TITLE: TRAINING LOAD RESPONSES TO FOOTBALL GAME PROFILE-BASED TRAINING (GPBT) FORMATS: EFFECTS OF LOCOMOTIVE DEMANDS MANIPULATION.

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HEAD TITLE: TRAINING LOAD IN GAME PROFILE-BASED TRAINING

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Abstract

The aim of this study was to compare internal and external load profiles of different game profile-based training (GPBT) formats among elite young football players. Twenty-one participants (age: 18.7 ± 0.6 years) performed three sessions of three GPBT formats, which were matched for training volume but structured with different high-speed running and sprint demands: i) performed along linear paths (GPBT-L); ii) performed as repetitive actions of short distance including many multi-directional changes of direction (GPBT-S) and, iii) a combination of the other two protocols, that is linear high-speed runs and sprint efforts with a single change of direction (GPBT-M). External load outputs were collected using GPS units, physiological and perceptual responses were monitored with heart rate (HR) monitors, and ratings of perceived exertion (RPE), respectively. While no differences were found between formats for HR and RPE, distinct external load profiles were observed for high-speed running (HSD) and sprint distances (SD), (GPBT-L > GPBT-M > GBPT-S, all $p < 0.05$), and high-intensity acceleration and deceleration efforts (HIE), (GPBT-S > GPBT-M > GPBT-L, all $p < 0.05$). Moreover, the GPBT-S format was characterized by greater intra-session variability for HSD, SD, and HIE **(CV% = 24.2%, 16.5% and 20.4%, respectively)** and inter-session variability for HSD and SD **(CV% = 10% and 15.7%, respectively)** compared to the other two formats. Considering their load profiles and the associated reliability scores, football practitioners can implement **GPBT** formats interchangeably to elicit necessary internal load responses and selectively to prioritize specific external load outputs.

Key Words: athletic development; global positioning system; high-intensity running; training load; tracking technology

Introduction

Football is a physically demanding team sport with an intermittent locomotive profile characterized by high-intensity activities such as accelerations, decelerations, changes of direction and sprints, which are repeatedly performed throughout a match and interspersed with passive (i.e., standing) or active (e.g., walking, jogging) low-intensity recovery periods **[1-3]**. Besides the physical and underpinning physiological capabilities required to cope with such locomotive demands [1], football performance also relates to technical skills such as dribbling, passing, and shooting [4], as well as effective tactic strategies in attacking, defending, and transitioning match play situations [2]. Considering the multifaceted nature and contextual interplay between the football performance determinants, coaches and practitioners seek appropriate training drills that integrate physical stimuli and technical-tactical tasks for optimizing players' development [3].

A valid conditioning method has been recently proposed by Dello Iacono et al. [5] to address **some of** these multidimensional needs – Game-profile based training (GPBT) – that combines technical and physical football-related activities performed at target intensities along fixed paths, accurately marked on-field, intending to induce specific training loads and physiological responses [6] that mimic **locomotor** match-play demands. The use of GPBT as an integrative conditioning method in football has many benefits. First, similarly to other game-based training methodologies (e.g., small-sided games) [7, 8], GPBT may be advantageous to simultaneously practice technical skills under given physical constraints [6, 8, 9]. Second, GPBT can induce comparable internal load responses and greater external load outputs than official matches [5]. Third, implementing GPBT during the last months of a competitive football season contributes to improving physical capabilities associated with football performance such as jumping, linear sprinting, repeated sprint ability, change of direction, and intermittent running in young football player [6, 10]. Finally, it helps to mitigate the intra- and inter-session variability of internal and external load responses commonly observed during game-based methodologies [10], thus allowing higher consistency of the expected conditioning stimuli and a likely more individualized strategy to optimize training adaptations. **However, while GPBT has been endorsed as an effective integrative conditioning method, it is not free of disadvantages. In particular, it cannot replicate team and individual players decision-making and behavioral elements, which characterize the tactical dimension of football match-play. As such, its suitability as a single training tool able to fully address the multidimensional nature of football should be considered with caution.**

