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Article

Acute Effects of Different Formats of Small-Sided and Conditioned Handball Games on Heart Rate Responses in Female Students During PE Classes

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Abstract: The aim of this study was to analyze the impact of different formats (2-a-side, 3-a-side and 4-a-side) on heart rate responses of female students during small-sided and conditioned handball games. The heart rate responses were measured using heart rate monitors during physical education classes. Eight female students participated in the study (15 ± 0.0 years). The one-way ANOVA showed statistical differences with moderate effect between the three different formats ($F_{(2, 1674)}$ = 86.538; *p-value* < 0.001; η_p = 0.094; *Power* = 1.0). The results showed that smaller formats (2-a-side and 3-a-side) increased the heart rate responses of female students during small-sided and conditioned handball games during physical education (PE) classes. The results also suggested that 2-a-side games can be used for anaerobic workouts and the 3-a-side and 4-a-side games can be better used to reach lactate-threshold and for aerobic workouts of high intensity.

Keywords: Handball; heart rate; physical education; small-sided games; task constraints

1. Introduction

Small-sided games have been used in recent pedagogical methodologies to simultaneously develop the physiological, physical, technical, tactical and sociological contents in team sports games [1]. Usually, small-sided games are based on task constraints that change some characteristics of a formal game but maintain the main characteristics [2]. The constraints that are more often used by coaches are field size, the number of players per match (format) or some modifications of the rules [3]. However, other task constraints can be used such as the training regimes, the specific coaches' instructions, the limitations of touches in the ball or the position and size of goal (small goals and regular goals) [1].

One of the main concerns about small-sided games compared with other training methods is efficacy in terms of physiological stimulation. Buchheit *et al.* [8] studied 4-a-side games and intermittent running as two methods to stimulate the aerobic system to a high intensity. The results showed that higher values in 4-a-side handball games were achieved compared with intermittent running with regard to VO2 (maximal oxygen consumption), mean VO2, aerobic energy and distance covered. On the other hand, higher values of HRmax, blood lactate, anaerobic energy and rate of perceived exertion were recorded in intermittent running. Buchheit *et al.* [8] suggested that the 4-a-side game is a valid alternative to intermittent running to develop the cardiorespiratory system. Following this idea Buchheit *et al.* [9] examined the effects of two 10-week programs using small-sided games and a regular intermittent running program. Results showed that both programs statistically improved performance in the 10-metre sprint, repeated sprints and 30-15 intermittent fitness test (a specific fitness test to assess the ability to recover and to perform repeat intermittent activity). Nevertheless, no statistically significant differences were detected between both programs. Therefore, it was observed that both programs were effective in developing the players' performance [9].

The previous studies were applied in handball training context. Most recently, in the case of physical education (PE) classes, Clemente and Rocha [10] studied the effects of three different handball games formats on male students' heart rate responses. The results showed statistical differences as regards heart rate responses between 2-a-side, 3-a-side and 4-a-side games. The higher mean heart rate values were recorded during the 2-a-side game and the lower values during the 4-a-side game. Moreover, the higher frequencies of ball contacts and dribbles were observed in the 2-a-side game. Following this study, Clemente and Rocha [11] also studied the effect of two field sizes on the heart rate responses of male students during small-sided handball games. The results showed that higher mean heart rate values were recorded during the small-sided games played in a bigger space. Moreover, it was observed that a higher useful time of a game was recorded in the bigger field. Clemente and Rocha [11] suggested that the higher useful time and the bigger space decrease the opportunity to recover during the practice, thus increasing the heart rate values associated with a bigger field.

When these task constraints are adopted in Physical Education (PE), some didactical orientations should be noted, such as: fitness development, technical/tactical learning and the acquisition of specific

social and psychological behaviors [4]. As regards these orientations, the concepts of fitness and health are very important and should be considered to promote active lifestyles and reduce the risk of certain diseases [5]. Moreover, the use of small-sided games are related to great enthusiasm, commitment and motivation among students [6-7]. These results support the argument that small-sided games are a great methodological alternative for Physical Education. Despite the overall possibilities of small-sided and conditioned games, the study of their effects on students during PE contexts are not yet detailed enough [5]. Usually, the majority of studies about this topic only consider the players in sports training context, thus reducing the possibility to understand how students without regular practice can be affected by small-sided and conditioned games. Therefore, the aim of this study was to analyze the effects of different formats (2-a-side, 3-a-side and 4-a-side) of small-sided and conditioned handball games during PE classes in female students without regular practice.

2. Methods

2.1. Participants

This study relied on the voluntary participation of eight female students (15 ± 0.0 years old; 52.3 ± 2.8 kg; 159 ± 3.4 centimeters of height; 17.3 ± 0.8 Body mass index) without regular practice outside the school context, thus representing the majority of the real community of Physical Education. These participants belonged to a single PE class and were randomly selected to the study. Before the study, the experimental approach was described to each participant. During this explanation the participants apparently showed no kind of physical or psychological disease. All parents signed a Free and Clarified Consent Form respecting the Helsinki Declaration.

