Programming high-speed and sprint running exposure in football

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Abstract

Purpose: To gain knowledge on the beliefs and practices of football practitioners applying high-speed and sprint running exposure programming strategies.

Methods: One hundred and two football practitioners from twenty-two different countries, participated in a survey study consisting of a survey including five domains: demographic and professional characteristics (*Who*), importance of high-speed and sprint running exposure for physical capabilities development, preparation for competition, and injury prevention strategies (*Why*), exposure timing (*When*), methodological procedures for exposure monitoring and training scheduling (*What*), effectiveness of common training practices (*How*). Data were analyzed using a combination of descriptive statistics, generalized mixed-effects and multinomial logistic regression models.

Results: Data revealed five main findings: (1) overall agreement on the importance of exposure for physical capabilities development, preparation for competition, and injury prevention strategies; (2) different exposure timing and selective training scheduling for starting and non-starting players across typical and congested weeks; (3) lack of consensus on the conceptual constructs defining high-speed and sprint running metrics and the methodological procedures used for monitoring; 4) a probable association between match-related outcomes and exposure strategies used in training; and 5) a broad range of training methods considered as effective to elicit exposure.

Conclusions: This study provides actionable insights into the planning, implementing, and monitoring strategies for high-speed and sprint running exposure in football. While some conform with the evidence on high-speed and sprint running training in football, further research and professional debate is warranted to develop empirical knowledge and provide pragmatic recommendations helping practitioners in adopting evidence-informed decisions.

Keywords

External load monitoring, performance, strength and conditioning, training load

Introduction

Training load programming and its constituent components (i.e., planning, implementing, monitoring) are paramount in management strategies aiming to optimize football (soccer) training.[1] In fact, compelling evidence exists on the relationships between training load and (i) physical development, (ii) football performance, and (iii) injury risk among football players of any sex, age and competitive level.[2–4]

Programming training load has become a more challenging task in modern football due to the high physical demands associated to the evolving locomotor profile of this sport as well as to the increasing number of matches played across repeated congested-fixture periods during a season.[5,6] Of particular interest is the ongoing debate among football practitioners about the most appropriate training load programming strategies pertaining to high-speed (HSR) and sprint running (SR) exposure.[7,8] While HSR and SR exposure seems to be determinant of physical preparation[3,4], football performance[9–13] and injury mitigation strategies[14,15], evidence-based recommendations are somewhat lacking and much remains unknown in this domain.

With recent developments of tracking technology, accurate and reliable HSR and SR exposure monitoring is now a widespread routine in applied football settings.[16] In a recent study describing the practices to develop sprint performance in elite football code athletes, Nicholson et al. identified that practitioners use integrated monitoring approaches to inform sprint training prescription as well as a combination of training strategies, methods and protocols for sprint development.[17] Nonetheless, little is known of the beliefs and practices of football practitioners applying specific HSR and SR exposure programming strategies whilst facing the contextual day-to-day challenges. Gaining knowledge of beliefs and common practices in this domain can provide actionable insights for decision-making processes, serve as basis for further professional debate as well as inform future applied football research. Therefore, the aim of this study was to survey: 1) the beliefs of practitioners about the importance of HSR and SR exposure in football, and 2) the associated common practices and methods for their monitoring and training prescription and implementation.

Methods

Subjects

A convenience sample of football practitioners was recruited via email, personal or group messaging applications (e.g., WhatsApp), and promoted on social media (e.g., Facebook, Twitter) through the professional networks of the research team. Eligibility criteria were: be ≥18 years old; be a football practitioner (e.g., any member of the coaching, performance, support, or medical staff); currently work or have worked in elite, professional or semi-professional level; have experience with HSR and SR exposure programming (i.e., planning, implementing monitoring) practices. Participants provided informed consent, and the study received University ethical approvals (RETH[S]21/014).