The high intra- and inter-session reliability in training responses associated with GPBT suggests that by manipulating the locomotor demands of GPBT and designing alternative formats, it would be possible to induce selective external load outputs and associated internal load responses **[11]**. In particular, a GPBT format including longer high-intensity running and sprinting bouts compared to the original GPBT format may ensure exposure to greater high-speed running and sprint distances and associated cardiovascular responses **[12]**. Conversely, a format including shorter and repeated acceleration and deceleration bouts with multiple changes of direction would be preferable for peripheral adaptations due to likely greater neuromuscular stimuli and mechanical loads [13]. These assumptions are demonstrated in the literature regarding game-based training methodologies, whereby a task-constraint approach manipulating game formats and pitch dimensions can impact on the players' internal and external loads [8]. However, evidence confirming similar effects resulting from GPBT formats manipulation needs to be provided yet. Moreover, it would be worth examining the stability of the internal and external loads associated with different GPBT formats to inform a similar bespoke GPBT training approach for football practitioners. This may be particularly pertinent when working with young football populations, as exposing players to appropriate external loads and target training intensities consistently over time is imperative to fulfil long-term physical development and mitigate injury occurrence [14].

Therefore, the aims of the present study were twofold. First, to compare the internal load responses and external load outputs to three GPBT formats structured with different high-speed running and sprint demands among elite young football players. Second, assuming specific and distinct training load profiles resulting from the three GPBT formats, we aimed to examine the intra- and inter-session reliability of the training load responses.

Materials and Methods

Study design

A randomized crossover design was used to compare the training load responses to three GPBT protocols, matched for training volume (i.e., total distance × duration), but structured with different formats of high-speed running and sprint demands. The study was conducted during the first part of the regular season (October to December)**, and commenced ten weeks after the beginning of the pre-season period**. Data were collected over 10 weeks with participants completing nine experimental sessions, three for each GPBT format in a randomized order. To control for the effects of residual fatigue induced by previous official matches and interaction with complementary training sessions, and the order of experimental trials, data collection was conducted on the same days of the weekly schedule (i.e., M+2 and M+4), and only during weeks in which a single official match was played over the weekend. All sessions were completed on the same natural grass field, at the same time (i.e., 3:00 pm-5:00 pm) of the day, and were supervised by two coaches and two researchers. Participants and coaches were instructed to avoid intense training on the day (i.e., M+3) between two consecutive experimental sessions, and to refrain from caffeine and alcohol ingestion for 24 hours before each session.

Participants

The sample size was estimated using *a priori* power analysis in the G*Power software (Heinrich-Heine-Universitat Dusseldorf, Germany). A repeated-measures analysis of variance (ANOVA) design with an $\alpha = 0.05$, $\beta = 0.8$ and *large* effect sizes (all ES ≥ 0.8) observed in previous studies comparing the external load outputs between GPBT and either game-based methods or official matches [5, 10], required sample size of twenty-one participants. Twenty-one male outfield football players took part in the study (age: 18.7 ± 0.6 years, stature: 178.4 ± 1.3 cm, body mass: 74.2 ± 2.8 kg, maximal heart rate [HR_{max}]: 202 ± 1.7 beats·min^{-1} and of body fat [%]: 9.3±1%, maximal aerobic velocity [MAV]: 16.5 ± 1.5 km·h^{-1}). Players were members of a U-19 football team participating in the national youth league and the UEFA Youth League group stage. They had at least six years **(range: 6-8)** of experience in systematic training within a professional youth academy framework. They trained once a day for about 90 min, five days per week, and underwent technical, tactical, strength, and speed training. **Inclusion criteria for participating to this study were: 1) Participation in ≥ 90% of the training sessions completed during the pre-season and the first part of the regular season; 2) Any musculoskeletal injury resulting in the loss of one or more football matches in the preceding 2 weeks before study initiation; 3) Any longstanding injury (≥ 6 weeks) in the lower extremities in the preceding 6 months before study initiation.** Players gave written informed consent after receiving a detailed explanation about the potential risks of the training. The study was conducted according to the Declaration of Helsinki, and the design was fully approved by a University Ethics Committee.

