# Time in heart rate zones during training and matches in professional football: a descriptive analysis of nearly 1000 microcycles from 20 teams

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In collaboration with

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### Headline

Quantifying the cardiovascular load that football players accumulate across a microcycle remains a central question in applied sport science. Heart rate (HR) monitoring is the most widely available proxy for cardiopulmonary stress in team sport settings (Buchheit & Hader, 2025), and time spent in high HR zones (THRZ) has been repeatedly linked to changes in aerobic-related physiological and performance markers in elite players (Akubat et al., 2012; Castagna et al., 2011, 2013; Malone et al., 2016, 2019; Manzi et al., 2013; Rabbani et al., 2019; Stagno et al., 2007). Drawing on a pooled re-analysis of 12 such studies, Buchheit et al. (2025) recently proposed that approximately 30 (±20) minutes per week above 86-91% HRmax, or above the HR corresponding to 4 mmol·L$^{-1}$ blood lactate, represents a minimal effective dose for maintaining or improving cardiometabolic function in team sport athletes. Whether this benchmark, derived from a small number of controlled studies, is actually reached in the day-to-day training of modern professional football teams is unknown.

It is important to be clear about what this 30 (±20) min·week$^{-1}$ figure represents and what it does not (Buchheit et al. 2025). The number was derived by pooling regression-based dose-response analyses from 12 studies in team sport athletes and identifying the weekly time-in-zone at which the regression line crossed zero change in fitness, that is, the point at which players neither improved nor lost fitness (Buchheit et al., 2025). It therefore reflects the minimum exposure associated with maintaining rather than improving cardiometabolic function. The ±20 range reflects the considerable heterogeneity of the underlying studies: populations spanned different team sports, different competitive levels, and both pre-season and in-season contexts, and the zone definitions used were not identical, ranging from >86% to >91% HRmax depending on the study and outcome marker. The figure should therefore be read as an informed ballpark for a minimum maintenance dose, not as a precise prescription. With this in mind, comparing real-world practice to this range remains useful because it offers the only empirically grounded reference point currently available for what teams should be accumulating in HR-based load.

Most existing empirical descriptions of microcycle load come from single teams or small samples (e.g., Malone et al., 2015; Castagna et al., 2013), making it difficult to know whether reported patterns reflect general practice or one club's choices. The relative contribution of matches versus training to weekly HR-zone exposure has also received limited attention in spite of being central to how practitioners design compensation work for non-starters (Buchheit et al. 2024). Match HR data, in particular, are known to overestimate true aerobic demand because of stress, caffeine, cardiac drift, and contextual demands (Bangsbo, 1994; Buchheit et al., 2025), meaning that combining training and match time-in-zone without distinction may not represent equivalent physiological stimuli. Lastly, beyond the weekly aggregate, it is also of practical interest to understand which days of the microcycle most consistently deliver high HR exposure, since this informs how the weekly target can be distributed across sessions.

Firstbeat Sports (Firstbeat Technologies, Jyvaskylä, Finland) collects HR data across a large number of professional football clients, providing a unique opportunity to characterize training practices at a scale representative of the broader professional football population. In this paper, we make use of a pooled dataset of 948 microcycles from 20 anonymous professional teams to describe weekly and daily time spent >80% and >90% HRmax across both training and match days, and to examine how this exposure differs between players classified as starters versus non-starters in the previous game.

### Aim

To describe weekly and daily time spent >80% and >90% HRmax across 948 six-day microcycles from 20 professional football teams, with attention to (i) whether the published 30 (±20) min·week$^{-1}$ HR-based dose is reached in practice, (ii) the relative contribution of training versus match exposure, (iii) differences between starters and non-starters in the previous game, and (iv) which days of the microcycle most consistently accumulate time in high HR zones.

### What this data can and cannot tell us

Before presenting the findings, it is important to be explicit about what this dataset allows us to claim and what it does not. Several limitations affect interpretation throughout the paper, and practitioners should keep these in mind when comparing their own teams to the numbers reported here.

- **HRmax accuracy was trusted, not verified.** All HR zones are defined as percentages of individual HRmax, which means the validity of every minute reported in this paper depends on each club having entered an accurate

HRmax for each player. As discussed in Buchheit et al. (2025), HRmax is often estimated rather than directly measured, and even when measured, the value can vary across testing modalities and may be underestimated relative to the true individual maximum. We had no means to audit how HRmax was determined in each of the 20 teams and simply trusted the values stored in the Firstbeat platform. Any systematic over- or under-estimation of HRmax at a given club will shift that club's reported time above 80% or 90% HRmax accordingly, which is a further source of noise on top of those listed above.

- **Starter versus non-starter classification was a proxy.** Without access to actual playing minutes, players were assigned to the 'starter' or 'non-starter' group based on a TRIMP cutoff in the first game of the cycle. Some 'non-starters' likely played meaningful minutes, and some 'starters' may have been substituted early. The categories should be read as informed groupings, not exact playing-time strata.
- **Training session content was not available.** A day labelled 'MD-4' across teams may correspond to very different sessions (technical, extensive vs intensive tactical, generic conditioning, small-sided games, recovery). Day-level averages therefore, mix heterogeneous content, and any signal we detect at the day level reflects what teams do on average rather than what is prescribed by a given session type.
- **Microcycle structure was inferred from measurement timestamps, not training schedules.** We had no access to the actual training timetables of the clubs. A day with no Firstbeat recording was treated as a rest day, but it could have been a tactical session, gym work, or simply an unrecorded session. When a team ran two pitch sessions in a day, only what was recorded counted toward that day's total. Game tags are also coach-based. All microcycles in this paper should therefore be read as measurement-based reconstructions rather than schedule-faithful descriptions.
- **Some values appear physiologically improbable.** For example, the dataset shows non-trivial >90% HRmax exposure for starters on MD+1/MD-6. It is rare for starters to perform high-intensity work the day after competing, so part of these values likely reflects non-metabolic HR elevation, classification errors, or measurement artifacts rather than true high-intensity training. We have no means to verify or clean this at the individual level.
- **Cycles are not independent observations.** The same players and teams contribute multiple microcycles to the dataset. The confidence intervals reported alongside the effect sizes do not account for this clustering and should be treated as approximate. A formal mixed-effects analysis was beyond the scope of this descriptive work.
- **Between-team variability is substantial.** Team-level median weekly >90% HRmax in training ranges from 0 to 33 minutes across the 20 teams in the sample (>80% HRmax ranges from 2.8 to 100 minutes). Population averages therefore mask considerable heterogeneity in periodization culture, and practitioners should not interpret the central tendency as a uniform 'typical' team.
- **No position, fitness, or anthropometric data were available.** Stratification by playing position, individual physical profile, or other relevant athlete characteristics was not possible. The findings are therefore aggregated across all roles and profiles, even though previous work (Malone & Buchheit, 2025) has shown that adaptation to HR-based load can differ by profile.

