

External and internal loads on soccer players in various organisational forms of small-sided games

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Abstract:

The aim of this study was to identify differences between the external and internal loads on soccer players in small-sided games with different content orientations. We assumed that the way to score a goal (gain a point) significantly affects the movement characteristics and reaction of the circulatory system of players during the games. The research group consisted of 18 players ($n = 18$) from the junior team (age: 16.5 ± 0.21 years, VO_{2max} 56.06 ± 2.84 ml.kg⁻¹.min⁻¹, HR_{max} 196.42 ± 5.31 b.min⁻¹) from the football club in Slovakia who participate in the highest level competitions. Based on the data obtained using sports testers and software from Polar Team PRO, we evaluated the external and internal loads on the monitored players such as the total distance, distance covered during high-intensity run (17 km/h<) and sprint (over 24 km/h<), number of accelerations (2 m.s⁻²<), number of decelerations (2 m.s⁻²<), time spent in HR zones 4 and 5, HR_{max} and HR_{avg} . To determine statistical significance, we used the non-parametric statistical method, i.e., the Kruskal-Wallis H-test. We set the level of statistical significance at the 5% (1%) level. During the games, the HR values ranged from the submaximal to the maximum load intensity zones; however, we did not identify statistically significant differences in the time spent in the HR 4 and 5 bioenergetic zones, max heart rate and average heart rate. The players attained the highest accelerations in SSG3 (30.50 ± 6.19) and overcame the highest decelerations in SSG1 (30.83 ± 4.62); however, there were no significant differences in these indicators in the chosen games. The distance covered at high intensity (17 km/h<) was the largest in SSG1 (91.17 ± 14.72 m) and the smallest in SSG3 (48.83 ± 36.07 m), but not significant. The differences in total distance covered were not statistically significant. The obtained results suggest that the number of high-intensity accelerations and decelerations (2 m.s⁻²<) was not significantly affected by the way of scoring a goal.

Key Words: Football, Small-sided games, Internal load, External load, Acceleration, Deceleration

Introduction

In the systematic training process small-sided games (SSG) have a dominant presence, because if we can correctly determine the variables affecting the external and internal load during these games, such as work and rest ratio, content of the game, dimensions of the playing area, pitch surface, number of players and goal scoring rules, we can develop almost all movement skills by specific means with the exception of maximum running speed (Djaoui et al., 2017) and strength abilities.

Monitoring the training load represent a key component in the optimization and individualization of the systematic training process. External load monitoring includes the analysis of key locomotion variables such as total distance, total distance covered in different speed zones, the number of accelerations and decelerations by using the Global Positioning System (GPS). Internal load monitoring is defined by biological stress factors (physiological and psychological) that affect the athlete during training or a match (Bourdon et al., 2017).

One of the most key parameters to monitor is the decelerations and the meters covered in the sprint because this is where the eccentric forces are the highest and the occurrence of non-contact injuries are the greater level if the load is inadequate (Malone et al., 2017; Malone et al., 2018).

With the help of GPS, it is possible to differentiate the workload of individual players. These differences may be influenced by a lot of factors such as playing level (Mohr et al., 2003; Santos et al., 2021), player function (Bradley & Noakes, 2013) or age (Abade et al., 2014; López-Fernández et al., 2020; Santos et al., 2021). It has been well documented that in high performance sports like in football the maximum benefits are achieved when the training stimuli is similar to competitive demands (Bompa & Carrera, 2015). The intensity of football-specific training drills with the ball can be affected or manipulated by several factors to provide different technical, tactical, physical and physiological responses. These variables are: the number of participating players (Hill-Hass et al., 2009; Clemente et al., 2014; Halouani et al., 2017), size of the football pitch (Castillo et al., 2020; Köklü et al., 2013; Djaoui et al., 2017), encouragement by coach (Rampinini et al., 2007) work and rest ratio (Nagy et al., 2020b), game space configuration (Gantois et al. 2022; Sannicandro et al., 2019), presence of floaters (Lozano et al., 2020; Rábano-Muñoz et al., 2019; Lacomme et al., 2018; Castellano et

al., 2016; Torres-Ronda et al., 2015). However, most studies have chosen SSGs with a goalkeeper in standard goal, and, thus the tactical approach of scoring in SSGs was kept very similar to scoring in real match play. Only few studies have modified the game rules by implementing different sizes of goal and number of goals (Brandes et al., 2017; Clemente et al., 2014) or scoring zones (Halouani et al., 2014). The changes in the tactical approach of scoring goal trigger significant changes in the physiological response, time-motion characteristics and tactical behaviour during SSG (Brandes et al., 2017).