Yo-Yo Intermittent Running Test Level 1 (YYIRTL1)

One week before the study commencement, participants performed the YYIRTL1 [15] **on the same football pitch where all GPBT training sessions took place.** Pacing for the YYIRTL1 test was broadcast using speakers placed on the sides of the field. **The end of the test was determined when the player failed to arrive within 2 m of the end line on 2 consecutive tones.** The final speed corresponding to the last shuttle of the YYIRTL 1, namely maximal aerobic velocity (MAV), was used to calculate the individual intermittent running distances in the GPBT protocols. Finally, HR_{max} values measured throughout the YYIRTL1 were used to calculate the individual internal load responses.

GPBT protocols

The GPBT protocols consisted of 2 sets by 8 min of intermittent bouts combining physical and technical activities [5]. The three formats used in this study were designed with different high-speed running and sprint demands: i) GPBT-L, in which high-speed runs and sprints were performed along linear paths (Figure 1), ii) GPBT-S, in which high-speed runs and sprints were performed as repetitive actions of shorter distances including many multi-directional changes of direction (Figure 2) and, iii) GPBT-M, in which high-speed runs and sprints were designed as a combination of the other two protocols, that is linear high-speed runs and sprint efforts with a single change of direction (Figure 3). Participants moved alternately from the left to right side of the protocols' setup or vice versa after each bout lasting 1 min. Exercise intensity was set at 50-75-105% (for low-, moderate-, and high-speed running, respectively) of the MAV reached during the YYIRTL1. However, in both GPBT-M and GPBT-S protocols, adjustments of high-speed running and sprint distances were made to account for the number of changes of direction. In particular:

- A distance reduction of about 3% was applied to moderate- and high-speed runs including a change of direction (GPBT-S) [11].
- A distance reduction of about 5% was applied to sprints for every change of direction greater than 45° (both GPBT-M and GPBT-S) [16, 17].

Linear (GPBT-L) and equivalent (GPBT-M and GPBT-S) intensity intermittent running distances were marked on the field using colored cones **and adjusted for each player individually**. Participants ran through these distances while listening to an **acoustic** signal broadcasted using speakers placed on the sides of the field to ensure that they could work out at the prescribed pace. Each GPBT protocol was performed at the beginning of a training session after a 20-min standardized warm-up **(10 min of jogging, 5 min of dynamic stretching exercises, and 5 min including short accelerations and change of direction drills).**

*****Figures 1-3 about here*****

Load monitoring

External Load

External load metrics were collected with 21 GPS units working at a sampling frequency of 15 Hz (SPI-Pro X II, GPSports, Canberra, Australia). All devices were always activated 20-min before the data collection to allow for the acquisition of satellite signals [18]. The minimum acceptable number of available satellite signals was 8 (range 8-11), while the horizontal dilution of precision during the trials was 0.7 ± 0.1 [19]. To avoid inter-unit error, each player wore the same GPS device for all training sessions. **Good to moderate** ranges of validity **(Measurement bias from criterion method = -1.92% to -3.16%)** and reliability **(CV% = 6.2-12.4)** have been reported for measures of distances and speeds collected with 15 Hz GPS devices during common football-based movements [20, 21]. Following each session, GPS data were downloaded and extrapolated using the manufacturer's software package (GPSports Team AMS software v 2011.16). The external load variables recorded in our study were:

- Relative distance covered per minute (RD; $m \cdot min^{-1}$);
- Relative distance covered per minute (HSD; $m \cdot min^{-1}$) in a high-speed zone (≥ 15 and < 21 $km \cdot h^{-1}$) [20, 22];

- Sprint efforts, defined as any locomotive activity reaching a threshold speed ≥ 21 $km \cdot h^{-1}$ and lasting at least 0.5 s. Relative sprint distance (SD; $m \cdot min^{-1}$) was calculated accordingly as the distance covered above the sprint threshold speed [22];
- High-intensity efforts per minute (HIE; $n \cdot min^{-1}$), calculated as the sum of sprints and high-intensity deceleration (≤ -2 $m \cdot s^2$) and high acceleration (≥ 2 $m \cdot s^2$) per minute [22].