Design

A cross-sectional, survey study design was used to survey practitioners' beliefs and practices pertaining to HSR and SR exposure programming in football. The survey (Supplementary file 1: https://osf.io/8dfbs) was designed in English language using an online platform (Qualtrics^XM, Provo, UT, https://www.qualtrics.com/au). Questions were developed based upon domain expertise of the authors as well as in consultation with academic peers and football practitioners. Pilot surveys (n = 5, Supplementary file 2: https://osf.io/s6we9) were tested to achieve agreement among the authors prior to the release of the final version, and data were collected between March 9th and July 5th, 2022.

Survey Content

As illustrated in Figure 1, the survey included 5 domains:

- *"Who"* – Participants details including demographic data and professional characteristics of the participants and their working environment.
- *"Why"* – An array of 5-point Likert scales (from *"strongly disagree"* to *"strongly agree"*) questions on the perceived importance of HSR and SR exposure for: a) development of physical capabilities; b) preparation for competition; c) injury prevention strategies.
- *"When"* – A combination of ranked and multiple checkbox options to compare exposure timing: a) match versus training; b) typical (i.e., two matches 1-week apart) versus congested-fixture weeks (i.e., 3 matches across the week); c) starting versus non-starting players.
- *"What"* – An array of 1–2 loops of combined questions (checkbox, numerical values, and open-ended text) were used to gain understanding on the methodological procedures implemented for monitoring exposure and scheduling training.

- *"How"* – A 5-point Likert scale (from *"not effective at all"* to *"extremely effective"*) examining agreement levels on the effectiveness of common training practices for exposure training.

***** Figure 1 around here *****

To avoid ambiguity around definitions and questions interpretation, written examples were provided throughout the survey. Furthermore, participants were given the option to elaborate on their responses or provide more details using open-ended text.

Data Handling

Data from questions with pre-set answers (i.e., predefined single or multiple choices) were converted into standardized codes using a designated Microsoft Excel spreadsheet (Microsoft Corporation; Redmond, WA, USA); all automated responses were checked for veracity. The remaining data (i.e., open-ended answers) were analysed independently by two authors (TS and ADI) using the same standardized codes. Relevant information was added or discarded through a discussion between the same two authors, while a third author (MB) acted as moderator in a case of disagreement. The full dataset is available as Supplementary file 3: https://osf.io/qde2t.

Statistical Analysis

All statistical analyses and visualizations were conducted in R language and environment for statistical computing using the *ggeffects, lme4, nnet, sjPlot* and *tidyverse* packages while model assumptions were checked using the *DHARMa* package (4.2.1; R Core Team, Vienna, Austria). Due to the cross-sectional and observational study design, data are presented using a variety of descriptive statistics. Single and multiple-choice questions are reported using mean and standard deviation (mean ± SD), median and interquartile range (IQR), mode, range and frequencies (absolute [counts], relative [%]).

Regarding the *"When"* domain, we compared HSR and SR exposure scheduling between starting and non-starting players using a generalized mixed-effects model. Since *players status* (starting versus non-starting) was treated as binary outcome variable, a binomial error distribution was specified with a logit-link function to predict the odds associated to the predictor variable *exposure timing* (categorical variable with 3 levels [match, full-squad training, complementary training]). Two contrasts were set to examine: 1) Odds between match versus the two training options pooled together; 2) Odds between full-squad training and compensatory training. Moreover, random effects were assumed for participants. However, upon generating the model outputs summary, we noted that the within-subject variance explained by the random effects was zero. Therefore, we opted to use a more parsimonious generalized model by retaining *exposure timing* as a predictor and removing the random effect for participants. Akaike information criterion score was examined to confirm the selection of the final model to obtain the best-fit model while maintaining model parsimony. Odds ratios are presented to aid interpretation of the findings. To validate the assumptions of the generalised mixed-effects model, tests for uniformity of residuals, under and over dispersion, outliers and zero-inflation were performed using a simulation-based approach, which confirmed the absence of significant violations of the model fit.[18]