Given these constraints, the strength of this dataset lies in volume rather than precision. With 948 microcycles drawn from 20 professional teams, systematic patterns can emerge above the noise of individual misclassifications and missing context. We therefore treat the findings as descriptive snapshots of current population-level practice rather than as causal claims or individual prescriptions. Practitioners should compare their own teams to these reference distributions with awareness of the caveats above.

## Methods

### Dataset

Anonymised HR monitoring data from professional football teams using Firstbeat Sports were aggregated at the microcycle level. Inclusion required a six-day cycle bracketed by two consecutive matches, with at least four valid training days and complete data for the first (previous) game. After filtering, the sample comprised 948 microcycles from 20 distinct teams. The dataset was filtered to include 20 teams in total — 19 from Tier 1 (Top Flight) and 1 from Tier 2 (Second Division) — spanning 9 professional leagues across 9 countries.

### Heart rate zones

Heart rate zones were defined as proportions of individual maximal HR (HRmax), with high-intensity zones defined as >80% HRmax and >90% HRmax. HRmax values were derived from each player's profile within the Firstbeat platform. HRmax is calculated by default using formula MaxHR = 210 - Age x 0.65. HRmax is automatically updated on the platform, when new MaxHR is detected by Firstbeat Algorithm. Daily time in each zone was computed across all sessions and stored as a per-day total.

### Starter versus non-starter classification

Because actual playing minutes were not available, players were classified into 'starter' or 'non-starter' groups based on the TRIMP value recorded during the first (previous) game of the cycle. A cutoff of 171 (corresponding approx. 70 min of play time on average) was applied. This classification is acknowledged as a noisy proxy for true starter status (see the limitations section).

### Aggregations and reporting

Weekly aggregates were computed for training only (sum across the six training days excluding the match), for the match only (the first game of the cycle), and for the combined weekly+match total. Daily distributions across the microcycle were also retained. For percentage-by-class summaries, weekly accumulations were binned into four classes (<10, 10-30, 30-60, >60 minutes). Distributions are reported as medians and interquartile ranges. Between-day comparisons used Hedges' g with 95% confidence intervals; these intervals do not account for the non-independence of observations and are treated as approximate. Team-level medians were also computed to characterise between-team variability.

TRIMP-based summaries are not reported in this paper. Because TRIMP was used to derive the starter versus non-starter classification, any further TRIMP-based analysis comparing these groups would be partly circular. Reporting is therefore restricted to time in HR zones, which is independent of the classification rule. Future studies using datasets with verified appearance and minutes-played annotations would be valuable for confirming the patterns reported here.

Extraction, processing, and aggregation of the data as well as the final review of the paper were carried out by Firstbeat

Technologies (JP & TM). The planning of the analyses, evaluation of the aggregated data, and the scientific processing with conclusions were conducted by MB.

## Results

### Weekly accumulation

Table 1 reports the median weekly minutes in >80% HRmax and >90% HRmax separately for training only, match only, and the combined total, split by starter status. At the broader >80% HRmax threshold, training alone delivered a median of approximately 61 minutes per week to both starters and non-starters. The match contributed approximately 55 additional minutes for starters but only 9 minutes for non-starters, reflecting the underlying classification: the non-starter group includes many players who did not play at all in the previous match.

At the stricter >90% HRmax threshold, training delivered a median of only 6 to 8 minutes per week. The match added approximately 19 minutes for starters and effectively nothing (median 0 minutes, 75th percentile 3 minutes) for non-starters. Combining training and match, starters reached a median of approximately 25 minutes per week in >90% HRmax, while non-starters remained around 8 minutes per week.

Table 2 presents the proportion of player-weeks falling into four exposure classes. At the broader >80% HRmax threshold, 83% of starter weeks and 76% of non-starter weeks exceeded 30 minutes in training alone, with roughly half exceeding 60 minutes. Combining training and match, 95% of starter weeks and 81% of non-starter weeks exceeded 30 minutes. At the strict >90% HRmax threshold, the picture is markedly different: only 14% of starter weeks and 18% of non-starter weeks exceeded 30 minutes in training alone. With the match included, 49% of starters reached at least 30 minutes, while the proportion of non-starters remained at 21%.