Internal Load

Heart rate responses

HR responses were monitored to provide individual mean heart rate percentage ($\%HR_{mean}$) expressed relative to the HR_{max}. HR responses were recorded using the POLAR Team² Pro system (Polar Electro Oy, Kempele, Finland) sampling at 5 s intervals, then filtered using a software-embedded proprietary algorithm. The HR_{max} values used as a reference for the HR responses during GPBT were those measured during the YYIRTL1 test.

Rating of perceived exertion (RPE)

Perceived effort was measured via the 11-point rating of RPE scale [23]. **Subjective ratings were given within 15 min after completing each session. Players were presented with a printed and laminate version of the RPE scale, and then asked to report their individual perceived effort separately from their teammates as to avoid any potential bias.** The question "How much effort did you exert?" was presented at the top of the scale which ranged from zero ('no effort') to 10 ('maximal effort'). Players were familiarized with this method as it **had been** commonly used by the coaching staff as a load monitoring tool **for the last two season after training sessions and matches.**

Statistical Analysis

Data are presented as mean ± standard deviation (SD) and confidence interval (95% CI). The intra- and inter-session reliability of the training load responses were expressed as Coefficient of Variation (CV%: SD/mean*100) [24]. Intra-session reliability was calculated to examine the group variability in each of the three sessions completed for each GPBT format. Inter-session reliability was calculated to examine the individual variability across the three sessions for each GPBT format. **Based on previous recommendations, CV% values were rated as good, moderate or poor when lower than 5%, between 5% and 10%, or greater than 10%, respectively** [21]. The normality of the absolute data was investigated using the Shapiro-Wilk test, and skewness and kurtosis values smaller than 2 served as an indication of normality. The normality of the residuals for each combination of the independent variables was tested using the Shapiro-Wilk test and visually inspecting normal Q-Q plots. The homogeneity of variance of the outputs between the three protocols was examined with Levene's test. We compared the effects between the three protocols on external and internal load responses using a 3 (protocol: GPBT-L, GPBT-M, GPBT-S) × 3 (session: session 1, session 2, session 3) repeated-measures Analysis of Covariance (ANCOVA). For this purpose, the different high intensity running and sprint distances across protocols due to the adjustment made to account for the number of changes of direction were used as covariates. Significance was at $p < 0.05$. If significant main effects were identified, then post hoc analyses were conducted using the Holm-Bonferroni correction. Finally, Cohen's *d* (Mean difference/SD average) effect sizes (ES) were determined to provide qualitative descriptors of standardized effects and interpreted using the following criteria: trivial <0.2, small 0.2–0.5, moderate 0.5–0.8 [25]. All statistical analyses were conducted using IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA)

Results

The intra- and inter-session CVs of all dependent variables are reported in Table **I. Good to moderate** reliability scores were observed for the majority of the internal load responses and external load outputs across all protocols (all CVs < 10%), except for intra-session HSD, SD and HIE (24.2%, 16.5% and 20.4%, respectively), and inter-session HSD and SD (10% and 15.7%, respectively) measured during the GPBT-S format.

Descriptive and inferential statistics of the absolute data and comparisons between protocols are reported in Table **II** and Figures 4 and 5. A main effect for protocol was observed on HSD ($F_{2, 40} = 179.1$, $p < 0.001$), SD ($F_{2, 40} = 387.1$, $p < 0.001$) and HIE ($F_{2, 40} = 704$, $p < 0.001$). Post hoc analyses revealed two consistent patterns: GPBT-L > GPBT-M > GPBT-S for HSD and SD and, GPBT-S > GPBT-M > GPBT-L for HIE. A main effect for session was observed on HSD ($F_{2, 40} = 30.13$, $p < 0.001$), SD ($F_{2, 40} = 15.18$, $p < 0.001$), HR_{mean} ($F_{2, 40} = 3.37$, $p = 0.04$) and RPE ($F_{2, 40} = 10.35$, $p = 0.002$). Post hoc analyses revealed a progressive increase (Session 3 > Session 2 > Session 1) in HSD and SD with a concurrent decrease (Session 1 > Session 2 > Session 3) in HR_{mean} and RPE for consecutive sessions consistently across protocols. Finally, no main effects for protocol or session were found on RD ($F_{2, 40} = 2.06$, $p = 0.14$) and ($F_{2, 40} = 2.90$, $p = 0.06$), respectively, no main effects for protocol on HR_{mean} ($F_{2, 40} = 2.85$, $p = 0.07$) and RPE ($F_{2, 40} = 1.08$, $p = 0.35$), and no interaction between protocol and session on any of the dependent variables.

