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Game-profile-based Training in Soccer: A New Field Approach

ABSTRACT

The aim of the study was to profile and compare the time-motion, physiological, and neuromuscular responses of both national youth league (NYL) and UEFA Youth League (UYL) matches with those of an experimental game-profile-based training (GPBT) protocol. Time-motion traits and physiological, perceptual, and neuromuscular responses were investigated in 24 male soccer players across 14 matches and 6 GPBT training sessions, for a total of 420 samples. The GPBT had a greater influence on time-motion traits and perceptual responses than the NYL and UYL matches (all $p < 0.001$). No significant GPBT vs. matches differences were found for mean heart rate (%HR) or BLa ($F = 1.228$, $p = 0.304$ and $F = 0.978$, $p = 0.385$, respectively). Finally, the GPBT protocol led to greater impairment of the neuromuscular explosive performances when compared to those of the post-match scores (SJ: $F = 19.991$, $p < 0.001$; CMJ: $F = 61.703$, $p < 0.001$). Results identified the GPBT protocol as characterized by relatively greater high-intensity workloads than official NYL and UYL matches, requiring increased demanding efforts. In light of these outcomes, the GPBT protocol can be considered an advantageous training method for elite soccer players, capable of stimulating the physical effort and physiological capabilities required during a match. This approach is favorable when designing a training intervention according to the principle of sport specificity, as it is based on the specific metabolic demands.

Key Words: metabolic demand, global position system, team sport, training and testing

INTRODUCTION

The responses of internal and external physical loads during official soccer matches have been heavily investigated in the recent years (42). Such outcomes have been collected in order to profile the nature of specific exercise patterns, with the aim of providing a theoretical reference framework capable of matching the physical requirements for efficient participation at elite levels and, as consequence, a means for optimizing the training design.

In a team sport such as soccer, the requirement for frequent changes in the type of movements (e.g., walking, running, sprinting, jumping, tackling), speed (e.g., accelerations, decelerations), direction, and technical tasks features the activity profile as intermittent (42) in nature. Briefly, high-intensity running and sprint-type activities are considered to be crucial determinants for successful performance (11). Previous analyses showed that both male and female outfield soccer players cover distances of between 9 and 12 km during the matches (51). Of these, 8% to 12% were represented by high-intensity running or sprinting, with inter-player differences occurring due to the specific playing role (51). Reported peak sprint-velocity values among soccer players are 31-32 km·h⁻¹. The number of sprints (37) ranges between 17 and 29 per game for each player, with mean sprint duration ranging between 2 and 4s, and the vast majority of sprint displacements are shorter than 20m (51). Interestingly, Faude et al. (18) identified straight sprinting as the single most frequent action in goal situations by both the scoring player and the assisting one.

The current data have been widely reported for adult professional soccer players with regard to competition level and position on the field during official matches (4,7,11,13), while few studies have been published regarding the activity patterns and

physiological demands of younger ages (1,3). Castagna et al. (12), investigating the activity profile of young soccer players (< 12 years), reported an average distance of $102 \pm 6 \text{ m} \cdot \text{min}^{-1}$ of match play with $114 \pm 73\text{m}$ performed at maximal speed. Similarly, Aslan et al. (3), have recently found that U-17 soccer players, competing in the Turkish youth league, covered an average distance of $109 \pm 3 \text{ m} \cdot \text{min}^{-1}$ and $152 \pm 72\text{m}$ of high intensity sprint. However, in spite of the increasing focus on the optimization of physical and tactical skills in talented young soccer players, no studies have been published regarding the match demands of international tournaments and competitions at youth level. In fact, there seems to be a clear need to have reference values regarding the demands according to young age groups at elite level given that the knowledge of the specific game requirements may guide soccer academies and youth teams to prepare young athletes for a future career by developing soccer-specific motor skills and physiological capacities.

In light of the current scientific evidence, optimal performance in soccer results from the interaction between the different players' physical and physiological constraints and their technical-tactical capacities. Although technical-tactical skills are considered to be predominant factors, individual physical and physiological capabilities must also reach a certain level for players to be successful (7,47). Some studies have found differences in the fitness of players (4,7,42,47) thus suggesting contradictory results between physical performance during the actual match and the players' maximum physiological capabilities. One might speculate that despite being physically fit, players do not operate at their physiological maximum due to the collective game pace imposed to each player (10). However, superior levels of fitness and soccer related physical capabilities

may help players in coping with potential worst playing scenarios characterized by greater demands, as frequently imposed by higher-level opponents. The evidence of concurrent fitness components for the successful participation in soccer suggests that the exercise training prescription should be multi-dimensional (13,26,49). Accordingly, the use of training methodologies such as small-sided games (SSGs (2)) and soccer-specific tracks (26,34), able to simultaneously improve technical and tactical skills under specific physical loads, while also maintaining the players' higher motivation in comparison with nonspecific training situations, has increased over the years (25,26). As a consequence, research in soccer should investigate the competition demands, and highlight those training methodologies that better fit the required time-motion and physiological responses of players' performance development.