We used multinomial logistic regression models to investigate how exposure target determined from match-related outcomes (i.e., percentage of total match exposure) affect HSR and SR training strategies in typical weeks. First, we considered match outcomes as continuous variables in view of their normal distribution observed during the exploratory data analysis step. To this end, the responses (n = 5 and n = 4 for high-speed running and sprint exposure subsets, respectively) corresponding to *"match outcomes >200%"* were removed from the original data sets upon verifying that their removal improved the predictive accuracy and overall fit of the model without affecting the point estimates. We provide the code underpinning the procedural steps leading to this decision in the Supplementary file 4: https://osf.io/erv3p. Since *exposure strategy* was treated as a categorical outcome variable with three levels (single session, two sessions with micro-doses, multiple sessions with micro-doses), two binomial error distributions were specified with logit-link functions to predict the relative odds (two sessions with micro-doses or multiple sessions with micro-doses versus single session) associated to the continuous predictor variable *match load outcomes* (%). For micro-dosing we refer to the practice of splitting up the total weekly external training load exposure into multiple (two or more) sessions spaced out across the week.[19] For the interpretation of the outputs, we avoid using a dichotomous approach based upon traditional null hypothesis significance testing, which has been extensively criticized.[20] Alternatively, in the discussion section we contextualize the practical implications of the results by providing examples with an emphasis on the predicted probabilities to aid interpretation of the findings.

To validate the linear multinomial logistic regression models, the assumptions of independence of irrelevant alternatives, linear relationships between log-odds of the outcome and independent variable and independence of errors were confirmed.

Results

The "Who"

One hundred and two football practitioners (female: n = 1; male: n = 100, unknown: n = 1) with 9.3 ± 9.1 years (range: 1 to 45) of experience volunteered to participate in this study. Respondents' characteristics and working environment details are presented in Table 1 and 2 respectively.

***** Tables 1 and 2 around here *****

The "Why"

The perceived importance of exposure to HSR and SR was comparable across the three training load domains (Figure 2).

***** Figure 2 around here *****

The "When"

Practitioners reported the greatest exposure (ranked 1st) for starting and non-starting players during official matches (n = 77) and complementary training sessions (n = 61), respectively. Full-squad training was ranked 2nd by most practitioners for both groups (Figure 3). The generalized model revealed a main effect of exposure timing on player status (Table 3). Figure 4 illustrates the scheduling strategies during typical and congested weeks. For starting players (panel A), exposure was more commonly scheduled on MD–3 (44%) during typical weeks, with no training exposures scheduled in congested weeks (60%). Exposure among non-starting players (panel B) was more commonly scheduled *"immediately post-match"* (24%), on MD+1 (21%) and M–2 (22%) during typical weeks, and *"immediately post-match"* (38%) in congested weeks.

***** Figure 3, table 3 and figure 4 around here *****

The "What"

Figure 5 presents a summary of the methodological procedures used for HSR and SR monitoring. Generally, practitioners used absolute thresholds (n = 46 and 38 for HSR and SR, respectively), often in combination with individualised speed thresholds (n = 32 and 37). Maximum speed and maximal aerobic speed were the most common anchors among practitioners using individualised thresholds alone (n = 24 and 27 for HSR and SR, respectively).

***** Figure 5 around here *****

As shown in Figure 6, most practitioners reported using match-related outcomes as a reference for HSR (n = 68) and SR exposure (n = 72) prescription during the training micro-cycle. However, there was a large between-practitioner variability regarding the exposure target (i.e., percentage of total match exposure). Nearly half (n = 49) reported prescribing two sessions with micro-doses, with the remaining prescribing a single session (n = 33) or multiple sessions with micro-doses (n = 18).

***** Figure 6 around here *****

Overall, the multinomial logistic model revealed a probable association between match outcomes and exposure strategy. Specifically, a greater exposure target was associated to an increased relative probability of implementing two sessions with micro-doses and a concurrent reduced relative probability for either a single session or multiple sessions with micro-doses both for HSR and SR training. The model outputs are reported in Table 4 with the associated predicted probabilities displayed in Figures 7 and 8.

***** Table 4 and figures 7 and 8 around here *****

The "How"

The perceived effectiveness of common training methods to elicit HSR and SR exposure is displayed in Figure 9.

