Case study

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"You can't play in the Premier League without good sprint distance": Exploring the perceptions of professional soccer coaches in England on the usefulness and application of training load data

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Abstract

The aim of this case study was to explore professional youth soccer coaches in England's perceptions of training load variables and how the information can support their practice. Semi-structured interviews were conducted at a single soccer club with five academy coaches (U16-U23) with reflexive thematic analysis utilised to develop overarching themes within each central organising concept. Within the first concept of variable selection through principal component analysis, whereby coaches responded to examples of variable groupings and visualisations, coaches reported that this method was difficult to understand, yet the ability to show information on a 2D-scatterplot was appealing. Coaches typically reported high favourability towards variables such as total, high-speed, and sprint distances, however had little support for accelerations and decelerations. In the second concept of daily use, themes emerged for the use of training load data in the evaluation of session physical outputs, such as if players outputs were higher or lower than usual and using this information to make decisions for future training sessions and supporting their subjective observations. A final concept, longitudinal use, comprised of the themes relating to comparisons to first team training methodologies and load planning. Taken together, these results highlight the training load variables of importance to coaches alongside key concepts of their practice that sports scientists can support with appropriate feedback of data. How this information is utilised in data feedback processes, however, requires investigation. Furthermore, how these results are generalisable to coaches from alternate soccer clubs and age groups should be studied.

Keywords

Association football, decision-making, feedback, periodization, youth sport

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Introduction

One of the principal aims of professional youth soccer coaches is to plan, deliver, and evaluate training (i.e., practice) sessions that facilitate the acquisition of soccer-specific skills (e.g., physical, technical, tactical, psychological) required to meet the demands of the game.[1] With the complex and ever evolving physical demands of soccer,[2–4] professional clubs are investing heavily in multidisciplinary teams (MDT) of staff to support coaches to improve physical skills (i.e., 'fitness'), manage fatigue, and reduce injury risk.[5,6] For example, within the MDTs sports scientists typically utilise data collected from tracking technologies such as Global Positioning Systems (GPS) during training to manage the physical load (i.e., training load (TL)) of the players to optimally physically prepare them for competition.[7,8]

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Training load information can be fed back to coaches to help inform their decision making in terms of player logistics, drill design, and session volume. Once collected, TL data must be transformed into useful information using appropriate statistical analysis and reported using suitable reports and visualisations that address the needs of the coach.[9–11] It must also be considered that this data forms only part information that coaches will use to arrive at decisions. It is suggested that the decision-making ecology of coaches is a dynamic and complex process involving a continuous interplay between the environment, objectives, and individual constraints where contextual factors must also be considered.[12,13] This must therefore be considered when designing TL feedback systems and how the effect of aspects such as the amount and complexity of information[14] and timing of feedback[15] fit into the wider decision-making process.

Despite the plethora of potential variables that can be produced by tracking technologies, the effectiveness of this information is quantified by the ability to impact the coach and their training program.[16] To achieve this it is crucial for sport scientists to select the most important but understandable pieces of information for coaches.[17] Coaches have reported that while they find TL data collected by GPS as useful, receiving 'too much' information was viewed as a barrier towards their use.[18] This is further compounded given the high collinearity between variables reported in professional soccer and rugby.[19–22] For example, significant relationships were reported between total distance (TD) and PlayerLoad (PL) ($r = 0.98$) in soccer,[22] yet both variables are often fed back to coaches simultaneously via reports and concomitantly utilised as input variables in dose-response and descriptive studies.[23–25] This may mean that variables used in feedback systems to coaches share similar information and thus create data redundancy, with the potential increase in the complexity of information increasing the cognitive load of decision makers and making the identification of key messages and information slower.[26]

To reduce the reported barriers, recently data reduction approaches such as principal component analysis (PCA) have been used.[20–22,27–29] For example, two studies reported reducing 12 TL variables to 2 principal components (PCs) in both rugby and soccer players, with both explaining 81% of the variance in the dataset.[20,22] In soccer players, the first PC was comprised of variables relating to running volume such as TD and high-speed running distance (HSRD), while the second PC contained variables relating to short intensive efforts such as accelerations (ACC), decelerations (DEC), and changes of direction (COD). Practitioners can then select variables to use from each PC or create single PC scores by multiplying the standardised TL data by component loadings and visualise the outputs on simple 2D-scatterplots[20] allowing for the feedback of complex datasets without any significant loss of information. This can promote heuristic decision-making which may be quicker and less cognitively demanding for coaches and therefore may promote buy-in to the use of TL feedback.[30–32] The usefulness and practicality of PCA results in soccer is still relatively unknown and requires exploration.

