Int. J. Morphol.,
42(3):749-755, 2024.

Small-Sided Games vs. High-Intensity Interval Training on Body Composition of Female Handball Players

Juegos Reducidos vs Entrenamiento Interválico de Alta Intensidad sobre la Composición Corporal de Jugadoras de Balonmano

Mila Vukadinovic Jurisic; Damjan Jaksic; Stefan Maricic; Anja Obradovic & Jelena Obradovic

JURISIC, M. V.; JAKSIC, D.; MARICIC, S.; OBRADOVIC, A. & OBRADOVIC, J. Small-sided games vs. high-intensity interval training on body composition of female handball players. *Int. J. Morphol., 42(3)*:749-755, 2024.

SUMMARY: The purpose of this study was to compare the effects of different training programs based on small-sided games (SSG) and high-intensity interval training (HIIT) on the body composition of female handball players. A total of 45 female handball players (age: 16.13±0.89 years; training experience: 6.18±1.33 years) were assigned to three groups: game group (GG; N = 15), running group (RG; N = 15), and control group (CON; N = 15). The training programs lasted eight weeks, with two training sessions per week. The GG performed three vs. three small-sided games on a 20 m x 20 m court; the RG performed 15 s HIIT running followed by 15 s of active recovery; the CON group maintained regular handball training. Regardless of the group assignment, all participants were measured for each of the following variables: Body height, body mass, fat-free mass, fat mass, muscle mass, intracellular water, and extracellular water. The results demonstrate significant differences ($p<0.001$) between groups following the training programs in fat-free mass, fat mass, intracellular water, and extracellular water, but no significant differences ($p>0.01$) in muscle mass. The GG showed significant ($p<0.001$) greater improvement in these body composition variables than RG and CON. Body composition variables improved with GG, moving from 2.04 % in fat mass to 1.3 % in extracellular water. In the RG, results show significant improvements ($p<0.001$) only in intra- and extracellular water. The CON shows improvements in fat-free mass, muscle mass, intracellular water, and extracellular water. To conclude, eight weeks of SSG in handball provide better changes in body composition compared to HIIT 15 s - 15 s and handball training alone.

KEY WORDS: Team sport; Female athletes; Conditioning.

INTRODUCTION

Handball is a team sport where players perform high-intensity actions such as short running, change of direction speed, jumps, and duels (one-on-one situations) between them (Jaksic *et al*., 2023). The number of these activities in modern handball has increased, probably because of the changes in the game rules (International Handball Federation, 2022); however, it has not been scientifically proven yet. Practically, the new rules from 2022 (the throw-off of the ball after a goal can be taken even if the opposing players are not in their own half and from a 4 m diameter circle, replacing the goalkeeper with an attacking player, no goalkeeper in the goal, and seven players on the field) accelerate the handball game, and demand from the players to be faster and more agile. Therefore, it is necessary to design training methods to improve motor and physiological performance, technical-tactical content, and body composition of female handball players. It is necessary to note that to choose the optimal training method, one must be familiar with the athlete's initial body composition and the demands of the sport or physical activity itself. Authors (Granados *et al.*, 2013) have reported that successful handball players have specific body composition. Specifically, elite female handball players average are taller, heavier, and have a lower percentage of body fat compared to female handball players who play at lower or regional level leagues (non-elite) (Moss *et al*., 2015; Masanovic *et al*., 2021). Additionally, it is important to note that the body composition of female handball players differs according to playing position (Vila *et al*., 2012).

Female handball players' body composition is related to grip strength, countermovement jump (CMJ), throwing velocity, 30 m speed, and anaerobic power (Kale & Akdogan, 2020). In detail, top-elite female handball players with a lower percentage of fat mass and a higher fat-free mass have achieved better results in CMJ, 20 m speed, and aerobic capacity (Moss *et al*., 2015). Besides that, body composition also plays a significant role in preventing sports injuries (Fousekis *et al*., 2012). Athletes with a better ratio of fat-free mass to fat mass have a lower risk of injury because the mechanical load on

University of Novi Sad, Faculty of Sport and Physical Education, Novi Sad, Serbia.