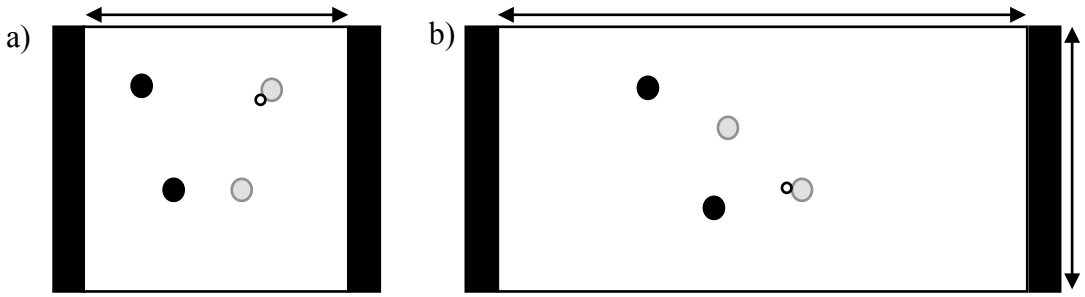
2.2. Apparatus

The players' actions were captured using a digital SLR (Canon EOS 500D) with the capacity to process images at 30 Hz (*i.e.,* 30 frames per second). The camera was placed at 4.53 m above ground to capture the whole task. Official handball balls (Molten IH2R) were used for this specific age group. The two teams wore blue and red vests. The students were randomly selected to constitute the teams. The students' heart rate was assessed by eight heart rate monitors (Polar R400sd) periodically recording every five seconds.

2.3. Procedures

The aim of the small-sided and conditioned games was to promote the pass and penetration. Therefore, the way to score was changed. It was mentioned to students that could only score a goal when receiving a pass from a colleague beyond the opponents' endline. All other rules followed handball regulations. Six practice conditions were analyzed and organized into three formats of the game (2-a-side, 3-a-side and 4-a-side) and two practice spaces (smaller and bigger) (see Figure 1): *i*) 2-a-side in smaller space; *ii*) 2-a-side in bigger space; *iii*) 3-a-side in smaller space; *iv*) 3-a-side in bigger space; *v*) 4-a-side in smaller space; and *vi*) 4-a-side in bigger space. Nevertheless, for this study only the influence of format was considered during the analysis.

Figure 1. (a) smaller space (10×7.5 meters); and **(b)** bigger space (20×7.5 meters).



Each task took five minutes and the main goal was to catch the ball thrown by one teammate beyond the opponent's defensive line. Only two games were performed per session, thus, there was a 5-minute recovery period between games (ratio activity/recovery of 1:1). The study was developed during three weeks and the sample was only collected on Wednesday at the same time period to reduce the circadian variability.

Before each practice condition, the students had heart rate monitors fitted and calibrated, periodically recording every five seconds [10]. The variable analyzed was the female students' absolute heart rate, directly measured by the heart monitors.

2.4. Statistical Procedures

The one-way ANOVA was used to establish the statistically significant differences between three formats of small-sided handball games (2-a-side, 3-a-side and 4-a-side). The assumption of normality distribution of one-way ANOVA in the three formats was studied using the Shapiro-Wilk test. It was found that the distributions were not normal in the dependent variable. Although it was not normal, since $n > 30$, using the Central Limit Theorem [12], we made the assumption of normality. It is important to highlight that the sample was the heart rate during the whole game and not the number of participants. The analysis of homogeneity was carried out using the Levene test. It was found that there is no uniformity of practice under the previously mentioned conditions. However, despite the lack of homogeneity, the F test (ANOVA) is robust to homogeneity violations when the number of observations in each group is equal or approximately equal [12], which is the case. As with the assumption of normality, violation of this assumption does not radically change the F value [12]. We used the Scheffé post hoc test [13] for this type of data. The classification of the size effect (*i.e.*, measure of the proportion of the total variation in the dependent variable explained by the independent variable) was done according to Marôco [12] and Pallant [13]. This analysis was performed using the IBM SPSS program (version 19) for a significance level of 5%.

3. Results

In table 1 it is possible to observe that the 2-a-side game has a higher average heart rate in both practice spaces (173.139 beats/min in smaller space and 179 beats/min in bigger space). Conversely, the lower heart rate average occurs in the 4-a-side game (154 beats/min in smaller space and 163.117 beats/min in bigger space).

Table 1. Descriptive statistics of mean heart rate in small-sided handball games.

Format	Field Space	Mean Heart Rate	Standard Deviation
2-a-side	Smaller	173.139	20.878
	Bigger	179.544	21.003
	Total	176.342	21.156
3-a-side	Smaller	156.140	15.642
	Bigger	170.187	20.332
	Total	163.163	19.439
4-a-side	Smaller	154.083	22.740
	Bigger	163.117	23.490
	Total	158.600	23.540

By comparing the mean heart rate recorded in the three small-sided handball games, it is possible to observe significant statistical differences with moderate effect ($F_{(2, 1674)} = 86.538$; *p-value* < 0.001; η_p= 0.094; *Power* = 1.0).

