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Effects of Environmental Context on Physiological Response During Team Handball Small Sided Games

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ABSTRACT

International Journal of Exercise Science 10(8): 1263-1274, 2017. This study examined the distance covered and physiological effects of altering the number of players during small-sided games (SSG) in team handball. Twelve professional female handball players [24.6±3.7 years, 172±6.2 cm, 68.2 ± 9.9kg, 22.7 ± 2 kg/m^2] participated in this study. The SSG were played, first with five on each side (SSG 5), then four (SSG 4), then three (SSG 3). Each game was four minutes long, followed by three minutes of rest. The distance covered and time spent in four speed zones (based on player movement speed) were selected for analysis: Zone 1 (0–1.4 m/s), Zone 2 (1.5–3.4 m/s), Zone 3 (3.5–5.2 m/s), and Zone 4 (>5.2 m/s). Statistically significant differences were found in Zone 2, between conditions SSG 3 and SSG 4 (p=.049, ω^2= .32). The highest average heart rate (HR) occurred during SSG 3. Average HR between SSG 3 (89.7 % HRmax) and SSG 5 (87.8 % HRmax) (p= .04, ω2= .26) were also significantly different. Participant HR response between the speed zones was not statistically significant. HR response was negatively correlated with the number of players within the SSG condition. Statistically significant results were found for RPE between SSG 3 and the other two SSG conditions (SSG 4, p = .01, and SSG 5, p = .00). These results indicate that changing the number of SSG players can be used to manipulate the physiological response during handball training.

KEY WORDS: Heart rate, time motion analysis, specificity training, metabolic conditioning

INTRODUCTION

Team handball (officially called handball) is an Olympic sport that is played throughout the world. Adult handball players demonstrate a physiological profile such that 1) greater than 80% of the playing time of each match is spent above 85% maximum heart rate (HR_{max}), 2) players' mean heart rate percentage ($\%HR_{mean}$) is 82-90% of HR_{max} (3,9,32), and 3) blood lactate ranges between 2 and 6 mmoL/l during the matches (35). In men's handball, the typical distance covered during the match is 4464-5600 m per match (42), whereas in women's handball the typical distance covered is 3399-5251 m per match (3, 27). Such data illustrates that handball is a sports game of intermittent high intensity, with sizeable distances covered during match play.

In order to reproduce the physical, technical and tactical requirements of match play, coaches in team sports often use small-sided games (SSG) in their training programs (19, 25, 29, 38, 41). Coaches in a variety of sports use SSG to develop technical and tactical skills (22), improve endurance (18, 21), or as part of generic fitness training program (16). During SSG, players experience scenarios similar to those they encounter in competitive matches (3, 30). The differences players encounter during SSG typically include pitch or court size (30, 44), the inclusion/exclusion of specific attack/defense zones (13, 41), the number of players (22), the duration of the game (44), or a combination of these variables (18, 22, 31, 36). In short SSG provides coaches of any team sport a means of altering the environmental context (26) in which players execute any given training task, drill, or scrimmage. In turn this affords coaches unique ways to stimulate sport-specific adaptations to training.

Recent studies have demonstrated that sport-specific SSG conditioning drills are effective in achieving desired training intensities, thus, promoting sport-specific aerobic fitness training in soccer, handball, and rugby (5, 15, 21, 36). These and other studies clearly show that SSG may be effectively used to integrate physiological conditioning into sport-specific training. One area of interest is the usage of variations in SSG team sizes to elicit different physiological, perceptual, and time-motion characteristics (18, 30, 36, 40). One such example involves playing a squad with a fixed numerical advantage against another squad with a fixed numerical disadvantage (17). Handball coaches particularly favor the use of SSG in training to increase the number of ball contacts and the total sprinting distance covered during scrimmage conditions, as well as to immediately facilitate the correction of errors made during play that are less easily addressed during actual match play (14). However, despite a growing interest within the sport science literature on SSG as a form of training, few studies to date have addressed this training methodology in handball and none have addressed the influence of SSG upon women handball participants.