To the best of our knowledge only one study has documented the long-term effects of a soccer-specific endurance training protocol that includes a specially designed track (26) in a group of male youth elite soccer players. In essence, this training intervention was shown to be effective for improving the $\text{Vo}_{2\text{max}}$ of soccer players, with no negative interference effects on strength, jumping ability, or sprinting performance. Although it is well known that exercise-constraining manipulation can affect physiological responses and the potential effect for performance improvement, no previous study has attempted to investigate the acute effects of a game-profile-based training (GPBT) protocol that replicates the technical, physical, and physiological demands of match play provided by the current literature regarding elite adult professional soccer players. This information could prove to be valuable, because a better understanding of the training stimulus during preset GPBTs would likely help to optimize

the players' workload through training drills similar to those occurring during real game situations and, in turn, to prepare young players for the specific demands of the higher adult levels.

Consequently, the aim of the present study was to describe and compare the time-motion and physiological profiles of both official soccer matches and a GPBT experimental protocol in a group of young elite soccer players.

METHODS

Experimental Approach to the Problem

This study adopted a fully controlled observational design with pre-post condition assessments. Physiological responses and time-motion traits' requirements during official matches were compared with those induced by the experimental GPBT format in elite soccer players. Performance test measurements at pre- and post-condition points were collected and compared in order to assess the reliability of the measures. Post-match outcomes were analyzed for 14 games of the U-19 team between September 2015 and December 2015. Eight of these games were played as part of the National Youth League (NYL), while 6 games were part of the UEFA Youth League (UYL) group stage. Additionally, the post-GPBT acute responses were obtained from 8 training sessions for between-conditions comparisons. Inclusion criteria for the players were: having played at least 3 full 45-min periods during the official matches and having participated in at least in 90% of the training sessions throughout the data collection. These criteria were

necessary in order to reasonably ensure that the players experienced a situation where (near) maximal effort was achieved.

Subjects

Twenty-four elite male soccer players took part in the study (age 18.3 ± 1.1 years, height 179.4 ± 2.3 cm, body mass 74.3 ± 4.1 kg, maximal HR 202.5 ± 2.9 beats min^{-1} , and percent of body fat $8.9 \pm 1.4\%$). Players were members of a U-19 soccer team participating in the NYL and in the UYL during the 2015-16 season. They trained once a day for ≈ 90 min, 5 days per week, and underwent technical, tactical, strength, and speed training. All the players and/or their parents/guardians gave their 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 protocol was fully approved by the Institution's Ethics Committee.

Procedures

GPBT Protocol

All GPBT-based sessions started with low-intensity running (10 min) and passing drills for warm-up (5 min). As for the cool-down strategy, both training sessions and official matches ended with a standardized protocol that included static stretching exercises of 30s duration for each of the following muscles: hip flexors, extensors, adductors and abductors, knee flexors and extensors, and ankle plantar flexors. This standardization prevented any potential effect of different post-activity recovery strategies on the physical and physiological variables assessed post training and post matches. The GPBT protocol consisted of 3 bouts of 8 min of combined physical and technical

activities, such as walking; low-, moderate-, and high-intensity intermittent (HIIR) running; sprinting with changes of direction (COD); and passing drills. From a methodological perspective, the protocol was organized in terms of intermittent training consisting of 30s of high- and very-high physical and technical efforts interspersed by 30s of active walking and low-intensity running recovery. An example of the GPBT protocol pattern is presented in Figure 1. The choice of the running velocities was justified by the fact that this kind of protocol allows athletes to elicit and maintain their $VO_2\text{max}$ (17). Exercise intensity (controlled by the intermittent running distance covered over the field) was set at 50-75-105% (for low-, moderate-, and high-intensity running, respectively) of the Yo-Yo intermittent recovery test level 1 (YYIRTL1) (27) final speed that was preventively performed; previous reports have shown that a similar protocol was able to induce an intensity that corresponds to ~120% of $VO_2\text{max}$ (14,17). Sprinting and repeated sprint effort (RSE) displacements were set shorter than 20m (51) and with directional angles for COD ranging between 60° and 135° (8). Finally, the selection of walking and low-intensity running efforts as active recovery traits of the GPBT was dictated by a previous investigation of Osgnach et al. (35), reporting a mean distance of low-intensity (from 0 to $8 \text{ km}\cdot\text{h}^{-1}$) locomotion activity $49.1\pm 3.5 \text{ m}\cdot\text{min}^{-1}$ covered by 399 professional Italian "Serie-A" soccer players during 56 official matches. All the GPBT sessions were performed on the same natural grass soccer field under similarly ambient conditions ($25\text{-}27^\circ\text{C}$ and 58% relative humidity).