There is currently no agreed consensus of which variables practitioners such as sport scientists should feedback to their coaches, yet previous studies have indicated that they most frequently select variables such as ACC, TD, HSRD, and metabolic power to evaluate training.[23] Coaches provided some insight into what they may look for from TL data, with information related to work rate/intensity, and high-intensity actions the most frequently selected responses, yet examinations of soccer coaches understanding and interpretation of such variables is currently limited.[18] As coaches are typically the primary decision-makers (e.g., session design), using information they understand (i.e., conceptual understanding and ability to act upon the information provided), and which can effectively support such decisions is critical,[16] particularly as coaches have reported they find TL data useful to evaluate their sessions, yet a lack of a common goal with the practitioner can be a potential barrier.[18] One way to potentially address this and bridge the gap between science and application is by coaches and practitioners working collaboratively with applied researchers and 'co-create' a feedback process.[33–35] This approach has previously been used with professional youth soccer coaches to adapt their practice activities and behaviours to be more aligned with the scientific literature.[36,37] However, there is a need to firstly what variables coaches understand and find useful, or how physical data captured in training sessions can best support their practice. Doing so would provide information for practitioners to understand how they may need to modify their current feedback process, bridging the knowledge translational gap.[38]

To that end, the aim of the present study was to gain a greater understanding of professional soccer coaches' perceptions on their use of TL data, and how it can be more effectively fed back by practitioners. A case study approach was adopted, defined as a concentrated investigation of a single group (i.e., club) where the research team examine in-depth data.[39] Variable selection will be discussed to understand which coaches deem useful to support their practice and evaluate their sessions, followed by pertinent questions coaches have regarding the use and application of TL data. Furthermore, the intention of the current study was to act as the initial phase of a co-creation process that precedes the creation of TL monitoring feedback tools.

Methods

Research design

An exploratory research design was utilised, with semi-structured interviews employed to elicit in-depth insights

into coaches' perceptions and experiences regarding the use and application of TL data. A case study approach was adopted to enable an in-depth examination of coaches' perceptions within a single elite academy context.[39] Semi-structured interviews were employed as they provide a flexible method for exploring coaches' experiences and decision-making processes and have been widely used in previous research examining coaches' perceptions across a range of sports.[37,40–42] For example, such studies have shown that coaches frequently draw on instinct and intuition in their decision-making and program design, with individual variation in the perceived usefulness of sports science support.[40,41,43]

Interviews were conducted between the lead researcher (PN) and coaches working across the U16 to U23 age groups. Each interview was conducted in two stages: (1) to stimulate discussion around TL variables perceived as important for practice and (2) to explore additional directions in which TL data could support coaches' training design and decision-making. All participants provided written informed consent. The study was designed in accordance with the Declaration of Helsinki and approved by the local University ethics board. All participants provided written informed consent.

Participants

Five professional coaches belonging to a Category One English Premier League Academy were recruited via convenience sampling. All coaches were known to routinely collect and utilise TL data and volunteered to take part in the study. At the time of data collection (2022–23 season), the club's senior (i.e., first) team competed in the English Premier League. Coaches worked with U23 ($n = 2$), U18 ($n = 1$), and U16 ($n = 2$) age groups. Participants had a mean age of 41.0 ± 3.5 years and an average 8.1 ± 2.9 years full-time coaching experience. Two coaches held Union of European Football Association (UEFA) 'pro' coaching license, and three coaches held the UEFA 'A' coaching license. The inclusion criteria were that coaches were professional (i.e., full-time), had worked with their age group for at least one full season, and TL data was routinely (daily) collected via GPS with their team. This ensures coaches were familiar with TL data and how it was utilised within their specific age group. Such an approach aligns with case-study logic, where the aim is not to maximise sample size but to purposefully select information-rich participants embedded within a single club/organisation. The sample therefore reflects the full population of coaches within this specific academy context who met the study criteria, allowing an in-depth, contextually grounded exploration of TL practices within the bounded case. While the number of participants is small,[44] this is consistent with qualitative case-study designs that privilege depth, contextual specificity, and insider knowledge over breadth. The intention was not to achieve data saturation in a generalisable sense but to capture the perspectives of all relevant practitioners involved in TL processes within this academy environment.[45,46]

To guide the interviews, a semi-structured interview schedule was developed by the research team which utilised domain-specific expertise, and findings from similar related research.[18,22] Pilot testing of the interview guide was conducted with 1 sport scientist (U16) and 1 assistant coach (U16) to improve clarity and relevance.[47] Minor modifications in question wording and explanations (e.g., how results from PCA were explained) and pilot data were not included in the final analysis. As both pilot participants were from the same club as the main sample, the pilot may have reinforced local terminology, assumptions, and shared expectations.

