ANALYSIS OF LOAD AND PLAYERS' EFFORT IN 4vs4 SMALL-SIDED HANDBALL GAMES IN RELATION TO COURT DIMENSIONS

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Abstract:

The aim of the present study was to analyse load to which players were exposed and effort they invested in 4vs4 small-sided handball games in relation to various court dimensions. Eight male amateur handball players participated in three eight-minute 4vs4 (plus goalkeepers) small-sided handball games. The three court dimensions were 12×24 m, 30×15 m and 32×16 m. Using Global Positioning System devices (SPI pro elite 15Hz, GPSports), time-motion video analysis, and Borg's scale for rating of perceived exertion (RPE), the following performance, physiological and psychological parameters were recorded: cyclic movements for distance covered, acyclic movements for the number of technical actions executed, heart rate, and RPE. The total distance travelled increased with the increase in court size (948.1±64.5, 1087.2±92.0 and 1079.8±90.6 on the 24×12 m, 30×15 m and 32×16 m court, respectively; p<.05). The distance covered by the players in four speed zones revealed a substantial difference between the games played on the 24×12 and 30×15m courts in the first and third (p<.05; moderate ES) speed zone. On the 24×12 m court the players covered more distance while moving in the first speed zone, but less distance when moving in the third speed zone (p<.05; moderate ES). On the 30×15 m court the players covered less distance while moving in the first speed zone, but they covered more distance by moving in the third speed zone (p<.05; moderate ES). There were no substantial differences found for the second and fourth speed zone cyclic movements and distances covered on all the three experimental court sizes. No statistical differences between the games played on various court dimensions were found in acyclic movements. No statistical differences were found in the analysis of heart rate either. Further analysis of players' self-evaluated effort confirmed the trend of heart rate values, showing no statistical differences in the RPE values among the three different court dimensions. Our findings indicate that changing court dimensions during 4vs4 small-sided handball games could influence load imposed on players and their exertion.

***Key words**: sport-specific training, exercise intensity, Global Positioning System (GPS)*

Introduction

Intensity and volume of work, or load intensity and load volume of match play in handball are dynamically heterogeneous due to the very nature of this team sport in which two opposing teams alternately take the role of either an attacker (in ball possession; striving for scoring a goal) or a defender (defending own goal trying not to concede a goal) and clashing on the play court in a struggle to win over each other (Šibila, Vuleta, & Pori, 2004). During games, players are exposed to both high and low load. Work load in a match play is a combination of both the acyclic (intermittent) activities (e.g., in attack, passing the ball, various types of shot at goal, jumps, feints, falls, body contacts with an opponent when breaking through or tackling in defence, etc.) and cyclic movements (running, walking, jogging, cruising, moving sideways or backwards). Therefore, during the course of match play, work or load, which varies in intensity and volume, alternates continuously with periods of relative rest, i.e. standing or slow walking (Šibila, et al., 2004).

Data on cyclic movements, collected by motion-time analysis, revealed significant differences in the total distance travelled with a greater distance travelled by wings, who spent a higher percentage of time sprinting (running speed above 5.2 m/s) (Bon, 2001; Luig, et al., 2008). This trend has also been confirmed during 2×20 min matches (Šibila, et al., 2004). Differences among the players of different playing positions are also apparent in acyclic activities: significantly more passes and shots are executed by back players compared with others (Pori, Mohorič, & Šibila, 2009). In order to get an insight into physiological demands of handball, researchers have most frequently analysed players' heart rate (HR) and blood lactate concentrations (LA). The average HR during official matches has been reported to be approximately 82% of the maximal HR (HRmax) (Póvoas, et al., 2012). Blood lactate concentration ranged between 2 and 6 mmol·l^{-1} (Pori, Bon, & Šibila, 2007). Different sport games require various levels of anaerobic endurance, but in each and every one of them it is an important component of performance.