Consequently, the purpose of this study was to examine the distance covered and physiological response of altering the number of players during SSG in handball. This study is the first known investigation involving women handball participants, as well as the first to address the physiological response of SSG to alter the number of players during scrimmage conditions.

METHODS

Participants

Twelve professional female handball players [age 24.6 ± 3.7 years, height 172 ± 6cm, body mass 68.2 ± 9.9kg, BMI 22.7 ± 2 kg/m^2, percent bodyfat 14.7 ± 4.7%, lean muscle mass 30.3 ± 3.2 %, and maximal heart rate 201.3 ± 3.9 beats/min] agreed to participate in this study. All participants were members of the Czech Republic women's handball team who played in the Women Handball International League, and six of them were members of the junior or senior Czech Republic handball teams. The participants reported an average of 15 years of experience within organized handball play. The participants' training schedule during the competitive season consisted of six training sessions per week, with a league game played at the end of the week. All participants were notified of the research procedures, requirements, benefits and risks before giving informed consent. The Institutional Review Board at Palacky University Olomouc approved all of the procedures before this study was initiated.

Protocol

This study examined the distance covered and physiological effects of altering the number of players during SSG in team handball. The SSG were played, first with five on each side (5 vs. 5), then four (4 vs. 4), then three (3 vs. 3). Each game was four minutes long, followed by three minutes of rest. The distance covered and time spent in four speed zones (based on player movement speed) were selected for analysis: Zone 1 (0–1.4 m/s), Zone 2 (1.5–3.4 m/s), Zone 3 (3.5–5.2 m/s), and Zone 4 (>5.2 m/s).

Testing was done at a sports hall on high-quality, indoor courts with polyurethane (synthetic rubber) floors, possessing a consistent indoor temperature of 21-23°C. The court dimensions were 40 m x 20 m with the area of 800 m^2, which is standard for handball courts. The goalkeeper area was standard (149 m^2), making the playable area approximately 651 m^2. Assessments were completed every Monday from 19:00-20:30 over a six-week period during the competition season. Standardized training conditions included a 15-minute warm-up (light running, stretching, and ball passes) followed by 3 bouts of SSG for 4 minutes, with 3 minute rest periods between bouts. Bouts were performed in the following order: first with five on each side (SSG 5), then four (SSG 4), then three (SSG 3) as done in previous studies on basketball and soccer (7, 8, 11, 14, 36). All SSG scrimmages were played according to standard handball rules, with a zone defense ratio of 0:5, 0:4 or 0:3. All rules were the same, except for: 1) the usage of 2 minutes of suspension for fouls, and 2) 7-meter penalty throws. The games were coordinated by the coach.

Time motion analyses: Each of the 18 SSG bouts in this study were recorded using two digital camcorders (Panasonic SDR-H80 and Canon HF10) mounted approximately six meters from the sideline and nine meters above the court. Each camera recorded one half of the court, and all matches were recorded by the same member of the research team.

The video recordings were analyzed using Video Manual Motion Tracker 1.0 software (Computer Integrated Systems for Microscopy and Manipulation, Chapel Hill, NC, USA), using previously published methods based upon inverse projection techniques (20). The calibration process involved transfer of the real plane of the handball court onto a computer model, ensuring that the court lines overlapped. An orthogonal coordinate network (with distances of 0.5 m) was then generated over the entire court, and the video recording began. Coordinates [X, Y] were assigned to each point in the real plane of the court, and then transformed into the plane coordinates on the screen. Using this procedure, a formula for an inverse projection function was determined. The domain of this function was the set of real numbers on the plane of the screen, and the range of the function is the set of real numbers on the real plane of the court (20).