Monitoring and knowing the structure of sports (movement) performance during the match is also crucial when looking for answers to which type of game to choose. On the other hand we look at different types of games mainly from the movement characteristics, but we must remember that they also develop the technical, tactical and psychological components of sports performance also. Optimizing and individualizing the training load have key importance for several reasons. One of them is achieving maximum adaptation to the given stimulus, finding the so-called "sweet spot" in dosage should be neither undertrained nor overtrained, because both phenomena are undesirable and increase the risk of injury. If we can find a suitable dose of load, we can adequately develop the player's movement skills. We know from research that players will spend more time in higher heart rate zones during SSGs with fewer players (Owen et al., 2011; Clemente et al., 2012; Clemente et al., 2014). The number of high intensity accelerations ($3 \text{ m}\cdot\text{s}^{-2}$) is greater in large-sided games. Accelerations at a speed of $2 \text{ m}\cdot\text{s}^{-2} - 3 \text{ m}\cdot\text{s}^{-2}$ occur statistically more significantly in small-sided games (Gaudino et al., 2014). During games with a larger field size, players cover a greater distance at submaximal and maximal intensity (Hodgson et al., 2014; Gaudino et al., 2014; Riboli et al., 2020).

Knowing that the task constraints manipulation could affect the physiological responses and, therefore, the potential beneficial effect for individual and team performance improvement. It is important to know, how different scoring rules: stop-ball, scoring to 2 mini-goals, and shooting on goal with standard size affect the internal and external load, the number of individual technical-tactical actions. Thus, the main aim of the present study was to compare the effects of three different goal (point) scoring rules. The findings could potentially provide valuable and reliable information to coaches for the design of different forms of SSGs as part of their training process.

Material & methods

The research group consisted of 18 players ($n=18$) of the youth team (age: 16.5 ± 0.21 years, $\text{VO}_{2\text{max}}$ $56.06 \pm 2.84 \text{ ml}\cdot\text{min}^{-1}\cdot\text{kg}^{-1}$, HR_{max} $196.42 \pm 5.31 \text{ b}\cdot\text{min}^{-1}$) of the football club from Slovakia who participate in the highest level of competition. Based on the data obtained using sports testers and software from Polar Team PRO where evaluated player locomotor activity, such as total distance covered, total distance covered in high intensity run ($17\text{km}/\text{hod}$), sprint (over $24\text{km}/\text{h}$), number of accelerations ($2 \text{ m}\cdot\text{s}^{-2} <$) and decelerations ($< -2 \text{ m}\cdot\text{s}^{-2}$). Validity and reliability 10Hz GPS was investigated and approved by Johnston et al. (2014), Scott et al. (2016) and Akyildiz et al. (2022). We also monitored internal responses such as HR_{max} , HR_{avg} and time spent in bioenergetic zone 4-5 derived from % of HR_{max} (Table 1) according to Moravec et al. (2007) by using a Polar Team Pro (Kempele, Finland). These indicators are defined as "internal load" according to Bourdon et al. (2017)

To determine statistical significance, we used the non-parametric statistical methods Kruskal-Wallis H-test. We set the level of statistical significance at the 5% (1%) level.

The HR_{max} was calculated by field test from Hipp (2007). During testing players have to run 50 metres in a defined area, which they will be overcoming with various intensity. The test includes 6 repetitions in every single set of run. Players went through 4 sets and in each one of them was the intensity gradually increased to the maximal subjective intensity.

