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# The effect of pitch size manipulation during small sided-games performed by different age category football players: a pilot study

Mário C. Espada[1,2,3,*], José M. Gamonales[4,5,6], Carlos E.L. Verardi[7,8], Dalton M. Pessôa Filho[7,9], Cátia C. Ferreira[1,4], Ricardo A.M. Robalo[1,10], Amândio A.P. Dias[11], Víctor Hernández-Beltrán[4], Fernando J. Santos[1,2,10]

[1]Escola Superior de Educação, Instituto Politécnico de Setúbal, 2914-504 Setúbal, Portugal
[2]Life Quality Research Centre (CIEQV-Leiria), 2040-413 Rio Maior, Portugal
[3]CIPER, Faculdade de Motricidade Humana, Universidade de Lisboa, 1499-002 Lisboa, Portugal
[4]Optimization of Training and Sports Performance Research Group, Faculty of Sport Science, University of Extremadura, 10005 Cáceres, Spain
[5]Faculty of Health Sciences, University of Francisco de Vitoria, 28223 Madrid, Spain
[6]Doctoral Program in Education & Technology, Universidad a Distancia de Madrid, 28400 Madrid, Spain
[7]Department of Physical Education, São Paulo State University (UNESP), 17033-360 Bauru, SP, Brazil
[8]Graduate Program in Developmental Psychology and Learning, Faculty of Science, São Paulo State University (UNESP), 17033-360 Bauru, SP, Brazil
[9]Graduate Program in Human Development and Technology, Institute of Bioscience, São Paulo State University (UNESP), 13506-900 Rio Claro, SP, Brazil
[10]Faculdade de Motricidade Humana, Universidade de Lisboa, 1499-002 Lisboa, Portugal
[11]Egas Moniz Center for Interdisciplinary Research (CiiEM); Egas Moniz School of Health & Science, 2829-511 Caparica, Portugal

***Correspondence**
mario.espada@ese.ips.pt
(Mário C. Espada)

**Abstract**

This research aimed to analyse the pitch size manipulation effect on internal and external load and to study the age effect on the studied variables in different small-sided games (SSGs) formats. Male U-12 (n = 8), U-15 (n = 8) youth football players, and U-23 (n = 8) professional cohorts participated in the study. Two SSGs formats were analyzed, goalkeeper (GK) + 4 *vs.* 4 + GK, 3 minutes play in 20 × 30 m and 24 × 36 m, with 3 minutes rest between bouts. The variance analysis Anova two-way was used to analyse two independent factors, pitch size, and age group. The playing area manipulation had an effect under the following variables: distance ($p < 0.001$), speed 0–6 km/h ($p < 0.001$), speed 12–18 km/h ($p < 0.001$), speed 18–21 km/h ($p < 0.001$), accelerations (Ac.) 1–2 m/s$^2$ ($p < 0.001$), decelerations (Dc.) 2–3 m/s$^2$ ($p < 0.001$), metabolic power (Pmet) ($p < 0.001$) and high metabolic load distance (HMLD) ($p < 0.001$). The age group influenced the distance covered ($p < 0.001$), speed 0–6 km/h ($p < 0.001$), speed 6–12 km/h ($p < 0.001$), speed 12–18 km/h ($p < 0.001$), speed 21–24 km/h ($p = 0.030$), Ac. 1–2 m/s$^2$ ($p < 0.001$), Ac. 1–2 m/s$^2$ ($p < 0.001$Pmet ($p < 0.001$), HMLD ($p < 0.001$) and training impulse (TRIMP) ($p < 0.001$). Playing area manipulation in football SSGs promotes an increase in external load intensity, namely, larger areas are suitable for larger effects at high speeds (>21 km/h) and TRIMP. A careful and detailed evaluation of training tasks, considering the different age category football players, is important to optimize the planning in football, aiming at improving players' condition and performance and avoiding health problems and injuries.

**Keywords**

Reduced games; Global positioning system; Training; Internal load; External load

## 1. Introduction

The search for higher quality sports training sessions, associated with avoiding any kind of healthcare issues such as injury or illness, is a goal of clubs and coaches aiming at the development of well-prepared players. Football is a team sport of great technical-tactical complexity characterized by moments associated with high running and execution speed, that in many circumstances decide the result of the game [1]. Due to the different rhythms adopted by the players in synergy with the moments of the game of football, the metabolic processes tend to be broad and complex [2, 3], in a sport that has become worldwide popular, resulting in an increase in the number of season competitions and games involving highly prepared and specialized players [4]. This evidence observed in the game is relevant and related with the need of deepening the knowledge about training tasks that promote the ideal stimulation according to the age of the football players [3].

Training monitoring is critical for football coaches to prescribe and quantify training load, as well as analyzed the effects on players [5, 6] since they play a key role, namely in designing training sessions [7, 8]. The internal load is related to the physiological and psychological effects resulting from training or competition, measured through heart rate (HR), blood lactate (BLa), oxygen uptake ($VO_2$), rating of perceived exertion (RPE) or training impulse (*e.g.*, TRIMP-Edwards) that monitors the time spent in the different HR zones [9]. Devices with the global positioning system (GPS) and accelerometers allow the analysis of external load measurements (distance, speed, and power, among other performance indicators), which translate the work performed by players in training and competition [9–11]. Therefore, the use of inertial devices is essential to quantify the load of training and matches. A recent review examined variations and evolutionary trends in game-related physical parameters of professional players, highlighting that at the end of the competition period (ECP), increments in the total distance (small), and sprint (moderate) were of substantial magnitude compared to the beginning of the competition phase. The authors added that from the middle to the ECP, the observed increments were of small magnitude in these external load variables [12].