Following implementation and calibration per manufacturer specifications of the above-noted technical parameters, the movement trajectory of a player was manually copied during the match using an electronic pen on an electronic tablet. The system saved each point of the player's movement trajectory, which was defined by a set of values [X, Y, t], where X and Y were the orthogonal coordinate axes in the screen plane and t is the time variable (20). This method enabled the recording of the total distance covered, as well as the immediate and average locomotion speeds of the players during a match or a training session. The assessment of one SSG took 30-60 minutes. The same member of the research team operated the software program and consequently evaluated all 18 SSG, as a means of increasing internal consistency. The computing module, which was specifically devised and developed to calculate kinematic data, enabled the generation of results using numerical or graphical parameters. All data were transformed, synchronized, and digitally smoothed prior to statistical analysis.

The participants' gross-movements were categorized into speed categories based upon previously published methods (10, 34, 42). These categories included: Zone 1: standing and walking 0-1.4 m/s; Zone 2: jogging (1.5-3.4 m/s); Zone 3: high-intensity running (3.5-5.2 m/s), and Zone 4: maximal speed running, or sprinting (>5.2 m/s). Each video was analyzed to count the number of acyclic activities, such as; shots to the goal, dribbling, passes, or action per team.

Physiological measure/Heart Rate: The players' heart rates (HR) were monitored during all the training exercises in five-second intervals using TEAM Polar2Pro monitors (Polar Electro, Kempele, Finland), and HR were monitored during live playing time (the complete time that the players were on the court). Individual participant maximal HR values (HR_{max}) were measured by means of the Yo-Yo Intermittent Level 1 Recovery Test, a valid and reliable field test of repeat intervals calculated through the following equation: Yo-Yo IR1 test:VO2max (mL/min/kg) = IR1 distance (m) × 0.0084 + 36.4 (28). All participants were familiar with this test, as it is performed as part of a conditioning test before and during the season.

Heart Rate Zones: Heart rate zones were divided into intensity intervals according to methods described by McInnese et al: <75 HR_{max}, 76-80 HR_{max}, 81-85 HR_{max}, 86-90 HR_{max}, 91-95 HR_{max} and, 96-100 HR_{max} (28) . These intensity intervals were calculated as a means of quantifying the physiological response to the SSG conditions. The average time spent in each heart rate zone for each SSG training exercise also was computed, as were the HR_{mean} and HR_{max} values of each player. These were computed as both the absolute and relative values $\%HR_{max}$ and the percentage of average heart rate ($\%HR_{mean}$).

Ratings of Perceived Exertion: Global ratings of perceived exertion (RPE) were assessed using the RPE 6-20 scale (4) and recorded one minute after each SSG condition. Standardized instructions for RPE (4) were modified so that participants gauged their RPE to the SSG condition just completed, rather than their perceived exertion at the time of rating. RPE ratings were collected individually for each participant at a distance of 2m or greater, as a means of avoiding potential influence on each other's score.

Statistical Analysis

Software Statistica (12.0 version, StatSoft, Inc., Tulsa, OK, USA) was used to process the data. One-way ANOVA and Bonferroni post-hoc test were used to compare the average heart rate values during the SSG conditions. Lilliefors' test of normality and Leven's test of homogeneity were used to assess the data prior to completion of the ANOVA. The results were completed by effect size calculation as $\omega^2 = [F \cdot (k-1)]-k+1 / [F \cdot (k-1)]+n-k+1$, where F is ANOVA value, k is number of groups, and n is a sample size. All results are reported as means and standard deviations. Statistical significance was determined at $\alpha < 0.05$.

RESULTS

This study addressed the distance covered and physiological response of altering the environmental context of match play via the number of players during SSG in handball. The longest total distance covered by players was 527.3±70.9 m, during the SSG 3 condition (Table 1). However, the differences between the SSG conditions for total distance covered (SSG 5 - 497.4 ± 51.8 m, SSG 4 - 503.9 ± 41.7 m, and SSG 3 527.3 ± 70.9 m, respectively) were not statistically significant. The time spent in speed Zone 2 covered the longest distance regardless of the SSG condition, but there were no statistical differences between them. A statistically significant difference was found in the speed Zone 3 between SSG 3 and SSG 4 ($p=.049$, $\omega^2= .32$). The longest distance covered in the two fastest zones occurred during the SSG3, when compared with other SSG conditions.