**Table 1. Median (IQR) minutes per week in >80% HRmax and >90% HRmax across training, match, and combined exposures, by starter status.**

| | >80% HRmax Training only | >80% HRmax Match | >80% HRmax Combined | >90% HRmax Training only | >90% HRmax Match | >90% HRmax Combined |
|---|---|---|---|---|---|---|
| Starters (n=371) | 60.9 (40.9-90.2) | 54.8 (40.2-73.9) | 126 (90.5-155.5) | 6.5 (1.0-19.2) | 18.6 (5.8-31.3) | 28.7 (10.4-37.6) |
| Non-starters (n=577) | 62.3 (32.1-89.3) | 9.1 (0.5-20.0) | 74.25 (40.0-106.7) | 8.3 (0.4-20.9) | 0 (0-3.1) | 10.2 (0.9-26.2) |
| All (n=948) | 61.3 (34.2-89.3) | 21.0 (5.0-46.3) | 93.5 (131.2-53.6) | 7.2 (0.7-20.1) | 2.1 (0-13.8) | 16.3 (2.2-35.6) |

**Table 2. Percentage of player-weeks across four classes of weekly minutes in >80% HRmax and >90% HRmax.**

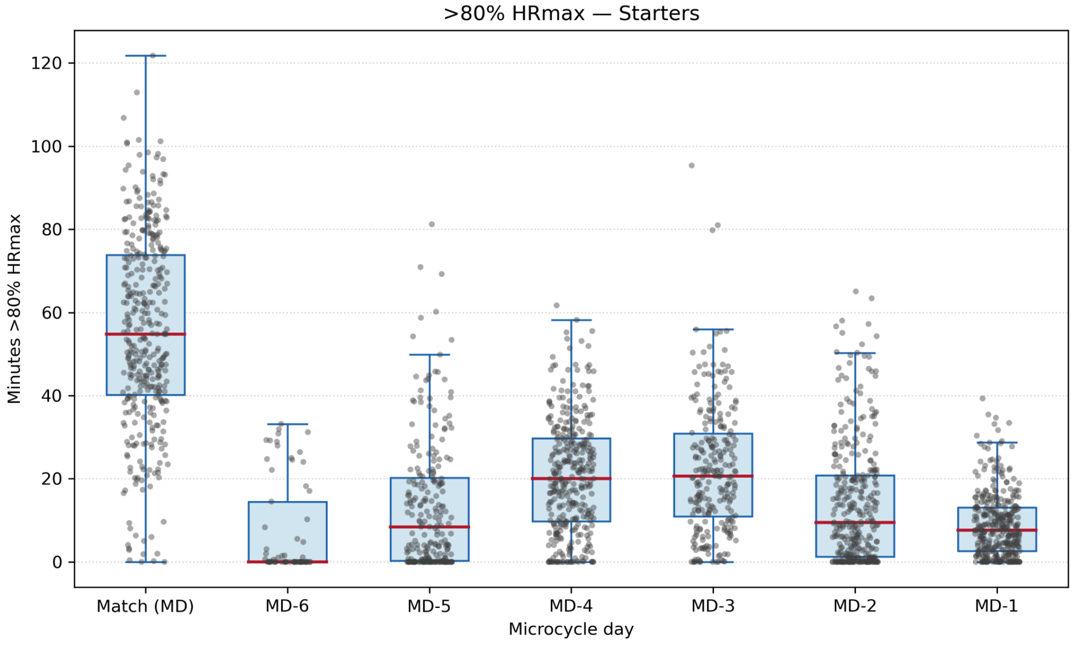
| | | <10 min | 10-30 min | 30-60 min | >60 min | ≥30 min |
|---|---|---|---|---|---|---|
| >80% HRmax Training only | Starters | 6.7 | 10.2 | 31.8 | 51.2 | 83.0 |
| | Non-starters | 9.5 | 14.6 | 24.4 | 51.5 | 75.9 |
| >80% HRmax Match only | Starters | 4.0 | 10.8 | 42.3 | 42.9 | 85.2 |
| | Non-starters | 52.7 | 38.5 | 8.8 | 0.0 | 8.8 |
| >80% HRmax Training + Match | Starters | 3.0 | 1.9 | 6.5 | 88.7 | 95.1 |
| | Non-starters | 6.9 | 12.3 | 19.6 | 61.2 | 80.8 |
| >90% HRmax Training only | Starters | 59.8 | 26.1 | 12.1 | 1.9 | 14.0 |
| | Non-starters | 54.1 | 28.4 | 13.7 | 3.8 | 17.5 |
| >90% HRmax Match only | Starters | 33.2 | 40.7 | 24.8 | 1.3 | 26.1 |
| | Non-starters | 91.7 | 8.0 | 0.3 | 0.0 | 0.3 |
| >90% HRmax Training + Match | Starters | 24.8 | 26.7 | 32.1 | 16.4 | 48.5 |
| | Non-starters | 49.4 | 29.8 | 16.1 | 4.7 | 20.8 |

### Daily distribution across the microcycle

Figures 1 and 2 show the daily distribution of minutes in >80% HRmax and >90% HRmax, respectively, with the match (MD) presented first and the training days arranged from MD-6 (day after the match) through MD-1 (day before the next match). Each dot represents one microcycle, with the boxplot summarising the median and interquartile range.