According to the above, having an increasingly better knowledge of the physiological (internal load) and physical (external load) effect on the task constraints manipulation (space, number, rules, presence/absence of goalkeepers, training regimen and trainer incentive) is essential for the coach to properly use the small-sided games (SSGs) in the training process [13]. These are only some examples of manipulation of constraints during football SSGs, another commonly used example is the game objective (goal or ball possession), it all depends on the objective for the training task by the football coaching staff. It was previously suggested that football club structures (chairs, directors, team managers, coaches and others) should consider that regular training monitorization is vital to improve the detection and prevention of injuries and, at the same time, improve sports performance [14], which is related to the evidence that when football players reach the maturation phase and specialize in certain mission-tactical game functions, anthropometric, body composition and physical fitness characteristics become relevant and possibly affect performance in the game [15].

SSGs are exercises that the coach plans for the training session, in which the correct task constraints manipulation allows the achievement of physical, technical and tactical training objectives [10, 11]. From the physical and physiological point of view, to perceive the different variables' response of the principal components of analysis [16], to the application of SSGs, as our study intends to do, it is essential that the coach has a concrete view of the manipulation task constraints and how to manipulate them in the training process.

The task constraint manipulation, namely pitch size, influences physiological effects since the larger playing areas were previously associated with more intensity (HR, BLa, RPE) [17, 18]. Moreover, the HR response significantly increases in the larger playing areas (>100 $m^2$) [19]. The fact that HR increases concomitantly with pitch size is significant in several studies conducted with young football players (<U-23) [20–24]. Furthermore, the time associated with high internal load zones (HR >80%) can be determined using the training impulse (TRIMP-Edwards), a method to quantify training load based on HR and duration of an exercise, which provides an understanding regarding which SSGs formats can promote the desired adaptations and therefore, more precisely plan the sessions training load [25].

Furthermore, regarding the external load, previous studies have found that pitch size influences the workload performed by players in SSGs [17, 18]. The increase in physical requirements with the increase of the playing area in age categories younger than 23 years old, was previously observed in external load variables distance covered [19, 23], distance in high-speed running [19, 22, 23], distance in sprints (>16 km/h) [26], sprints frequency (>18 km/h) [27] and maximal sprint frequency (>25 km/h) [28]. Studies have also shown different results associated with high-intensity accelerations (Ac.) and decelerations (Dc.) (>3 $m/s^2$) with increasing pitch size. Castillo *et al*. [26] observed with U-12 football players that the playing area increase promotes an increase in high-intensity Ac./Dc. However, Casamichana *et al*. [21] verified in players with a mean of 21 years of age, a decrease in high-intensity Ac./Dc. with the increase in pitch size in width and depth.

Considering the reported high-speed running distance and Ac./Dc. [29] it is expected that the value of the high metabolic load distance (HMLD) will be influenced by the increase in the playing area, and age will regulate and condition different effects on the HMLD. Moreover, metabolic power (Pmet) is a useful indicator aiming at the classification of intensity of displacement in team sports [30], this variable was previously observed to increase in line with the increase of the pitch size [31].

In football age categories, studies highlight the influence on physical response of SSGs, more specifically at the level of distance covered, speed and distance covered at high intensity and Ac./Dc. [27, 28, 32]. Regarding the physiological response, Santos *et al*. [33] found small effects of age on HR when comparing U-12 and U-15 players in 4 *vs.* 4 SSGs. Of note, López-Fernández *et al*. [32], on the other hand, found that age (U-14, U-16 and U-18) influenced HR zones in some formats of SSGs (3 *vs.* 3, 4 *vs.* 4, 5 *vs.* 5 and 6 *vs.* 6).

According to the analysis in several recent systematic review studies, we can verify that the studies developed analyzed SSG protocols in certain age groups [10, 11]. Our study, in addition to comparing in each age group the constraints manipulation effects, proposes to add knowledge about the age effect on physical and physiological demands, analyzing other variables of training load control that can give another explanation about the training load intensity in the use of SSGs [34], which have been less used in studies with youth football players. Hence, the aim of our study was to analyze the effect of pitch size manipulation on distance, speed zones, Ac./Dc. zones, HMLD, Pmet and TRIMP in 4 *vs.* 4 outfield players SSGs with goalkeeper (GK) participation and goal objective. We considered the following study hypotheses: (1) There is a positive effect of pitch size on distance, high speed, Ac./Dc., HMLD, Pmet and TRIMP; (2) There is a mixed negative and positive effect of the age category on different internal and external load variables.

## 2. Materials and methods

## 2.1 Participants

A total of 24 male football players of different age categories U-12 (n = 8), U-15 (n = 8) and U-23 (n = 8) participated in this study. These age categories were considered because they represent pre-puberty (U-12), post-puberty (U-15), and mature (U-23) football players [35, 36]. The U-12 and U-15 players were part of a team certified with a 3-star formation entity by the Portuguese Football Federation (the maximum for this age categories). The U-23 players played in a professional football club, certified as a 4-star formation entity (maximum is 5-star). Table 1 presents the participants' characteristics (mean and standard deviation).