*****Figure 1 near here*****

External Load Data Collection. The time-motion variables were collected with 24 GPS units working at a sampling frequency of 15 Hz (SPI-Pro X II, GPSports, Canberra, Australia). A special vest was tightly fitted to each player, which held the receiver between the scapulae. All devices were always activated 20-min before the data collection to allow for the acquisition of satellite signals (33). The minimum acceptable number of available satellite signals was 8 (range 8-11) (50). In addition, in order to avoid inter-unit error, each player wore the same GPS device for all matches and training sessions (41). Although the literature investigating the validity and reliability of 15 Hz devices is quite limited and contradictory (41), two fairly recent studies involving the use of such technology (1,30) reported acceptable ranges of variability for all measures of distances and speeds in common soccer-based movements. Specifically, Koklu et al. (30) highlighted that there were no significant differences between test and re-test measurements (coefficient of variation (CV, %) 2.4-3.81%; 95% Limits of Agreement (95% LoA) 0.17-1.35%) for distance measures relative to linear sprints of 10 and 20 m. In addition, Abade et al. (1) used the same GPS technology for profiling the time-motion responses of young soccer players through a speed zone classification similar to that in our study's design. Finally, this technology was previously validated by Barbero-Alvarez et al. (5) and determined to be reliable for monitoring peak and maximum speed during sprinting activities in soccer players (5). Therefore, the variables recorded in our study were: the relative distance covered per minute (RD; m/min), and the relative distance covered per minute (HSD; $\text{m}\cdot\text{min}^{-1}$) in a high-speed zone ($> 19 \text{ km}\cdot\text{h}^{-1}$) (1,35). As recently suggested by Schimpchen et al. (40), we avoided using an absolute value for the sprinting threshold definition. Conversely, we adopted the same individualized

thresholds' calculation method that uses a percentage of peak running velocity (PV) reached during in-game sprinting. An absolute sprinting threshold was set to 25.2 km·h⁻¹, and this velocity was taken as a reference point. Thus, to individualize sprinting thresholds as a percentage, the equation below was used:

$$(25.2/\text{in-game PV}) \times 100$$

From this, a group mean percentage was calculated and applied to each player's in-game PV in order to define their individualized sprinting thresholds. Runs with a maximal velocity higher than the individual thresholds were defined as sprints. Another time-motion parameter that was the object of investigation in our study was the quantitative evaluation of the relative high-intensity efforts per minute (HIE/min). This variable was calculated by summing up the relative number of occurrences per minute of sprints, and the locomotion activities included, in one of the following two acceleration categories: high deceleration (HD; < -2 m·s⁻²) and high acceleration (HA; > 2 m·s⁻²) (35). Finally, the following five power categories were used: low power (LP; from 0 to 10 W·kg⁻¹), intermediate power (IP; from 10 to 20 W·kg⁻¹), high power (HP; from 20 to 35 W·kg⁻¹), elevated power (EP; from 35 to 55 W·kg⁻¹), and maximum power (MP; >55 W·kg⁻¹) (35). For each of these power categories, relative time (%) was quantified.

Internal Load and Perceptual Data Collection. Maximal heart rate (HR_{max}) was determined by the completion of the YYIRTL1 (31), where the highest values of HR reached during the test corresponded to the HR_{max}. HR was continuously monitored throughout the GPBTs and the official matches by HR monitors (Polar Team Sport System, Polar-Electro OY, Kempele, Finland) recording at 5s intervals. Individual mean

HR during match play and GPBTs were determined in order to indicate the internal load. HR data were therefore expressed as percentage of HRmax (%HRmax). Blood lactate samples (BLa; $\text{mmol}\cdot\text{L}^{-1}$) were collected at the third minute (22) after the end of the GPBTs and the official matches by a portable analyzer (Arkray Lactate Pro LT-1710, Kyoto, Japan). Players indicated their rating of perceived exertion (RPE) (28) using the category rating 10 (CR-10) scale modified by Foster et al. (19), immediately at the end of the official matches and training sessions, using a standardized questionnaire.

Jump Performance Tests. Finally, the squat jump (SJ) and countermovement jump (CMJ) tests were performed to evaluate the acute effects of both official matches and GPBT sessions on the explosive abilities of the lower limb muscles. In a recent investigation, these jumping tests were reported to be highly repeatable and suitable for neuromuscular fatigue monitoring, due to the immediate and prolonged fatigue-induced changes (20). These tests were performed in a randomized order according to the protocol described by Bosco et al. (6). Each player was selected and tested before and immediately after both halves of the matches and following the training sessions, at least twice for each exercise condition, for a total of 9 samples (3 official NYL matches, 3 UYL matches, and 3 GPBT sessions). During the testing sessions all players performed 3 trials for each jump, with a passive recovery of 60s between jumps. The jump performance (in cm) was estimated from the flight time using the Optojump apparatus (Microgate Srl, Bolzano, Italy). To reduce any interference with the experiment, participants were prohibited from consuming any known stimulant (e.g., caffeine) or depressant (e.g., alcohol) 24 h before testing.