The test included:

Field width run (50 m)

- low-intensity run (warm-up) – $120-130 \text{ b}\cdot\text{min}^{-1}$ – 6 times,
- medium intensity run – $130-150 \text{ b}\cdot\text{min}^{-1}$ – 6 times,
- submaximal intensity run – $150-170 \text{ b}\cdot\text{min}^{-1}$ – 6 times,
- maximal (subjective) intensity run – once.

There was a 30 seconds rest interval between the repetitions and 60 seconds between the sets. According to the maximal heart rate (HR_{max}) we determined 5 load zones. These zones were determined on the basis of level of difficulty, which were defined by percentages of the HR_{max} values.

Table 1 Intensity zones of load according to the heart rate (Moravec et al. 2007)

Zone	% from HR_{max}	Character
Zone 1	50-59%	Very low intensity
Zone 2	60-69%	Low intensity
Zone 3	70-79%	Medium intensity
Zone 4	80-89%	Submaximal intensity
Zone 5	90-100%	Maximal Intensity

Table 2 Variants of small-sided games (NR – Number of repetitions, NS - Number of series)

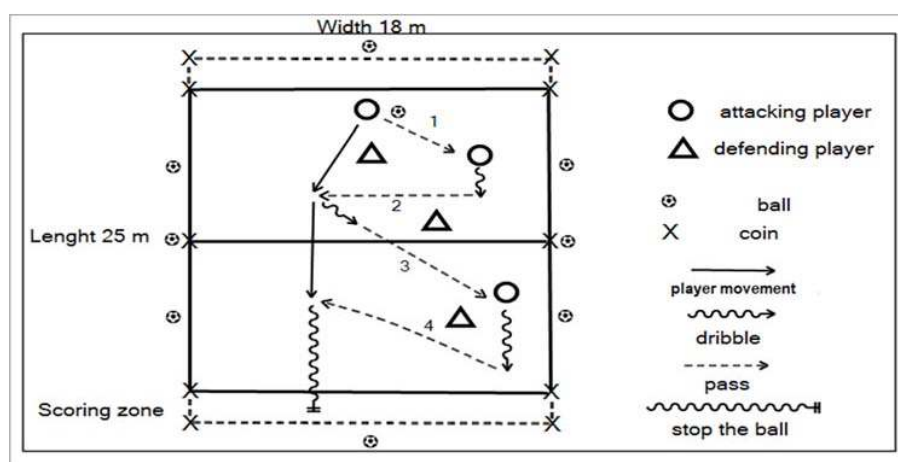
SSG	Players	GK's	Field dimensions		Size of field	Dosing of load				
	(n = 6)	(n = 2)	width [m]	length [m]	[m ²]	Load interval [min.]	Rest interval [min.]	NR	NS	Total Load [min.]
SSG1	3/3	0/0	18	25	450	2	1	6	1	12
SSG2	3/3	0/0	18	25	450	2	1	6	1	12
SSG3	3/3	1/1	18	25	450	2	1	6	1	12

SSG1

Focus: improvement OIGA – ball dribbling

Game description

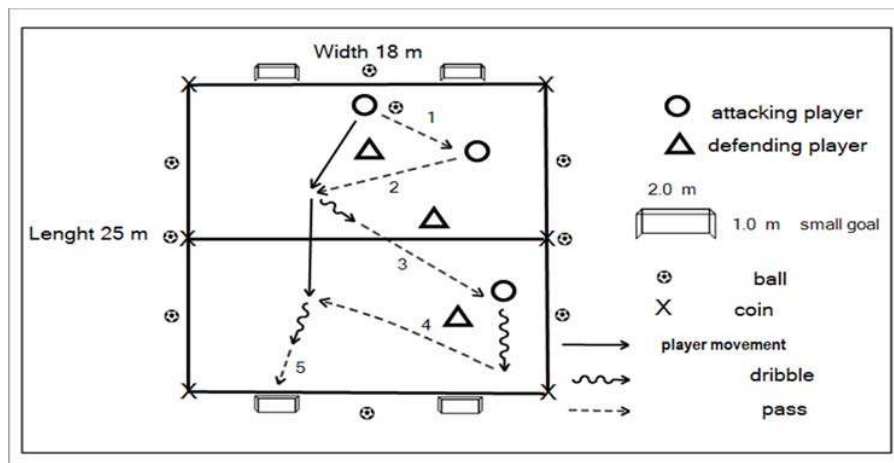
Players played the game in a defined area with an unrestricted number of ball contacts. On both sides of the playing field width was created an area (1 m), into which the players had to move and stop the ball. In this way, they scored a point. If the ball got outside the playing field, then the team put the ball into play from the place, where the ball left the playing field. (Figure 1, Table 2)