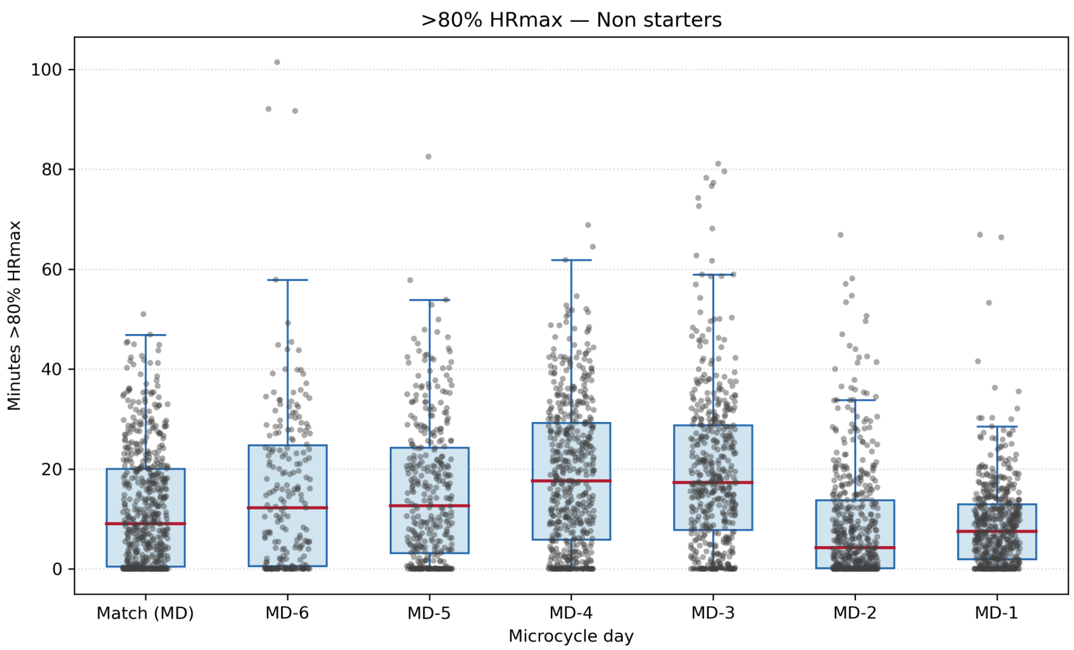
At >80% HRmax (Figure 1), the match dominates the cycle for starters (median ∼55 minutes), followed by MD-4 and MD-3 as the loaded training days (median ∼20 minutes each). MD-1, MD-2, and MD-6 deliver lower exposures. For non-starters, the match contributes substantially less (median ∼9 minutes), and the loaded training days (MD-4, MD-3) sit at similar levels to those of starters. Some non-starters show notable MD-6 exposure (median 12 minutes), consistent with post-match compensation work in part of the sample.

At >90% HRmax (Figure 2), the same overall shape is preserved but the absolute values are much lower. The match clearly stands out as the day with the highest >90% HRmax exposure for starters (median ∼19 minutes), while training days deliver only 1 to 2 minutes of median >90% HRmax exposure. For non-starters, no training day approaches the 30-minute target, and the match column shows essentially zero >90% HRmax minutes for the median player.



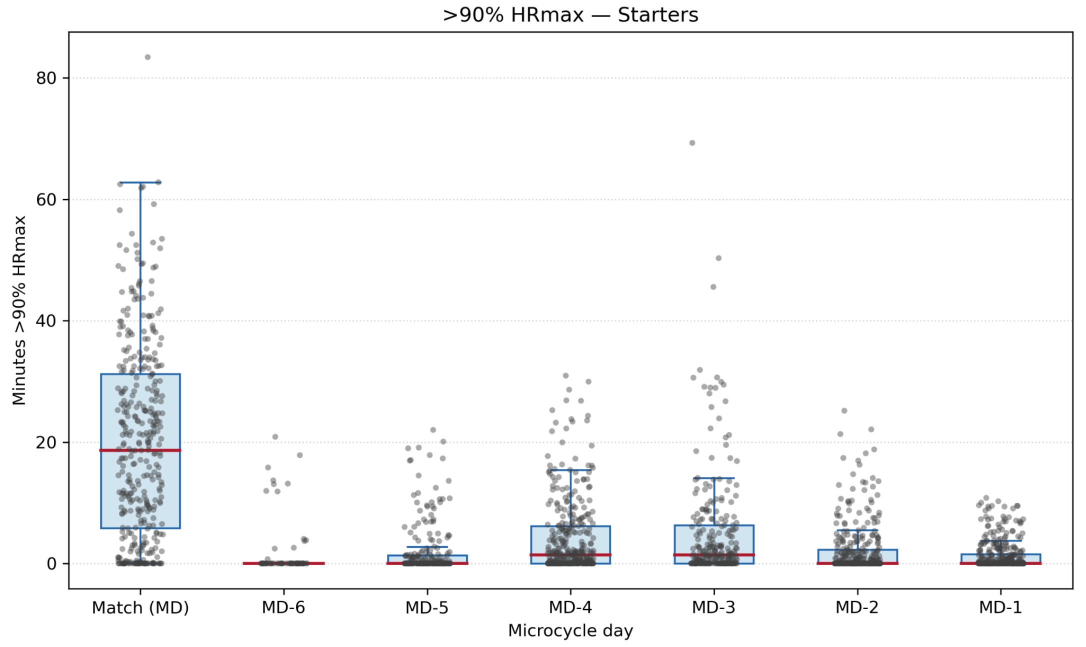

Box shows median and interquartile range (spread); whiskers extend to 1.5×IQR. Each dot is one microcycle (one observation).

**Fig 1a. Daily minutes in >80% HRmax across the microcycle for starters. Each dot represents one microcycle; the box shows median and interquartile range; whiskers extend to 1.5×IQR.**