Statistical Analyses

All data are presented as means \pm standard deviation (SD) with a 95% confidence interval (95% CI). The Kolmogorov-Smirnov test was used to ensure normal distribution of the variables. The Intra-Class Correlation Coefficient (ICC) was used to determine the consistency of the measures at pre-condition points. For the intra-test reliability, the spreadsheet of Hopkins (27) was used to determine the typical error of measurement for the jump tests and BLA at pre- and post-condition points, expressed as a Coefficient of Variation (CV%) with a 95% confidence interval (95% CI). Knowledge of the Standard Error of Measurement (SEM) allowed the calculation of the minimal detectable change at the 95% confidence interval (MDC_{95}) (52). The MDC_{95} , calculated as $MDC_{95} = SEM \times \sqrt{2} \times 1.96$, reflects the minimum amount of change in the measurement that would be required to exceed the level of measurement error. Two-way ANOVA with repeated measures was used to examine the data for time (pre-test, post-test) and condition (GPBT vs. NL vs. UYL) differences in order to determine the effects of each effort regimen. In addition, the effect size of the difference (Cohen's d) was determined and the modified scale by Hopkins (www.sportsci.org/resource/stats/2002) was used for the interpretation of d : trivial, < 0.2 ; small, $0.2-0.6$; moderate, $0.6-1.2$; and large, > 1.2 . The alpha test level for statistical significance level was set at $p \leq 0.05$. Statistical analysis was performed using SPSS Statistics 21 software (SPSS Inc., Chicago, IL, USA).

RESULTS

Descriptive data for physiological, time motion, and performance variables are reported in Tables 1 and 2. A summary of the intra-test reliability analyses of the performance variables is presented in Table 3, including ICCs, CVs %, SEM, and MDC₉₅ with associated 95% CI. At pre- and post-test intervention points all the performance variables showed highly intra-test reliable data. The MDC₉₅ for the SJ, CMJ, and BLa test values ranged between 1.60 and 1.79 cm, 2.17 and 2.43 cm, and 0.26 and 0.34 mmol·L⁻¹, respectively.

Between-groups differences were found in all the time-motion variables (Table1). The results showed no between-groups differences for Mean HR and BLa (Table 1). Post-GPBT RPE was significantly higher than post-NL and post-UYL matches (Table 1). Time and group effects were detected in both SJ and CMJ performance values (Table 2).

*****Tables 1, 2, and 3 near here*****

DISCUSSION

The primary aim of this study was to profile and compare the physiological and time-motion responses of national and international matches with those of the experimental GPBT format in elite young soccer players. Firstly, the most interesting and novel value of this study is the comprehensive description of responses in official matches typical to elite youth soccer players. In addition, one main finding was that the GPBT protocol has a higher influence on time-motion characteristics and perceptual responses than the physiological loads. Furthermore, the controlled formats led to greater impairment in the neuromuscular explosive performances when compared to those of the post-match scores.

National vs. International matches outcomes

In this study, the time-motion responses (Table 1) of both the NYL and UYL highlighted the finding that the total distance covered and the percentage distribution of time spent in the different metabolic power zones were in line with previous studies reporting the game activity demands of young and adult professional soccer players (3,4,24,35,36). The results showed that during match play young soccer players ran $110.9 \pm 7.7 \text{ m} \cdot \text{min}^{-1}$ and $112.7 \pm 4.8 \text{ m} \cdot \text{min}^{-1}$ during NYL and UYL, respectively (Table 1). The overall running pattern results were slightly higher than those previously reported by Buchheit et al. (9), for youth soccer players (ranging from 93.5 to 108.8 $\text{m} \cdot \text{min}^{-1}$) indicating that both NYL and UYL official games are played at higher relative running demands. Moreover, distances covered during high-speed activities (e.g., HSD), accounting for between 3 and 4.5% of the total match distance, resulted comparable to those found in previous research (9). For example, Buchheit et al. (9), reported that elite youth academy soccer players of the same age group, assessed by the mean of time-motion analysis technology (i.e. GPS) and using identical activity categories as those applied in our study, covered high speed distances ranging between 3.7 and 5% of the total distance covered. However, these outcomes appear to be far from those produced by adult elite professional players. Specifically, Suarez-Arrone et al. (43), and Torreno et al. (48) previously reported that elite adult soccer players performed high-intensity activities for 9.6% and 9.2% of the distances covered, respectively. These **evidences suggest** that **elite junior and senior levels** in soccer might be **characterized by** increased running demands and sprinting performance. The results of the current study confirm the notion that the patterns of movement of young soccer players are similar to those of adult

players (9,39), while the relative time and distances covered at high intensities **appear to be age dependent**. As is well known, the relatively small amount of time spent performing high-intensity activities does not reflect the overall intensity of a competitive match **in which other tasks, like accelerations, decelerations, changes of direction and challenges with opponents, represent additional demanding efforts**. However, a full understanding of the official match loads and the related performance differences between elite professional and young soccer players, could be used as a reference for designing optimal and appropriate long-term programs for the intended physical and physiological adaptations. Therefore, future research is required to profile and compare the specific game-related demands between elite adult and young soccer players.