Researcher positionality and semi-structured interviews

At the time of data collection, the lead researcher was employed as a sports scientist within the academy sports science department of the participating professional football club. Given the pre-existing professional relationships between the researcher and participant(s) careful consideration of researcher positionality was integral to the study design and interpretation.[48] The lead researcher has > 10 years' experience as practitioner at several professional soccer clubs in England at both senior and youth levels. Their role consisted of daily feedback of TL data and conversations with coaches. In the context of the current study, the lead researcher supported the club's U23 players and thus has established day-to-day working relationships and rapport with coaches within the study. This familiarity was considered to facilitate openness and honesty during interviews. Importantly, the researcher was not in a managerial role or position of legitimate power (i.e., team selection etc.). Still, we acknowledge that existing professional relationships may introduce risks such as impression management, club/organisational loyalty, and/or a reluctance to critique current feedback practices. These dynamics may have influenced how openly some coaches were willing to discuss certain aspects of the clubs' processes. It has been reported that professional soccer can be a competitive, 'cut-throat', and 'uncaring' working environment, controlled by traditional values built around authoritarianism, hierarchical defence, and masculinity.[49] For instance, studies have offered qualitative narratives of individuals experiencing difficult working relationships with colleagues.[50,51] Therefore, a lead researcher who also works within professional soccer can lead to more natural and authentic interactions with coaches', facilitating trust, open communication, and accurate interpretation of their responses within this unique context.[52] The remaining members of the research

team were academics who has extensively published across various disciplines related to professional soccer, with one member having previously worked within the professional game for > 5 years. Prior to the interviews, qualitative research training was provided by a senior member of the research team who has considerable experience and expertise of undertaking qualitative research within professional soccer environments. This training confirmed the importance of avoiding overtly scientific terms and using active listening techniques (e.g., regular eye contact) to help establish and maintain rapport with the coaches.[53] Before each interview, participants were verbally informed of the study purpose and procedures and were assured anonymity and confidentiality.

The first stage involved the dissemination of findings from previous work in this field[18,22] Here the coaches were reminded of the purpose of the interview and the overarching aim of the broader project to which it belonged. Furthermore, response anonymity was stressed alongside a reminder that there were no favourable answers as the research was to improve data feedback practice within the club. Following several initial open-ended questions to establish rapport (i.e., can you tell me about your coaching journey to date?), outcomes from Nosek et al.[18] relating reported barriers to the effectiveness of TL data (i.e., high volume of information, poor communication, and absence of a shared goal) were then briefly presented to stimulate discussion. We acknowledge that presenting these findings before stimulating coaches' own views means this stage of the interview was not purely exploratory and may have primed participants' thinking. This approach may have introduced a degree of confirmatory bias or shaped how coaches framed their experiences. The intention was to support reflection on known issues within the organisation.

During the second stage of the interview, the high collinearity between TL variables reported in Nosek et al.[22] were presented via a PowerPoint (Microsoft, U.S.A) on a large screen beside results from PCA. Three possible uses of PCA were explained: (1) using PC scores (multiplying the standardised TL data for each variable for a session by the variable loading on each component to give a single score in arbitrary units AU); (2) selecting a single variable from each component; and (3) aggregating variables that measure similar physical constructs and that are measured in the same units (count of efforts or sum of metres). To contextualise and visualise this information, an example was provided to the coach as a 2D-scatterplot. Coaches were then prompted to share their understanding of the results and explore what variables they considered worthwhile for everyday practice. As the PCA options were defined by the research team based on previous research,[22] coaches were responding to pre-specified analytical choices rather than independently generating feedback structures from first principles. As such, coach interpretations reflect reactions within the framework presented, rather than wholly naturalistic preferences.