Sport-specific demands do, in turn, influence athletes' anaerobic capacity (Sporiš, et al., 2014). To meet the team sport-specific demands, more specific training methods have been developed. Following these developments, several authors have focused their attention on the investigation of physiological and technical properties and effects of specific drills. Game-specific drills, performed on courts of various sizes and by various number of players, are an excellent example of this trend in research (Abrantes, Nunes, Maçãs, Leite, & Sampaio, 2012; Aroso, Rebelo, & Gomes-Pereira, 2004; Da Silva, et al., 2011; Dellal, Hill-Haas, Lago-Penas, & Chamari, 2011; Gabbett, Walker, & Walker, 2015; Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011; Jones & Drust, 2007; Katis & Kellis, 2009; Kelly & Drust, 2009; Kennett, Kempton, & Coutts, 2012; Köklü, Aşçi, Koçak, Alemdaroğlu, & Dündar, 2011; Rampinini, et al., 2007; Tessitore, Meeusen, Piacentini, Demarie, & Capranica, 2006). Varying duration of these drills has also been a line of investigation (Fanchini, et al., 2011; Hill-Haas, et al., 2011; Tessitore, et al., 2006). In particular, the main question of several studies in different team sports was whether exercises performed with the ball can be used as a substitute for traditional, generic training methods, more precisely physical conditioning methods without the ball (Hill-Haas, et al., 2011; Impellizzeri, et al., 2006; Kelly, Gregson, Reilly, & Drust, 2012; Little & Williams, 2006; Sassi, Reilly, & Impellizzeri, 2004).

Compared with the generic training/physical conditioning methods, those reproducing specific game situations may be regarded more functional since they provide a useful physical conditioning stimulus together with technical and tactical training components (Hill-Haas, et al., 2011; Impellizzeri, et al., 2006; Sassi, et al., 2004). In handball, there is a lack of scientific knowledge about how to set up small-sided games (SSGs) in terms of the number of players, court size, and game duration. In spite of a substantial growth of research related to specific training methods in many team sports, only a few studies on SSGs in handball have been published so far (Buchheit, et al., 2009a, 2009b; Clemente & Rocha, 2014; Corvino, Tessitore, Minganti, & Šibila 2014; Moss & Twist, 2015). The first study by Buchheit et al. (2009a) compared a traditional intermittent running exercise with a specific four-a-side drill played on a regular-sized court. The authors reported greater time spent close to maximal oxygen uptake, lower HR and blood lactate levels, and a similar rating of perceived exertion (RPE) during the handball-specific exercise. The second study by Buchheit et al. (2009b) highlighted the improvement of repeated sprint ability (RSA) and high-intensity intermittent running performance in young players (as measured by the 30-15 Intermittent Fitness Test) following high-intensity interval training and specific game-based handball training. While both methods were equivalent in improving most of the performance test measures, SSGs could be preferred due to their greater specificity. However, only one type of SSG (i.e. 4vs4 on a standard 40x20 m handball court) was used in these two studies. Whether the variations in numbers of players and court dimensions could be as efficient at developing physical performance is presently unknown.

Beside the data about players' metabolic response to the load of SSGs, researchers also attempt to obtain data about cyclic activities (e.g. walking and running at different speed) and acyclic activities (e.g. jumps, shots, passes, changes of movement directions) performed during a game. For this purpose, a wide range of different measurement methods of notational and time-motion analysis were introduced. In this field, the introduction of Global Positioning System (GPS) technology has been a significant innovation. In recent years, GPS tracking of players has been adopted to collect information on time-motion characteristics for all kinds of games (Brewer, Dawson, Heasman, Stewart, & Cormack, 2010; Castellano & Casamichana, 2010; Macutkiewicz & Sunderland, 2011).

The aim of this study was to investigate the effect of three different court dimensions on effort, assessed by HR and rate of perceived exertion, and load, assessed by running intensity and the number of technical actions performed during 4vs4 SSGs in handball. Based on previous studies in soccer (Casamichana & Castellano, 2010; Rampini, et al., 2007), we expected to observe both a greater load of and more effort exerted in match play on increased court dimensions.

Methods

Sample

Eight amateur players (average age 29±4 years, range 24-33 years; average body height 183.75±8.22 cm; average body mass 84.50±9.56 kg) on an Italian Serie A1 league team (the second tier championship in Europe) were recruited to participate in this study.

The players had at least six years of experience in handball training (four times per week) and competitions; they participated in the national championship at the time of the investigation. Participants were volunteers and took part in the present study after giving their written consent. All procedures received the approval of the Ethics Committee of the Faculty of Sports, University of Ljubljana.