The U-15 and U-12 players trained four times a week plus one match every weekend. U-15 football players' training sessions were associated with 90 minutes and U-12 colleagues to 60 minutes. U-12 players competed in the regional championship in football 7 and 9-a-side format, U-15 players competed in the national championship of Portugal and U-23 players competed in the Portugal "Revelation League" (competition format aiming competitive moments for younger players, who in most cases regularly train with club A teams).

About the inclusion criteria associated with the outfield players participating in the SSGs, these were: (1) players without injuries in the last two months; (2) players participation in all training sessions in the last six weeks before data collection; and (3) players participation in the total playing time in the last month of competition prior to data collection. It was also considered the time of affiliation in the club and the years of practice of the football modality. This study considered the Helsinki Declaration ethical standards for research in the sports and exercise sciences scope [37].

## 2.2 Studied variables

WIMU PRO$^{TM}$ (RealTrack Systems, Almeria, Spain) inertial devices were used, for data collection. These devices are Federation International de Football Association (FIFA) certified and have several sensors: four triaxial accelerometers (1000 Hz) with a full-scale output range of $\pm 16$, $\pm 16$, $\pm 32$ and $\pm 400$ g; three triaxial gyroscopes (1000 Hz) with a full-scale output range of 2000 degrees/seconds; a three-dimensional magnetometer; a 10 Hz Global Positioning System (GPS) chip; and a 20 Hz Ultra-wideband (UWB) chip [38]. The system provides high ecological relevance for analysis of real training and match situations related to physical demands [39] and was previously validated in other studies on football [40]. The sampling frequency for data collection was 100 Hz in the accelerometer, gyroscope and magnetometer sensors and 10 Hz for GPS [41]. Players used Garmin$^{TM}$ bands (Garmin Ltd., Olathe, KS, United States) for HR evaluation, this wearable technology emits data to WIMU devices, using Advanced and Adaptive Network Technology (ANT)+ technology.

The dependent variables assessed in this study were: Distance (meters)—total covered meters. Speed (km/h)—distance covered at different intensities (0–6 km/h; 6–12 km/h; 12–18 km/h; 18–21 km/h; 21–24 km/h and >24 km/h). The Ac. (m/s$^2$)—distance covered (meters) in different Ac. zones (0–1, 1–2, 2–3, >3 m/s$^2$). Also Dc. (m/s$^2$)—distance covered (meters) in different Dc. zones (0–1, 1–2, 2–3, >3 m/s$^2$). The defined speed, Ac. and Dc. intervals result from the outputs of the WIMU devices analysis program, SPRO [16]. HMLD (meters)—distance covered when metabolic power is >25.5 W/kg [29]. It is measured considering the distance covered at high speed (>21 km/h) and the distance covered in Ac. and Dc. (>3 m/s$^2$).

The Pmet (W/kg) was determined as the product between the speed (S) and the energy cost (EC) resulting from the inclination and Ac. (Pmet = EC $\times$ S). It is the energy spent by the player per minute per kg [41, 42]. TRIMP (a.u.) was calculated using the Edwards training load method that determines the internal load by measuring the product of the accumulated training duration of five HR zones by a coefficient related to each zone (50 to 60% of HRmax $\times$ 1; 60 to 70% of HRmax $\times$ 2; 70 to 80% of HRmax $\times$ 3; 80 to 90% of HRmax $\times$ 4; and 90–100% of HRmax $\times$ 5). Edwards' TRIMP formula: duration in zone 1 $\times$ 1 + duration in zone 2 $\times$ 2 + duration in zone 3 $\times$ 3 + duration in zone 4 $\times$ 4 + duration in zone 5 $\times$ 5 [9, 43].

## 2.3 Procedures

Players were evaluated in a single session that took place near the end of the 2021–2022 season. The study was developed with players who have time to practice in the modality, being adapted to this type of training task. The training tasks were only repeated once so that there was no influence of fatigue. The data were collected in the most distant training from the previous and subsequent competition journey. In the U-12 age group, with competition on Saturday, Tuesday and in the U-15 and U-23 age group, with competition on Sunday on Wednesday. The games occurred in the afternoon period, with an average temperature of 22 °C and relative humidity of 60%. Twenty-four hours prior to the experimental session, the players were instructed to maintain their habits, which included 8 hours of sleep the night before the data collection session and maintaining the nutritional routine. Throughout the recovery periods in the SSGs players could drink fluids.

One hour before the training session, the football players were informed about WIMU system-related procedures, the devices were previously prepared and identified. GPSs were calibrated and synchronized according to the procedures described by Bastida-Castillo *et al.* [40]: WIMU system was turned on and afterward, we waited 30 seconds and pressed the button to start recording as soon as the system's operating system was started. After these procedures, WIMU devices were placed on WIMU PRO$^{TM}$ sports vests, adjusted to the players' bodies, and located on the back of the upper trunk, as usual in football matches.

Before data collection the players performed a warm-up lasting 25 minutes consisting of 5 minutes of slow running, 12 minutes of specific football technical exercises, followed by 3 minutes of Ac. and speeds in progression. The warm-up ended (5 minutes) with a ball possession game task lasting 5 minutes. SSGs were performed immediately after, 4 *vs.* 4 outfield players SSGs with GK participation and goal objective. SSG 1 was played in 20 $\times$ 30 m (60 m$^2$ per player) and SSG 2 in 24 $\times$ 36 m (86 m$^2$ per player). The methodological procedures are described in Fig. 1.

