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The Effects of Small-Sided and Conditioned Games on the Heart Rate Responses, Technical and Tactical Performances Measured by Mathematical Methods

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Abstract: The aim of this study was to identify the effects of format and task condition on heart rate responses and technical/tactical performance measured by mathematical methods. Ten male basketball players (14.75±0.46 years old; 5±1.4 years of training) from a Portuguese youth regional league participated voluntarily in this study. Results revealed that the format had significant main effects and large effect size (Pillai's Trace = 0.692; $F_{(10, 78)}$ = 4.124; p = 0.001; η_p^2 = 0.346; Power = 0.996) on heart rate responses and technical/tactical performance. It was also found that task conditions had a significant main effects and a large effect size (Pillai's Trace = 0.623; $F_{(10, 78)}$ = 3.526; p = 0.001; η_p^2 = 0.311; Power = 0.988) on heart rate responses and technical/tactical performance. Smaller formats had the highest heart rate responses, volume of play, attacks with ball, efficiency index and performance scores. The task condition with two targets had the highest heart rate responses and the task with endline had the highest values of volume of play, attacks with ball, efficiency index and performance score. In sum, it was found that smaller formats are similar to anaerobic workouts and to can be used to increase technical actions. The bigger formats are appropriated to high intensity aerobic workouts and to can be used to increase the complexity of the task.

Key words: Basketball, small-sided games, performance analysis, measurement, metrics

INTRODUCTION

The possible effect of Small-Sided Games (SSG) on the physiological and time-motion variables of team sport players has been explored by Hill-Haas *et al.* (2011). In fact, the use of these games have such great value in that it allows players to simultaneously develop fitness and technical/tactical performance (Owen *et al.*, 2014). Variables such as field dimensions, formats of play, specific rules or goals can be applied to develop different small-sided conditioning games and to induce different physiological responses and technical/tactical performances (Davids *et al.*, 2013).

Generally, studies that compared different formats of basketball games found that smaller basketball formats induced more increases in physiological parameters such as heart rate responses and blood lactate concentrations than bigger basketball formats (Castagna *et al.*, 2011; McCormick *et al.*, 2012; Pinar *et al.*, 2009; Sampaio *et al.*, 2009). The majority of last-mentioned studies that compared the 2v2, 3v3, 4v4 and 5v5 formats found that higher heart rate responses and blood lactate concentrations were achieved in the 2v2 format and the lowest in the 5v5 format. Heart rate responses varied between 80 and 91% of HRmax (McCormick *et al.*, 2012; Pinar *et al.*, 2009; Sampaio *et al.*, 2009) which indicate that different basketball formats may be used to achieve different training targets.

In other team sports such as soccer, bigger field dimensions induced higher heart rate responses and blood lactate concentrations (Casamichana and Castellano, 2010; Williams and Owen, 2007). Moreover, the non-use of regular goals or targets also increased the physiological responses when compared to the use of regular targets (Mallo and Navarro, 2008; Sassi *et al.*, 2004). Additionally, a restriction in the number of consecutive touches per player increased the heart rate responses by increasing playing speed (Dellal *et al.*,

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2011). Therefore, a multiple set of task conditions induces different physiological responses in team sport players. Nevertheless, SSG are not only used to change the workload of play but also to induce various technical/tactical responses. These responses must also be analysed in order to determine its influence on players' performances.

In this regard, Pinar *et al.* (2009) observed that the regular 5 versus 5 format decreased the participation levels of players. The participation levels decreased due to the fact that two to three players monopolised the game in certain cases. However, a comparison between the 3 versus 3, 4 versus 4 and 5 versus 5 formats showed that a higher number of passes, shots and rebounds were performed in the smaller format. A further comparison between the 2 versus 2 and 4 versus 4 formats revealed that the smaller format increased the mean number of dribbles, passes, close range shots, rebounds and ball screens (Klusemann *et al.*, 2012). With regard to offensive played-balls, McCormick *et al.* (2012) found that a higher number of offensive plays were performed in the 3 versus 3 than the 5 versus 5 format. Despite these findings with regard to SSG, researchers have thus far not investigated the possible influence of task manipulation during different formats of SSG on technical/tactical performances.