Methodology

Experimental procedures

The games were played on three different court sizes: 24×12 m, 30×15 m and 32×16 m. For each court size, an eight-minute drill of continuous exercise without substitutions was performed. This drill duration was chosen on the basis of previous studies (Buchheit, et al., 2009a; Tessitore, et al., 2006). Consistent verbal encouragement, provided by the coach to ensure a high work-rate, was allowed (Rampinini, et al., 2007).

The study was conducted over a 6-week period, with one experimental session per week; one experimental condition was applied in two successive weeks. All the experimental sessions were scheduled at the same time of the day (on a Tuesday during a regular training session) to avoid any effect of circadian rhythms on the measured variables (Drust, Waterhouse, Atkinson, Edwards, & Reilly, 2005). In this way, every player performed two eight-minute drills on each experimental court size. Before each experimental session, the players put on a specific vest to support the GPS and heart rate devices, after which they performed a standardized twenty-minute warm-up. In the SSGs, the defence was a zone defence that mimicked the central part of a hypothetic 5-1 defence with the back centre and front centre (peak) defender and two mid-defenders; the attackers held the positions of the left, right and central backcourt players and the one of line player (pivot). In the drills the official handball rules were applied with the following exceptions:

1) throw-in after a goal conceded or the opponent's shot on goal was immediately taken by the goalkeepers from their goal area, and the investigator was always available to replace the ball when it was thrown out of the playing area (Buchheit, et al., 2009a),
2) the two-minute suspension rule was not applied and the referee sanctioned only acceptable fouls.

For all experimental drills the referee was always an official referee of the Italian Handball Federation.

Player's load

SPI pro elite GPS system 15Hz (GPSports) was used to track performed cyclic movements and distance covered. The following variables on cyclic movements were thus obtained: 1) total distance (in metres) covered in each of the three experimental conditions; 2) percentage of time spent in the first speed zone (0 to 1.4 m/s); 3) percentage of time spent in the second speed zone (from 1.4 m/s to 3.4 m/s; 4) percentage of time spent in the third speed zone (from 3.4 m/s to 5.2 m/s); and 5) percentage of time spent in the fourth speed zone (above 5.2 m/s) (Pori, Kovačič, Bon, Pori, & Šibila, 2005; Šibila, et al., 2004). The distance covered in each speed zone was also detected. However, the validity and reliability of this technology has been questioned in literature (Duffield, Reid, Baker, & Spratford, 2010; Jennings, Cormack, Coutts, Boyd, & Aughey, 2010; Petersen, Pyne, Portus, & Dawson, 2009). The findings of these studies revealed that 1Hz and 5Hz GPS devices have acceptable levels of accuracy and reliability when measuring a total distance and peak speeds achieved in high-intensity intermittent exercises.

With the aim of providing valuable information about acyclic activities, a time-motion analysis was applied. This analysis was done by a video camera positioned on one side of the court. The footage was then analysed to count the number of the following acyclic activities: shots on goal, piston movements towards the goal, passes, jumps (every jump that players performed during a drill: jump passes, jump shots and defensive jumps when blocking opponents' shots on goal), tackling (interfering with attacking actions by body checking or holding the opponent to deny his/her further play), changes of direction (players' cutting activity with a pronounced deceleration and acceleration, independent of game phase), number of actions per team. The piston movement towards the goal is a basic attacking movement in which a player moves continuously forwards and backwards executing a few powerful and rapid steps to endanger defence and create a scoring opportunity (European Handball Federation, 2011). The action is defined as a part of the game from the moment of coming into possession of the ball to the moment of losing the ball or scoring a goal (Rogulj, et al., 2004).

Players' effort invested

In order to assess the individual HRmax, players performed a 30-15 Intermittent Fitness Test (Buchheit, 2008; Buchheit, et al., 2009c). The speed at the last fully completed stage was retained as VIFT. The maximal heart rate reached at that moment was considered player's HRmax.

Data on players' HR was collected during all SSGs. The individual minimum HR was noted by the participants (each morning in bed for five consecutive days), and this data, together with the maximum HR obtained at the end of the 30-15 Intermittent Fitness Test, was used in the Karvonen formula (HR(%)=[100*(HR-HRmin)]/[HRmax-

HRmin]) to calculate the HR reserve (Duarte, et al., 2010). The reference scale was as follows: <50%, 50-70%, 70-90% and >90% of the relative HR reserve. Next, the percentage of time spent in each HR zone was calculated for subsequent statistical analysis.