**TABLE 1. Characterization of the football players.**

| Age category | Age (yr) | Height (m) | Total Body Mass (kg) | Body Fat (%) | Years of Practice |
|---|---|---|---|---|---|
| U-12 | 11.7 ± 0.5 | 1.59 ± 0.09 | 38.8 ± 4.2 | 11.3 ± 2.5 | 5.2 ± 1.9 |
| U-15 | 14.7 ± 0.8 | 1.68 ± 0.05 | 57.3 ± 3.9 | 10.5 ± 2.3 | 7.6 ± 1.3 |
| U-23 | 20.1 ± 1.5 | 1.83 ± 0.04 | 76.1 ± 3.6 | 10.1 ± 2.2 | 13.3 ± 1.5 |

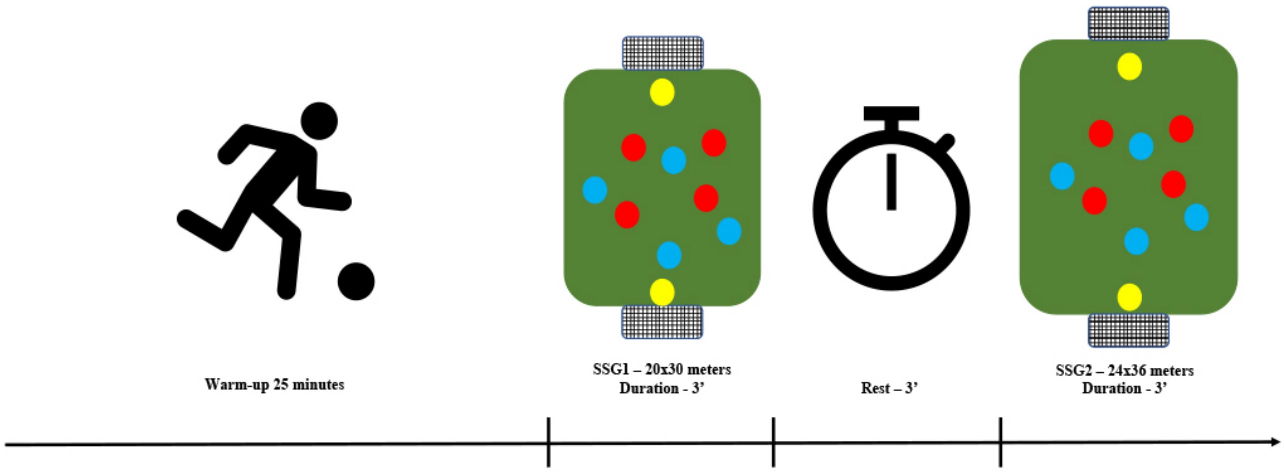


**FIGURE 1. Methodological procedures for data collection.** SSG: small-sided games.

The SSGs teams were randomly constituted, and the definition of specific tactical missions was not considered. The practice of SSGs lasted 3 minutes, with 3 minutes of recovery between bouts. So that there were no time breaks in practice the assistant coaches had balls in their hands so that they were quickly put into play. The coaches issued feedback for encouragement. The rules define that the execution of the sideline throw is done with the foot and that when there is a goal the ball is put into play by the opposing GK. The remaining regulatory management is done according to the football rules.

After SSGs play WIMU devices were collected and placed in the WIMU smart station using PC mode. Individual files were downloaded and later analysed with WIMU SPRO (WIMU SPRO, Almería, Spain).

## 2.4 Statistical analysis

Data analysis was performed through descriptive analysis—Mean (M) and Standard Deviation (SD). The sample size estimation was calculated using G*power (v.3.1.9, University of Kiel, Kiel, SH, Germany), with a statistical power of 50% and an error probability of 0.05, associated with 18 subjects. The normality of the distribution was evaluated with the Shapiro-Wilk test. The variance analysis ANOVA two-way was used to analyse two independent factors, pitch size and age group, considering a significance degree of $p < 0.05$. Age category differences were evaluated with the Bonferroni *post hoc* test. The effect size (ES) was determined by calculating the eta-square (Small—<0.06), Moderate (≥0.06 and <0.15), or Large (≥0.15) [44, 45]. The statistical procedures were performed using SPSS 26.0® (SPSS. Inc., Chicago, IL, USA) and Microsoft Excel software (v.16.78, Microsoft, Redmond, WA, USA.

## 3. Results

Table 2 shows the effects of the independent factors, pitch size and age group, under the variables dependent on the internal and external load. It is possible to verify that the playing area had a large effect under the variables distance ($p < 0.001$; ES = 0.30), speed 0–6 km/h ($p < 0.001$; ES = 0.22), speed 12–18 km/h ($p < 0.001$; ES = 0.42), speed 18–21 km/h ($p < 0.001$; ES = 0.20), Ac. 1–2 m/s$^2$ ($p < 0.001$; ES = 0.17), Dc. 2–3 m/s$^2$ ($p < 0.001$; ES = 0.29), Pmet ($p < 0.001$; ES = 0.24) and HMLD ($p < 0.001$; ES = 0.29). At Ac. 2–3 m/s$^2$ the recorded effect was moderate ($p = 0.02$; ES = 0.11).