In this study, the results of the time-motion traits of both official matches and training sessions showed low inter-session and inter-match variability, as identified by similar trends in most of the collected data (Table 1). The only parameter reporting high variable scores was the HSD (CV% between 32-40% and SEM between 7-9%). Uncertainties of a similar magnitude have previously questioned support for the use of GPS technology during team sport match analyses focusing on sprinting and high acceleration movement patterns (41). In our study, when applied to the HSD responses of elite soccer match play and GPBT, this uncertainty indicates average distances of 1.8 and 2.9m respectively. Although this magnitude is important for discriminating whether or not a movement pattern will be most affected by this inaccuracy, it might also be that this variability is match-related, since it depends upon specific playing positions and constitutes a key characteristic of elite matches and training sessions (51). For example, previous research (9) into elite youth match play has shown differences in match running

performance between **player`s** roles showing center backs with lower high intensity running distances compared with all other positions and, both strikers and wingers displaying the highest values. In addition, the higher variability of HSD covered during the GPBT compared to that of official matches could confirm the diversity of the stimuli promoted during a soccer practice session, probably due to the inclusion of physical and technical drills with diverse aims, variable intensity, and different volume loads. Indeed, since game-profile-based training has different responses in this age group, additional coaching intervention may be required, promoting more appropriate adaptations across the training sessions and eliciting variability according to different role and age demands. This methodological approach would likely provide players with physical and physiological advantages when encountering worst case scenarios due to the highly demanding playing situations.

GPBT vs. official matches outcomes

One main finding of the current study was that the controlled and repetitive locomotion changes of the GPBT, requiring players to walk, jog, run, and sprint intermittently and repeatedly across the protocol setup, had a greater effect on the time-motion characteristics (RD and HSD) and on the RPE than did the official matches (Table 1). However, despite imposing a greater external training load, this exercise methodology had no effect on the physiological responses. One possible reason for this outcome may be a "pacing effect" that occurred due to the relatively long duration (≈ 40 seconds) of LP activities designed in the GPBT protocol. In fact, the intermittent nature of the GPBT, with the presence of in-between bouts of passive recovery phases, may

have led to a partial restoration of phosphagen stores and lower glycogen depletion, thereby reducing the physiological load (17,38). Accordingly, Dupont et al. (13) have reported that a passive recovery during short-intermittent exercises intervals allows the replenishment of the alactacid and oxymyoglobin energy sources, which are partially depleted during the previous work. Moreover, it is well known that phosphocreatine (PCr) provides part of the energy during intermittent runs at supra-maximal velocities. During rest periods of intermittent exercise, PCr recovery is dependent upon oxygen availability (23). Indeed, short passive recovery periods allow a greater quantity of PCr to be resynthesized, due to a high amount of O₂ being available. According to Tabata et al. (44), muscle lactate and PCr are partly restored during each passive recovery from short intermittent exercise. Consequently, the inclusion of short recovery periods between exercise periods at supra-maximal velocities may be beneficial for higher amounts of myoglobin and hemoglobin to be reloaded and for the PCr resynthesized.

Our data highlighted a greater effect of GPBT on the perceptual responses expressed as RPE, when compared with official matches. Recently, Gaudino et al. (21) demonstrated the high correlation between RPE measures and high-speed running and accelerations during soccer training. Our results conform to the conclusions of these authors, who showed that speed, acceleration, and impacts are likely to be strong predictors of RPE in soccer. As a consequence, the higher values of RPE found in our study may have been dictated by the greater values of relative HSD and HIE compared to those reported by these previous, similar investigations (21). Indeed, the findings of the current study seem to confirm such evidence, highlighting the correlation between HSD and HIE outcomes with the reported post-GPBT perceptual scores. Furthermore, the

time-motion traits' analysis revealed higher relative time (%) values for high power categories ($> 20 \text{ W}\cdot\text{kg}^{-1}$) and lower values for low power categories ($< 10 \text{ W}\cdot\text{kg}^{-1}$) during GPBT (Table 1), in comparison to those of official games. To the best of our knowledge, this is the first study to provide an overall description of the metabolic (HR%, BLa and time spent in each metabolic power zone) and mechanical (number of sprints, accelerations, and decelerations) demands of official matches and specific game-profile-based training in elite young soccer players. A detailed analysis of these responses is critical, as it allows an in-depth understanding of the workload imposed, which consequently has practical implications for the prescription of the adequate type and amount of stimulus during exercise training. Based on these results, we can consider GPBT as characterized by relatively greater high-intensity workloads, requiring repeated and more frequently-demanding efforts such as HIE and HP.

The comparison between post-matches and post-GPBT effects on the neuromuscular explosive abilities revealed a different impact on the jumping performances. Results indicate the high repeatability of the SJ and CMJ scores (Table 3), confirming that these tests offer good sensitivity to altered neuromuscular function and, conceivably, to neuromuscular fatigue. Previous neuromuscular repeatability investigations have considered a $<10\%$ CV as indicative of a repeatable test (20,45). In our study, 95% CI of CV% performance in all tests examined ranged between 1.54% and 2.36%, thus suggesting their high repeatability.