***** Figure 9 around here *****

Discussion

This study provides insights into beliefs and practices of football practitioners regarding programming strategies for HSR and SR exposure. The main findings were: (1) overall agreement on the importance of exposure for physical capabilities development, preparation for competition, and injury prevention strategies; (2) different exposure timing and selective training scheduling for starting and non-starting players across typical and congested weeks; (3) lack of consensus on the conceptual constructs defining HSR and SR metrics and the methodological procedures used for their monitoring; 4) a probable association between match-related outcomes and exposure strategies used in training; and 5) a broad range of training methods considered as effective to elicit exposure.

The *"Why"*

We observed consistent agreement between practitioners from several countries on the importance of exposure across the three domains of training load management strategies. In fact, most respondents at least *"somewhat agreed"* that exposure has an important role for physical capabilities development (n = 93), preparation for competition (n = 95) and injury prevention strategies (n = 95). These findings are not surprising considering the evidence on the athletic surrogates to football performance and the locomotive demands of match play, which require players to perform HSR and SR actions repeatedly during a match to fulfil positional-specific tactical responsibilities.[5,9,10,21] HSR and SR activities are also the most frequent locomotive actions preceding goal situations, performed by either the scoring player or the assisting one.[11,12] Therefore, their perception as key training contents for competition preparation seems appropriate. Similar findings were also observed in the study of Nicholson et al., in which practitioners reported that the main rationale for sprint development training prescription was targeting the sport-specific locomotive demands and induce physical adaptations underpinning a positive transfer onto football performance.[17] Finally, as injury prevention is an established priority of training load management strategies, with injury-mechanism studies highlighting the harmful association between unaccustomed volumes and spikes in sprint and near-to-maximal speed distances and muscle injury occurrence[14,15,22,23], it seems logical that practitioners strongly agreed on the importance of exposure in this respect.

The *"When"*

The responses pertaining to the scheduling domain revealed actionable insights. The odds to expose non-starting players to HSR and SR were nearly 3 times greater in training than matches compared to starting players (Table 3). This finding aligns with the evidence reporting the strong association between playing status and HSR and SR exposure.[24,25] In fact, the absent or partial match-induced exposure among non-starting players requires compensatory strategies that can be actioned only in training. Interestingly, further analyzing the timing domain data indicated that full-squad training was not considered the elective option to ensure the greatest exposure among non-starting players. Practitioners ranked complementary training as the most appropriate alternative, with a probability to induce the largest exposure even 4 times greater than full-squad training (Table 3). From an operational perspective, this implies that different exposure strategies are required between starting and non-starting players within the same micro-cycle. In typical weeks, when consecutive matches are played seven to eight days apart, this programming task is reasonably manageable. However, its complexity increases considerably in congested-fixture weeks due to the multifactorial demands arising from the interactions between players status and scheduling constraints. In fact, previous and upcoming matches are also key factors to consider when planning adjustments to exposure within a micro-cycle. In this scenario, practitioners should consider implementing synchronous, but distinct, exposure strategies as an optimal solution addressing the intricacies between the training load management demands and constraints described above.[25] Data from this survey study reflect this assumption. To illustrate, 99 practitioners indicated that the preferred scheduling options for starting players in typical weeks would be any days from at least 48h post the previous match (i.e., MD+2) to not later than 48h prior to the upcoming match (i.e., MD-2). In congested weeks, while most practitioners (n = 61) considered exposure unnecessary for starting players, still 30 of them indicated MD-2 (in reference to the upcoming 2nd and 3rd matches) as the most appropriate option. These findings are likely reflective of the robust evidence on the recovery kinetics of inflammation status, muscle damage, perceptual responses, and physical performance, which require between 48h to 72h to return to baseline levels after football matches.[26] While the same reasons may explain part of the responses on scheduling strategies for non-starting players, we observed large between-practitioner variability regarding the most appropriate timing both in typical and congested weeks. To explain, while 54 participants selected a mixture of days between MD+2 and MD-2 as the best scheduling option in typical weeks, the remaining 46 participants suggested *"immediately post-match"* and MD+1 as preferred alternatives. An opposite balance was observed for congested weeks, with *"immediately post-match"* and MD+1 indicated by practitioners and the two MD-2 relative to the upcoming matches indicated by 39 practitioners. Although further qualitative details were not collected in this study, we speculate that other contextual factors may influence scheduling decisions for non-starting players such as: travelling schedule constraints especially when playing away with late evening kick-off time, facilities and training ground availability for compensatory sessions immediately post-match, relative importance placed on previous and upcoming matches and the associated rotation strategies between starting and non-starting players.