Statistical analysis

The statistical package SPSS (17.0) was used for the analysis. Data were presented as M±SD and the alpha level for significance was set at p≤.05. A parametric statistical approach was chosen for continuous variables (total distance, percentage of time spent and distance covered in particular HR zones and speed zones, and RPE). The Kolmo-gorov test was first applied to confirm the normal distribution of the data. Two separate multivariate analyses of variance (MANOVA) for repeated measures were applied. In the first MANOVA, the four HR zones were the dependent variables and the court size was the independent variable (within factor). Likewise, in the second MANOVA the four speed zones were the dependent variables and the court size was the independent variable (within factor). MANOVA was chosen because it offers several advantages over multiple univariate ANOVAs, including the feasibility to measure multiple facets of a problem, to improve statistical power, and to reduce Type I error rates (Tabachnick & Fidell, 2001). Furthermore, two separate within-subjects repeated measures analyses of variance (ANOVA) were used to test the differences in the total distance covered and RPE values for each court size. To control for the assumptions that must be met in this kind of analysis, Mauchly's sphericity test was applied. When the sphericity assumption was violated, the Greenhouse-Geisser corrections were taken into account. In order to avoid Type I statistical errors, univariate effects within MANOVAs were examined only if the overall MANOVA was significant. When univariate effects were detected, multiple comparisons *t*-tests with Bonferroni corrections were used. A non-parametric (i.e. chi-square) approach was chosen for acyclic activities (i.e. number of events in the game). To provide meaningful analysis for significant comparisons of results obtained from small groups, Cohen's d effect sizes (ES) between groups were also calculated in the parametric statistical approach. An ES<0.2 was considered trivial, the one from 0.3 to 0.6 small, ES<1.2 was considered moderate and ES>1.2 large (Hopkins, 2006). Additionally, to determine a meaningful interpretation for comparison of variables that have required a non-parametric approach (i.e. chi-square) from small groups, the phi effect sizes between groups were also calculated. Values 0.1, 0.3, 0.5 were then considered as small, medium, and large effect sizes, respectively (Huck, 2000).

Results

The results of the distance-covered analysis are shown in Table 1. The only statistical difference was found between the data obtained during the 4vs4 game on the 30×15 m and the 24×12 m court: distance covered by players increased parallel with the enlargement of court size from the small court (24×12 m) to the medium court (30×15 m) (from 948.1±64.5 m to 1087.2±92.0 m), but not from the medium court to the large one (32×16 m) (1079.8±90.6 m).

Table 1. Total distances covered in each experimental condition of the 4vs4 SSGs

Court dimensions	Total distances (m)
24×12 m	948.1±64.5
30×15 m	1087.2±92.0*
32×16 m	1079.8±90.6

Note. *=significant difference vs 24x12 m (p<.05; large ES).

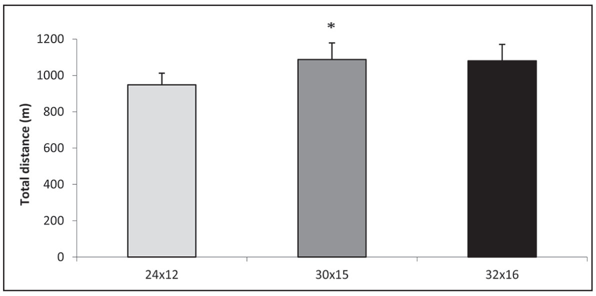

*Figure 1. Total distances covered in each experimental condition (court size) of the 4vs4 small-sided handball games; *=significant difference vs 24x12 m (p<.05; large ES).*

The distances covered by players moving in either of the four speed zones are reported in Table 2. Statistical analysis revealed substantial differences between the 24×12 m and 30×15 m court sizes in the first and third (p<.05; moderate ES) speed zones. On the 24×12 m court, players covered more distance in the first speed zone but less distance in the third speed zone (p<.05; moderate ES). Statistical differences were also found between the 32×16 m and 24×12 m court. On the larger size court, players covered less distance in the first speed zone but more distance in the third speed zone (p<.05; moderate ES). There were no substantial differences found for the second and fourth speed zone in all the experimental conditions.