CMJ and SJ pre- and post-condition scores of SJ and CMJ showed greater impairment of jumping performances due to the GPBT when compared to official matches (large effects vs. small effects), as shown in Table 2. The persistent post-match

reductions in the explosive performances were similar to those reported for adult male (29) and young male soccer players (46). Jumping performance is positively linked to both of two key phases of the muscles` behavior: the force development for braking and the accelerating actions (32). Thus, the different acute effects on jumping performance can be explained by the greater amount of HIE demanded during GPBT (Table 1), which increased the number of braking and accelerating phases. Moreover, the ability to brake and accelerate may suddenly require a high rate of horizontal force development, which seems to be transferable on a vertical axis (15,16). Indeed, the reduced performances following the GPBT regimen could have been induced by the inhibition or limitation of common neuromuscular characteristics (e.g., stretch reflex and the storage of elastic energy) that occur in the stretch shortening cycle of the muscle involved during explosive activities such as jumping or sprinting (6).

In conclusion, the current study confirms that the movement patterns of official matches in youth competitions are similar to those of adult players but differ greatly in relative time and distances covered at high intensities. In addition, in light of the acute physical, physiological and biomechanical responses associated with the GPBT, it is proposed that this training protocol, when properly designed and regularly planned in the soccer training agenda, may induce specific adaptations and transference effects in enhancing consequent performance outcomes. Therefore, it might be interesting to design further studies with the aim to obtain clearer evidence of the optimal training dose (i.e., volume, density and intensity) and training regimens (i.e., number and typology of constrains) of GPBT required for achieving effective physical and physiological adaptations.

PRACTICAL APPLICATIONS

In summary, the main findings from the present study are that the total distance, distances run at high speed, acceleration and deceleration, and high metabolic power responses were greater in the GPBT in comparison with official games, in young soccer players. Furthermore, the experimental format resulted in greater impairments of explosive neuromuscular capabilities, due to the greater amount of high intensity efforts. Thus, in accordance with the concept of training specificity and in light of these outcomes, the GPBT protocol could be considered as an advantageous training method capable of inducing acute effects on certain physical abilities of elite soccer players. Coaches and athletes are encouraged to integrate this conditioning methodology into the planning of their regular soccer training, given that the GPBT may be used as a specific training method for attempting long-term adaptations according to the specific discipline, the performance model, and sport-related playing demands. From a methodological perspective, the accurate periodization of GPBT into the training schedule should require one or more weekly training sessions of different volumes and intensities according to the current and specific phase of the season. In addition, the planned modifications of the GPBT protocol contents, such as locomotor activities at different paces, number of high intensity efforts like sprints over variable distances, COD performed with different directional angles and specific technical demands, should limit the risk of getting a ceiling effect of performing the same exercise over time and, in turn, would likely lead to long-term specific performance development of elite young players.

References

1. Abade, EA, Goncalves, BV, Leite, NM, and Sampaio, JE. Time-motion and physiological profile of football training sessions performed by under-15, under-17 and under-19 elite Portuguese players. *Int J Sports Physiol Perform* 9: 463-470, 2014.
2. Aguiar, MV, Botelho, GM, Goncalves, BS, and Sampaio, JE. Physiological responses and activity profiles of football small-sided games. *J Strength Cond Res* 27: 1287-1294, 2013.
3. Aslan, A, Acikada, C, Guvenc, A, Goren, H, Hazir, T, and Ozkara, A. Metabolic demands of match performance in young soccer players. *J Sports Sci Med* 11: 170-179, 2012.
4. Bangsbo, J, Norregaard, L, and Thorso, F. Activity profile of competition soccer. *Can J Sport Sci* 16: 110-116, 1991.
5. Barbero-Alvarez, JC, Coutts, A, Granda, J, Barbero-Alvarez, V, and Castagna, C. The validity and reliability of a global positioning satellite system device to assess speed and repeated sprint ability (RSA) in athletes. *J Sci Med Sport* 13: 232-235, 2010.
6. Bosco, C, Luhtanen, P, and Komi, PV. A simple method for measurement of mechanical power in jumping. *Eur J Appl Physiol Occup Physiol* 50: 273-282, 1983.
7. Bradley, PS, Carling, C, Gomez, DA, Hood, P, Barnes, C, Ade, J, Boddy, M, Krustup, P, and Mohr, M. Match performance and physical capacity of players in the top three competitive standards of English professional soccer. *Hum Mov Sci* 32: 808-821, 2013.
8. Brughelli, M, Cronin, J, Levin, G, and Chaouachi, A. Understanding change of direction ability in sport: a review of resistance training studies. *Sports Med* 38: 1045-1063, 2008.
9. Buchheit, M, Mendez-Villanueva, A, Simpson, BM, and Bourdon, PC. Match running performance and fitness in youth soccer. *Int J Sports Med* 31: 818-825, 2010.
10. Carling, C. Interpreting physical performance in professional soccer match-play: should we be more pragmatic in our approach? *Sports Med* 43: 655-663, 2013.
11. Carling, C, Le, GF, and Dupont, G. Analysis of repeated high-intensity running performance in professional soccer. *J Sports Sci* 30: 325-336, 2012.