Table 1. Total distance and distances covered in the four speed zones in each SSG. Data were expressed as mean±SD.

SSG	Total distance (m)	1st speed zone (m)	2nd speed zone (m)	3rd speed zone (m)	4th speed zone (m)
5vs.5	497.4±51.8	153.4±38.4	173.1±46.1	108.3±35.1	62.6±31.2
4vs.4	503.9±41.7	151.4±45.9	179.7±45.9	107.9±36.1*	64.9±32.9
3vs.3	527.3±70.9	134.6±39.3	187.5±40.5	127.9±37.9	77.3±45.6

Note: * = Significant difference at $\alpha< 0.05$.

Table 2 illustrates that the greatest mean heart rate was reached during SSG 3. A statistically significant difference was found in HR means between SSG 3 (89.7 $\%HR_{max}$) and SSG 5 (87.8 $\%HR_{max}$ $p=.04$, $\omega^2=.26$). No significant difference was found in HR response between individual intensity zones. Players spent the most of their time in zone >85$\%HR_{max}$, during the SSG 3 condition, players spent 94% of the scrimmage time in the zone above 85% HRmax, compared to 89% in the same HR zone during SSG 4, and 79% during SSG 5. An inverse relationship was found between RPE and number of players on the court, as RPE ratings increased across the SSG conditions from SSG 3 and 4 ($p =.01$), and SSG 3 and 5 ($p =.00$), respectively.

Table 2. Rating of perceived exertion's values, Heart rate and Time spent in Heart Rate zones in each SSG. Data were expressed as mean±SD.

SSG	RPE	%HR_{mean}	<75 HR_{max} (%drill time)	75-80 HR_{max} (%drill time)	80-85 HR_{max} (%drill time)	85-90 HR_{max} (%drill time)	90-95 HR_{max} (%drill time)	95-100 HR_{max} (%drill time)
5vs.5	15.1±2.3*	87.8±4.2*	0	2	19	41	37	1
4vs.4	16±1.8*	88.8±3.9	0	0	11	29	51	4
3vs.3	16.6±1.5	89.7±3.9	0	0	6	39	53	7

Note: * = Significant difference at $\alpha < 0.05$.

Acyclic activities were measured in each SSG condition to determine if the player number had an effect on shots on goal, dribbling, passing, and so on. No significant difference was found in frequency of acyclic activities during the specific game activities among SSG conditions (Table 3).

Table 3. Frequency of acyclic activities in each SSG. Data were expressed as mean±SD.

SSG	Total -attacks	Shots	Passes	Dribbling
5vs.5	18±1.7	15.1±2	59.8±7.4	12.6±2.5
4vs.4	19±2.9	16.6±2.5	63.6±8.5	16.8±1.1
3vs.3	19.6±1.7	18.7±2.8	53.8±5.1	21.4±1.4

DISCUSSION

This study tested the impact of environmental context of SSG in handball upon time-motion measures and physiological responses. The results indicate that the number of players participating in handball SSG influenced the environmental context of handball scrimmage conditions, the time-motion measures exhibited during scrimmage, and the physiological response experienced by the players. The greatest total distance covered occurred in the SSG 3 (527.3 ± 70.9 m or 131.8 m/min ±17.7 m/min), whereas smaller distances occurred during SSG 4 (503.9 ± 41.7 m, or 125.9 ± 10.4 m/min) and SSG 5 (497.4 ±51.8 m, or 124.4 ± 12.5 m/min). These differences between the SSG 4 and SSG 5 conditions were not statistically significant but are comparable with the work of Corvino et al.(10), which indicated that environment influenced time-motion measures and physiological response experienced by handball players. Corvino et al (10), in a study comparing the physiological response of young adult males (28 ± 3 years) playing SSG 3 on three different court dimensions (12×24m, 30×15m and 32×16m), reported players covered significantly more distance (136.9 m/min) playing on a modified court with the greatest dimensions (32x16m) (10). Thus, the present findings support previous work suggesting that modification of scrimmage conditions may be used to influence time-motion characteristics in handball. Nonetheless, despite methodological differences, the present findings suggest that the environmental constraint of SSG involving fewer players on the court can simulate greater distance covered during scrimmage conditions, as has been established in previous studies using male participants. The present findings are the first to demonstrate this phenomenon among female participants.