In the final section of the interview, exploratory questions were asked to help identify ways in which TL data can support coaches on a day-to-day basis and more longitudinally. All interviews were audio recorded on a digital voice recorder (Sony ICD-PX240, Sony, Japan) totalling 111 min ($M = 37 \pm 11$ min) and notes were made by the lead researcher on key discussions and phrases, alongside any notable non-verbal expressions from the coaches. Where appropriate, follow-up questions were used to clarify or expand upon participants' responses.

Data analysis

All interviews were audio recorded and transcribed verbatim to capture both the content and dynamics of the conversation. This resulted in 56 pages (14,962 words) of single-spaced text. Data were analysed using reflexive thematic analysis, which allows for an interpretative and flexible engagement with patterns of meaning while recognising the role of the researcher subjectivity as a resource for knowledge production rather than a threat to credibility.[44] Both deductive and inductive approaches were employed. Deductive analysis was used in the initial stages of the interviews to explore coaches' understanding and perceptions of PCA. Where new or unanticipated patterns of meaning arose withing this section, these were incorporated into the analysis.[54] Inductive analysis was subsequently applied to later stages of the interviews to generate insights into how training load data were perceived to support coaching practice. Braun and Clarke's[55] six-phase framework for reflexive thematic analysis was used as an organising guide rather than a prescriptive procedure. Familiarisation with the dataset involved repeated listening to the audio recordings and multiple readings of transcripts, alongside the recording of initial analytical notes. To ensure participant anonymity, names were replaced with labels, e.g., 'C1', with the number not representative of any age group hierarchy the participant coached with. Initial codes were created by extracting key phrases or sentences from the transcripts into a custom Excel (Microsoft, U.S.A) spreadsheet and iteratively developed into themes and sub-themes through reflexive interpretation of shared patterns of meaning across the dataset. To ensure rigor and trustworthiness, initial codes, themes, and subthemes were discussed with members of the research team and practitioners at the club not involved in the study who acted as critical friends.[56] Credibility was further enhanced via member reflections, in which an open dialogue existed with coach participants during analysis where findings could be discussed and clarified to ensure accurate interpretation from all members of the research team.[57] Finally, a non-hierarchical thematic map was developed and refined which reflected the central concepts, themes, and sub-themes (**Figure 1**).

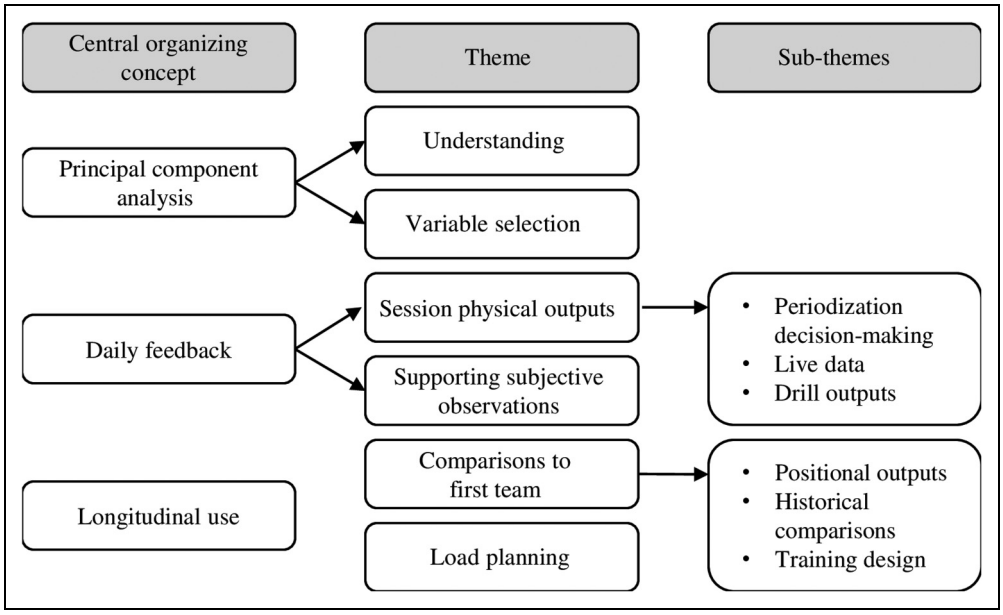

Figure 1. Thematic map of central organising concepts, themes, and subthemes. 140 × 83 mm (300 × 300 DPI).