*****Tables I and II, and Figure 4 and 5 about here*****

Discussion

In this study, we examined the training load responses to three different GPBT protocols among elite young football players. Four main findings emerged: (i) distinct patterns for HSD, SD, and HIE across protocols; (ii) a progressive increase in HSD and SD with a concurrent decrease in HR_{mean} and RPE across consecutive sessions in all protocols; (iii) greater intra-session variability for HSD, SD and HIE and inter-session variability for HSD and SD during the GPBT-S protocol; (iv) similar HR and RPE responses across all protocols.

Conditioning methods in the form of GPBT integrate time-motion analysis data, movement patterns, and technical skills to replicate the **locomotor** demands of football [5, 6, 9-11]. Apart from their inherent ecological validity, GPBT methods are suggested as effective for inducing acute physiological, metabolic, and mechanical responses [5, 11] which can lead to cumulative central and peripheral adaptations underpinning beneficial long-term training effects [6, 9, 10]. Building on the findings of Dello Iacono et al. [5, 10] we investigated further the training load responses to two GPBT protocols designed as different formats of high-speed running and sprint demands. A main finding of the current study is that the three GPBT protocols are characterized by specific external load profiles, and as such can be selectively used to ensure required HSD, SD, and HIE exposure. We assume that the distinct formats of high-intensity running and sprint demands may have led to specific external load outputs. Our assumption is supported by two main observations. First, a progressive increase in HSD and SD was observed when protocols changed from formats including short distances combined with multiple or single changes of direction to a format designed as linear paths without changes of direction (GPBT-L > GPBT-M > GPBT-S). Opposite of this, a progressive increase in HIE was found as protocols changed from a linear path profile to the other two structured as repetitive shorter distances combined with single or many changes of direction (GPBT-S > GPBT-M > GPBT-L) (Figure 4). Second, our findings are in agreement with previous studies [16, 26, 27], from which emerge that HSD and SD covered during high-intensity intermittent running and repeated sprint exercises similar to those embedded in the GPBT protocols of this study, are dependent on the number and directional angles of the changes of direction tasks. On one hand, the linear running paths in the GPBT-L protocol allowed players to reach higher speeds and cover greater HSD and RD, but this came at an expense of less HIE. Conversely, the fact that players were required to accelerate and decelerate on more occasions during GPBT-M and GPBT-S protocols, led to greater HIE and concurrent lower HSD and SD compared to the GPBT-L. These findings have practical importance and suggest GPBT protocols may be alternatively selected to address specific training targets. For example, GPBT-L may be preferable to ensure HSD and SD exposure for conditioning and injury prevention purposes. At the team level, it can be implemented during training blocks in which high intensity running and sprinting capabilities development or maintenance is a priority. At the individual level, it may be used as a complementary strategy of HSD and SD exposure management, particularly for non-starter players whose cumulative exposure due to sole training sessions is insufficient [28, 29]. On the other hand, GPBT-S and partly GPBT-M may be chosen to improve lower limbs' muscular capabilities (e.g. force, rate of force development and power) and the coordinative ability to perform changes of direction while running at high intensity, key physical and motor components of agility [30], which in turn is recognized as a crucial determinant to successfully compete at the highest level in football [1, 31].