12. Castagna, C, D'Ottavio, S, and Abt, G. Activity profile of young soccer players during actual match play. *J Strength Cond Res* 17: 775-780, 2003.
13. Dellal, A, Chamari, K, Wong, DP, Ahmaidi, S, Keller, D, Barros, MLR, Bisciotti, GN, and Carling, C. Comparison of physical and technical performance in European professional soccer match-play: The FA Premier League and La LIGA. *Eur J Sport Sci* 11: 51-59, 2011.
14. Dellal, A, Varliette, C, Owen, A, Chirico, EN, and Pialoux, V. Small-sided games versus interval training in amateur soccer players: effects on the aerobic capacity and the ability to perform intermittent exercises with changes of direction. *J Strength Cond Res* 26: 2712-2720, 2012.
15. Dello Iacono, A, Martone, D, and Padulo, J. Acute effects of drop-jump protocols on explosive performances of elite handball players. *J Strength Cond Res*, 2016. [Epub ahead of print]
16. Dello Iacono, A, Martone, D, Milic, M, and Padulo, J. Vertical- vs. horizontal-oriented drop-jump training: chronic effects on explosive performances of elite handball players. *J Strength Cond Res*, 2016. [Epub ahead of print]
17. Dupont, G, Blondel, N, and Berthoin, S. Performance for short intermittent runs: active recovery vs. passive recovery. *Eur J Appl Physiol* 89: 548-554, 2003.
18. Faude, O, Koch, T, and Meyer, T. Straight sprinting is the most frequent action in goal situations in professional football. *J Sports Sci* 30: 625-631, 2012.
19. Foster, C, Florhaug, JA, Franklin, J, Gottschall, L, Hrovatin, LA, Parker, S, Doleshal, P, and Dodge, C. A new approach to monitoring exercise training. *J Strength Cond Res* 15: 109-115, 2001.
20. Gathercole, RJ, Sporer, BC, Stellingwerff, T, and Sleivert, GG. Comparison of the Capacity of Different Jump and Sprint Field Tests to Detect Neuromuscular Fatigue. *J Strength Cond Res* 29: 2522-2531, 2015.
21. Gaudino, P, Iaia, FM, Strudwick, AJ, Hawkins, RD, Alberti, G, Atkinson, G, and Gregson, W. Factors influencing perception of effort (session rating of perceived exertion) during elite soccer training. *Int J Sports Physiol Perform* 10: 860-864, 2015.
22. Gharbi, A, Chamari, K, Kallel, A, Ahmaidi, S, Tabka, Z, and Abdelkarim, Z. Lactate kinetics after intermittent and continuous exercise training. *J Sports Sci Med* 7: 279-285, 2008.
23. Haseler, LJ, Hogan, MC, and Richardson, RS. Skeletal muscle phosphocreatine recovery in exercise-trained humans is dependent on O₂ availability. *J Appl Physiol (1985)* 86: 2013-2018, 1999.

24. Helgerud, J, Engen, LC, Wisloff, U, and Hoff, J. Aerobic endurance training improves soccer performance. *Med Sci Sports Exerc* 33: 1925-1931, 2001.
25. Hill-Haas, SV, Dawson, B, Impellizzeri, FM, and Coutts, AJ. Physiology of small-sided games training in football: a systematic review. *Sports Med* 41: 199-220, 2011.
26. Hoff, J, Wisloff, U, Engen, LC, Kemi, OJ, and Helgerud, J. Soccer specific aerobic endurance training. *Br J Sports Med* 36: 218-221, 2002.
27. Hopkins, WG Measures of reliability in sports medicine and science. *Sports Med* 30: 1-15, 2000.
28. Impellizzeri, FM, Rampinini, E, Coutts, AJ, Sassi, A, and Marcora, SM. Use of RPE-based training load in soccer. *Med Sci Sports Exerc* 36: 1042-1047, 2004.
29. Ispirlidis, I, Fatouros, IG, Jamurtas, AZ, Nikolaidis, MG, Michailidis, I, Douroudos, I, Margonis, K, Chatzinikolaou, A, Kalistratos, E, Katrabasas, I, Alexiou, V, and Taxildaris, K. Time-course of changes in inflammatory and performance responses following a soccer game. *Clin J Sport Med* 18: 423-431, 2008.
30. Koklu, Y, Arslan, Y, Alemdaroglu, U, and Duffield, R. Accuracy and reliability of SPI ProX global positioning system devices for measuring movement demands of team sports. *J Sports Med Phys Fitness* 55: 471-477, 2015.
31. Krustup, P, Mohr, M, Amstrup, T, Rysgaard, T, Johansen, J, Steensberg, A, Pedersen, PK, and Bangsbo, J. The yo-yo intermittent recovery test: physiological response, reliability, and validity. *Med Sci Sports Exerc* 35: 697-705, 2003.
32. Laffaye, G, Wagner, PP, and Tombleson, TI. Countermovement jump height: gender and sport-specific differences in the force-time variables. *J Strength Cond Res* 28: 1096-1105, 2014.
33. Maddison, R, and Ni, MC. Global positioning system: a new opportunity in physical activity measurement. *Int J Behav Nutr Phys Act* 6: 73, 2009.
34. McMillan, K, Helgerud, J, Macdonald, R, and Hoff, J. Physiological adaptations to soccer specific endurance training in professional youth soccer players. *Br J Sports Med* 39: 273-277, 2005.
35. Osgnach, C, Poser, S, Bernardini, R, Rinaldo, R, and di Prampero, PE. Energy cost and metabolic power in elite soccer: a new match analysis approach. *Med Sci Sports Exerc* 42: 170-178, 2010.
36. Pereira Da, SN, Kirkendall, DT, and Leite De Barros, NT. Movement patterns in elite Brazilian youth soccer. *J Sports Med Phys Fitness* 47: 270-275, 2007.