The aim of this study was to determine the effects of different SSG formats and task conditions on heart rate responses and technical/tactical performances measured by mathematical methods.

MATERIALS AND METHODS

Participants: Ten male basketball players from a Portuguese youth regional league participated voluntarily in this study. All players' parents signed the free and Clarified Consent Form respecting the Helsinki Declaration. Players' age, years of training in basketball, height, body mass, maximal aerobic capacity and resting heart rate were: 14.75±0.46 years old, 5±1.4 years of training in basketball, 175±7.1 cm, 60±4.7 kg, 46.72±3.13 mL/kg/min, 69.63±4.96 bpm at rest. Players were asked to maintain normal daily food and water intake during the period of study intervention. All players were familiarised with the experimental procedures and requirements of the games before the study began. Players were also instructed on how to control the heart rate monitors.

Testing procedures: In this study, all players were tested during one session per SSG format applied. The study was carried out for 3 consecutive weeks by performing three SSG for each session. All SSG had the same duration and lasted for 5 min with 3 min of passive recovery between games. The SSG were performed on the same day of the week in order to avoid changes in physiological responses due to circadian variations. Data sampling took place on Wednesdays in order to ensure full recovery between matches. A recovery time of aleast 24 h was required before the day of data collection which meant that no training took place on Tuesdays. The study took place in November of 2013 to 2014. All training sessions were performed on a basketball court with a pavilion and ambient temperatures ranged between 19 and 23°C. Before the study commenced, players had already been training for 3 months which consisted of basketball-specific training sessions which each lasted between 80 and 100 min for a frequency of 4 times a week and was interspersed by one match a week. During the 1st week, the players were subjected to 2 versus 2 SSG format with 2 neutral players during which three different task conditions were randomly applied. In the 2nd week, they performed 3 versus 3 SSG format with 2 neutral players during which three different task conditions were randomly applied. During the 3rd week, three task conditions were randomly applied during a 4 versus 4 SSG format with 2 neutral players. Therefore, all together nine SSG formats were examined. The HR responses were recorded during all the games.

Small-sided and conditioned games: The main aim of the SSG used in this study was to promote a specific tactical behaviour during the game. For such aim was used a modified game adopting task constraints to augment the players' perception about a specific aspect of game (Tan *et al.*, 2012). One of the principles that were used during the design of the SSG was exaggeration. Exaggeration entailed that elements of games were modified to exaggerate a tactical idea while maintaining the dynamics of an official game, although (Tan *et al.*, 2012). Therefore, small-sided and conditioned games were used instead of regular SSG. The games were developed to promote the tactical principle of penetration which refers to the success of players or a team to penetrate the opponent's defensive block. Therefore, no regular basket shooting was promoted. Players were rather motivated to maintain different widths of cross defensive lines to penetrate opponents' defences. Each game had two neutral players that only played out of the sideline. The neutral players (+2) only provided coverage to the players/team with possession of the ball.

Each game was designed in such a way that a field ratio per player of ~41 m^2 was maintained. The 2 versus 2 with 2 neutral players he games were therefore played

with field dimensions of 15×11 m whereas the 3 versus 3 with 2 neutral players games were played on 19×13 m field and the 4 versus 4 with 2 neutral players on a 22×15 m field. It was the maximum width of an official basketball court in order to better achieve the main goals of SSG. Nevertheless, it was progressively increasing at the formats. For each format, three different tasks depending on task condition were applied (Fig. 1).

