

The mobile learning technique for measuring internal intensity in recreational basketball

Alejandro Sánchez-Lima¹, Miguel Ángel Pérez-Toledano², Santos Villafaina³, Juan Manuel García-Ceberino^{4,5*}

¹ Escuela Municipal de Deportes, 06380 Jerez de los Caballeros, Spain.

² Department of Computer Science, Quercus Software Engineering Group, University of Extremadura, 10003 Cáceres, Spain.

³ Physical Activity and Quality of Life Research Group (AFYCAV), Faculty of Sport Sciences, University of Extremadura, Av. de la Universidad s/n, 10003 Cáceres, Spain.

⁴ Faculty of Education and Psychology, University of Extremadura, Av. de Elvas s/n, 06006 Badajoz, Spain.

⁵ Optimization of Training and Sports Performance Research Group (GOERD), Faculty of Sport Sciences, University of Extremadura, Av. de la Universidad s/n, 10003 Cáceres, Spain.

* Correspondence: Juan Manuel García-Ceberino; jmanuel.jmgc@gmail.com

ABSTRACT

Coaches seek to identify the task constraints that compel players to exert greater effort to enhance performance. This empirical, cross-sectional study, conducted using a single-case manipulative strategy, compared the internal intensities elicited by different tasks (i.e., 1 vs. 1, 2 vs. 2, 3 vs. 3, 4 vs. 4, and 5 vs. 5) in recreational basketball using a mobile learning technique during a session of increasing complexity. In addition, perceived effort was analysed. It involved 59 players (34 boys and 25 girls; mean age = 14.61±1.78 years) from a public institution in the southwest of Spain. Intensities measured included heart rate, monitored via smartphones, and perceived effort, assessed using a pictorial-curvilinear scale. The correlation between both measures of intensities was calculated using Pearson's correlation, revealing positive correlations in the training tasks ($p < 0.05$). Tukey's post hoc test revealed no statistically significant differences ($p > 0.05$) in heart rate between the 3vs.3 in ½ court and 4vs.4 with space repetition compared to the 5vs.5 game. Both tasks should be incorporated in training as they elicited physiological demands similar to those in a competition situation.

KEYWORDS

Constraint; Game Situation; Game Space; Heart Rate; Perceived Effort

1. INTRODUCTION

Physical activity and sport are present in society and hold great importance in the socio-cultural aspects of people's lives. Physical activity encompasses all activities performed throughout the day that involve skeletal movement and, therefore, energy consumption, such as playing, walking, cycling, etc. (World-Health-Organization, 2022).

According to the different classifications of sport (Blázquez & Hernández, 1984; Bouet, 1968; Durand, 1968), basketball is a team sport of cooperation-opposition, played in a common game space and with the simultaneous participation of players. They seek to put the ball into the opposing team's basket, located at a certain height. Moreover, conventional 5vs.5 basketball is an intermittent and dynamic sport, in which movements are performed at different intensities, accompanied by jumps (Mancha-Triguero et al., 2019). Thus, this sport is considered as an intervallic sport: intense efforts and periods of low intensity are combined with efforts of moderate intensity and long recovery periods (Drinkwater et al., 2008). Therefore, knowing the intensities reported by players during competitive matches is relevant for the control of training (Feu et al., 2023; Reina et al., 2020).

According to Staunton et al. (2022), there is an incorrect use of the term “load” in sport and exercise science. This term describes a mechanical variable, which indicates a force, and must be accompanied by the SI-derived unit of the Newton. Therefore, they suggest using the term “intensity” in research and practice. This term has been used in the study. In training or competition, players are subjected to different efforts (external intensities, eTL), which cause controlled fatigue (internal intensities, iTL). The eTL refers to the physical demand experienced by players (Mujika, 2013). Objective eTL includes kinematic (distances covered in meters, accelerations, decelerations, different speed ranges, etc.) and neuromuscular variables (Player Load, etc.), and can be accurately monitored using inertial movement units. Moreover, the Comprehensive System for the Analysis of Training Tasks (SIATE) (Ibáñez et al., 2016) allows for the measurement of subjective eTL. Furthermore, the iTL, the primary variable in this study, refers to the physiological response observed in players as a consequence of the stimulus (eTL) presented by training or competition (Schelling, 2012). Objective physiological instruments include heart rate (HR) measured via HR monitors, lactate levels, and maximal oxygen consumption (Bourdon et al., 2017). Technological advancements also enable HR measurement using smartphones and their applications (Li et al., 2023; Perez-Siguas et al., 2023). Conversely, subjective iTL can be calculated using the Rating of Perceived Exertion (RPE) scale proposed by Borg (1998). Based on the RPE-Borg CR10 scale, Eston and Parfitt (2007) designed a