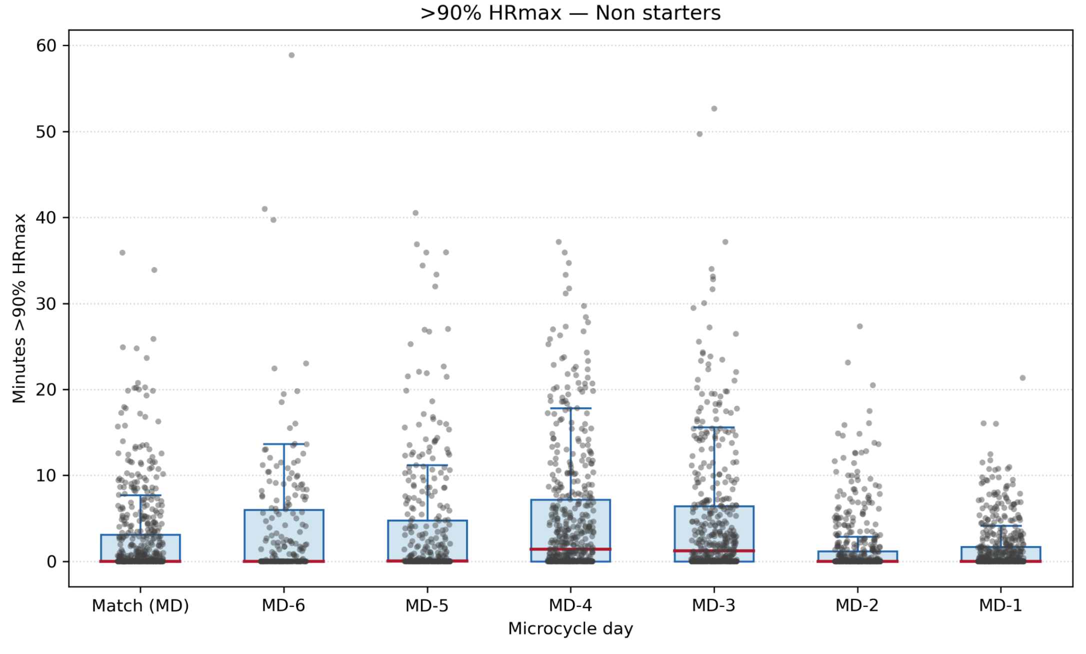

Box shows median and interquartile range (spread); whiskers extend to 1.5×IQR. Each dot is one microcycle (one observation).

**Fig 1b. Daily minutes in >80% HRmax across the microcycle for non-starters. Note the smaller match contribution and the comparatively higher MD-6 exposure relative to starters.**




Box shows median and interquartile range (spread); whiskers extend to 1.5×IQR. Each dot is one microcycle (one observation).

**Fig 2a. Daily minutes in >90% HRmax across the microcycle for starters. The match (MD) dominates >90% HRmax exposure; training days deliver markedly less.**




Box shows median and interquartile range (spread); whiskers extend to 1.5×IQR. Each dot is one microcycle (one observation).

**Fig 2b. Daily minutes in >90% HRmax across the microcycle for non-starters. No training day approaches the 30 min weekly target on its own, and the match contributes minimal >90% HRmax exposure given the underlying classification.**

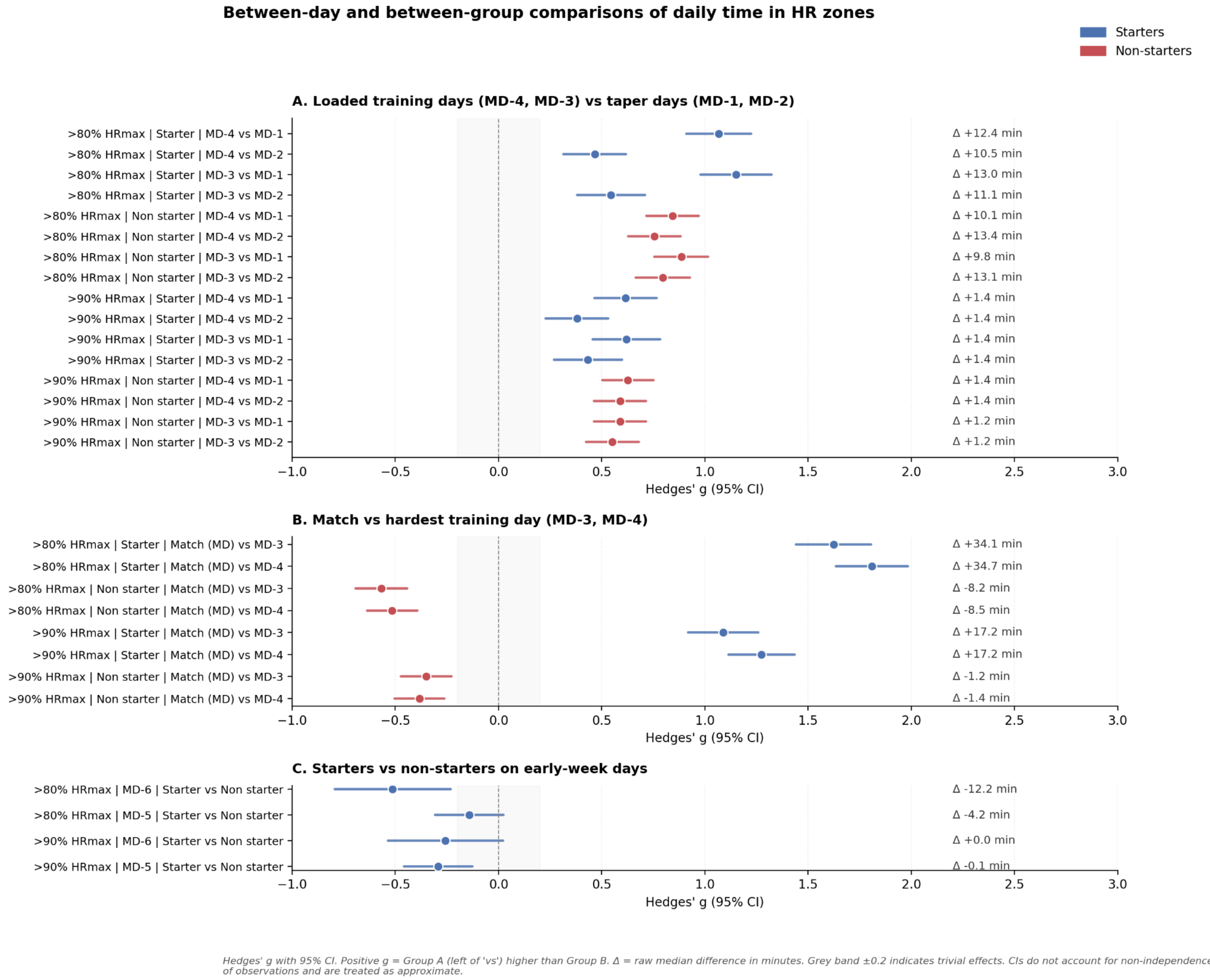



**Fig 3. Effect sizes for daily and between-group comparisons. Dots are Hedges' g; horizontal bars are 95% CI; Δ values to the right show the raw median difference in minutes. Grey band ±0.2 indicates trivial effects. Positive g indicates Group A (left of 'vs') higher than Group B. CIs do not account for the non-independence of observations and are treated as approximate.**

## Day-by-day and between-group comparisons

Figure 3 presents three panels of effect sizes (Hedges' g with 95% CI) alongside the raw median differences in minutes. The full numerical detail is provided as Supplementary Table S1.