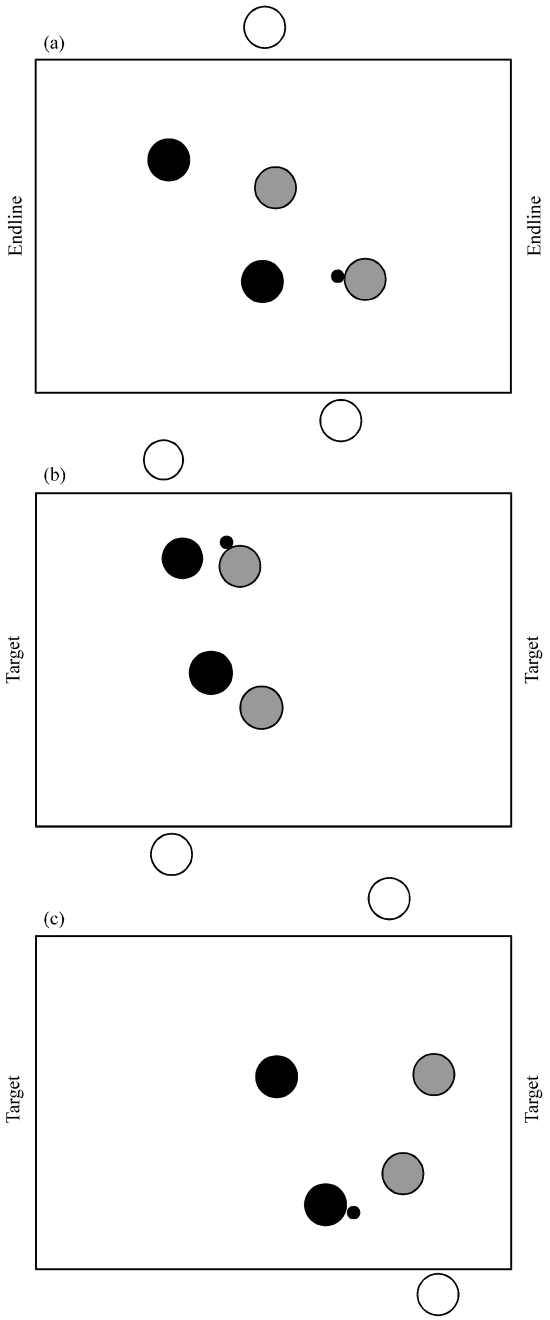

Fig. 1: Goal of games: a) task 1; b) task 2 and c) task 3

The task conditions were selected to increase the changes that the opposing team's defensive organisation will be disrupted so that the defence could be penetrated. In a regular classification, the basketball game is classified as an invasion game (Mitchell *et al*., 2006). What this means is that players must solve problems by changes in individual and collective handling of the ball to overtake use or avoid varying mobile obstacles (such as opponents) (Grehaigne *et al*., 2005).

In the first task (T1), the main goal of the game was to cross all endlines on the field by receiving (catching) the ball from one of the teammates thus no goals were used (Fig. 1a). During all tasks the neutral players provided coverage to the team with possession of the ball in a space on the sideline. In the second task (T2), two reduced targets of 2 m beginning from the corners of field were placed (Fig. 1b). In both previous tasks (1 and 2), the way to score was similar to task 1 but only in the reduced targets. In the third task (T3) one central target of 2 m was used and the way to score was to cross the central endline while possessing the ball (Fig. 1c).

Heart rate and time-motion information: The Yo-Yo intermittent recovery test 1 was used. This consists of 20 m runs repeated twice which are back and forward between the starting, turning and finishing lines at a progressively increased speed which is controlled by audio beeps from a tape recorder (Koklu *et al*., 2011). The test was performed in groups of five players. Heart rate was measured using the Polar RC3 GPS (Polar Electro, Finland) throughout the test. The maximum heart rate achieved by each player was also noted. The values from the test are presented in Table 1.

Those results come from a previous period of 3 months training in their teams. Such a period corresponds to 1/3 of the basketball season. Nevertheless, the official championship only started 1 month before the test thus the optimal or peak condition of players cannot be guaranteed.

For the measurement of resting heart rate, players (using the heart rate monitors) rested comfortably during

Table 1: Players' Yo-Yo intermittent recovery test performances

Player codes	Distance covered	VO_2 max
B1	560	41.1040
B2	1040	45.1360
B3	1480	48.8320
B4	1360	47.8240
B5	1000	44.8000
B6	1600	49.8400
B7	1360	47.8240
B8	1840	51.8560
B9	1120	45.8080
B10	920	44.1280

Mean: 46.7152; SD: 3.1322

Table 2: Observational variables collected from TSAP (adapted from Grehaigne *et al*., 1997)