Similarly, each of the conditions within the present study stimulated time-motion measures exceeding those reported for preliminary matches among female handball players. This is an important consideration for constructing practice activities in team sports, as some evidence in the sport science literature advocates practicing or training for team sports at speeds faster than expected in formal competition (37). Applying this concept to the present study and its findings, Belka et al (3) reported the distance covered during competition match for girls (17.9±0.3 years) was 113.3±9.7 m/min. and Manchado et al. (27) reported that senior women players covered a distance of 87.5 m/min (3,27) during competition. Thus, the present findings suggest that SSG 3, SSG 4, and SSG 5 may be used to stimulate player time-motion characteristics exceeding those reported for female handball players during competition by Belka et al (3).

Although the total distance covered was not significantly different between the three SSG conditions tested, the progressive increase in distance covered by individual players from SSG 5 to SSG 3 does suggest that players undergo greater physiological stress during scrimmages involving fewer players. This finding supports previous work by Platt et al. (33) and Jones and Drust (22), who found that high intensity efforts are increased when the number of players are reduced (22,33). These previous studies reported this trend of greater physiological stress in youth participants, whereas the present findings documented this trend of women athletes responding to SSG. However, the current findings contradict those reported by Hill-Haas et al. (16), who observed that maximal and mean sprint duration and distance in soccer were increased as the amount of players involved increased (16). Further study is needed to better understand such inconsistencies between research studies reported in the applied sport science literature.

Heart rate monitoring has been proposed as a valid and reliable method to assess and control exercise intensity during drills in team sports (7). This method is based on the assumption that HR constitutes a reflection of aerobic responses and consequently acts as an indirect measure of VO_2 demands (2). In the present study, the decreased number of players on the court increased the mean $\%HR_{max}$. This difference was significant between the SSG 3 and SSG 5 conditions. The present findings support the previous work of Rampinini et al. (36) and Da Silva et al. (43), which reported that a decreased number of the players on the court increased mean $\%HR_{max}$ (36, 43) in male participants. Further, mean HR_{max} in the present study approached values from competition matches (82-90% of HR_{max}) previously reported in the literature (3, 9, 32). In this regard, the decrease in players on the court during handball SSG clearly increased exercise intensity. These findings were supported by changes in the time participants spent at the respective intensity zones: during the SSG 3 condition, players spent 94% of the scrimmage time in the zone above 85% HR_{max}, compared to 89% in the same HR zone during SSG 4, and 79% during SSG 5. This effect may be influenced by the total covered distance, which (similar to HR) increases with decreased number of players on the court, as well as by differences exhibited by the sexes in court movement during handball training and competition. This physiological effect may also be related to the contextual effect of fewer defenders on the court, allowing offensive players freer paths to attack the goal, and consequently raising the HR response during this SSG condition. During competition play, athletes spend 81-90% of the playing time in the zone above 85% HR_{max} (3, 27, 39). In this regard, the values from the intensity zones in the present study correspond with physiological measures published on the competition match (3, 27, 39).

In this study, RPE was assessed during drills with the aim of evaluating the subjective psychophysiological response experienced by handball players. For each coach, it is important to receive the feedback about subjective perception of effort of players during the training process. This information can help coaches adjust training processes specifically for the individual athlete as warranted (increase or decrease of the intensity/load). In SSG, RPE appears to be a good indicator of the overall intensity of the activity when compared with HR and lactate concentration (11). In this study, a decrease in the number of players influenced the RPE values. Specifically, SSG 3 was significantly different than the other SSG conditions; these findings confirm previous work (1). One can deduce that the fewest players increase the training intensity, which increases RPE. This corresponds with previous studies that demonstrated better response of HR frequency and accurate values in RPE during high intensity exercise (6,36). The data from prior studies using SSG in soccer practice games indicate that more players on the field translated to lower RPE values (6, 24, 36, 43), which confirm the present findings.