Received: 2023-12-28 Accepted: 2024-02-08

the locomotive apparatus is less when the body composition is harmonious (Fousekis *et al*., 2012).

Game-based training and high-intensity interval training (HIIT) can improve motor abilities in female handball players. Specifically, Buchheit *et al*. (2009), reported that game-based training and HIIT produce similar increases in repeated sprint abilities (-3.72 % vs. -3.51 %) in female handball players. Jurisic *et al*. (2021) reported that HIIT enhances aerobic capacity greater than SSG in handball in female handball players but equally improves squat jump, CMJ, 20 m sprint, and explosive strength in the upper arm. Furthermore, the authors (Fristrup *et al*., 2020) found that SSG in handball improved the body composition of female handball players (age 24.1±2.6 years) by reducing fat mass by -3.7 % and increasing fat-free mass by +2.2 %. Alonso-Fernández *et al*. (2017) reported that eight weeks of mixed functional HIIT (Tabata method) showed positive effects on body composition by lowering body fat (3.45 %; $p<0.05$) in adolescent female handball players. Based on that, it can be observed that SSG in handball improved the motor abilities of female handball players, but not enough is known about body composition. A research gap has been observed in the deficiency of research on those training methods (SSG and running training - HIIT) and their influence on the body composition of female handball players.

A better understanding of training methods such as SSG and HIIT has scientific contributions but also the practical importance of choosing the means in the training process for better efficiency and better performance of handball players. Based on that, this study aimed to compare the effects of different training programs based on SSG and HIIT on the body composition of female handball players. We hypothesized that SSG in handball would lead to greater improvements in the body composition of female handball players compared to HIIT.

MATERIAL AND METHOD

Subjects: The forty-five female handball players (age: 16.11±0.93 years) from the same competition rank (First Handball League of Vojvodin, Serbia) were included in the study (Table I). All participants met the following criteria: (i) the chronological age of all participants was from 15 to 18 years; (ii) a minimum of 5 years of training experience. The exclusion criteria were a history of neurological or musculoskeletal disorders. The female handball players were divided into three groups: game group (GG; N = 15), running group (RG; N = 15), and control group (CON; N = 15). After explaining the experimental protocol, each subject provided a written informed parental consent (for those <18 years), and the participants' consent was obtained before commencing the study. The Ethical committee from the University of Novi Sad, Faculty of Sport and Physical Education, approved the experimental protocol (Ref. No 46-12-09/2020-1). This study was conducted in compliance with the Declaration of Helsinki.

Table I. Characteristics of participants.

Variables	Game group (N=15)	Running group (N=15)	Control group (N=15)
	Mean±SD	Mean±SD	Mean±SD
Age (years)	16.13±0.91	16.20±0.94	16.07±0.88
Body height (cm)	166.21±2.93	168.39± 6.32	168.44±4.19
Body mass (kg)	63.10±6.81	65.55±5.11	64.24±6.31
Training experience (years)	6.53±1.19	6.27±1.71	5.73±0.96

Procedures: The participants' anthropometric characteristics and body composition were performed in a sports hall over one day (between 9 a.m. and 12 p.m.). Anthropometric characteristics (body mass and height) were obtained first, followed by the body composition. The same researchers were involved in the initial and final measurements in the same order and with the same instruments.

Anthropometric characteristics: The anthropometric characteristics (body height and body mass) were measured according to the International Biological Program (IBP) recommendation. Body height was measured to the nearest 0.1cm using a Martin anthropometry (GPM in Switzerland), and body mass was measured to the nearest 0.1kg with portable digital scales (Omron BF214).