Observation variables	Operational definition
Gaining possession of the ball	
Conquered Ball (CB)	The player intercepted or stole the ball from an opponent or recaptured it after an unsuccessful shot
Received Balls (RB)	Player received the ball from one teammate and did not immediately lose control of the ball
Disposing of the ball	
Lost Ball (LB)	Player loses control of the ball
Neutral Ball (NB)	It is a routine pass to a teammate that does not put pressure on the opponent's team
Pass (P)	Pass to a partner that contributes to the displacement of the ball towards the opponent team's defensive region
Successful Shot on goal (SS)	A score was made

Volume of play: Volume of Play (VP) = CB+RB; Attacks with ball: Attacks with ball (AB) = P+SS; Efficiency index: Efficiency Index (EI) = AB/10+LB; Performance score: Performance Score (PS) = (VP/2)+(EI×10)

the recording for at least 10 min in a supine position and 7 min in a standing position in a quiet, semi-dark room with a temperature of 21-23°C (Gamelin *et al*., 2006). From this procedure, the mean for lowest three heart rate values achieved by each player was determined.

The heart rate was continuously monitored throughout the SSG and recorded at 1 sec intervals by light weight and portable heart rate monitors (Polar RC3 GPS with heart rate sensor). After each testing session, all heart rate data were downloaded to a computer using the dedicated software (Polar WebSync and Polar Pro Trainer 5.0) and stored. The data of resting and maximum heart rate per player was converted into percentage of heart rate reserve (%HRres) using the Karvonen's Method (Janssen, 2001).

Assessment of technical/tactical performance by mathematical methods: For the technical analysis, the Team Sport Assessment Procedure (TSAP) was used which was developed by Grehaigne *et al*. (1997). This instrument allows researchers to quantify information with regard to players' overall offensive performance in team sports (Grehaigne *et al*., 2005). It also reflects both technical and tactical aspects of game play by the use of macro-indicators (Table 2) that are related to successful game play (Grehaigne *et al*., 1997).

From those observational variables, it was possible to compute the following set of technical/tactical performance indices as suggested by the 2nd modified version of the TSAP instrument (Grehaigne *et al*., 2005): volume of play; attacks with ball; efficiency index and performance score.

Teams' actions were captured using a digital camera (GoPro Hero with 1280×960 resolution) with the capacity to process images at 30 Hz (i.e., 30 frames per second). The camera was placed on an elevated surface above the ground in a way that would capture the whole field. All games were recorded and stored on a computer. The TSAP analysis was performed by observing the games using dedicated software (VirtualDub 1.9.11) to observe each action frame for frame. The specific TSAP instrument was used to collect the data (Grehaigne *et al*., 2005). A test-retest reliability for the observations was performed, allowing a 20 days interval for reanalysis thus attempting to avoid task familiarity issues (Robinson and O'Donoghue, 2007). The Cohen's Kappa test was used on 25% of the data to do the reliability analysis. The kappa value was 0.85 an almost perfect score.

Statistical analyses: Data are displayed as meansand Standard Deviations (SD). The main and interaction effects of "format" and "task conditions" on the percentage of heart rate reserve, volume of play, efficiency index, performance score and attacks with ball were examined by using a two-way MANOVA, after validation of normality and homogeneity. When the MANOVA detected significant statistical differences between the two factors, a two-way ANOVA for each dependent variable was used. Tukey's HSD was used for post hoc comparisons. All of the statistical analyses were performed using IBM SPSS Statistics (Version 21) and statistical significance was set at $p<0.05$.

Effect size and the power of the test were classified as follow (Hopkins *et al*., 1996): very small: 0-0.01; small: 0.01-0.09; moderate: 0.09-0.25; large: 0.25-0.49; very large: 0.49-0.81 and nearly perfect: 0.81-1.0.

RESULTS

Descriptive statistics of heart rate responses and technical/tactical profiles during two formats and three task conditions were reported in Table 3 and 4.