Given that the interviews were undertaken on a small sample of coaches from the same club, generalisability is low. Previous research within professional soccer is typically characterised by small sample sizes and is considered methodologically appropriate.[52] However, we aim to provide a rich description of the findings and stimulate some debate, providing readers with an opportunity to contemplate our findings by critiquing, refining, and elaborating on in their own professional context.[58]

Results and discussion

Data from coach interviews were organised into three central organising concepts based on the sections of questions in the interview and are represented as a non-hierarchical thematic map (**Figure 1**).

Principal component analysis

The first central organising concept was PCA and consisted of two themes: (1) understanding; and (2) variable selection, which were identified deductively based on answering the research question. These were further comprised of several sub-themes (**Figure 1**).

Understanding. There were mixed responses from coaches regarding the understanding and usefulness of the results from PCA. Whilst it appeared that using a single PC score to represent training could be useful, the score calculation was confusing. For instance, coaches stated:

"*I think I would just prefer just the [PC] score, then within time you'd get to know what a good score is for that moment in time, what seems right"* (C3).

"*I like the way it's laid out, if you were looking at whether a session's hit the mark or not you can see straight away… how it produces the [PC] score is a bit beyond my scope of understanding. Actually, you've thrown me a bit there"* (C1).

"*That's difficult for me to understand to be honest, I'm not sure if I'd find it useful, I think seeing the actual data would be easier for me personally"* (C5).

Responses suggested that coaches who were positive towards the use of PC scores were due to how the data could be visualised on a 2D-scatterplot. This type of visualisation can, however, also be used for reporting the original data. While not the aim of this study, this type of heuristic feedback chart allows an attractive and easy comparison of data points between training sessions,[20,30] however based on the findings in this study, the use of this data visualisation method with sports science TL data requires further exploration.

"*As an overview in terms of hitting the quadrant you want to hit it's very good. I like seeing all the previous data points too, it's an easy comparison"* (C1).

When discussing the single and aggregated variable options, several coaches mentioned that whilst aggregated variables might be useful for an overview of a session, certain single variables for individual players would need to be

Table 1. Selected variables from each coach (TD = Total distance; HSRD = High-speed running distance; SD = Sprint distance; HR = Heart rate).

Age group	Variables selected
U15/16	TD, HSRD, HR
U15/16	TD, HSRD, SD, HR
U18	SD, HR
U23	TD, HSRD, SD, HR
U23	TD, HSRD, HR

presented also. Taken together, these results suggest that presenting a visual overview of the session using the two most appropriate variables, followed by further variables for individual players may seem appropriate for coach feedback.

> "*I guess if we add similar metrics together, extensive would be the high-speed measures and sprint together and intensive would be the three [intensive] efforts [accelerations, decelerations, changes of direction]"* (C1).

Variable selection. Coaches were requested to identify variables they found important and useful in evaluating outputs within their sessions and were encouraged to suggest any variables and not solely those fed back currently or used in PCA. All coaches referenced TD and either HSRD or sprint distance (SpD) as useful variables, which is consistent with previous research indicating that 82% of coaches valuing high intensity actions in their evaluation of their training[11] (**Table 1**). This may be due to the ease of understanding these metrics, alongside an understanding of the physical requirements of professional soccer match play. For example, it has previously been shown that HSRD and SpD have increased significantly over seven seasons.[59] Individual differences between coaches did exist, with one coach suggesting only SpD as useful rather than HSRD. Given SpD may only make up a small proportion of a training microcyle,[60] additional education may be required to support the use of HSRD. Furthermore, no coaches referenced variables pertaining to efforts of high-speed or sprint, rather preferring distances which may be due to distances allowing a direct comparison of which player has "ran more" whilst the number of efforts may not. For example, coaches stated:

> "*Total distance and high-speed running for me, and you can't play in the Premier League without good sprint distance"* (C4).

While the results from Nosek et al.,[22] which reported that variables relating to intensive efforts, such as ACC, DEC, and COD, were able to provide information on additional variance in TL data, there was no evidence of support for their use by coaches. One explanation provided by a coach is that these variables accrue easily within any session, however, to plan and execute a session with large HSRDs and SpDs is more difficult. Furthermore, several coaches mentioned that these types of variables were barely considered by the MDT when evaluating training sessions. Given these variables are important contributors to post-match fatigue[61] and are required to discriminate between soccer training practices and positional outputs throughout the training week,[62,63] their use in evaluating training sessions seems warranted. Sports scientists may therefore need to provide education to coaches on the importance of these variables. For instance:

> "*I'm not too fussed about even the intensive stuff…you have to plan specifically to get the high-speed and sprint, but those [intensive efforts], you get in any session you put on"* (C1).