pictorial-curvilinear scale aimed at children and adolescents. Subjective monitoring of training intensities, particularly the session RPE, is associated with performance and injury prevention. It should not be interpreted as a physiological or biomechanical intensity (Coyne et al., 2018), but rather as a psycho-physiological one. Despite subjective instruments, potentially being more sensitive than objective measures (Saw et al., 2016), session RPE remains the most widely used subjective iTL across most sports (Burgess, 2017).

Coaches, who are primarily responsible for planning, designing, and executing training, can vary eTL and iTL by modifying the structural and formal parameters (constraints) of training tasks. To this end, coaches can use the SIATE, which records different constraints grouped into three major categorical variables: pedagogical, organizational, and subjective eTL (Ibáñez et al., 2016). The manipulation of these constraints results in the design of training tasks, such as analytical tasks without opposition (e.g., 1vs.0, 2vs.0...), individual games with opposition (1vs.1), Small-Sided Games (SSGs) of numerical inequality (e.g., 2vs.1, 3vs.2...), SSGs of numerical equality (e.g., 2vs.2, 3vs.3...), and full games (5vs.5 in conventional basketball). In team sports like basketball, it is increasingly common to employ SSGs played on smaller courts, with modified rules, altered numbers of players, and tactical exaggeration (Reina et al., 2018). SSGs integrate all the specific demands of basketball and represent various useful options for enhancing the effectiveness of the training process (Stojanović et al., 2021). In addition, SSGs combine physical conditioning with the development of technical-tactical skills under the pressure of opponents (Figueiredo de Souza et al., 2024). By manipulating the constraints of training tasks, coaches can replicate competitive intensities in a non-competitive environment (Feu et al., 2023). For this purpose, it is essential to understand and analyse the intensities. Proper training planning involves knowing the distribution of efforts throughout the week, as optimizing performance allows for the definition of objectives and control over players' progress (Barrett et al., 2016). To achieve this, it is essential to consider both the eTL and iTL.

The use of mobile apps for sports practice is widespread among adolescents (Ubago et al., 2022). Smartphones have become a valuable pedagogical resource that connects with personal needs and interests. Another advantage is that most of these apps are cost-free. Thus, monitoring HR with smartphones has become a promising tool for improving personal health, as evidenced by the increasing number of studies on their potential health benefits (Li et al., 2023; Perez-Siguas et al., 2023). Likewise, knowing the intensities of the competition will enable coaches to design and optimize training (Feu et al., 2023). For these reasons, this study quantified and compared the iTL elicited by different training tasks in adolescents engaged in recreational basketball, using the mobile

learning technique, during an intervention session of increasing complexity. Additionally, the RPE perceived by participants was also analysed. We hypothesized that: (1) the 3vs.3 SSG in ½ court will report higher iTL; and (2) this same game situation will report iTL close to the 5vs.5 full game with large space repetition.

2. METHODS

2.1. Design and Participants

An empirical and cross-sectional research was carried out with a single-case manipulative strategy (applied context) (Ato et al., 2013), with manipulation of the variables by the researchers. They designed an intervention session of increasing complexity based on the proposed training tasks. The session was structured into five training tasks, plus a warm-up and cool-down. Furthermore, to ensure the ethical considerations of scientific research with human beings, the ethical guidelines of the 1975 Declaration of Helsinki (with modifications in later years) and the Organic Law 3/2018, of December 5, on the protection of personal data in research and guarantee of digital rights were followed. Approval was received from the University Bioethics Committee (approval code: <Blinded for peer review>).

The study included 59 recreational basketball players (34 boys and 25 girls; $M \pm SD$, 14.61 ± 1.78 years), between the ages of 11 and 18 years. They belonged to a public sports institution in the southwest of Spain and held a federative license. To participate in this study, parents or legal guardians had to sign an informed consent. Information regarding the participants is provided in Table 1.

Table 1. Descriptive information about study participants

Sociodemographic and anthropometric variables	Boys	Girls	All
		($M \pm DT$)	
Age (years)	15.50 ± 1.38	13.40 ± 1.50	14.61 ± 1.78
¹ Experience (years)	4.29 ± 2.02	3.04 ± 1.31	3.76 ± 1.85
Weight (kg)	66.40 ± 15.70	59.10 ± 10.20	63.30 ± 14.00
Height (m)	1.73 ± 0.07	1.64 ± 0.06	1.69 ± 0.08
Body Mass Index (kg/m^2)	22.10 ± 4.93	22.10 ± 4.04	22.10 ± 4.53

Note. M = Mean; SD = Standard Deviation; kg = Kilograms; m = meters; ¹Years practicing basketball.

