and DM managed to replicate the peak HIR and sprint match demands within the microcycle, while AM (only HIR), and FW did not reach this peak intensity (*Figure 3*), suggesting an under-preparation of the worst-case scenario occurring in matches for positions with highest peak high-speed running match requirements (AM, FW). The lower microcycle peak TD for DM, AM, and FW in the present study is to some extent in line with the findings from Oliva-Lozano et al. (31) who reported that only the recovery session replicated match peak 5-min TD, while all the main sessions showed significantly lower peak TD compared to match. Lacome et al. (17) compared different formats of SSG from 4v4+GK (90 m^2 per player) to 10v10+GK (311 m^2 per player), where only the largest game format reached peak match intensity for TD and distance covered >14.4 $km{\cdot}h^{-1}$, again highlighting the importance of large surface areas to allow players to cover more space and higher velocities to be reached.

Moreover, the peak 5-min MD+1 (*Figure 4*) in general shows an underloading of the high-velocity movements and TD. Unsurprisingly, peak ACC match demands were overloaded in the non-starter session, and all positions except FW managed to reproduce peak DEC match demands. Dalen et al. (28) reported that SSG 4v4+GK replicated peak 5-min ACC match demands, whilst providing very small amounts of HIR and practically no sprinting. The frequent use of this or similar game formats on small areas in the MD+1 session may explain the discrepancies reported in this study. These findings imply that the non-starter training was effective in improving the players' ability to repeatedly accelerate and decelerate, while not preparing players for the specific worst-case scenario of high-velocity demands of match play, enlarging a possible already-existing performance gap between starters and non-starters.

Strengths and limitations

The present study has several strengths. To the best of the authors' knowledge, this is the first study to quantify cumulative and peak training load of both main and non-starter sessions relative to match in a professional football team. The opportunities to work with and collect data from athletes within a professional setting are limited, making studies on this population highly valuable. Furthermore, all matches and training sessions were measured by the same tracking system, reducing potential measurement errors and differences between systems. Additionally, a full season of competitive home games was analyzed to estimate the match demands of the playing positions, compared to other studies where only a few friendly games of varying length was measured (11).

Even though the present study gives valuable information about training load of a professional team, it is not without limitations. Firstly, only one team was analyzed in this study and the results may be highly specific for this team due to different methodologies and strategies used by coaches, and therefore generalization of the findings to other teams is not recommended. Following this, the small sample size might increase the risk of a statistical type II error and failing to detect true differences. This however, is not unique to our study as it is a common obstacle when working with professional football players. Moreover, the unpredictable nature of professional football with changes in schedule and training sessions, in addition to the COVID-19 situation, could not be controlled by the researchers and led to a smaller number of standardized weeks and compensatory sessions included in the sample. Regarding the non-starter sessions, we also included recordings from non-standardized weeks, meaning ten out of sixteen MD+1 observations took place two or three days before the next game. This might have prevented coaches planning a high load in these sessions due to tapering strategies often observed in football teams with declining training loads as MD approaches aiming to minimize fatigue (11, 15, 16). However, these sessions were included as they represented the actual additional training load of non-starters throughout the season, and in fact showed very similar load compared to sessions five days or more away from the next game. Furthermore, we did not include any measure of internal load (e.g., heart rate, RPE), and the fact that we did not report other physical actions within the peak 5-min period may lead to an underestimation of the actual load if not considered in training prescription. Finally, differences in speed and acceleration thresholds, and possible measurement errors with different tracking systems must be considered when comparing results from other studies.

5. Conclusion

In summary, playing positions with the highest match demands of HIR (AM and FW) and sprint (FW) distances showed the lowest load relative to match in these thresholds during the training week, both in total and peak load, while ACC and DEC seem to overload match demands for all positions. Due to limited game-time, non-starters risk being underloaded, especially in HIR and sprint as the compensatory session MD+1 did not replicate high-velocity demands of match play. The results from the present study gives detailed information of importance for coaches and practitioners about external training load in a professional football team, highlighting the need of a more position-specific approach to training. Future research should further investigate load of exercises relative to match intensity to facilitate training periodization, as well as protocols to effectively load non-starters in the highest speed thresholds, while considering the effect on physical capacity and performance.