Despite measures of internal load not being included in the present study, all coaches referred to heart rate (HR) information. There was an understanding from some coaches that the HR response is important in driving fitness. This supports previous research which shows that HR-based indices of internal TL are highly related to changes in aerobic fitness,[64,65] whilst external load measures from GPS may not be.[66] Moreover, HR was ranked the fifth most used variable to measure TL by sports scientists,[23] finding commonality between coaches and sports scientists. This internal training load is an important component of the training process as it represents the individual's psychophysiological response to an applied external training load and is the pertinent catalyst for training adaptations.[7,67] This provides a possible explanation for its value to coaches, as it offers insight into in how players respond to exercise performed rather than simply quantifying work completed. This distinction is important as the same external workload can be achieved in numerous ways, each of which may elicit a different internal response[68,69]:

> "*I'd like to see heart rates to see how hard they're working, you can probably judge some level of fitness from this too, did they find that session hard or not and why?"* (C5).

Daily feedback

The second central organising concept was daily feedback which consisted of two themes: (1) session physical outputs; and (2) supporting subjective observations. These were further comprised of several sub-themes (**Figure 1**).

Session physical targets. When coaches were prompted to discuss how TL data supported them on a day-to-day basis to aid their decision-making, differences existed between the age groups. Coaches in the U18 and U23 age groups reported using the data to evaluate whether physical targets

had been met and that training can be modified the following day based on whether targets were missed, met, or exceeded. The act of modifying training based on previous days TL data was not used by U16 coaches. These differences may be due to the differing periodization strategies used by each age group. In a seven-day microcycle, typically U23 s train for 4 consecutive days leading up to the game, followed by 2 days' rest. U18 s have 1 day off after a game, 2 days of training followed by 1 days' rest and 2 more days of training leading into a game. U16 s have 1 days' rest after the game followed by a double training session and a single session, followed by 1 days' rest, a single session 2 days before the game and 1 days' rest 1 day before the game. Given the significantly different programs, it is understandable why the viewpoints may differ here as 4 days of consecutive training will require increased player management compared to schedules with no more than 2 days of consecutive training. These results support those from previously surveyed coaches who reported that training is only sometimes modified based on previous data.[70]

"*It's rare that we have to go higher it's usually who has to be deloaded"* (C2).

Given the data, it would seem important to create a process in which thresholds can be used to identify when a subsequent session needs to be modified. Multiple statistical approaches are available that can report meaningful changes such as Z-scores, smallest worthwhile change (SWC), coefficient of variation (CV), and effect sizes.[9,11,71] With such approaches, there must be agreement within the MDT as to how these are understood and utilised, such as what size of a change in training output means training is modified the following day and for which variables. For example, whilst small, moderate, and large changes in an individual athletes data can be identified by using 0.3, 0.9, and 1.6×CV, and flagged as green, amber and red respectively,[9,71] which one of these thresholds should be used is less clear. It's likely that this discussion will depend on multiple factors including session content, individual player characteristics (e.g., injury history), and match schedule.

Both U18 and U23 coaches referred to the positive use of live data within the session, with the idea of giving players additional work should they not hit specific targets. Though live data is considered an accurate tool,[72] its application is currently underexplored. For example, as well as additional work, it has the potential to encourage behaviour change within the session, as soccer players have reported that they are likely to change their effort levels in response to live data.[18] While the coaches perceived potential value in live data, this remains underexplored within the literature and warrants further investigation.

"*I think this is where the live data's really useful to see where we're at and if we need to modify the session"* (C3).

All coaches had a desire to understand the reasons for higher or lower outputs, with reference to the practice activities that make up a session, in contrast with previous studies where only 29% of coaches surveyed wanted information regarding individual activities.[18] This may be due to the higher number of first team coaches surveyed (53%) compared to only developmental age group coaches in the present study. While we are unable to fully determine the underlying cause from our current data, it may be possible that younger age group coaches who often focus of skill acquisition[36] may seek more detailed contextual information regarding training session content compared to first team coaches, which requires further investigation. Moreover, there was a desire for this information to be expressed in a similar 2D-scatterplot as shown with the PCA results, with drill intensities expressed in relation to match intensities.