Table 2. Comparison of average differences (I-J) between the three small-sided handball games.

	2-a-side	3-a-side	4-a-side
2-a-side		13.178*	17.742*
3-a-side			4.563*
4-a-side			

* The average difference is statistically significant for a level of p-value < 0.001

More specifically, post hoc tests show differences between 2-a-side, 3-a-side and 4-a-side games, where the highest heart rate occurs in the 3-a-side game. Between 3-a-side and 4-a-side, it is also possible to observe significant statistical differences, with the female students' lowest heart rate in the 4-a-side game.

4. Discussion

The aim of this study was to analyze the impact of different formats (2-a-side, 3-a-side and 4-a-side) on heart rate responses of female students during small-sided and conditioned handball games.

Previous studies on the influence of small-sided handball games among male students demonstrated that the 2-a-side had higher average heart rate in two practice spaces (171 beats/min and 177 beats/min) [10]. Conversely, the lower heart rate average occurred in the 4-a-side sub phase (159 beats/min and 167 beats/min) [10]. Similar to Clemente and Rocha's [10] study on male students, this study on female students showed that higher values of heart rate were achieved in the games shapes with fewer players.

In fact, these results are in line with other team sports such as football [1,3], basketball [14] or rugby [15]. One of the main hypotheses to explain this increase of heart rate in small-sided games with fewer players is the individual participation and requirements from the player. Considering that the increase of technical and tactical actions by each player can be a predictor of intensity rise [16], it is possible to suggest that small-sided games with fewer players are synonymous with an activity with higher heart rate intensity [10]. This fact can be justified by the need of each player to contribute actively to the success of the team because, in a team of only two players, if one member does not actively participate, the opportunities for success decrease [5].

Thus, considering one of the multiple factors that induce heart rate responses in female students, it is important to identify whether the physiological requirements are enough to properly stimulate the cardiorespiratory system for fitness development. Using the Tanaka *et al.* [17] formula, the maximal Heart Rate (HRmax) of each player was estimated. Therefore, the %HRmax of each player was computed based on the maximal heart rate of each player and the mean heart rate achieved during each small-sided game (Table 3).

Table 3. Descriptive statistics of %maximal heart rate (HRmax) on the three small-sided handball games.

Format	Field Space	%HRmax
2-a-side	Smaller	87.665
	Bigger	90.908
	Total	89.287
3-a-side	Smaller	79.058
	Bigger	86.171
	Total	82.614
4-a-side	Smaller	78.017
	Bigger	82.591
	Total	80.304

The heart rate values range between 78.017%HRmax and 90.908%HRmax. These values are very interesting because they allow many kinds of workout targets (such as anaerobic, lactate threshold or aerobic workout). Using these values, it is possible to develop programs such as threshold lactation, VO2max or anaerobic training. Based on values reported in this study, it is possible to develop a threshold lactate workout training using the 3-a-side or 4-a-side game played in a bigger space, with 1–8 repetitions and 6–30 minutes per game. For an anaerobic workout training, it is possible to use the 2-a-side games or the 3-a-side played in bigger spaces, with 2–4 sets of 4–8 repetitions and 20 seconds to 3 minutes of repetitions duration. In order to develop the VO2max the 2-a-side handball game played in a bigger space with 4–8 repetitions and 3–6 minutes per repetition is recommended. These values are specific for soccer games, but can be very similar for all invasion team sports [18].

Thus, this study showed that small-sided games with a higher number of players increase heart rate responses. Moreover, it was possible to observe that small-sided handball games can achieve values of

between 75 and 90%HRmax. Therefore, small-sided games are a great opportunity to keep students motivated and engaged with the practice [6-7], and, at the same time, to develop the students' fitness. Thus, the adoption of small-sided games is strongly recommended in the context of Physical Education, fully developing the students in a physiological, physical, technical, tactical and social way [10].

5. Conclusion

The aim of this study was to examine the influence of the number of female students per small-sided handball game on heart rate responses during Physical Education sessions. The results showed statistical differences of heart rate responses between the 2-a-side, 3-a-side and 4-a-side games. The higher mean heart rate was achieved in the 2-a-side game and the lower was achieved in the 4-a-side game. Thus, the small-sided handball games with fewer female students increases heart rate intensities. This study had some limitations such as the size of sample and the small number of games conducted during the study. Thus, it is strongly suggested to increase the sample size and also to develop a specific program for PE classes, trying to compare this kind of approach (small-sided and conditioned games) with a more traditional approach using analytical training and running methods. Moreover, the tactical behavior must be studied in order to understand how students develop their strategic positioning in the field to optimize their physiological responses and reduce the effects of fatigue.

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Conflicts of Interest

The authors declare no conflict of interest.

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