The short duration of the games in the present study and the reduced number of players in SSG conditions allowed participants to perform a relatively high amount of acyclic movements in a short period. This finding likely has value in shaping practice schedules, and it is supported by previous work by Corvino et al. (10) and Buchheit, et al. (5), which showed that SSG may be used to stimulate changes in physiological response while maintaining consistency of technical parameters of play (e.g. number of team actions, passes, shots on goal, piston movements toward goal, and defensive activities) which are valuable for sport-specific training (5,10). Consequently, the present findings suggest that fewer players on the court means longer distance covered in the high speed zone, similar to the study conducted by Hill-Haas, Dowson, Couts, and Rowsell (17) that examined SSG in soccer. Interestingly, the results shown here for the 1st speed zone had the opposite effect. The results indicated that as the number of players on the field increased, the distance covered became higher. According to statistics compiled by the International Handball Federation (IHF), the best teams historically demonstrate higher number of shots per game than do less successful teams (e.g. teams behind them in league standings or teams that not qualified for international championships). The data presented here suggests that training routines, such as SSG 3, can improve quality of shots preparation under higher intensity by increasing the number of repetitions of the players. Incorporating a higher number of repetitions of close range shots has been shown to be a key performance indicator in basketball, as well as men's handball, in differentiating winning from losing teams (12, 40, 45). However, it is likely that technical elements executed without the ball occur more frequently in SSG 5 than in SSG 3 (23). Thus, handball coaches are advised to consider this relationship when constructing practice plans. As noted in Table 3, fewer players on the court increased all three assessed indicators. Individual players provide more passes (9, 8 resp. 6x), close range shots (3.1, 2.1 resp. 1.5x) and use dribbling (7.1, 2.1 resp. 1.3x) in SSG 3, SSG 4 or SSG 5.

Overall, the results of this study provide insight into the physiological response to different SSG routines during women's team handball practice. The present findings indicate that while the magnitude of the response is different, women handball players exhibit time motion and physiological responses similar to those reported in the literature for men handball players. Significant differences were seen between SSG 3 and SSG 5 in both average HR and RPE, with participants experiencing higher HR and reporting higher RPE during SSG 3. This study modified previously used methodology (3) to focus on an under-represented population in the sport science literature. In spite of these strengths, the results should be interpreted in light of the following limitation. The current study did not control all factors which impact physiological response to exercise such as nutrition and hydration status. Despite this limitation, these findings help to describe the impact of SSG in handball, and gives coaches and sport scientists a better understanding of the interactions between environmental context during scrimmage scenarios and the physiological impact upon players. Accurate information about technical characteristics, environmental context, and physiological response during handball SSG is valuable for coaches and sport scientists interested in using evidence-based methods in training.

The ability to perform repeated sprints is important during sports of intermittent intensity such as handball. Rather than rely upon generic, non-sport-specific training, SSG may be used to improve repeated sprint ability during handball-specific conditioning, making SSG an appealing training option for strength and conditioning coaches. This study showed that altering the number of players during SSG is an effective way to regulate training intensity in handball preparation. This study also showed that the number of players can be a key factor on player preparation/development. Small number of players (3 vs. 3) in SSG can imitate competition intensity load, and can be useful for training variation, or as a technical/tactical training method for defensive, transition and attacking plays in handball training. When instituting this type of sport-specific conditioning, the training load should be carefully monitored to prevent players from overreaching and overtraining. From this point of view, the use of SSG with a reduced number of players on the court is useful and practical, and thus strength and conditioning coaches should consider implementing this practice into handball training regimens.

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