**Figure 1** SSG1 – improvement OIGA – ball dribbling**SSG2**

Focus: improvement OIGA – passing

Game description

Players played in a defined area with an unrestricted number of ball contacts. They tried to work adequately with the space, to constantly search for the free areas in order to cooperate with their teammates. The players had to make at least 3 passes between each other, and then they could pass the ball into a small goal (2 x 1 m) and thus score a point. If the ball got outside the playing field, then the team put the ball into play from the place, where the ball left the playing field. (Figure 2, Table 2)

**Figure 2** SSG2 – improvement OIGA – passing

SSG3

Focus: improvement OIGA – shooting

Game description:

Players played the game in a defined area with an unrestricted number of ball contacts. They could pass the ball between themselves six times at most, then had to be the offensive phase of the game finished by shooting on the goal. After scoring the goal, the game started from the goalkeeper, whose team received goal. (Figure 3, Table

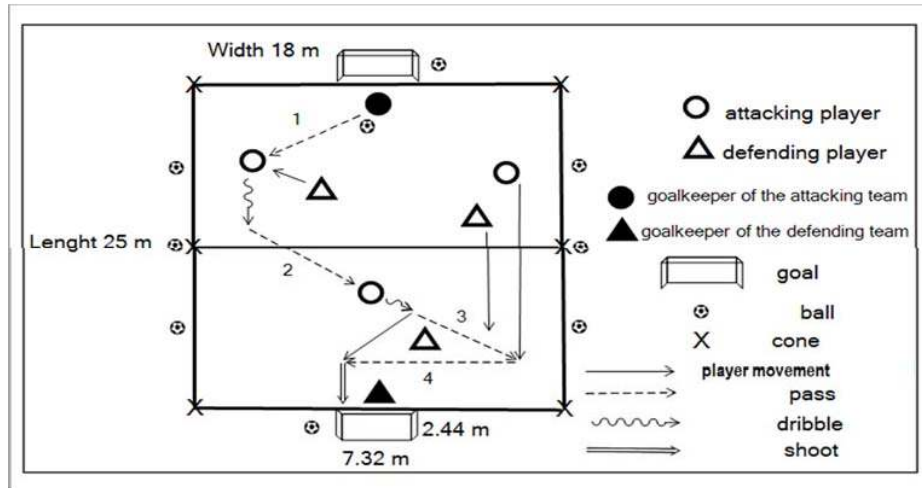


Figure 3 SSG3 improvement OIGA - shooting

Results**Internal load**

In SSG3, players spent the most time in bioenergetic zones 4 and 5 ($13:16 \pm 01:56$ min) ($73.69\% \pm 11.76\%$), further in SSG1 ($12:46 \pm 02:23$ min) which represented $70.93\% \pm 14.50\%$ and least in SSG2 ($12:04 \pm 02:31$ min) ($67.04\% \pm 15.34\%$), the differences were not significant.

We did not show significant differences either in the HR_{max} values, SSG1 (189 ± 5.96 b.min⁻¹), SSG2 (187 ± 4.08 b.min⁻¹) and SSG3 (191 ± 6.62 b.min⁻¹) or in the HR_{avg} , SSG1 (164 ± 5.58 b.min⁻¹), SSG2 (162 ± 5.15 b.min⁻¹), SSG3 (167 ± 8.80 b.min⁻¹). More detailed information can be seen on Figure 4, 5 and 6.