A convenience sampling method was used. A public sports institution was selected that authorized the study and was also located less than 30 kilometres from the principal investigator.

Moreover, all players who completed the entire intervention session were included in the study, while those who did not participate in some of the proposed tasks were excluded.

2.2. Variables and Instruments

The study's dependent variables were HR (physiological demand) and RPE (psycho-physiological demand). HR was measured using smartphones and the Heart Rate Monitor app (Google Play or App Store). This app requires placing the tip of the finger in front of the camera to capture the heartbeat. RPE was measured using the pictogram: “How tired are you?” (Eston & Parfitt, 2007). The response is given on a Likert scale from 0 to 10, where 0 = not at all tired and 10 = very tired, I am going to stop, I cannot take it anymore.

The independent variables were the constraints of the training tasks (i.e., situation and game space) recorded in the SIATE system (Ibáñez et al., 2016), which allowed for designing different types of tasks. In this regard, the game situation is a pedagogical variable that refers to the players' grouping (the first number indicates the attackers and the second the defenders). The game space is a load variable that refers to the area within the court where players practice training tasks (static, ¼ court, ½ court, large space, and large space repetition).

The SIATE system (Ibáñez et al., 2016) was used to design the training tasks for the intervention session. Specifically, the following training tasks were designed: 1vs.1 individual game with opposition in ¼ court; 2vs.2 SSG in ¼ court; 3vs.3 SSG in ½ court; 4vs.4 SSG with large space repetition; and 5vs.5 full game with large space repetition. Additionally, the time recommendations according to the task type established by García-Ceberino et al. (2021) were followed. Moreover, the intervention session also consisted of a warm-up and a cool-down task. Appendix 1 details the pedagogical, organizational, and load variables (constraints) used. In this way, the coach (and researchers) knew the subjective eTL of the tasks before the players practiced them. In women's basketball, a significant correlation has been shown between the intensity recorded by inertial movement units and the SIATE system ($r = .897$; $r^2 = .804$) (Reina et al., 2019).

The purpose was to employ several methods of intensity quantification and not to use just one in isolation. Bourdon et al. (2017) pointed out that it is appropriate to combine objective and subjective instruments to quantify intensity, ensuring a balance between the athlete's perception and the quantifiable practice.

2.3. Procedure

Once all necessary authorizations were obtained, players first received training on the importance of HR measurement in physical-sports practice. In this context, using the mobile learning technique, players tested an application to calculate their HR after playing various tasks (similar to the tasks of the intervention session) in order to enhance their interest and participation. Similarly, they were trained using a pictorial-curvilinear scale, which allowed them to understand their degree of fatigue. As a result, they were familiar with the intensity measuring instruments.

On another day, the intervention session of increasing complexity (Appendix 1) was carried out. The coach set a date for the researchers to go to the basketball court. Prior to the practice of the training tasks, sociodemographic and anthropometric data of the players were collected. At the beginning of the intervention session, the protocol was explained to the players, and a space was indicated where they could leave their smartphones while they played the different training tasks. Immediately after completing each training task, the players measured their HR and, at different tables located in the basketball court, indicated their RPE to a researcher. Each player was assigned a different table to indicate his or her RPE to the researcher, to avoid grouping all the players and wasting time between the completion of the tasks and the data collection. Data were collected before (basal), during, and after the intervention session.

2.4. Statistical Analysis

First, assumption tests for hypothesis testing (Kolmogorov-Smirnov, Rachas and Levene tests) were performed, indicating the use of parametric tests ($p > .05$). Thus, the correlation between HR and RPE recorded in each training task was calculated using Pearson's correlation (Field, 2013).