The *"What"*

The large heterogeneity between respondents regarding velocity thresholds is not surprising and likely arises from the different arbitrary thresholds between software manufactures and methodological choices related to player's age, performance level, or sex.[27] Practitioners reported utilizing various methods (often in combination) to establish individualized HSR and SR thresholds. Whilst the reasons underpinning the use of a particular or mixed methods cannot be ascertained from the current data, they may derive from human and technology resources availability, the utilization of approaches across different stages of the season (e.g., pre versus in-season), or simply reflect the lack of consensus and conceptual constructs for individualized velocity thresholds in football.[7,28,29] For example, the use of multiple physiological markers (i.e., running speed corresponding to the respiratory compensation threshold or maximal oxygen consumption) and performance measures (i.e., maximal aerobic speed or maximal sprint speed) characterising the transitions between intensity domains would enhance the understanding and interpretation of the individual's training and match demands.[30] Similarly, an individualized approach to HSR and SR exposure monitoring may facilitate appropriate recovery and periodization schedules to manage loads and optimize adaptation to training.

A deeper analysis of how using match-related outcomes as exposure target influences training strategies for starting players during typical weeks, revealed a common trend. A greater exposure target was associated to an increased relative probability of implementing two sessions with micro-doses and concurrent reduced probabilities for a single session or multiple sessions with micro-doses. To contextualize, when the exact match outcomes (i.e., 100%) were used as target, the probabilities of implementing single, two, or multiple sessions were 33%, 48% and 19%, respectively, for HSR and 32%, 53% and 15%, respectively, for SR. However, a target exposure two-fold (i.e., 200%) greater than match outcomes was associated to 18%, 79% and 3% probabilities for single, two, or multiple sessions, respectively, for HSR and 29%, 68% and 3% for SR (Figures 7 and 8). While these findings should be interpreted with caution in view of the uncertainty of the predictive model (e.g., overlap of the confidence intervals), it is highly probable that the preferred strategy consists of two sessions with micro-doses especially when the reference target is greater than match-related outcomes (i.e., >100%). It is legitimate to assume that the rationale for this choice is to mitigate the risk that unaccustomed cumulative (e.g., from different drills within a session) HSR and SR training loads might produce adverse effects (e.g., excessive metabolic stress, muscular damage, fatigue), thus requiring appropriate exposure strategies to facilitate optimal recovery and adaptations. Spacing out the target weekly HSR and SR exposure across multiple sessions or bouts may still induce stimuli that effectively develop or maintain key physical capacities (e.g., acceleration, maximal speed, aerobic and anaerobic power) while limiting excessive fatigue especially in proximity to match-day.[19,31] Applying these findings in the context of the scheduling domain, a practical suggestion would be to plan two sessions between MD+2 and MD-2, possibly ~48h apart and with the cumulative exposure either equally or unevenly split according to the preferred periodization approach. This solution reflects externally valid evidence on football micro-cycle periodization as well as represents a reasonable compromise for full-squad training when selective strategies between starting and non-starting players are not feasible or practical.[32,33]