The effect of the age category on the dependent variables was observed on the distance covered ($p < 0.001$; ES = 0.47; U-12 *vs.* U-15—$p < 0.001$; U-12 *vs.* U-23—$p < 0.001$), speed 0–6 km/h ($p < 0.001$; ES = 0.22; U-12 *vs.* U-23—$p < 0.001$), speed 6–12 km/h ($p < 0.001$; ES = 0.25; U-12 *vs.* U-15—$p < 0.001$; U-12 *vs.* U-23—$p = 0.02$), speed 12–18 km/h ($p < 0.001$; ES = 0.38; U-12 *vs.* U-15—$p < 0.001$), and speed 21–24 km/h ($p = 0.03$; ES = 0.15; U-12 *vs.* U-15—$p = 0.03$). Fig. 2 highlights the internal and external load in different age-categories football players during the different format SSGs.

Also, differences were observed in Ac. 1–2 m/s$^2$ ($p < 0.001$; ES = 0.18; U-12 *vs.* U-15—$p = 0.01$), Dec. 1–2 m/s$^2$ ($p < 0.001$; ES = 0.22; U-12 *vs.* U-15—$p < 0.001$), Pmet ($p < 0.001$; ES = 0.47; U-12 *vs.* U-15—$p < 0.001$; U-12 *vs.* U-23—$p < 0.001$), HMLD ($p < 0.001$; ES = 0.35; U-12 *vs.* U-15—$p < 0.001$; U-12 *vs.* U-23—$p < 0.001$) and TRIMP ($p < 0.001$; ES = 0.26; U-12 *vs.* U-23—$p < 0.001$).

**TABLE 2. Analysis of variance for the factors pitch size and age group.**

| | U-12 | | U-15 | | U-23 | | ANOVA two-way | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Pitch size | | Age category | |
| Variables | SSG1 | SSG2 | SSG1 | SSG2 | SSG1 | SSG2 | *p* | ES | *p* | ES |
| Distance (m) | 274.20 ± 12.06 | 308.45 ± 33.60 | 328.91 ± 35.26 | 368.78 ± 23.59 | 321.47 ± 26.73 | 352.09 ± 31.61 | <0.001 | 0.30 | <0.001*§ | 0.47 |
| Speed 0–6 km/h | 124.67 ± 6.86 | 116.26 ± 11.26 | 116.95 ± 11.84 | 95.31 ± 11.44 | 115.73 ± 13.95 | 108.98 ± 15.88 | <0.001 | 0.22 | <0.001§ | 0.22 |
| Speed 6–12 km/h | 119.88 ± 14.53 | 124.45 ± 22.05 | 137.39 ± 27.81 | 167.23 ± 22.79 | 149.38 ± 33.86 | 145.75 ± 25.79 | 0.17 | 0.04 | <0.001*§ | 0.25 |
| Speed 12–18 km/h | 27.20 ± 10.15 | 60.94 ± 21.66 | 62.49 ± 18.08 | 90.88 ± 16.74 | 51.93 ± 24.66 | 79.01 ± 18.37 | <0.001 | 0.42 | <0.001* | 0.38 |
| Speed 18–21 km/h | 2.21 ± 2.58 | 6.35 ± 7.28 | 6.53 ± 5.13 | 11.91 ± 11.70 | 3.27 ± 2.77 | 14.00 ± 8.57 | <0.001 | 0.20 | 0.11 | 0.10 |
| Speed 21–24 km/h | 0.00 ± 0.00 | 0.49 ± 1.39 | 3.35 ± 2.89 | 3.44 ± 4.77 | 1.15 ± 1.97 | 3.99 ± 5.83 | 0.26 | 0.03 | 0.03* | 0.15 |
| Speed >24 km/h | 0.00 ± 0.00 | 0.00 ± 0.00 | 2.24 ± 4.40 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.19 ± 0.50 | 0.21 | 0.03 | 0.18 | 0.08 |
| Ac. 0–1 $m/s^2$ | 44.71 ± 7.33 | 47.63 ± 13.94 | 47.22 ± 10.25 | 52.41 ± 15.31 | 41.25 ± 7.82 | 51.90 ± 10.63 | 0.06 | 0.08 | 0.61 | 0.02 |
| Ac. 1–2 $m/s^2$ | 47.56 ± 10.70 | 60.32 ± 13.39 | 60.66 ± 10.40 | 75.07 ± 16.87 | 56.32 ± 12.73 | 61.15 ± 11.92 | <0.001 | 0.17 | 0.01* | 0.18 |
| Ac. 2–3 $m/s^2$ | 37.77 ± 11.81 | 43.47 ± 12.07 | 40.41 ± 11.06 | 54.86 ± 11.06 | 45.33 ± 9.50 | 51.18 ± 7.97 | 0.02 | 0.11 | 0.20 | 0.07 |
| Ac. >3 $m/s^2$ | 12.60 ± 10.00 | 10.26 ± 9.24 | 22.00 ± 14.19 | 13.33 ± 14.19 | 19.85 ± 6.45 | 17.50 ± 5.66 | 0.10 | 0.06 | 0.06 | 0.12 |
| Dec. 0–1 $m/s^2$ | 44.69 ± 6.73 | 45.61 ± 7.72 | 43.62 ± 8.05 | 40.17 ± 8.90 | 46.52 ± 7.00 | 47.98 ± 10.02 | 0.88 | 0.00 | 0.20 | 0.07 |
| Dec. 1–2 $m/s^2$ | 43.66 ± 6.62 | 43.85 ± 12.96 | 61.77 ± 20.41 | 58.43 ± 11.45 | 53.36 ± 15.46 | 52.85 ± 10.70 | 0.76 | 0.00 | <0.001* | 0.22 |
| Dec. 2–3 $m/s^2$ | 24.62 ± 10.40 | 36.72 ± 14.03 | 30.85 ± 8.72 | 47.94 ± 11.37 | 33.39 ± 6.68 | 43.57 ± 9.10 | <0.001 | 0.29 | 0.05 | 0.13 |
| Dec. >3 $m/s^2$ | 17.84 ± 4.42 | 19.35 ± 10.69 | 20.91 ± 10.30 | 25.41 ± 10.97 | 24.53 ± 9.48 | 23.80 ± 12.30 | 0.55 | 0.00 | 0.26 | 0.06 |
| Pmet (W/kg) | 823.90 ± 44.67 | 906.47 ± 109.69 | 975.31 ± 110.49 | 1093.30 ± 63.02 | 983.46 ± 71.77 | 1065.14 ± 110.20 | <0.001 | 0.24 | <0.001*§ | 0.47 |
| HMLD (>25.5 W/kg) | 44.14 ± 6.29 | 60.68 ± 17.09 | 67.65 ± 18.79 | 84.14 ± 13.95 | 62.21 ± 14.75 | 85.82 ± 19.44 | <0.001 | 0.29 | <0.001*§ | 0.35 |
| TRIMP-Edwards (a.u.) | 11.78 ± 1.35 | 11.54 ± 1.50 | 12.28 ± 1.49 | 12.98 ± 1.18 | 13.44 ± 1.01 | 13.45 ± 1.02 | 0.67 | 0.00 | <0.001§ | 0.26 |