Body composition: Bioelectrical impedance (BIA) Maltron Bioscan 920-2 (Maltron BioScan 920 v1.1, Maltron International Ltd, UK) measured parameters of body composition: fat-free mass (%), fat mass (%), muscle mass (kg), intracellular water (%), and extracellular water (%). The protocol of body composition measurement with BIA was according to the standard testing manual of Maltron International (Maltron Bioscan 920-2 operating and service manual). Previous study has demonstrated the reliability and validity of measurements obtained by bioelectrical impedance analysis (de Castro *et al*., 2018).

Before the measurements, the players were asked to follow a recommendation by Rech *et al*. (2008) not to perform any physical exercises during the 12 hours before measurement, not to eat or drink anything during the 4 hours before the evaluation, to urinate at least 30 min before the evaluation, not to take any diuretics during the seven days before the measurement, and

not to consume alcohol during the 48 hours preceding the measurement.

Training programs: The CON group applied handball training for eight weeks. A more detailed description is presented in Table II.

The GG applied SSG in handball for eight weeks. A detailed explanation is in Table II. The SSG in handball is conducted according to the rules: (i) played three against three (ii) a 20 m x 20 m court (iii) they played with handball no. 2, circumference 54 cm - 56 cm and weight 325 g - 375 g (iv) the goals were 120 cm x 90 cm (v) the rules of the handball game were modified: walking as well as driving the ball was not allowed; the defense players would have to stop the attack players with a regular foul, and the penalty would be a throwback; the maximum attack before the ball is lost was 20 s.

The RG applied 15s - 15s HIIT for eight weeks. A detailed explanation is in Table II. The players run at the final speed of the Yo-Yo IRT 1 test to record the maximal aerobic speed (MAS), according to Krustrup *et al*. (2003). When determining the MAS, players intermittently ran 15s (velocities ranging from 90-95 % MAS) and walked 15s as active recovery.

Monitoring training intensity during training was determined by rating perceived exertion using the CR-10 Borg scale (Borg, 1982). The players were familiarized with the scale before the training programs. The players were asked to individually score the perceived level of effort performance during the training. Also, training intensity was monitored via heart rate using Polar RS800CX (Polar Electro Oy, Kempele, Finland).

Statistical analysis: Data are presented in figures. Bars represent means ± standard deviation (error lines). A mixed-design repeated-measures analysis of variance (RM ANOVA) was used to test the main effects of groups (3) x time (2) on the selected variables. Additionally, differences within each group were assessed using one-way analysis of variance (ANOVA), followed by Tukey post hoc tests for pairwise comparisons. Statistical analyses were performed using R 4.3.2 statistic software with the arsenal, ggplot2, ggpattern, and patchwork packages. Arsenal was used for statistical calculations, and ggplot2, ggpattern, and patchwork were used for data visualization. Significance was set on $p<0.05$.