Practical Applications

This study has important practical applications for the training of professional football players. The large positional differences of physical match demands must be considered when planning training and players should train to cope with their specific requirements of competition. To achieve sufficient HIR and sprint distances for the most demanding playing positions we recommend frequently playing on relative pitch areas close to those observed in official matches (~325 m^2 per player) and/or the addition of running-based drills. Furthermore, as the compensatory session effectively replicated match ACC and DEC demands whilst HIR and sprint demands were largely underperformed, the SSG in non-starter training should be complimented by running drills or football-specific drills where high-velocity movements are more prominent to ensure a more optimal stimulus to maintain or develop acceleration and high-speed running capabilities of players with limited game time.

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Appendix A

CHYRONHEGO

GEO TRANSPONDER
PRODUCT INFO

GEO Transponder

High-precision GNSS transponder for real-time positioning

The most accurate GNSS transponder for football on the market (ref. FIFA ETPS Validation Study). Used for outdoor and small stadiums with TRACAB GO. Compatible with third party sensors via Bluetooth, such as heart rate monitors.

Specifications

Sizes and Weight	
Dimensions (WxLxD)	90 x 45 x 15 mm
Weight	63 g

Radio	
Frequency (Configurable)	5 - 5.9 GHz
Power Emission	0 - 10 dBm

Battery	
Type	Lithium Ion
Duration	8 hours

Interfaces	
Bluetooth	4.0 (Low Energy)

Sensors	
GNSS	10 Hz GPS, GLONASS, GALILEO
IMU	Accelerometer, Magnetometer and Gyro
Temperature	-20 to 60 °C

FOR MORE INFORMATION ABOUT CHYRONHEGO VISIT:
HTTP://CHYRONHEGO.COM/

GEO TRANSPONDER
PRODUCT INFO

FIFA EPTS Validation Study Results

VICTORIA UNIVERSITY MELBOURNE AUSTRALIA

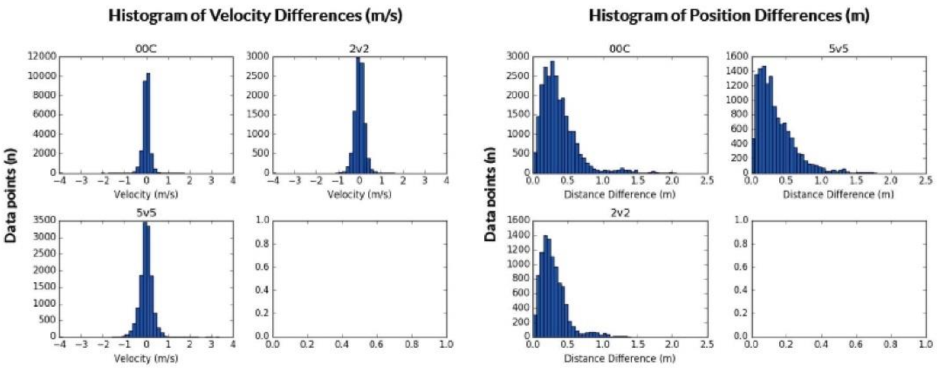
CHRYON HEGO GPS

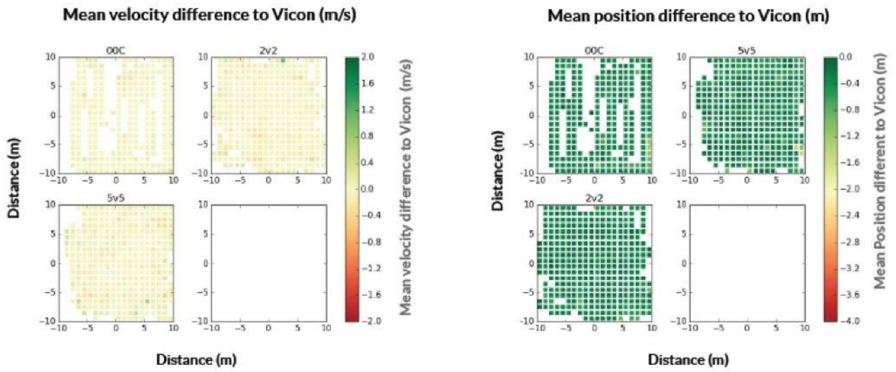
FIFA

Rating by FIFA Velocity Band

	0-7 km/h	7-15 km/h	15-20 km/h	20-25 km/h	25+ km/h
Velocity RMSD (m/s)					
Position RMSD (m)					
Velocity mean difference (m/s)	0.06	0.04	-0.10	-0.11	
Velocity SD difference (m/s)	0.15	0.19	0.13	0.06	

Legend	Well-above	Above	Standard	Below	Well-below





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Appendix A: Results from the FIFA Validation Study for the ZXY Tracking System.

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