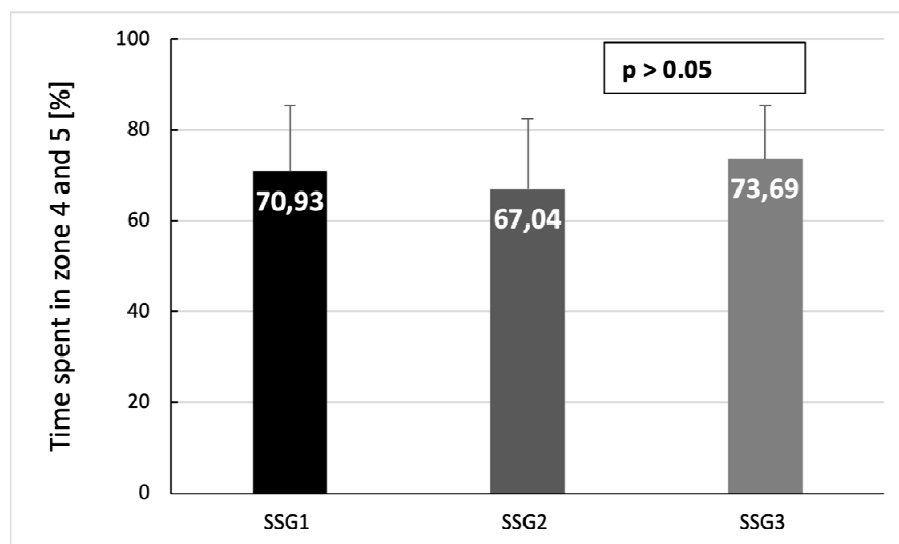


Figure 4 – Time spent in zone 4 and 5 [%] and standard deviation

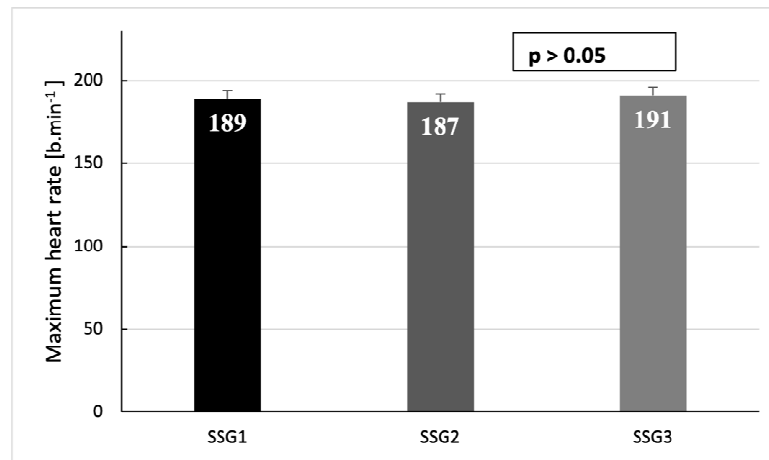


Figure 5 – Maximum heart rate [b.min⁻¹] and standard deviation

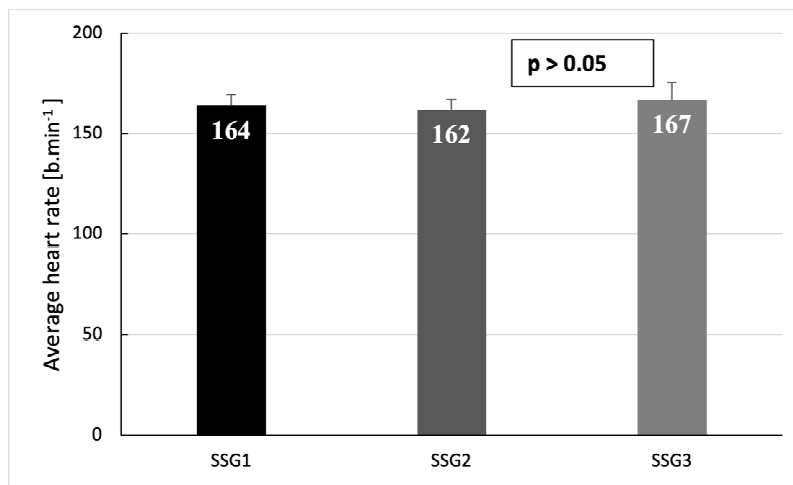


Figure 6- Average heart rate [b.min⁻¹] and standard deviation

External Load

We did not found statistically significant differences in the total distance covered in the games we realized. The greatest total average distance was covered by the players in the game SSG1 (1607m ± 148m), then in SSG3 (1574m ± 110.28m) and the least total average distance was covered by the players in SSG2 (1437m ± 192m). The difference between the largest average distance covered in SSG1 and the smallest in SSG2 is 170m. (Figure 7)

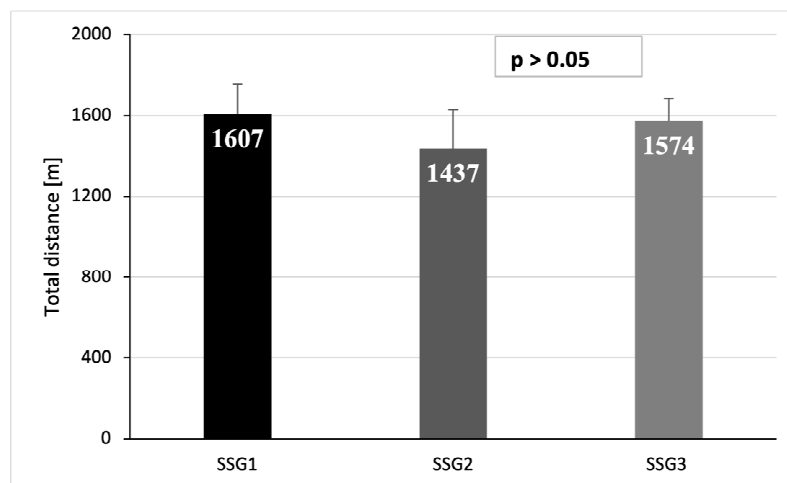


Figure 7 – Total distance [m] and standard deviation