"*Maybe there's some use for some inter-department CPD on what certain practices give you, what would I get from an 8 vs. 8 over this distance in these dimensions"* (C3).

A further reason for utilising individual activities data was that a report containing only total session outputs include any top up running given to players due to not hitting targets within practice. This therefore fails to highlight that a player had poor effort levels within practice and may even show them as having done 'more' due to having to run after the session. Reporting outputs within individual activities would highlight their low outputs prior to any top up runs. For instance, a coach stated:

"*If you're using the live data and topping players up after the session, how do we know if players are hiding within the possessions or games…we can't show this [GPS report with total session values] to a player and dig them out if they've done more running due to top ups"* (C4).

Research examining running outputs in different small-sided games indicates that increasing the area size used leads to higher TD, HSRD, and SpD, whilst smaller areas have higher numbers of ACC and DEC.[62,73,74] Moreover, it has been demonstrated how analysis of activities compared to match play intensities can provide coaches with contextualised information on which activities overload position-specific match demands which may help coaches understand their practices further.[73] These analyses should also be conducted 'in-house', as teams of different age groups, styles of play, and coaching philosophies may produce differing results.[75–77] Adding individual player outputs for each activity on TL feedback reports may lead to additional content and complexity, a main barrier for

coaches use of TL data.[18] Thus, further exploration on how this can be implemented is required.

Supporting subjective observations. Two coaches mentioned TL data as useful to validate their own subjective observations of the training session. It appeared that the data could be used to make sure any possible actions they take, such as praising hard work or requesting increased effort were supported by objective data.

> "*I like to marry it with what I've seen in the session, so if I think a particular player hasn't worked hard within in a session and then the data shows it backs it up and I can be confident in any action I need to take. There's been times in the past where we've dug out a player for not running enough during a session but the report after told us otherwise which might, I guess, make a player lose trust"* (C5).

A potential drawback from this approach is the possibility for the relationship between the players and the coaches to be impaired if the data is used incorrectly. It may further decrease the 'buy in' from players towards the use of TL data. For example, if the coach queries a player's effort, yet the subsequent data does not support, they may question the use of GPS units in the first place. Furthermore, if coaches are making training decisions underpinned by incorrect subjective observations, this could lead to unfavourable loading conditions and the possibility of increased injury risk.[78] The congruence between soccer coaches and players intended and reported training intensity, reported players perceived their sessions as significantly 'harder' than their coaches' intentions.[79] Therefore, having objective data from GPS is important to provide coaches with this information so they understand what has occurred during the session.

Longitudinal use of training load data

The third central organising concept was longitudinal use of TL data and was comprised of two themes; (1) comparisons to first team; and (2) load planning, with comparisons to first team divided further into subthemes: (1) *positional comparisons*; (2) *training design*; (3) *historical comparisons.*

Comparisons to first team. All coaches commented on how TL data can be used to prepare players for the transition to the first team, specifically how players compare to their positional equivalent in the first team. One of the main aims of youth soccer academies is to facilitate the acquisition of skills, including physical, required to meet the demands of the professional game.[80] Therefore, having knowledge of the difference in outputs across age groups is important and can provide important feedback to coaches who can, with the aid of their sports scientist, design training programs to ensure these targets are met. Currently limited research exists comparing the training outputs from youth to the first team, likely due to club confidentiality of training practices. Comparisons of training between youth teams indicated a continuous increase in training outputs from the U12 s through to U18 s.[81] This may be due to an increase in session duration up to the U15 s, however, from U16 s to U18 s, it is likely an increase in running density with no further increase in session durations.[80,81] Ensuring players at these younger age groups have similar outputs to the above age groups, however, is perhaps not a priority. Moreover, recent research has shown that weekly aggregates of TD are similar between U23 and first team, however HSRD and SpD were significantly lower for the U23 s.[82] It was noted that during matchplay, the outputs for these measures were similar between squads, suggesting the differences likely occurs during training, however no information on differences for each day of the microcycle were provided. How this information is used would require an MDT discussion. For example, having direct comparisons to first team data on a daily training report may increase the complexity, whilst a monthly or mesocycle review may seem more feasible.

> "*We should be understanding what elite is to draw comparisons with the players I think that would be brilliant. How close is what we're currently doing to our seniors? That should guide our outputs in some way at least"* (C2).