## Loaded versus taper days (Figure 3 Panel A)

Contrasting the loaded training days (MD-4 and MD-3) with the taper days (MD-1 and MD-2) showed positive effects across both zones and both groups, with all confidence intervals clearly above zero. At >80% HRmax, effects ranged from moderate to very large (Hedges' g 0.47 to 1.15), with the largest contrasts found when comparing the loaded days to MD-1. At >90% HRmax, effects were moderate (g 0.38 to 0.63) and consistent across the four comparisons. The pattern was similar in starters and non-starters, indicating that the day-by-day periodisation shape is preserved regardless of starter status. This is the clearest signal in the dataset and the one most robust to the noise introduced by mixed session content across teams.

## Match versus hardest training day (Figure 3 Panel B)

For starters, the match exceeded the hardest training day by very large margins at both zones: Hedges' g 1.62 to 1.81 at >80% HRmax (raw median difference around 34 minutes) and 1.09 to 1.27 at >90% HRmax (raw median difference around 17 minutes). For non-starters, the pattern reversed: their hardest training day exceeded their match contribution at >80% HRmax (g around -0.52 to -0.57) and at >90% HRmax (g around -0.35 to -0.38). This partly reflects the underlying classification, since non-starters by definition received limited match exposure, but it is informative because it shows that at >80% HRmax, structured training delivers more high-intensity exposure than the match itself for this group. At >90% HRmax, the same direction was observed but the absolute magnitudes were small (raw difference around 1 minute), reflecting the very low >90% HRmax exposure achieved during training in general.

**Starters versus non-starters on the early-week days (Figure 3 Panel C)**

On MD-6, the day after the match, non-starters accumulated more >80% HRmax than starters (Hedges' g -0.51), consistent with post-match compensation work being scheduled for those who did not play. The raw median difference was approximately 12 minutes. By MD-5, this difference had largely disappeared (g -0.14), suggesting that whatever compensation effect is present is concentrated on the day directly after the match rather than carried forward. At >90% HRmax, between-group differences on the early-week days were small (g -0.26 to -0.29) and the raw median differences were essentially zero, indicating that the compensation visible at >80% HRmax does not translate into meaningful additional time above 90% HRmax for non-starters.

**Between-team variability**

Team-level median weekly minutes were computed for each of the 20 teams in the dataset. For training-only weekly >80% HRmax, team medians ranged from 2.8 to 100.1 minutes (median of team medians: 65.2 min). For training-only weekly >90% HRmax, team medians ranged from 0.0 to 33.1 minutes (median of team medians: 9.3 min), with 10 teams below 10 minutes, 8 teams between 10 and 30 minutes, and only 3 teams reaching or exceeding 30 minutes per week in training. This widespread underscores that the population averages presented above conceal substantial heterogeneity in how teams accumulate high-HR exposure.

**Discussion**

Drawing on a pooled dataset of nearly 1000 microcycles from 20 professional football teams, this descriptive analysis indicates that the published minimum maintenance dose of 30 (±20) min·week$^{-1}$ in high HR zones (Buchheit et al., 2025) is broadly met when measured at the >80% HRmax threshold, with about three quarters of player-weeks reaching this threshold in training alone, and over 80% when the match is included. At the stricter >90% HRmax threshold, however, the picture is markedly different: only 14 to 18% of player-weeks reach 30 minutes in training, rising to 49% in starters but only 21% in non-starters when the match is added.

A direct comparison between the present data and the published target is complicated by the fact that the original dose-response studies pooled by Buchheit et al. (2025) used thresholds ranging from 86 to 91% HRmax (Akubat et al., 2012; Castagna et al., 2011, 2013; Malone et al., 2016, 2019; Manzi et al., 2013; Rabbani et al., 2019; Stagno et al., 2007), whereas the Firstbeat dataset reports only the standard >80% and >90% HRmax boundaries. Our >80% HRmax category is therefore broader than the literature thresholds, and our >90% HRmax category is slightly stricter than most of them. The published 30 (±20) min·week$^{-1}$ target most likely sits somewhere between the two categories we can report. With this caveat in mind, our findings suggest that the recommendation is comfortably exceeded when interpreted against the broader >80% HRmax category, and largely undershot when interpreted against the stricter >90% HRmax category, with the gap particularly pronounced for non-starters. It is worth noting that the 30 (±20) min figure is a minimum maintenance dose: meeting it suggests that cardiopulmonary/metabolic function is unlikely to decline, but it does not imply that the dose is sufficient to drive further improvement, which would require additional exposure.

The dependence on match exposure for reaching the high-intensity dose is one of the clearest findings (Table 1 & 2). For starters, the match exceeds the hardest training day by very large effect sizes at both >80% HRmax (g ∼1.6 to 1.8) and >90% HRmax (g ∼1.1 to 1.3) (Figures 1 and 2; Supplementary Table S1, Panel B). This is consistent with prior reports that competitive matches in football routinely elicit prolonged time above 90% HRmax (Helgerud et al., 2001; Bangsbo, 1994; Kunzmann et al., 2022) and that single matches alone may approach or exceed the published minimal weekly dose. However, as discussed in Buchheit et al. (2025), match HR is influenced by factors beyond aerobic demand, including psychological stress, caffeine intake, cardiac drift, and contextual late-game elevations. A given number of >90% HRmax minutes accumulated in a match therefore, does not necessarily represent the same aerobic training stimulus as the same number of minutes accumulated in structured training. Treating match minutes-in-zone as equivalent to training minutes-in-zone may lead to overestimating the true aerobic load delivered to starters.