The players covered the most meters in high intensity ($17\text{km/h} <$) in SSG1 ($91.17 \pm 14.72\text{m}$), then in SSG2 ($62.33 \pm 29.17\text{m}$) and the least in SSG3 ($48.83 \pm 36.07\text{m}$). Although the difference between the SSG1 and SSG3 is not statistically significant, it represents a difference of 42.34m on average. (Figure 8)
From the point of view of sprint (over $24\text{km/h} <$) players covered in SSG1 $3\text{m} \pm 3,65\text{m}$, in SSG $1\text{m} \pm 1,12\text{m}$ and in SSG3 $0\text{m} \pm 0,75\text{m}$ ($p > 0,05$).

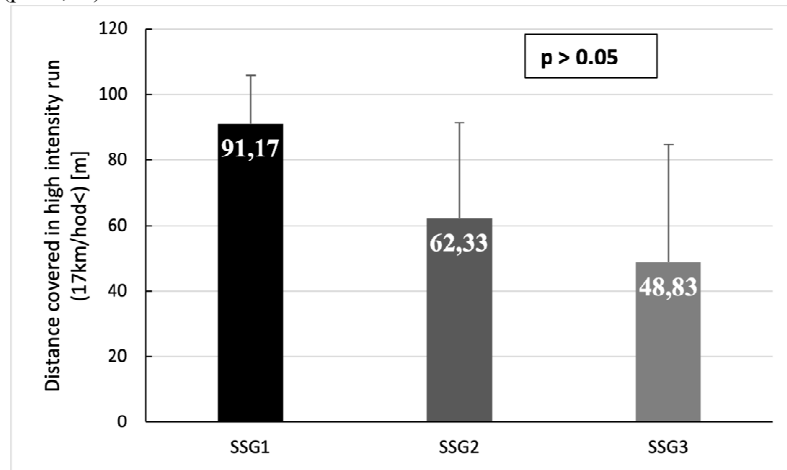


Figure 8 – High intensity run [m] ($17\text{km/hod} <$) and standard deviation

From the point of view of accelerations, the most intense was SSG3, players performed an average of 30.50 accelerations ± 6.19 in this game, followed by SSG1 (30.33 ± 5.72) and SSG2 (27.83 ± 6.59). (Figure 9)