*SSG1: 4 vs. 4 plus GK, 20 × 30 m; SSG2: 4 vs. 4 plus GK, 24 × 36 m. All SSGs with 3 min duration and 3 min rest (ratio 1:1). ES: effect size. Ac.: Accelerations. Dec.: Decelerations. Pmet: Metabolic Power. HMLD: High Metabolic Load Distance. SSG: small-sided games. TRIMP: training impulse. Statistically significant difference considered for $p < 0.05$. *Statistically significant difference between U-12 vs. U-15; §Statistically significant difference between U-12 vs. U-23; a.u.: arbitrary unit; ES: Small (<0.06), Moderate (≥0.06 and <0.15), Large (≥0.15).*

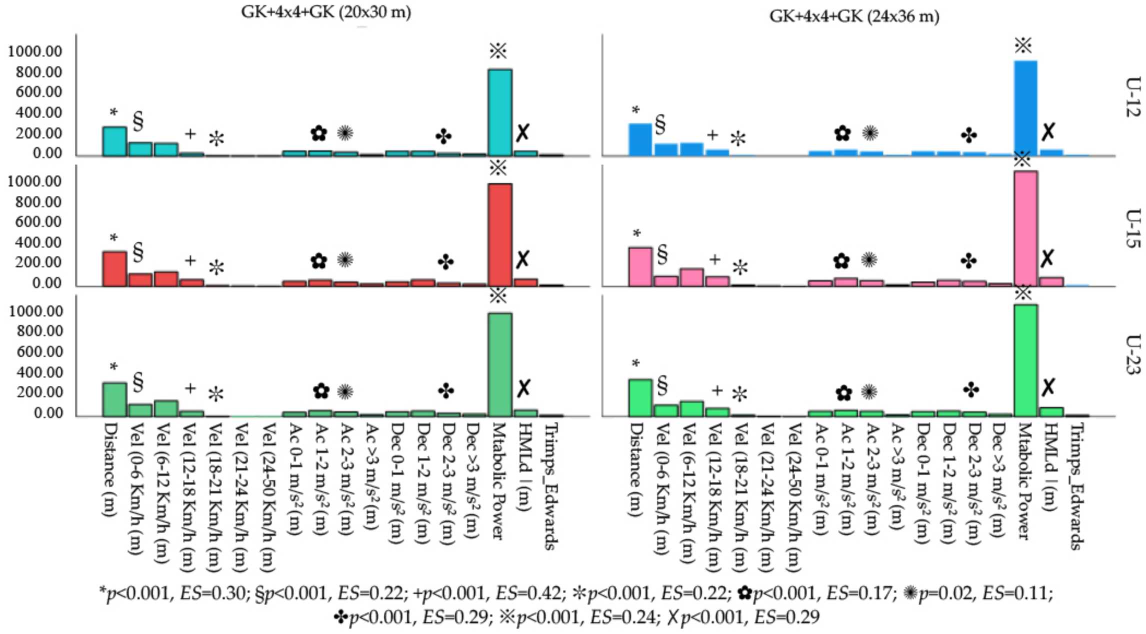


**FIGURE 2. Schematical presentation of internal and external load in different age-category football players associated with different format SSGs.** GK: goalkeeper; Ac: accelerations; Dec: decelerations; HMLD: high metabolic load distance; TRIMP: training impulse.