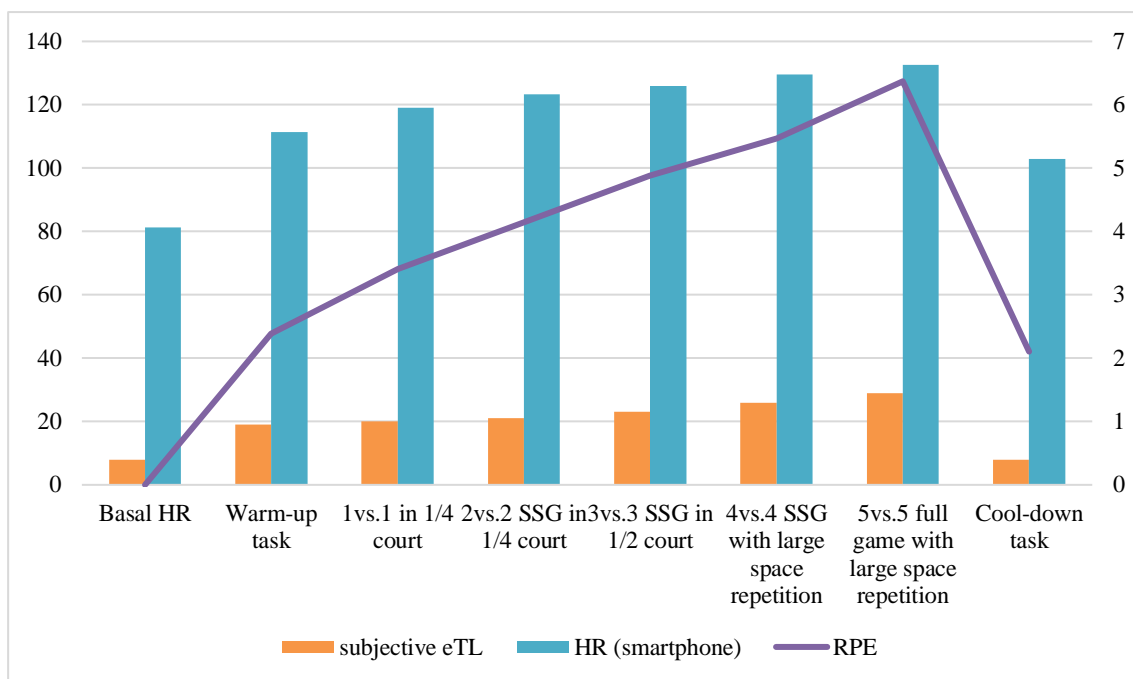
Next, the effect of the Sex*Category interaction on HR and RPE recorded in each training task was analysed using a Univariate General Linear Model (Field, 2013). Since significance was only recorded in the RPE perceived by players in the 3vs.3 SSG in $\frac{1}{2}$ court with a medium effect size ($F = 6.68$; $p = .01$; $\eta^2 p = .11$), the sample was pooled as a single-case.

A Repeated Measures ANOVA of and Tukey's post hoc test were used to compare the HR between the training tasks that composed the intervention session. The effect size was calculated with the Partial Eta-Squared (Field, 2013), interpreting the following values: low = .01; medium = .06; and large = .14. These same statistics were used for the RPE.

Jamovi v.2.3.24 software (The-jamovi-project, 2022) was used to perform the descriptive and inferential analysis. A significance level of $p < .05$ was considered.

3. RESULTS

Except for the basal measurement, there were positive correlations between HR and RPE in all training tasks, indicating that high HR values corresponded with high RPE values. There were strong correlations in the 4vs.4 SSG ($r = .62; p < .001$), and in the cool-down task ($r = .51; p < .001$). The warm-up task ($r = .30; p = .02$), 2vs.2 SSG ($r = .45; p < .001$), 3vs.3 SSG ($r = .48; p < .001$), and 5vs.5 full game ($r = .48; p < .001$) reported moderate correlation. The 1vs.1 situation reported a weak correlation ($r = .26; p = .04$). The lack of correlation in the basal measurement is possibly due to the fact that the RPE of players was minimal (RPE from 0 and 1). Figure 1 shows the descriptive results for subjective eTL, HR, and RPE.



Note. R = Heart rate; RPE = Rating of Perception Effort; SSG = Small-Sided Game

Figure 1. Descriptive results according to the constraints of the situation and game space

As can be seen, an increase in the number of participants (cognitive involvement) and game space led to an increase in physical and psycho-physiological demands. Specifically, the highest HR values correspond to 5vs.5 with large space repetition, while the RPE is systematically higher in training tasks with more players and larger space.

Taking into account the constraints of the situation and game space, significant differences were reported for HR, with a large effect size ($F = 81.70; p < .001; \eta^2p = .59$). Similarly, significant differences were reported for RPE, with a large effect size ($F = 240; p < .001; \eta^2p = .81$). Table 2

shows the pairwise multiple comparisons of the iTL according to the constraints used in the design of the training tasks.