After observing the significance of the format and the task conditions in the MANOVA, a univariate ANOVA analysis and relevant post hoc comparisons were performed for each dependent variable. Significant differences were found between the three formats for %HRres ($F_{(2, 42)} = 6.874$; $p = 0.003$; $\eta^2 = 0.247$; Power = 0.903; moderate effect size); volume of play ($F_{(2, 42)} = 16.488$; $p = 0.001$; $\eta^2 = 0.440$; Power = 0.999; large effect size); efficiency index ($F_{(2, 42)} = 14.718$; $p = 0.001$; $\eta^2 = 0.412$; Power = 0.998; large effect size); performance score ($F_{(2, 42)} = 21.310$; $p = 0.001$; $\eta^2 = 0.504$; Power = 1.000; very large effect size) and attacks with ball ($F_{(2, 42)} = 17.744$;

Table 3: Comparison of heart rate responses and time-motion profiles between formats. Values are average of the three task conditions

Parameters	2v2+2	3v3+2	4v4+2
%HRres	86.18 (4.86)[b, c]	78.19 (9.52)[a]	78.10 (5.07)[a]
Volume of play	14.33 (4.29)[b, c]	10.06 (3.86)[a, c]	7.33 (2.89)[a, b]
Efficiency index	1.23 (0.46)[b, c]	0.97 (0.32)[a, c]	0.70 (0.29)[a, b]
Performance score	19.46 (6.15)[b, c]	14.69 (4.67)[a, c]	10.53 (3.92)[a, b]
Attacks with ball	13.92 (4.85)[b, c]	10.94 (3.98)[a, c]	7.52 (3.01)[a, b]

Significantly different compared to 2v2+2[a], 3v3+2[b] and 4v4+2[b] at $p<0.05$

Table 4: Comparison of heart rate responses and time-motion profiles between three task conditions. Values are an average of the two formats

Parameters	T1	T2	T3
%HRres	78.14 (6.68)	82.48 (4.25)	79.48 (10.42)
Volume of play	11.29 (4.83)	9.41 (4.47)	9.12 (4.00)
Efficiency index	1.15 (0.45)[b, c]	0.89 (0.33)[a]	0.71 (0.27)[a]
Performance score	17.21 (6.53)[b, c]	13.59 (5.06)[a]	11.49 (4.60)[a]
Attacks with ball	13.00 (5.16)[b, c]	9.47 (3.61)[a]	8.24 (3.47)[a]

Significantly different compared to T1[a], T2[b] and T3[c] at $p<0.05$

$p = 0.001$; $\eta^2 = 0.458$; Power = 1.000; very large effect size). The highest values were observed for %HRres in the 2 versus 2 with 2 neutral players format and the lowest in the 4 versus 4 with 2 neutral players format. The highest values for volume of play, efficiency index, performance score and attacks with ball were found in the 2 versus 2 with 2 neutral players format and the lowest in the 4 versus 4 with 2 neutral players format.

Comparison of heart rate responses and technical/tactical performance between three task conditions were indicated in Table 2. Significant differences were found between the three task conditions for efficiency index ($F_{(2, 42)} = 13.348$; $p = 0.001$; $\eta^2 = 0.389$; Power = 0.996; large effect size) and attacks with ball ($F_{(2, 42)} = 13.172$; $p = 0.001$; $\eta^2 = 0.385$; Power = 0.996; large effect size). No significant differences were found between the three task conditions for %HRres ($F_{(2, 42)} = 1.401$; $p = 0.258$; $\eta^2 = 0.063$; Power = 0.284; large effect size) and volume of play ($F_{(2, 42)} = 2.818$; $p = 0.071$; $\eta^2 = 0.118$; Power = 0.524; moderate effect size). The highest efficiency index, performance score and attacks with ball scores were obtained for T1 and the lowest scores for T3.

DISCUSSION

The aim of this study was to determine the effects of different SSG format and task conditions on heart rate responses and technical/tactical performance of young basketball players. This study found that the smaller formats (i.e., 2 versus 2 with 2 neutral players) significantly increased heart rate responses and technical/tactical performance. In addition, higher values of heart rate responses were found in task condition 2 (with two targets) and higher technical/tactical performance in task 1 (no targets but endline).

Furthermore, an mean %HRres value of 86% was found for the 2 versus 2 with 2 neutral players format compared to a mean value of 78% for the 3 versus 3 with 2 neutral players and 4 versus 4 with 2 neutral players formats.