There was no significant effect of court sizes on acyclic activities (Table 3).

Finally, there was no effect of court dimensions on HR and RPE values (Tables 4 and 5).

Table 2. Distances covered in the four speed zones in each experimental condition of the 4vs4 SSGs

Court dimensions	1st speed zone (m)	2nd speed zone (m)	3rd speed zone (m)	4th speed zone (m)
24×12 m	227.3±20.1	613.4±66.6	114.1±52.3	3.9±5.9
30×15 m	212.0±27.7*	618.6±40.3	242.9±75.0*	19.6±25.4
32×16 m	176.3±42.9*	635.1±98.0	289.5±75.2*	13.9±11.1

Note. *=significant difference vs relative 24x12 m (p<.05; moderate ES).

Table 3. Acyclic activities in each experimental condition of the 4vs4

Court dimensions	Actions	Shots	Passes	TACKL	PM	Jumps	COD
24×12 m	32±2	46±2	78±8	5±1	4±2	6±2	3±2
30×15 m	27±1	41±4	75±10	5±1	3±1	6±2	2±2
32×16 m	26±2	41±5	74±13	3±2	2±1	5±2	2±1

Note. TACKL=stopping attackers using body and arms, PM=piston movements toward the goal, COD=changes of direction.

Table 4. Time spent in particular heart rate zones in each experimental condition of the 4vs4 SSGs

Court dimensions	<50% HRrel (% time)	50-70% HRrel (% time)	70-90% HRrel (% time)	>90% HRrel (% time)
24×12 m	0.9±0.7	3.0±1.0	40.0±26.4	56.1±27.7
30×15 m	4.2±3.3	3.9±1.8	47.7±32.8	44.1±33.6
32×16 m	3.3±1.9	4.7±3.5	59.1±35.3	32.9±38.7

Note. HRrel=relative heart rate calculated by the Karvonen formula.

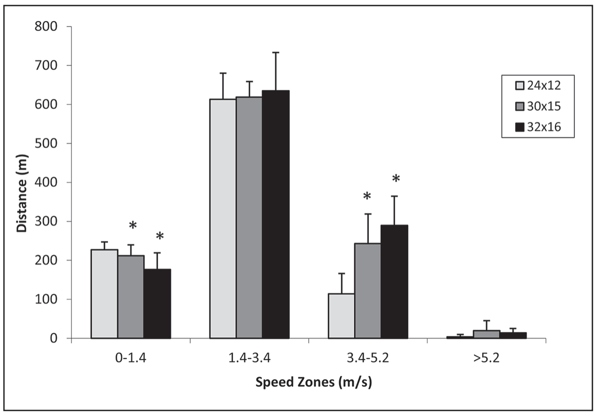

*Figure 2. Distances covered in the four speed zones in each experimental condition of the 4vs4 small-sided handball games; *=significant difference vs relative 24x12 m (p<.05; moderate ES).*

Discussion and conclusions

The results revealed that size of the handball court affected the load in 4vs4 SSGs and effort of the players invested in them. In general, almost all the parameters increased parallel to the increase in court size. The obtained results allow us to describe the main characteristics of SSGs in handball, with respect to both physical load and effort of players.

The data about total distance covered by players during 4vs4 SSGs confirmed that the players covered more distance as more space was available. In particular, statistical differences appeared between the data when games were played on the 24x12 m and 30x15 m courts (Figure 1). The values reached in distance covering on the 30×15 m court and on the 32×16 m court were almost the same.

Table 5. Rating of Perceived Exertion's values in each experimental condition of the 4vs4 SSGs

Court dimensions	RPE values
24×12 m	7.7±1.0
30×15 m	8.2±1.2
32×16 m	7.3±1.2

Note. RPE=Rate of Perceived Exertion.