While a direct comparison between age groups was deemed useful, there was also a suggestion by coaches of retrospectively being provided with TL at the corresponding age group from players that have successfully made the transition from youth to first team. Though this is an interesting suggestion, if a different coach was responsible for the player at the time, a difference in philosophy (e.g., tactics) of a new coach may mean using this data to identify successful players may be difficult. Furthermore, previous studies have shown high levels of interindividual variability in the pathways of professional soccer players (e.g.,.[83,84] Furthermore, given the reported increases in match outputs[2,59] it is likely training practices will have evolved to compensate for these, again making historical comparisons difficult.

> "*Comparisons with first team are useful but only between similar players, perhaps more useful is what first team players were doing at under 16, 18, and under 23 but this maybe be difficult, it's a different game now isn't it?"* (C3).

A further comparison with the first team that was identified specifically by coaches of the older age groups (U18 and U23) was regarding the actual content of the session. The suggested comparisons were around areas used for activities on each day of the microcycle in addition to

context around how physical outputs were attained in the session.

> "*I'd love to compare how our dimensions on a, say a strength or resistance day, compare to the first team guys, are our output within those drills comparable?"* (C3).

To the authors knowledge, there is currently no or little research examining how the physical outputs within sessions are attained and requires exploration. Simply reporting 'blind' distances without context on where or how they were produced disregards any technical or tactical considerations which are valuable when designing training.[85] Utilising this 'integrated' approach to compare training session design with the first team may help prepare players for the transition through.

Load planning. The second theme contained within the central organising concept of longitudinal use was 'load planning'. This centred around how sports scientists and coaches could use TL data together to plan periods of increased and decreased loads in advance of them happening.

> "*I'd like to see us have maybe planned weeks where we push them harder and one week out of the block where we reduce what we do"* (C4).

The responses from coaches highlight a desire to be more proactive in planning training outputs across long term schedules to avoid periods of unwanted high and low loadings and therefore having to manage players out of these periods. Herein lies a need for better communication between practitioners and coaches to plan these periods, supporting results from Nosek et al.[18] where coaches reported that poor communication is a barrier to their use of TL data. Poor communication between medical staff and coaches has been highlighted as a predominant risk factor for injury.[86] Recent work has shown that frequent informal communication between practitioners and coaches can play a pivotal role in coordinating decision-making in professional soccer.[87] Careful planning of longitudinal TL can help avoid unwanted spikes in loads which may be a risk factor for soft tissue injuries.[78,88] Planning loads around schedules, taking into consideration match difficulty shows some level of understanding of strategic periodisation in which specific games are considered more important and prepared for differently.[89] For instance, leading up to match play highlighted as significantly important and difficult, the MDT may agree on a period of decreased load to minimise fatigue to allow players to perform optimally. Though an attractive idea, whether decreased loading going into an important fixture aids performance and whether this is a technique utilised in soccer is unknown.

Summary

The present study aimed to explore the TL data variables coaches understood and found useful alongside how it can help support their practice. Several coaches reported difficulty interpreting PCA-derived outputs, suggesting the practical value of such approaches may depend on how intuitively the information can be communicated within coaching environments. Variables of TD, HSRD and SpD were unanimously selected as the variables coaches understood and found useful, yet variables related to intensive effort ssuch as ACC, DEC, and COD were not, despite previous results utilinsg PCA showng their potential importance.[22] Coaches highlighted the usefulness of a 2D-scatterplot to show an overview of the session in comparison to previous sessions, yet emphasized the need to see individual players outputs also. When highlighting areas in which TL can best support their practice, coaches identified using the data to make alterations in subsequent sessions to protect players from injury, drill information to provide detail on what parts of the session contributed to the overall outputs, and comparing data with that of the first team to enable players to be ready to transition. Taken together, this study highlighted the variables and practical uses from TL data specific to coach feedback. How these findings can be utilised in the feedback process to satisfy these reported requirements and increase effectiveness requires further study. For example, whilst numerous business intelligence reporting tools exist, such as Microsoft Power BI and Tableau, little research has evaluated their use in TL data feedback with coaches.

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Ethical considerations

The Liverpool John Moores University Research Ethics Committee approved this study and procedure (Ref: 22/SPS/ 012).

Consent to participate

Participants provided written informed consent to participate before data collection.

Consent for publication

All participants provided informed consent for publication.

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Data availability

The data that support the findings of this study are not publicly available due to the sensitive nature of the dataset and restrictions related to participant confidentiality within an applied setting.

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