These heart rate values suggest that a greater physiological demand is placed on players during participation in smaller formats of games. Very similar heart values of between 75 and 85% were also reported by previous research in this area (Castagna *et al*., 2011; McCormick *et al*., 2012; Pinar *et al*., 2009; Sampaio *et al*., 2009). Smaller game formats therefore seem to raise players' participation levels especially by increasing the number of attacking and defensive moves that they need to perform. A low number of players in the smaller format games would also experience more physiological demands due the reduced opportunities to recover during a match. This explanation is verified by the fact that the mean volume of play was almost double during participation in the 2 versus 2 with 2 neutral players (14.33) compared to the 4 versus 4 with 2 neutral players format (7.33). Furthermore, the attacks with ball and efficiency index scores were also the highest for the smaller format games. Therefore, the smaller formats force players to perform a higher number of technical skills as indicated by the highest mean volume of play, performance and attacks with ball scores for these formats. The use of neutral players in these formats promotes a momentary situation of 4v2 in attacking moments. Such condition decreases the defensive pressing against the team with the ball thus increasing the opportunity to perform successful actions and movements contributing to better learning and performance.

The comparison between different task conditions (T1 = endline; T2 = two targets; T3 = one target) showed that the highest mean heart rate responses were achieved in task condition 2 (82.48 %HRres). Nevertheless, no statistically significant differences were found between task conditions and heart rate responses. The highest mean heart rate for task 2 may have been caused by increased opportunities that players could explore over the length of the court and extra side to side movements that were necessary to evade opposing players due to use of two targets.

With regards to the technical/tactical performance, the highest mean values were obtained for task condition 1. In fact for the majority of technical/tactical performance parameters statistical differences existed between task condition 1 and the remaining conditions. However, no differences were observed between task conditions 2 and 3. It is therefore possible that the use of the endline and no targets in task condition 1 may have increase the individual participation levels mainly due to

an increase in attacking movements. The largest space to perform the finalisation in endline condition increased the opportunities to explore the field and to avoid the opponent players. Thus, the success increases as can be observed in the volume of play (conquered and received balls) and attacks with the ball (passes and shots). Moreover, the efficiency index reveals that success is great in condition 1 due to the highest volume of successful actions and the reduced volume of lost balls.

Practical applications: The mean heart rate values found in this study showed that a 2v2+2 format can be used to develop the anaerobic workout. On the other hand, the mean values observed in this study in3v3+2 and 4v4+2 can be more appropriated to develop a high intensity aerobic workout. To develop the anaerobic workout, an interval between 30 sec and 3 min is suggested to activate and exhaust the lactate system to its maximum. For high intensity, an interval workout is recommended (Janssen, 2001). It is suggested to develop 4-8 repetitions per each block of training with recovery periods between 30 sec and 3 min for a ratio of work/recovery of 1:1. The blocks may vary between 2 and 4, depending on repetitions per block (Little, 2009) with recovery intervals between blocks of 3-5 min. On the other hand, the high intensity aerobic workout can be prescribed in 8-15 min intervals (Janssen, 2001). Recovery periods of about 5 min and repetitions varying from four to five are suggested. In both cases, anaerobic and high intensity aerobic workouts must be performed without fatigue accumulation thus being recommended immediately after the warm-up. Moreover, the smaller formats increase the frequency of technical actions and their success. Such findings can be important mainly for training in younger players. In the case of younger players without a high level of expertise, it is important to increase their intervention in games. Findings from Pinar *et al.* (2009) suggest that the basketball game can be monopolised by two or three players in a regular basketball format (5 versus 5). In smaller formats, the individual participation increases thus better promoting the execution of technical actions. Similar effects are promoted by games without targets but with endlines. Smaller games (2 versus 2 or 3 versus 3) with task conditions such as the use of endlines are better to increase the volume of play and efficiency index. On the other hand, bigger formats with targets decrease individual participation but can increase the complexity thus promoting tactical behaviour and team coordination.

CONCLUSION

The aim of this study was to inspect the effects of format and task condition on heart rate responses and technical/tactical performance of young basketball players. The highest values of heart rate responses in smaller formats and in games with two targets were found. Lower heart rate values were found in the biggest format and games with endlines and not targets. It was also found that smaller formats and task conditions without targets (but with endlines) had the highest levels of volume of play, attacks with the ball, efficiency index and performance score. The biggest format played in the task condition with one central target decreased all technical/tactical performance variables.

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