## 4. Discussion

Lately, there has been an increasing interest in the search for specific training tasks that correspond to the requirements of the competitive moment in football. However, although research has been conducted with an emphasis on SSGs, particularly in team sports, evidence is scarce specifically with regard to different age categories, such as U-12, U-15 and U-23, and to our understanding, the literature remains uncertain about the influence of different SSGs constraints in different age categories. Accordingly, this study aimed to verify the effect of increasing pitch size in GK + 4 *vs.* 4 + GK SSGs on the variable's distances, speed, Ac./Dc., Pmet, HMLD and TRIMP. It was also an objective to verify the effect of age on the studied variables. Therefore, it is necessary to quantify football training and matches in order to know the factors and determinants of sports performance.

The main conclusions to be drawn from the present study are as follows: (1) The increase in the playing area (tone size) promotes effects at the level of external load (distance, speed, Ac./Dc., Pmet and HMLD); (2) It is necessary that the pitch sizes in the SSGs are larger to produce effects at high speeds (>21 km/h) and TRIMP; (3) The age category has influence on the different studied variables of internal and external load.

The first study hypothesis was partially confirmed, one that did not check the pitch size effect on all the variables under study. It was found that the size of the pitch influences the distance covered, speed 0–6 km/h, speed 12–18 km/h, speed 18–21 km/h, Ac. 1–2 $m/s^2$, Ac. 2–3 $m/s^2$, Dc. 2–3 $m/s^2$, Pmet and HMLD. In general, we found that the increase in the playing area promotes the distance covered in the different Dc. zones, and the Dc. >3 $m/s^2$, this increase only occurs in the U-12 and U-15 age categories. For the internal load variable TRIMP, there were no significant differences, considering the increase in the playing area. In the three evaluated age categories, it was possible to verify that the increase in pitch size promotes the increase in distances covered by football players, being more evident in the U-12 and U-15. This may be related to the fact that older players occupy the game space better, trying to restrict the spaces in the defensive process, and progress through the pass in the offensive process.

We can still verify that the distances covered of greater intensity also occur in older players, a fact that accompanied by better game knowledge, is reflected in the attack on spaces through higher speed displacements. This results trend, in which there is a greater effect of the distance covered with the playing area increase, was also observed in studies conducted with U-12 [26], U-15 [27] and U-23 [28]. The tendency to increase the distance covered, with the increase in the playing area was verified in studies conducted at young ages [22, 46], and Beato *et al.* [47] also recently observed when studying small, medium and large-sided games (SSG, MSG and LSG, respectively) in professional football, that some formats were more suitable to load some specific parameters, particularly distance per minute was greater during LSG than SSG and sprinting distance was greater in LSG compared to SSG. The study also found that the number of Ac. and Dc. was higher in MSG compared to SSG and LSG.

The SSGs played in this study did not favors high-speed displacements (>21 km/h). The pitch size increase had large effects on the speed zone 0–6 km/h, 12–18 km/h and 18–21 km/h. The relationship between the playing area increases and the distance covered at high speed is evident, and in the larger areas, the speed of >21 km/h increases [31]. More recently, Nunes *et al.* [27] found that the increase in pitch size in 4 × 4 SSGs promoted a large sprint effect (>18 km/h) in the U-11 age group and a small effect on the Under-15 and U-

23 age categories. Also, with SSGs 4 *vs.* 4, in the U-20 age group, Hodgson *et al.* [23] found that there were no significant differences in high speed, with the increase in playing areas. The game areas used in the study do not allow for reaching the maximum displacement speeds, as evidence previously observed in 7-a-side games (U-12) [48] and 11-a-side (U-15, U-23) [49, 50]. These observations likely demonstrate that larger pitch sizes are required to provide higher speed opportunities.

The Ac. and Dc. are valid indicators of neuromuscular activity [51], and higher intensity (>3 m/s$^2$) was verified in the smaller size format. These results are in line with what has been recorded, *i.e.*, smaller playing areas are promoters of more intense neuromuscular activity [31, 51, 52]. The increase in the game area promoted Ac. <3 m/s$^2$. It should be noted that the increase in the playing area promoted Dc. of greater intensity (>3 m/s$^2$). This demonstrates that the SSG formats studied can be a good training strategy to promote higher intensity Ac./Dc. Therefore, the number of Ac. and Dc. can be determining factors in the injuries of football players. Also, its quantification is necessary to prevent sports injuries.

Regarding Pmet, it is possible to verify that in the three age categories, there was an increase in metabolic power as a result of the increase in the playing area. The Pmet is an indicator that derives from speed and Ac. [41], being a variable that can be considered to quantify exercise intensity [24]. Therefore, we can consider that the pitch size increase promotes an intensity increase in the SSGs practice in these age categories. In line with de findings of Riboli *et al.* [31], we have noticed the speed increase concomitantly with the playing area increase, which in turn is also reflected in the Pmet. However, according to the said for the high-speed zones, the two SSG formats used may not allow the reaching of intensity required in the official game formats, mainly in the U-15 and U-23. Studies have allowed verifying, with players U-12, in a 7-a-sided official game, speed values >18 km/h and maximum speed of 23.2 km/h [48, 53]. In official game formats of 11 × 11, studies recorded maximum speed values between 28.7 km/h and 31.9 km/h for the age groups between U-15 and U-23 [49, 54]. Accordingly, the age and experience of the players seem to directly influence the speed performance in SSGs. Although high-intensity Ac. (>3 m/s$^2$) do not increase with a larger pitch size and high-intensity Dc. (>3 m/s$^2$) increase, the fact is that the different Ac./Dc. zones <3 m/s$^2$ increase with increasing play area.