37. Rampinini, E, Bishop, D, Marcora, SM, Ferrari, BD, Sassi, R, and Impellizzeri, FM. Validity of simple field tests as indicators of match-related physical performance in top-level professional soccer players. *Int J Sports Med* 28: 228-235, 2007.
38. Saltin, B Metabolic fundamentals in exercise. *Med Sci Sports* 5: 137-146, 1973.
39. Saward, C, Morris, JG, Nevill, ME, Nevill, AM, and Sunderland, C. Longitudinal development of match-running performance in elite male youth soccer players. *Scand J Med Sci Sports* 26: 933-942, 2016.
40. Schimpchen, J, Skorski, S, Nopp, S, and Meyer, T. Are "classical" tests of repeated-sprint ability in football externally valid? A new approach to determine in-game sprinting behaviour in elite football players. *J Sports Sci* 34: 519-526, 2016.
41. Scott, MT, Scott, TJ, and Kelly, VG. The Validity and Reliability of Global Positioning Systems in Team Sport: A Brief Review. *J Strength Cond Res* 30: 1470-1490, 2016.
42. Stolen, T, Chamari, K, Castagna, C, and Wisloff, U. Physiology of soccer: an update. *Sports Med* 35: 501-536, 2005.
43. Suarez-Arrones, L, Torreno, N, Requena, B, Saez, d, V, Casamichana, D, Barbero-Alvarez, JC, and Munguia-Izquierdo, D. Match-play activity profile in professional soccer players during official games and the relationship between external and internal load. *J Sports Med Phys Fitness* 55: 1417-1422, 2015.
44. Tabata, I, Irisawa, K, Kouzaki, M, Nishimura, K, Ogita, F, and Miyachi, M. Metabolic profile of high intensity intermittent exercises. *Med Sci Sports Exerc* 29: 390-395, 1997.
45. Taylor, KL, Cronin, J, Gill, ND, Chapman, DW, and Sheppard, J. Sources of variability in iso-inertial jump assessments. *Int J Sports Physiol Perform* 5: 546-558, 2010.
46. Thorlund, JB, Aagaard, P, and Madsen, K. Rapid muscle force capacity changes after soccer match play. *Int J Sports Med* 30: 273-278, 2009.
47. Tonnessen, E, Hem, E, Leirstein, S, Haugen, T, and Seiler, S. Maximal aerobic power characteristics of male professional soccer players, 1989-2012. *Int J Sports Physiol Perform* 8: 323-329, 2013.
48. Torreno, N, Munguia-Izquierdo, D, Coutts, A, de Villarreal, ES, sian-Clemente, J, and Suarez-Arrones, L. Relationship Between External and Internal Load of Professional Soccer Players During Full-Matches in Official Games Using GPS and Heart Rate Technology. *Int J Sports Physiol Perform* 1-22, 2016.

49. Torres-Ronda, L, Goncalves, B, Marcelino, R, Torrents, C, Vicente, E, and Sampaio, J. Heart Rate, Time-Motion, and Body Impacts When Changing the Number of Teammates and Opponents in Soccer Small-Sided Games. *J Strength Cond Res* 29: 2723-2730, 2015.
50. Varley, MC, Fairweather, IH, and Aughey, RJ. Validity and reliability of GPS for measuring instantaneous velocity during acceleration, deceleration, and constant motion. *J Sports Sci* 30: 121-127, 2012.
51. Vigne, G, Gaudino, C, Rogowski, I, Alloatti, G, and Hautier, C. Activity profile in elite Italian soccer team. *Int J Sports Med* 31: 304-310, 2010.
52. Weir, JP Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *J Strength Cond Res* 19: 231-240, 2005.

Figure Legends**Figure 1.** GPBT protocol setup.