The distinct external load profiles of the three GPBT protocols should be further **interpreted** alongside the reliability analyses, whereby we observed high intra- and inter-session variability in HSD, SD and HIE measured during the GPBT-S (Table **I**). Although a comprehensive investigation of the possible sources of higher variability in HSD, SD, and HIE is beyond the scope of this study, we attribute these outcomes to both systematic bias and random error of the measurements. We assume a trend of increasing variability in HSD, SD, and HIE as a result of the progressive accumulation of fatigue between repeated high-intensity running and sprinting bouts as the protocol duration progressed. Multiple changes of direction with sharp directional angles as in GPBT-S may have exacerbated such effects as a consequence of greater mechanical loads [16, 32], muscular strain, and metabolic byproduct (i.e. lactate) accumulation [33, 34], which likely led to alteration of lower limbs kinematics and motor performance [35].

Moreover, the interaction between the technical demands (i.e., pass tasks) and the multiple short accelerations, decelerations and changes of direction actions characterizing the GPBT-S format, may have contributed to increase variability of the locomotor patterns, due to the likely different technical abilities across the participants. Random error in HSD and SD outputs could have arisen due to inherent biological fluctuations and **partly due to the technical variability between** the GPS units. First, while in this study a large number of confounding variables were controlled, such as order of consecutive trials, residual fatigue from previous matches and training sessions, time of the day, diet and baseline warm-up, we cannot completely exclude any change of fitness status of the participants over the 10-week study duration, which could have partly affected the consistency of HSD, SD and HIE outputs across the sessions of the GPBT-S protocol. This assumption is supported by the main effect of session found on the majority of the dependent variables. In particular, we observed an increase in HSD and SD with a concurrent decrease in HR_{mean} and RPE consistently across all protocols (Figures 4 and 5), which presume beneficial physiological adaptations and increased fitness over the 10-week study duration. Second, an implicit error of HSD and SD measurements is expected due to the precision of the GPS technology used in this study, which is affected by running velocity, running distance, and movement pattern of the monitored activities [36]. Consistent with previous studies, we observed gradual lower reliability during activities characterized by higher running velocity [37, 38], shorter distance [39], and a greater number of changes of direction [38, 40, 41] with sharper directional angles (GPBT-S < GPBT-M < GPBT-L, Table **I**). However, the CV% values of HSD (range 1.8-10%) and SD (range 3.4-15.7%) from the three GPBT protocols were comparable and even smaller than the equivalent reliability scores reported in the literature about the same metrics collected during game-based standardized drills and proposed for monitoring purposes [42-44]. **More importantly, the relatively larger variability observed in HSD, SD and HIE during GPBT-S compared to both GPBT-L and GPBT-M, considerably attenuates when**

interpreting the CV% scores in absolute terms (Table I). Therefore, the consistency and predictability of the expected external load responses across different GPBT formats seems to be affected by the manipulation of locomotive demands to a minor extent. These findings have important practical implications and suggest that if football practitioners are willing to accept relative variability rates in the range of 5-9% **(0.7 ± 0.4 m·min^{-1} and 0.4 ± 0.1 m·min^{-1} for HSD and SD, respectively),** then monitoring of HSD and SD outputs during GPBT, and GPBT-L in particular, could be a feasible complementary approach when attempting to detect changes in performance which can be acted upon to make comparisons within and between players from the same team.