For non-starters, the picture is the opposite: their hardest training day delivers more >80% HRmax exposure than their match contribution (Figure 1b and 2b). The MD-6 comparison further suggests that some compensation work is happening in part of the sample, since non-starters on the day after the match accumulate more >80% HRmax than starters do at the same point in the week (Supplementary Table S1, Panel C). By MD-5, the groups have converged. At >90% HRmax, however, this compensation pattern is much weaker, and across the week non-starters reach the strict 30-minute >90% HRmax target in only one fifth of cases (versus nearly half for starters). This is consistent with a longstanding practical concern: structured compensation work for substitutes often delivers adequate volume at moderate-to-high intensity but does not consistently push players into the highest HR zones that may matter most for aerobic adaptation (Helgerud et al., 2007; Buchheit & Laursen, 2013). One likely reason is that compensation sessions in many clubs are designed around GPS-based targets such as total distance, high-speed running, or accelerations rather than around metabolic exposure (Buchheit et al., 2026; Little & Buchheit, 2025). Hitting an external load target does not guarantee that the player reaches the HR zones required for cardiovascular adaptation, particularly in fitter players whose HR response to a given running speed is often blunted. We have previously argued that the field's drift toward chasing GPS metrics without an accompanying rationale for metabolic load is a real limitation in current practice (Buchheit & Hader, 2025; Buchheit et al., 2026), and the present findings give an empirical illustration of the cost: GPS-driven compensation may deliver the external mechanical volume but miss the >90% HRmax stimulus that the metabolic dose-response literature points to. Practitioners working with non-starters should consider whether their compensation sessions are designed to elicit time above 90% HRmax, not just GPS-based targets or total HR-based load.

At the daily level, MD-4 and MD-3 emerge as the loaded training days across both groups, with moderate to very large effects relative to the taper days (MD-1, MD-2) (Figures 1 and 2; Supplementary Table S1, Panel A). This pattern is consistent with the predominant periodization logic described in the literature (Akenhead et al., 2016; Buchheit et al., 2024) and observed in single-team descriptions (Malone et al., 2015).

What is notable is that this signature emerges from a heterogeneous sample of 20 teams without any harmonisation of session content or day labelling, suggesting broad convergence on a typical microcycle shape despite differences in coaching philosophy. Several caveats temper these conclusions. The starter versus non-starter classification, derived from a TRIMP cut-off rather than playing minutes, is necessarily noisy and likely places some genuine substitutes in the non-starter group and some second-half-only players in the starter group. The absence of training session content means that day-level averages mix sessions of very different content across teams. Some values in the dataset, such as >90% HRmax exposure on MD-6 for starters, are physiologically improbable and likely reflect a mix of non-metabolic HR elevations, measurement artifacts, or classification errors that we have no means to clean. A further source of noise is the validity of HRmax itself: because all zones are defined relative to each player's HRmax, any team that relied on estimated rather than measured HRmax, or that worked with outdated values, will have shifted every reported minute above 80% or 90% accordingly. We had no means to verify how HRmax was determined across the 20 teams. Finally, the substantial between-team variability (team-median weekly >90% HRmax in training ranging from 0 to 33 minutes) means that the population averages reported here are not a 'typical' team but rather the central tendency of a heterogeneous group. Practitioners should compare their own teams to these distributions with this heterogeneity in mind.

Despite these limitations, the large sample size offers a level of empirical grounding that single-team descriptions cannot provide. With nearly 1000 microcycles, systematic patterns can emerge above the noise introduced by individual misclassifications and missing context. The strength of this dataset lies in its volume rather than in any single observation, and the findings should be read as snapshots of population-level practice rather than as prescriptions for individual teams.

## Conclusion

Across nearly 1000 microcycles from 20 professional football teams, weekly time in >80% HRmax broadly meets the published minimum maintenance dose of 30 (±20) min·week$^{-1}$ for cardiovascular fitness (Buchheit et al., 2025), even from training alone. The stricter >90% HRmax target is reached primarily through match exposure for starters and is largely unmet for non-starters, who appear to receive adequate >80% HRmax volume but limited >90% HRmax intensity from their compensation work. The match dominates the high-intensity weekly dose for starters and should not be treated as equivalent to the same minutes accumulated in training. Practitioners managing non-starters should pay particular attention to whether their compensation work is designed to deliver time above 90% HRmax rather than only hitting volume-based GPS targets and moderate to high HR exposure. The substantial between-team variability observed here cautions against treating any single benchmark as a universal target, and meeting the maintenance dose should not be confused with delivering a stimulus sufficient for fitness improvement. These findings should also be read with the understanding that all HR-zone calculations depend on the accuracy of each club's HRmax values, which we trusted rather than independently verified.