RESULTS

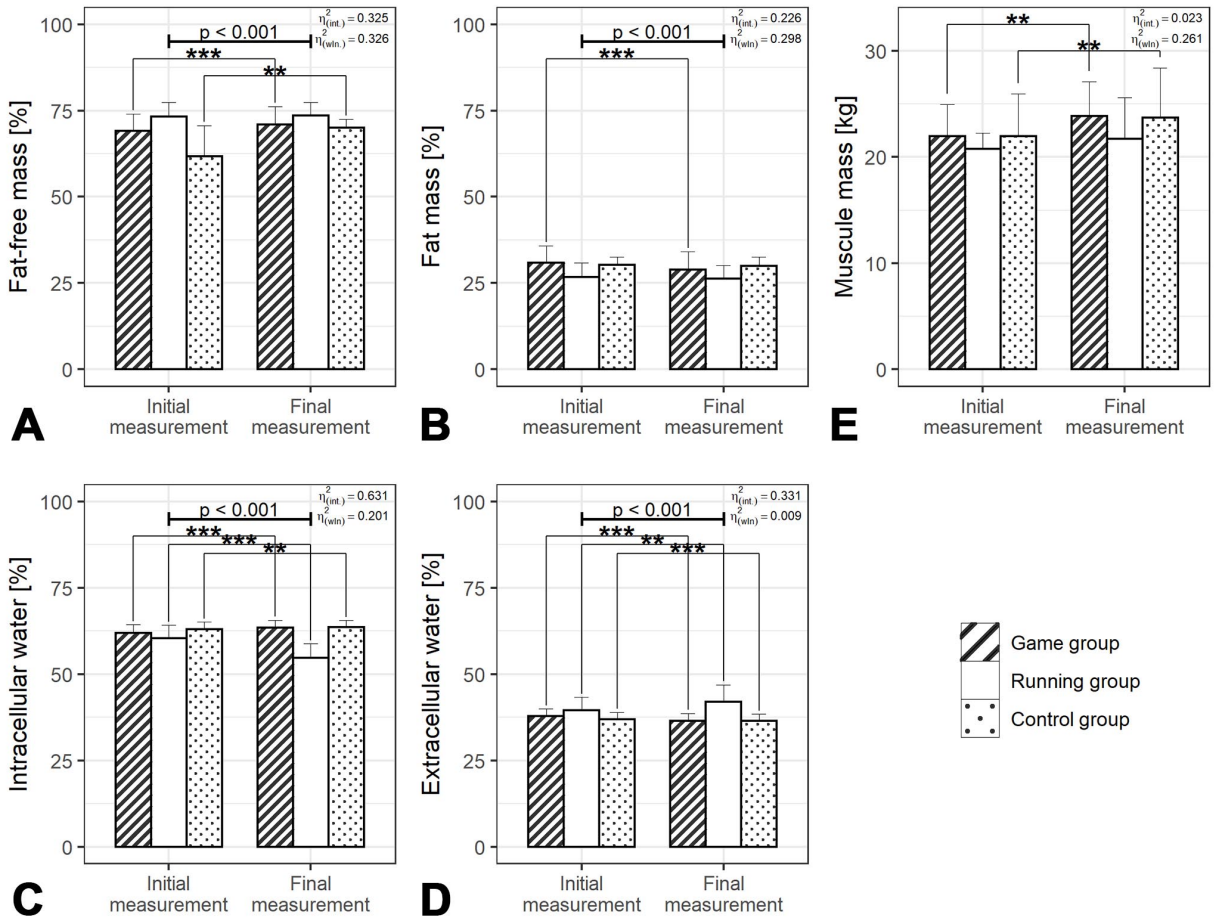
In this section, we will showcase the results of the conducted training programs over 8 weeks. These findings give us insights into how each training regimen affected the performance and overall well-being of our study participants. Figure 1 visually presents the discoveries offering a representation of the data gathered from our experimental trials. In the analysis, we will delve deeper into understanding the observed patterns and noteworthy distinctions, among the training programs.

Results from Figure 1 indicate that a significant difference between groups after the treatments exists in four of five variables. Only in variable Muscle mass (Fig. 1E) significant difference was not found. It also could be concluded that GG had significantly better results in all five variables after the treatment. Improvements were between 2.04 % in Fat mass and 1.3 % in Extracellular water. In RG, significant differences were found in Intra- and Extracellular water variables. Intracellular water in RG decreased from 60.4 to 54.7 (-5.7 %). In the meantime, extracellular water increased by 2.5 %. Third, HG had significant improvements in four variables. Only in Fat mass significant difference was not found, while in others, the difference was from 0.5 % (Fig. 1D) to 8.2 % (Fig. 1A), and the last one is the highest value of change after the eight weeks.

Table II. Description of the training programs for groups.