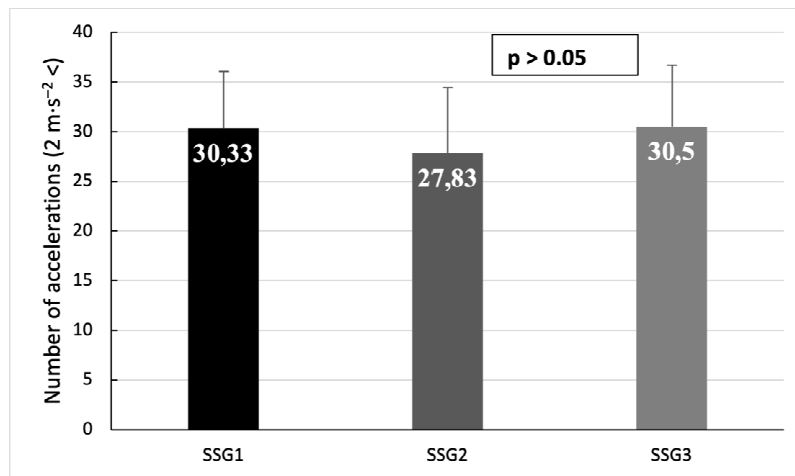


Figure 9 – Number of accelerations ($2\text{ m}\cdot\text{s}^{-2} <$) and standard deviation

In terms of decelerations, the most intense was SSG1, players in this game performed an average of 30.83 decelerations ± 4.62 , followed by SSG3 (28.33 ± 4.32) and SSG2 (25 ± 4). (Figure 10)

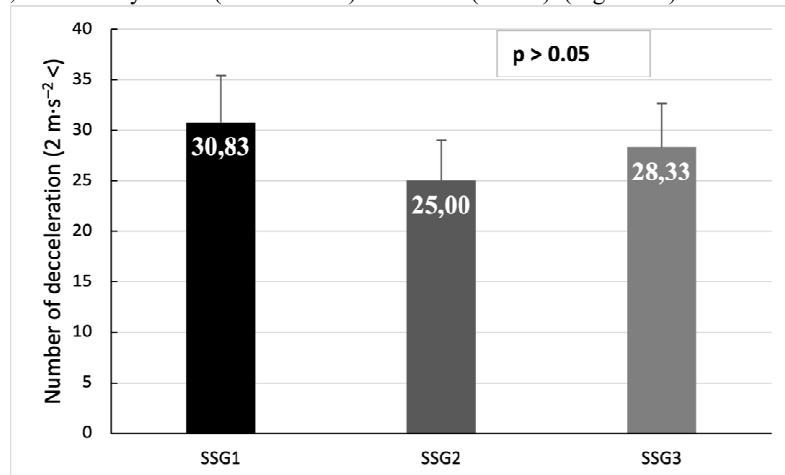


Figure 10 – Number of decelerations ($2\text{ m}\cdot\text{s}^{-2} <$) and standard deviations

Discussion

Rebelo et al. (2011) compared how the focus of the game affects the internal load of the players. During the games with goalkeepers, the time spent in zone 4 and 5 (above 80% of HR_{max}) was significantly higher than in a possession game. However, if we compare SSGs (SSG1, SSG2 and SSG3) with stop the ball rule, passing and shooting, we did not find any significant differences in the time spent in bioenergetic zones 4 and 5, nor differences in HR_{max} and HR_{avg} . Thus, our findings also contradict with the research made by Köklü et al. (2015), who in their work showed a significantly higher load in terms of HR when SSGs were played with the presence of goalkeepers. We think that SSGs with the aim passing the ball or scoring a goal into small goals place a higher demand on movement due to the fact that players have to get closer to the goal/zone than when they have the opportunity to shoot at a standard goal. Also, the compactness of the team or how close individual players are to each other during the offensive and defensive phases of the game can play a role. If we play with two small goals, the players are further apart in the defensive phase than when playing with a standard goal (Castellano et al. 2016). By using this knowledge in practice, it is possible to achieve the planned load from the internal load point of view in SSGs even without the presence of goalkeepers.