The distance covered in speed zones >21 km/h influences the values of HMLD [29]. In this study, HMLD increased with the pitch size increase. These observations likely demonstrate that in the three age categories, in the SSG with the largest playing area, there was an increase in the distance covered at speeds >21 km/h. Therefore, one might consider that higher intensities (speed >21 km/h) and HMLD present age effects when considering SSGs in football. Although accelerations >3 m/s$^2$ decrease with increasing pitch size, we have seen an increase in high-intensity Dc. (>3 m/s$^2$). Therefore, it is essential to increase research related to the object of study.

For instance, in TRIMP, the effect sizes caused by pitch size increase were small. TRIMP translates the accumulated training product into five HR zones (50–60%, 60–70%, 70–80%, 80–90% and 90–100% HR) [43], and present data showed that there were no significant changes in HR with the increase of the playing area. Previous studies have revealed that there are significant HR increments in-game areas >100 m$^2$ [18, 19], which may explain the results now obtained. Given that, in our study, the two areas of SSGs are less than 100 m$^2$, there is no significant variability of HR, which is proven in the effect that the pitch size has on TRIMP.

Regarding the second hypothesis, although we verified the influence of age on most dependent variables, the same is not the case at speeds 18–21 km/h, speed >24 km/h, Ac. 0–1 m/s$^2$, Ac. 2–3 m/s$^2$, Dc. 0–1 m/s$^2$ Dc. 2–3 m/s$^2$ and Dc. >3 m/s$^2$. In this way, the second hypothesis is not fully proven. Previous research also indicates that age has a different effect on external and internal load [27, 28, 32, 33]. The results presented can be explained due to the different development stages of the participants in our study, since maturation has a great effect on muscle strength [55], thus influencing neuromuscular activity in SSGs. Another relevant aspect is that, by the game knowledge, older players seek to attack and restrict spaces with greater intensity, promoting greater distances covered at high intensity, implying a higher physiological response [46].

As practical implications of our findings, although it is evident that increasing pitch size promotes external load, we can consider the SSG formats studied suitable for moments in the training process in which the coach wants to promote muscle tension through constant Ac., Dc. and braking. To reach levels of >21 km/h would be necessary to have a larger playing area. This issue will be more relevant considering the physical demands of official games in the formats played by the U-12 [48, 53] and in the competition formats in the age groups above the U-15 [49] and U-18 [56]. It will be necessary to use larger playing areas so that there is a more evident increase in the TRIMP, which may be relevant to achieve the adaptations desired by the coach.

It is important to highlight some limitations of our study, the number of participants in each age category makes it impossible to generalize the results, we suggest that future studies consider increasing the sample size. We also did not measure peak speed growth, an indicator that can be valuable in data interpretation. To verify the variability of the values related to the dependent variables, the evaluated tasks must be repeated and measured on different days. The main limitation of the study is the lack of documentation related to the study object. For this reason, it is recommended to expand the research on football players in different age categories. Future studies should also consider different HR zones to relate TRIMP value. It will also be important to repeat the SSGs, on different days, to verify possible variability in the external and internal load values, because fatigue or learning effects may have influenced players' performance in the second SSG.

## 5. Conclusions

The present study provides important information that football coaches can consider to better address training prescriptions. Increasing the playing area promotes effects at the level of external load (distance, speed, Pmet and HMLD). However, pitch sizes must be larger to produce effects at high speeds

(>21 km/h) and TRIMP. Another aspect that coaches should consider is that these exercise formats promote different effects on internal and external load, depending on the age of the players. A careful evaluation of training tasks is important to optimize the planning in football, aiming at improving players' condition and performance and avoiding health problems and injuries.

## ABBREVIATIONS

Ac., accelerations; BLa, blood lactate; Dc., decelerations; ES, effect size; GK, goalkeeper; GPS, global positioning system; HMLD, high metabolic load distance; HR, heart rate; LSD, large-sided game; M, mean; MSD, medim-sided game; Pmet, metabolic power; RPE, rating of perceived exertion; SD, standard deviation; SSG, small-sided game; TRIMP, training impulse; $VO_2$, oxygen uptake.

## AVAILABILITY OF DATA AND MATERIALS

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

## AUTHOR CONTRIBUTIONS

MCE and FJS—conceptualized the study; MCE, CCF and FJS—devised the methodology; MCE, CELV, DMPF, CCF and FJS—performed the formal analysis; MCE, CELV, DMPF, CCF, RAMR, AAPD and FJS—conducted the investigation; MCE, JMG, CELV, DMPF, CCF, VHB and FJS—wrote and prepared the original draft; MCE, JMG, CELV, DMPF, CCF, RAMR, VHB, AAPD and FJS—reviewed and edited the manuscript; MCE, CCF, RAMR, AAPD and FJS—analyzed the results using the software; JMG, CELV, DMPF and VHB—provided supervision. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

## ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Written informed consents associated with the football players aged 18 or over who participated in the study were obtained, as well as the written informed consents of the parents and guardians of underage players. This study considered the Helsinki and was submitted to the Ethical Committee of the Polytechnic Institute of Leiria (CE/IPLEIRIA/22/2021).

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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