The *"How"*

The responses on the effectiveness of common football training methods for HSR and SR exposure delineated what seemed to be a large consensus. Most practitioners indicated that conditioning (n = 85 and n = 75 for HSR and SR, respectively) and drill-based exercises (n = 63 and n = 54 for HSR and SR, respectively) were at least "*very effective*" to ensure adequate exposure (Figure 9). These findings were somewhat expected as training prescribed in the form of high-intensity or maximal-speed predetermined and fixed runs, executed without the ball or replicating football-specific paths with ball involvement allow to dictate and control the locomotive pace, whereby inducing the target exposure.[7,34–36] Surprisingly, game-based exercises were largely considered at least as "*moderately effective*" both for HSR (n = 90) and SR (n = 76) exposure. Whilst a quantitative interpretation of the practitioners' perceptions was not possible as responses could not be converted into metrics of HSR and SR exposure, this finding deviates from the literature on football sided-games training and the results of a recent systematic review and meta-analysis of our group on this topic.[28] Briefly, we found that sided-games training is inappropriate to induce HSR and SR exposure irrespective of the format characteristics and playing constraints, unless very extensive training volumes and formats including small numbers of players (i.e., from 2v2 to 4v4) and very high relative areas per player (>300 m^2) are used, which is rather impractical in the context of a full-squad environment. With the data from this survey unsuitable to provide clear explanations in this regard, we speculate that the possible reasons may be: misconception of HSR and SR definitions, with short-distance acceleration actions, which are very frequent in sided-games[37], wrongly interpreted as such; use of very low velocity thresholds (Figure 5), which may mislead and amplify the perception of HSR and SR exposure.

This study has some limitations worth considering. Using a convenience sample, the respondents' sex, roles and professional levels, and their working environment characteristics were not fully and equally represented. Therefore, it is possible that perceptions of other stakeholders involved in decision-making (e.g., coaches, players) were not considered. Second, the degree to which the data represent other clubs from different confederations/leagues, or athletes of different competition levels and age groups remains uncertain. Finally, being cognisant that current opinions represent only level 5 scientific evidence and higher quality literature on management strategies for HSR and SR exposure exposure in football is somewhat lacking, we acknowledge our findings may change with emerging evidence. Therefore, the perceptions and practices of practitioners should be re-evaluated in the future, based on new research recommendations.

Practical Applications

- Training load management should embed strategies for HSR and SR exposure considering its importance for players' health and performance.
- Standardizing monitoring processes may facilitate data sharing and knowledge exchange between coaching staff, sport science departments and research groups.
- Synchronous but distinct exposure scheduling and training plans are necessary for starting and not-starting players across typical and congested weeks.
- Enhancing communication between coaching and sport science staff may help developing or refining *ad-hoc* HSR and SR exposure training solutions.

Conclusion

Building upon the importance of training load management in football, this study provides actionable insights into the programming constituents of HSR and SR exposure strategies. Universally adopted definitions and methodological procedures are necessary for monitoring exposure systematically and objectively. Training scheduling and implementation should be guided by evidence-based and practice-informed decisions accounting for the contextual factors affecting football performance. While some findings of this study conform with the evidence on HSR and SR training in football, further research and professional debate is warranted to develop empirical knowledge and provide pragmatic recommendations helping practitioners in adopting evidence-based decisions.

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Figures Captions

Figure 1. A flow chart presenting the survey's domains and questions characteristics

Figure 2. A raincloud plot presenting practitioner's perceived importance regarding the exposure to high-speed and sprint running for physical capabilities development, preparation for competition, and injury prevention strategies. Labels represent the median and interquartile range (IQR)

Figure 3. Frequencies of ranking responses regarding the greatest to the least exposure of high-speed and sprint running during an official match (panel A), full-squad training (panel B), and complementary training (panel C) among starting and non-starting players.

Figure 4. Frequencies of high-speed and sprint running scheduling strategies among starting and non-starting players while considering typical and congested training weeks

Figure 5. Practitioner's methodological procedures for obtaining high-speed and sprint running velocity thresholds. Numbers represent mean ± SD, and mode [range]

Figure 6. Frequencies of the use/non-use of match-related outcomes as a reference for high-speed (panel A) and sprint (panel B), as well as their exposure targets (i.e., % of total match exposure) during a typical training week

Figure 7. Predicted probabilities of high-speed running exposure training strategies. Dotted vertical lines represent exposure targets equal to match outcomes (i.e., 100%) or two-fold the match outcomes (i.e., 200%)

Figure 8. Predicted probabilities of sprint running exposure training strategies. Dotted vertical lines represent exposure targets equal to match outcomes (i.e., 100%) or two-fold the match outcomes (i.e., 200%)

Figure 9. Perceived effectiveness of training methods to elicit high-speed and sprint running exposure

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