(In terms of external load, they found that players cover a greater distance at high intensity (18km/h<) in games with goalkeepers. From this point of view, the researches are not uniform, we can explain it by the fact that different type of games with goalkeepers can induce more motivation in the players and thus influence the training load similarly as presented in the research by Rampinini et al. (2007). However, we think that the players are maximally motivated even during the games without goalkeepers, we will achieve a load similar to that with goalkeepers.

Our measured values do not show significant differences in the distance covered at high intensity (17km/h<) compared to the SSG3 (with goalkeepers) versus SSG1 and SSG2 without the presence of goalkeepers, on the contrary, the players covered the most meters at high intensity in the game without goalkeepers aimed at stop the ball rule. We explain this by the fact that if the players aim to dribble the ball to a predetermined zone, it is connected with the need for a higher movement activity and also with the fact that the players have to overcome a greater distance if they want to reach a point/goal when they do not have the possibility to finishing from different distances.

Gábris (2015) found out that the level of repeated sprint ability (RSA) was not maintained in the second 6-week period when they stopped performing the experimental factor (30m sections performed with maximum effort until the players could no longer maintain the intensity above 90% of 1RM twice in a row). Our findings about the external load in the SSG we implemented partly explain why the RSA level could not be maintained without non-specific training stimuli. If we look at the data on the external load, we can conclude that the SSGs are not mainly about endurance in speed or of anaerobic endurance, because external intensity is only a small percentage at a high level (Djaoui et al., 2017), and it follows that SSGs in terms of fitness development stimulate predominantly aerobic performance with elements of specificity. Here, we would like to point out the importance of an optimal ratio between specific and non-specific training stimuli, because purely through training games (SSGs) we stimulate at least speed endurance (anaerobic endurance) and mainly aerobic performance (specific).

Conclusions

All types of games caused a submaximal to maximum load in terms of HR, but we did not show statistically significant differences in the time spent in the bioenergetic zones 4 and 5. We explain this by the fact that we prepared the individual SSGs in such a way that there was space for each player in each game the same (75m²). From this point of view, it may seem that the space for the player or pitch dimensions may have a greater effect on players' HR response than the focus of SSG.

We did not found differences in the number of accelerations and decelerations during the SSGs what we analyzed, so we can conclude that the size of the field and the number of players participating in a given game can have a greater influence on these two external load variables. We can consider the fact that players in games with a larger size and number of players cover larger distances at high intensity, the focus of the game on dribbling the ball, can also increase the volume of meters covered at high intensity, even if the number of accelerations will be similar to other orientations. Although this finding may seem somewhat paradoxical, because a player with the ball will be slower than without the ball, we explain it by the fact that if the players had the task of dribbling the ball to get a point, the movement activity of the players had to be more intense, more efficient and therefore faster.

Our findings, which talked about the number of meters in the individual speed zones, prove that we mainly develop aerobic performance with elements of specificity through SSGs, but we cannot optimally develop repeated sprint ability or maximum speed through SSGs, because players spent only a tiny percentage in maximum intensity speed zones. Our work suggest that if the game is focused on dribbling the ball and players do not have the opportunity to shoot at the goal, but must dribble the ball to the designated zone, this creates a greater need for more intensive movement activity, but our findings is not statistically significant.

In conclusion, we recommend regular monitoring and evaluation of the training load, with an emphasis on the usability of the obtained data. Quality feedback on players' training load allows us to correct the training load at the end of the training unit with non-specific means for players who have not reached the planned training load. A key parameter in monitoring and evaluating the training load is a person who tries to give meaning to the numbers so that they become usable in the training process and the monitoring does not become just an end in itself.

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