We were also interested to see how much distance was covered per minute. The total distance covered per minute during the 4vs4 experimental sessions was 118.5 m/min in a game on the 24×12 m court, 135.9 m/min in a game on the 30×15m court and 135.0 m/min on the 32×16m court. Comparing the obtained values with those of a regular handball match (79.8 m/min and 87.5 m/min reported in Bon, 2001, and Pori et al., 2009, respectively), we can see that in SSG types of drills players have to cover more distance per minute than in a handball match played on the regular-size court. The second comparison was done with the only previous study on handball that reproduced similar experimental condition (Buchheit, et al., 2009b). In the study, the authors analysed 2x225 second-periods of 4vs4 game played on the regular-size handball court. They found that players covered 154 m/min. This result, compared with our results, underlined once again the increase in the amount of cyclic movements parallel to the increase of space available for each player.

Our data is similar to the data obtained in studies on soccer SSGs (Barbero-Alvarez, Barbero-Alvarez, & Granda-Vera, 2007; Pereira Da Silva, Kirkendall, & Leite De Barros Neto, 2007). It is obvious that short duration of games and a reduced number of players in SSGs allow players to perform many cyclic movements in a short period of time. As different match analysis systems were applied in these studies, any comparison of results should be done with caution (Randers, et al., 2010).

The cyclic movements data classified into the four speed zones highlighted the fact that with the increases in space available, the distances players covered by running (3.4-5.2 m/s) increased as well (Figure 2). Indeed, statistical differences were found in the third speed zone between 24x12 m and 30x15 m court sizes and between 24x12 m and 32x16 m court sizes.

Another data that emerges from the research is that on the 24x12 m court players covered more distance in the first speed zone (walking). Since no difference was obtained in the second and fourth speed zones, we claim that less distance covered by running (the third speed zone) during 4vs4 on the 24x12 m court was *replaced* by more distance covered by walking (the first speed zone). This trend, highlighted by the analysis of cyclic movements classified into the four speed zones, has been confirmed by a previous study on 3vs3 small-sided-handball games (Corvino, et al., 2014) and by a soccer SSG study (Castellano & Casamichana, 2010).

No statistical difference was found during the analysis of acyclic movements. Technical parameters, like the number of passes, shots, actions, piston movements, defensive actions, as well as physical parameters like the number of jumps and changes of movement direction, did not change in response to different court dimensions. Other studies showed this trend also in other team sports: Tessitore et al. (2006), and Kelly and Drust (2009) found few differences in acyclic activities, such as ball passing, ball receiving, dribbling, interceptions and headings, in response to the change of court dimensions. Even though no statistically significant difference occurred in the number of acycling activities in relation to the court size, a clear drop was observed in the number of these activities parallel to the increases in the court size. The largest number of these actions was performed in the game on the 24×12 m court compared with the 30×15 m and 32×16 m court. In soccer, Kelly and Drust (2009) found a high number of tackles and shots performed on a smaller court. The increased number of tackles on the smaller SSGs court was attributed to a smaller area per player since it gave more opportunity for body contact between players. Even if we could not confirm significant differences between the three court sizes in the number of shots, it is interesting to note that in handball SSGs players also execute more shots during a game on a smaller court (Table 3). This can be justified by a greater proximity of goals, which can lead players to take attempts on goal more frequently (Aguiar, Botelho, Lago, Maças, & Sampaio, 2012). Corvino et al. (2014) obtained similar results during 3vs3 small-sided handball games.

No statistical differences were found in the analysis of players' HR during 4vs4 handball SSGs (Table 4). In other cases, such as studies of rugby (Gabbett, et al., 2012) and soccer (Aroso, et al., 2004; Da Silva, et al., 2011; Köklü, et al., 2011; Rampinini, et al., 2007), certain differences were observed. These studies reported the increase in distance covered and HR values of players parallel to the increase of court dimensions. Only two studies, to the authors' knowledge, found an inverse trend: HR values increased with the decrease of court dimensions (Katis & Kellis, 2009; Tessitore, et al., 2006).