## Practical applications

- For this sample of 20 teams, weekly accumulation above 80% HRmax in training alone (median ∼60 min·week$^{-1}$, ∼79% of weeks above 30 min) was clearly higher than the 30 min·week$^{-1}$ maintenance dose, while accumulation above 90% HRmax in training alone (median ∼7 min·week$^{-1}$, ∼16% of weeks above 30 min) fell well short of it. The published target was derived from studies using thresholds between 86 and 91% HRmax, so it sits between the two boundaries we can report here. The most honest reading is that training in this cohort delivers substantial high-intensity HR exposure in the broad sense, but only a small share of it reaches the strictest intensity band. Practitioners should ask their own teams the same question and decide, based on their objective (maintenance versus improvement) and current outcomes, whether the >90% HRmax dose currently being delivered is enough.
- The picture differs sharply between starters and non-starters. Starters reach the high-intensity dose primarily through match exposure, with the match dominating their weekly accumulation above 90% HRmax. Non-starters show evidence of compensation at 80% HRmax (with higher MD+1/MD-6 exposure than starters) but the compensation does not translate into time above 90% HRmax, where they remain well behind (only ∼21% of non-starter weeks reach 30 min combined above 90% HRmax). Designing genuine compensation work for non-starters, with the explicit aim of reaching time above 90% HRmax rather than only total HR-based load or GPS-based targets such as distance and high-speed running (Buchheit et al., 2026), appears to be an unmet need in current practice.
- MD-4 and MD-3 emerge as the loaded training days across the population, with the rest of the week typically recovering or tapering. This convergent pattern is consistent with classical microcycle periodization.
- Match HR data should not be treated as physiologically equivalent to training HR data. Match values are influenced by stress, caffeine, cardiac drift and contextual demands and likely overestimate true aerobic demand. Reporting training-only and match-only HR-zone exposures separately, rather than as a combined total, gives a clearer picture of the aerobic training stimulus actually delivered.
- Large between-team variability (team-median weekly >90% HRmax in training: 0 to 33 min) means population averages should not be used as individual team targets without considering the team's own context, training philosophy, and competitive schedule.
- The accuracy of every HR-zone-based decision depends on the HRmax value used to define the zones. Practitioners should ensure HRmax is measured, regularly updated, and treated as a foundational input rather than a static profile setting. An HRmax that is even 5 bpm off can move a player one zone in either direction and silently shift the apparent dose by several minutes per session.

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## Supplementary Table S1

Full numerical detail for all daily and between-group comparisons. Hedges' g with 95% CI and raw median difference in minutes. Positive g indicates Group A higher than Group B.

| Zone | Group / Day | Comparison | n(A)/n(B) | Median diff (min) | Hedges' g (95% CI) |
|---|---|---|---|---|---|
| **Panel A - Loaded vs taper days** | | | | | |
| >80% HRmax | Starter | MD-4 vs MD-1 | 349 / 364 | +12.4 | 1.07 (0.91-1.22) |
| >80% HRmax | Starter | MD-4 vs MD-2 | 349 / 339 | +10.5 | 0.47 (0.32-0.62) |
| >80% HRmax | Starter | MD-3 vs MD-1 | 258 / 364 | +13.0 | 1.15 (0.98-1.32) |
| >80% HRmax | Starter | MD-3 vs MD-2 | 258 / 339 | +11.1 | 0.55 (0.38-0.71) |
| >80% HRmax | Non-starter | MD-4 vs MD-1 | 513 / 536 | +10.1 | 0.84 (0.72-0.97) |
| >80% HRmax | Non-starter | MD-4 vs MD-2 | 513 / 502 | +13.4 | 0.76 (0.63-0.88) |
| >80% HRmax | Non-starter | MD-3 vs MD-1 | 467 / 536 | +9.8 | 0.89 (0.76-1.02) |
| >80% HRmax | Non-starter | MD-3 vs MD-2 | 467 / 502 | +13.1 | 0.80 (0.67-0.93) |
| >90% HRmax | Starter | MD-4 vs MD-1 | 349 / 364 | +1.4 | 0.62 (0.47-0.77) |
| >90% HRmax | Starter | MD-4 vs MD-2 | 349 / 339 | +1.4 | 0.38 (0.23-0.53) |
| >90% HRmax | Starter | MD-3 vs MD-1 | 258 / 364 | +1.4 | 0.62 (0.46-0.78) |
| >90% HRmax | Starter | MD-3 vs MD-2 | 258 / 339 | +1.4 | 0.43 (0.27-0.60) |
| >90% HRmax | Non-starter | MD-4 vs MD-1 | 513 / 536 | +1.4 | 0.63 (0.50-0.75) |
| >90% HRmax | Non-starter | MD-4 vs MD-2 | 513 / 502 | +1.4 | 0.59 (0.46-0.71) |
| >90% HRmax | Non-starter | MD-3 vs MD-1 | 467 / 536 | +1.2 | 0.59 (0.46-0.72) |
| >90% HRmax | Non-starter | MD-3 vs MD-2 | 467 / 502 | +1.2 | 0.55 (0.42-0.68) |
| **Panel B - Match vs hardest training day** | | | | | |
| >80% HRmax | Starter | MD vs MD-3 | 371 / 258 | +34.1 | 1.62 (1.44-1.81) |
| >80% HRmax | Starter | MD vs MD-4 | 371 / 349 | +34.7 | 1.81 (1.64-1.98) |
| >80% HRmax | Non-starter | MD vs MD-3 | 577 / 467 | -8.2 | -0.57 (-0.69 to -0.44) |
| >80% HRmax | Non-starter | MD vs MD-4 | 577 / 513 | -8.5 | -0.52 (-0.64 to -0.39) |
| >90% HRmax | Starter | MD vs MD-3 | 371 / 258 | +17.2 | 1.09 (0.92-1.26) |
| >90% HRmax | Starter | MD vs MD-4 | 371 / 349 | +17.2 | 1.27 (1.11-1.43) |
| >90% HRmax | Non-starter | MD vs MD-3 | 577 / 467 | -1.2 | -0.35 (-0.47 to -0.23) |
| >90% HRmax | Non-starter | MD vs MD-4 | 577 / 513 | -1.4 | -0.38 (-0.50 to -0.26) |
| **Panel C - Starters vs non-starters (early week)** | | | | | |
| >80% HRmax | MD-6 | Starter vs Non-starter | 65 / 210 | -12.3 | -0.51 (-0.79 to -0.23) |
| >80% HRmax | MD-5 | Starter vs Non-starter | 235 / 349 | -4.2 | -0.14 (-0.31 to 0.02) |
| >90% HRmax | MD-6 | Starter vs Non-starter | 65 / 210 | 0.0 | -0.26 (-0.54 to 0.02) |
| >90% HRmax | MD-5 | Starter vs Non-starter | 235 / 349 | -0.1 | -0.29 (-0.46 to -0.13) |