Table 2. Multiple pairwise comparisons of the iTL according to task constraints

Task		HR		RPE	
		<i>t</i>	<i>p</i> _{Tukey}	<i>t</i>	<i>p</i> _{Tukey}
Basal	Warm-up task	-11.41	< .001***	-14.12	< .001***
	1vs.1 in ¼ court	-14.40	< .001***	-21.46	< .001***
	2vs.2 in ¼ court	-13.79	< .001***	-21.82	< .001***
	3vs.3 in ½ court	-15.05	< .001***	-26.27	< .001***
	4vs.4 with large space repetition	-14.92	< .001***	-23.96	< .001***
	5vs.5 with large space repetition	-18.11	< .001***	-33.51	< .001***
	Cool-down task	-7.65	< .001***	-12.59	< .001***
Warm-up task	1vs.1 in ¼ court	-3.14	.05	-6.78	< .001***
	2vs.2 in ¼ court	-4.42	< .01**	-12.65	< .001***
	3vs.3 in ½ court	-5.12	< .001***	-15.83	< .001***
	4vs.4 with large space repetition	-8.38	< .001***	-15.91	< .001***
	5vs.5 with large space repetition	-8.19	< .001***	-21.01	< .001***
	Cool-down task	2.91	.09	1.53	.79
1vs.1 in ¼ court	2vs.2 in ¼ court	-1.66	.71	-4.78	< .001***
	3vs.3 in ½ court	-2.38	.27	-9.60	< .001***
	4vs.4 with large space repetition	-3.87	.01*	-10.46	< .001***
	5vs.5 with large space repetition	-5.99	< .001***	-14.77	< .001***
	Cool-down task	5.92	< .001***	6.90	< .001***
2vs.2 in ¼ court	3vs.3 in ½ court	-1.17	.94	-4.78	< .001***
	4vs.4 with large space repetition	-2.61	.17	-7.23	< .001***
	5vs.5 with large space repetition	-3.39	.03*	-11.82	< .001***
	Cool-down task	7.76	< .001***	10.69	< .001***
3vs.3 in ½ court	4vs.4 with large space repetition	-1.31	.89	-3.40	.03*
	5vs.5 with large space repetition	-2.68	.15	-8.44	< .001***
	Cool-down task	10.42	< .001***	12.62	< .001***
4vs.4 with large space repetition	5vs.5 with large space repetition	-1.26	.91	-4.45	< .001***
	Cool-down task	8.94	< .001***	11.88	< .001***
5vs.5 with large space repetition	Cool-down task	12.81	< .001***	18.05	< .001***

Note. *t* = Tukey's post hoc test; η^2p = Partial Eta-Squared; HR = Heart Rate; RPE = Rating of Perception Effort. **p* < .05; ***p* < .01; ****p* < .001.

There were no significant differences in HR between the 3vs.3 SSG in ½ court and 4vs.4 SSG with large space repetition compared to 5vs.5 with large space repetition. Therefore, both training tasks reported physiological intensities closer to competition. The session culminated with HR and

RPE intensities similar to those at the start, thanks to the previous design with the help of SIATE system (Ibáñez et al., 2016).

4. DISCUSSION

Understanding training and competition intensities is crucial for evaluating their effects (Feu et al., 2023). This study aimed to quantify and compare the iTL elicited by different training tasks in young adolescents practicing recreational basketball, utilizing the mobile learning technique during a session of increasing complexity. Additionally, the study analysed the RPE perceived by participants. The main findings revealed positive correlations between HR and RPE across all the training tasks in the intervention session. The 1vs.1 individual game in ¼ court elicited a significantly lower RPE compared to the tasks in the fundamental part of the session. In contrast, the 5vs.5 full game with large space repetition showed higher HR and RPE in descriptive results. No significant differences in HR were found between the 3vs.3 SSG in ½ court and the 4vs.4 SSG with large space repetition in relation to the 5vs.5 full game with large space repetition. Thus, both training tasks caused objective iTL similar to competition.