During the eight-minute SSGs, the players were close to their maximal HR values (>90% of HR_{max}) for 56.1±27.7% of total time in the game on the 24×12 m court, for 44.1±33.6% of total time in the game on the 30×15 m court, and 32.9±38.7% of total time on the 32×16 m court. This data confirmed high intensity of the SSGs drills in comparison with a regular match. In a regular match play, as reported by Póvoas et al. (2012), the average HR values during the entire match were at the level of 82±9.3% of HR_{max}. Only 10% of time in the 1st half and 4% of time in the 2nd half HR values were above 90% of players' HR_{max}. In longer bouts of SSGs (10 or 15 minutes), players may be forced to reduce intensity of their play to sustain physical demands of the entire match, i.e. they apply the strategy of rational exertion. Obviously, a comparison between the data of our research and handball players' HR values should be made with caution. As previous studies have revealed, players in team sports usually adopt pacing strategies and this can modify HR over a longer period of time, as in an entire match (Aughey, 2009; Duffield, et al., 2010; Mugglestone, Morris, Saunders, & Sunderland, 2013).

Like in our research, three other studies found no differences in HR values in response to the changes of court dimensions (probably due to a low age of subjects in Jones & Drust, 2007; limited sampling in Kelly & Drust, 2009; Corvino, et al., 2014). The trend is probably due to the same reasons: we have to consider that HR values are only a partial measure of load/player's effort, and that sometimes it may not be sensitive enough to the differences in actual metabolic demands, especially in handball SSG (Buchheit, et al., 2009a). This fact, joined with the limited sampling and a great variability of HR measures, were probably the reason for the obtained results.

It is interesting to look at the average data emerging from the HR monitoring. If we take into consideration the percentage of time during which our players were close to their HR_{max} and if exercising at >85% HR_{max} might be enough to improve maximal cardiovascular function together with the corresponding $VO2_{max}$ and the anaerobic threshold (Helgerud, Engen, Wisloff, & Hoff, 2001; Impellizzeri, et al., 2006), then the SSGs used here may be useful for improving aerobic endurance of handball players.

Obviously, when comparing regular match data with the data of this research on eight-minute bouts of 4vs4 SSGs, we should be careful because of pacing strategy that players adopt in all team sports when playing a regular match (Aughey, 2009; Mugglestone, et al., 2013; Gabbett, et al., 2015; Sampson, Fullagar, & Gabbett, 2015).

Further analysis of players' effort using RPE values confirmed the trend of HR values – no statistical differences in RPE values were obtained between the three different court sizes (Table 5). Comparing our results with those of Buchheit et al. (2009b), we found higher values of RPE even though players in our study had less available space. This difference (7.7±0.4 vs 6.3±0.5) could be due to a brief rest of 30 seconds inserted in the study of Buchheit and colleagues, which allowed players to recover. Nevertheless, comparisons between these two studies have to be made carefully because of the difference in the experimental procedures.

Findings of our research, regarding the load and efforts to which the handball players were exposed during the SSGs drills, may be helpful for handball coaches and physical conditioning trainers who wish to use sport-specific training methods. The high ratio of cyclic activity per minute and the high HR values recorded make SSG-type of drills extremely useful for aerobic power training. Furthermore, the presence of a large number of jumps makes SSGs, in particular the one played on the 24×12 m court, useful also for jump ability training under the conditions of fatigue. Small space available to trainees might limit the expression of their high speed run. Therefore, it would be advisable to use the regular handball court from time to time to do SSGs in order to allow players to express their maximum speed. Also, because of a large number of defensive activities, SSGs played on the 24×12 m court might be useful for the development of 1 vs 1 skill of handball players.

Considering a large number of shots on goal reported, SSGs played on all the three court sizes are useful for the development of the goal-scoring skill of handball players in circumstances of general fatigue.

Based on the results of this study, we can even speculate on what changes in court sizes, i.e. in space available for each player, might induce change in load of handball SSGs and players' effort invested in it: differences of 13 sqm or less do not lead to changes in load and players' effort. However, space differences of 17 square metres or more could induce changes in load and handball players' effort. As regards space available to each player, future studies should try to understand size limits of court dimensions for small-sided handball games: we hypothesize that a too large court size may induce decrements in load and players' effort. It would be very interesting to find out what that size limit might be.

The study by Rampinini et al. (2007) demonstrated that coach encouragement during small-sided soccer drills can modify effort of players. No studies on handball were made on this particular modification of SSGs; therefore, it could be very interesting to investigate the modification of load and players' effort in response to coach's encouragement in a relatively small and closed environment like a handball court.

In conclusion, in this study a high intensity of small-sided handball games was emphasized that, joined with the specific stimulus of playing handball on different court dimensions, makes this type of drill very useful also to professional adult handball players.

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