Another main finding of the current study was that the three GPBT protocols led to comparable internal load and perceptual responses despite their distinct external load profiles. One likely reason for such outcome is a compensatory mechanism made possible by the passive (i.e standing) and active recovery phases (i.e. jogging and walking) of relatively long duration (≈ 40 seconds overall) common to all protocols. From a physiological perspective, such phases may have allowed the restoration of both phosphagens and glycolytic energy sources [45], which were reasonably utilized and depleted in different proportions during the specific intermittent short high intensity and maximal exercise formats of the three GPBT protocols [11, 46]. Moreover, they were sufficiently long to attenuate substantial differences in metabolic byproduct (e.g., lactate) accumulation, neuromuscular load, and musculoskeletal demands between the GPBT protocols, with consequent similar HR and RPE responses [11]. Translated in practice, this finding can be viewed as both a strength and a weakness. On one hand, given the similar physiological and perceptual outcomes observed between the protocols, all can be implemented interchangeably or even concurrently to elicit beneficial cardiovascular adaptations. When the training goal is to improve intermittent high-intensity running performance and the underpinning maximal oxygen consumption capabilities, our findings indicate that the three GPBT protocols can be effective regardless of their formats [5, 10]. The main effect of session observed on HR_{mean} and RPE supports this hypothesis and suggests that cumulative positive responses occurred throughout the 10-week study duration in which participants performed nine GPBT sessions randomly (Figure 5). However, we note that clear conclusions cannot be made as our study did not include any pre-post physical testing procedure or a control group, whereby it is unclear if the observed acute responses were mirrored by beneficial adaptations over time. On the other hand, the ability to accurately estimate acute responses during GPBT and accordingly prescribe different formats using HR and RPE alone is limited. While HR and RPE responses confidently reflect the overall exercise intensity, both equally fail to discriminate between the combined physiological, locomotive, biomechanical, and psychological components of the effort, fatigue, and discomfort imposed on the body during exercise [47]. This could limit the ability to target specific adaptations especially in a team sport setting, in which a large number of athletes may have different conditioning needs. Consequently, football coaches and practitioners are advised to use a combination of internal and external load measures when implementing conditioning exercises in the form of GPBT protocols. This is particularly relevant for accurately monitoring the exact demands of these intermittent exercises thus developing training programs aimed at improving physical performance.

In light of the main findings of this study, and in line with the current scientific evidence on GPBT [5, 10], a few practical recommendations can be provided. First, GPBT protocols can be used interchangeably or concurrently to elicit necessary internal load responses underpinning beneficial long-term cardiovascular adaptations. Second, these protocols could be selectively prescribed in consideration of the specific external load outputs to prioritize. While the GPBT-L may be used to ensure controlled HSD and SD exposure, and the likely transference effects on high-intensity running and sprinting capabilities,

GPBT-S and GPBT-M may be chosen as adequate peripheral stimuli for the development of lower limbs' muscular capabilities and coordinative elements of changes of direction and agility tasks. However, a more cautious approach should be adopted when implementing the GPBT-S format due to the higher intra- and inter-session variability observed for HSD, SD and HIE responses. Third, sport scientists and football practitioners should assume 2 sessions of GPBT per week over a period of minimum 8 weeks as sufficient to induce conditioning adaptations [10]. Finally, GPBT could be implemented as a complementary load management tool when considering individual players' match time (e.g., starters vs non-starters) and associated HSR and SD exposure [28]. This approach could be particularly useful during congested fixture periods in which other conditioning alternatives may be unsuitable due to logistic constrains such as limited training time, pitch and players availability.

Moving on from this preliminary evidence, future studies are warranted to investigate the long-term adaptations of the three formats further, and more interestingly their dose-effect relationships when implemented over time separately. Also, while GPBT has been endorsed as an effective integrative conditioning method for young elite football players, mirroring evidence on adult professional is still lacking, which necessitates similar investigations in this population. Finally, it will be worth examining if any of the three GPBT formats used in this study or an *ad hoc* developed variant can be proposed as valid and reliable football-specific monitoring protocol when aiming to assess physical readiness and fitness or to detect fatigue-related indicators among football players.

This study is not without limitations. First, our participants were well accustomed to this form of training, so whether these findings translate to other individuals (e.g. young female players, adult male, and female players) require further research. Finally, another limitation was the absence of additional physiological measurements (e.g. hormonal and lactate concentrations), which may have helped in better understanding the metabolic responses and underlying mechanisms of the different GPBT formats.

Conclusion

Physical conditioning in the form of GPBT **training is a** valid training **method** to address specific responses in football players. **The proposed** GPBT **formats can be used** interchangeably**, concurrently or selectively** to **induce specific external load outputs and to** elicit necessary internal load responses underpinning beneficial long-term cardiovascular **and peripheral musculoskeletal adaptations.**

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