Combining objective and subjective instruments to quantify intensity ensures a balance between the athlete's perception and quantifiable practice (Bourdon et al., 2017). For this reason, HR and RPE were used to quantify iTL. In professional basketball, López-Laval et al. (2022) studied the relationship between two methods of intensity measurement during a training program, reporting correlations between HR and RPE. Similarly, Lupo et al. (2017) noted moderate to strong correlations between HR and RPE during training sessions in boys' youth basketball. In primary physical education, similar correlations were demonstrated, specifically in a basketball learning situation (García-Ceberino et al., 2022). Although these studies used HR monitors instead of mobile apps, their results were consistent with those of our study. Therefore, RPE is suggested as a valid and suitable subjective method to assess iTL in basketball players of different categories and levels (Coyne et al., 2018). It is cost-effective, easily accessible, and applicable. However, a prior learning process for athletes is recommended to ensure accurate responses. Without adequate RPE education, athletes might respond dishonestly to manipulate their perceived fatigue during training (Coyne et al., 2018).

The 1vs.1 individual game in ¼ court elicited significantly lower RPE, aligning with findings from Vaquera et al. (2018). These authors observed lower cognitive involvement in the 1vs.1 format due to reduced decision-making demands, as players did not need to pass the ball, communicate with

teammates, or react to their actions (Vaquera et al., 2018). The 5vs.5 full game with large space repetition elicited the highest HR and RPE, contradicting Hypothesis 1, which predicted that the 3vs.3 SSG in ½ court would elicit the highest iTL. The 5vs.5 full game's high objective and subjective iTL might be associated with accumulated mental fatigue or fatigue induced by previous tasks during the session, as well as higher cognitive involvement (Ibáñez et al., 2016). In a previous study, Sansone et al. (2020) found that semi-professional basketball players practicing different 3vs.3 SSGs showed that RPE was significantly associated with mental fatigue induced by varying these SSGs.

In this study, both the 3vs.3 SSG in ½ court and the 4vs.4 SSG with large space repetition reported HR values similar to those in competition. However, significant differences in RPE were found between these training tasks and the 5vs.5 full game. Thus, Hypothesis 2, which suggested that only the 3vs.3 SSG would have similar iTL values to the 5vs.5 full game, was partially accepted. These findings are consistent with Weaving et al. (2017), who also reported variations between HR-derived measures and session RPE. Vaquera et al. (2018) analysed HR and RPE during various training tasks in elite junior basketball players. Unlike our study, they found that the 2vs.2 SSG elicited a higher RPE despite lower HR values compared to the 5vs.5 format. Our results did align with Vaquera et al. (2018) in identifying the 5vs.5 full game as the task eliciting the highest average HR, likely due to the greater cognitive demands (Ibáñez et al., 2016). However, our results differ from Köklü et al. (2017), who reported that 2-a-side and 3-a-side full-court games elicited significantly higher physiological responses (HR and RPE) and more frequent technical actions than 5vs.5 matches in young basketball players. For these reasons, 3vs.3 and 4vs.4 SSGs should be regularly incorporated into training to achieve performance improvements, as they closely simulate competition intensity.

5. LIMITATIONS

This study has several limitations. First, we did not use inertial movement units of proven reliability. However, a key goal of this study was to employ low-cost and accessible tools, considering that many coaches, particularly in youth categories, may not have access to expensive and sophisticated technologies. Other limitations include the sample size and the number of sessions monitored. Future research should include larger samples and monitor intensities over longer periods to explore differences in intensities by sex and category. Additionally, it is recommended to randomize the training tasks in future intervention sessions to compare results with those of this study.

6. CONCLUSIONS

In the intervention session of increasing complexity, psycho-physiological demands increased with the number of players and game space, possibly due to higher cognitive involvement. In this regard, the format of 3vs.3 in ½ court and 4vs.4 with large space repetition led to an average heart rate similar to that of a 5vs.5 full game (real competition situation). However, effort perception should be adjusted individually. Coaches can use low-cost, accessible, and easy-to-use methods to quantify external and internal intensities, specifically employing the mobile learning technique to measure heart rate in youth categories. This information is valuable when designing training programs and adapting demands according to individual responses.

Practical applications suggest incorporating 3vs.3 and 4vs.4 SSGs to simulate HR similar to a full game (competition situation) and to improve tactical ability and decision-making under pressure (Figueiredo de Souza et al., 2024; Stojanović et al., 2021). However, RPE should be adjusted to individualize effort according to each player's response and to prevent possible injuries. This study demonstrated that varying task constraints, such as the number of participants and game space, influenced both HR and RPE (iTL). Furthermore, the mobile learning technique used in this study educated participants about the importance of monitoring HR to enhance personal health and relate it to physical-sports activities. Given the prevalence of smartphones among adolescents, using free, easy-to-use apps (Perez-Siguas et al., 2023; Ubago et al., 2022) as an educational resource is a practical approach. Sport professionals may find this information useful in designing training programs.

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AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

This research received no external funding.

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