Training	Game group (N=15)	Running group (N=15)	Control group (N=15)
Frequency	2 times/week	2 times/week	2 times/week
Duration	≈ 90 min (15 min general warm-up, 15 min warm-up with ball, 45 min small-sided games, 15min static stretching)	≈ 90 min (15 min general warm-up, 15 min warm-up with ball, 25 min running, 15 min static stretching)	≈ 90 min (15 min general warm-up, 15 min warm-up with ball, 25 min of drills that included low and high-intensity movement, 15 min static stretching
Intensity %HRmax	80 %-89 %HRmax	90 %	60 %-79 %HRmax
Borg scale	7.08±0.96	7.71±0.70	5.98±0.75
Type of activity	Game 3 vs. 3 on the field 20 m-20 m	High-intensity interval running	Running moderate to high intensity, change of direction movement, jumps, blocking

The strong and noticeable effect sizes (ranging from 0.226 to 0.631) highlight a meaningful connection between the type of group and changes in all variables. It's worth noting that the effect size for Muscle Mass is relatively smaller falling within the range. The compelling effect sizes found (ranging from 0.201 to 0.326) emphasize the influence of group intervention on all variables while showing large effect sizes. This highlights how impactful and influential group intervention can be in bringing about changes across the variables. Interestingly the effect size for Extracellular Water although still significant is comparatively smaller falling within the range. All this indicates a high impact of group intervention, on all body composition variables.



Abbreviations:
int. = Interaction Group x Time, wIn = Within Group
p – Significance of 3x2 RM ANOVA
*** – p < 0.001, difference within the group
** – p = 0.01, difference within the group

Fig. 1. Impact of each regimen on the performance and overall well-being of participants in our study. The analysis explores the observed patterns and significant differences across the training programs.

DISCUSSION

This study aimed to compare the effects of different training programs based on SSG in handball and HIIT on the body composition of female handball players. The major findings were that training programs based on SSG in handball caused large improvements in body composition compared to running training (HIIT) and handball training alone.

The training program based on SSG in handball led to the greatest changes in the body composition of female handball players compared to HIIT 15 s – 15 s. Specifically, the 8-week SSG in handball significantly increased fat-free mass, muscle mass, and intracellular water. In addition, this training program (SSG in handball) decreases fat mass and extracellular water. These results are in line with the results

reported by Tomar & Allen (2021), who found that 12-week SSG in handball reduced fat mass in male handball players (19.78 ± 1.05 years). However, contrary results were obtained in the study by Balasubramanian & Chittibabu (2014) where a 6-week SSG in handball did not reduce fat mass in male handball players. The SSG is high-intensity aerobic training with the ball. It consists of a brief period (second to a few min) of high-intensity movement followed by a pre-determined period of rest (Hoffmann Jr. *et al*., 2014). This alternation of high and low intensity leads to increased energy expenditure during the active period of training, the recovery period, and immediately after training (Talanian *et al*., 2007). In addition, this type of training induces fat oxidation due to increased blood flow throughout the body and in skeletal muscle, ultimately leading to a more significant reduction in fat mass (Boutcher, 2011).

Next, an 8-week combination of SSG in handball increased fat-free mass and muscle mass in female handball players, which could result from decreasing fat mass. Similar findings have been presented by Mendham *et al*. (2015), who found that 8 weeks of SSG increased fat-free mass among rugby players. In a systematic review, Khodadadi *et al*. (2023) demonstrate that duration of training programs (8 weeks and longer), high frequency of training (3 training per week and higher), training duration between ≤ 60 s and ≤ 90 s, and active rest is effective for promoting body composition changes, especially fat-free-mass, which is the case in this study. It is important to mention that changes in muscle mass could also be a consequence of SSG, where this training provides sufficient loading to induce myofibrillar protein synthesis, skeletal muscle hypertrophy, and increased leg strength (Mendham *et al*., 2015). Meanwhile, female handball players who perform HIIT 15 s - 15 s achieved larger increases in extracellular water and decreased intracellular water compared to other groups. The potential explanation for increased extracellular water in the body was caused by a decrease in fat mass and an increase in fat-free mass (Silva *et al*., 2014). The same authors noted that the increase in intracellular water occurs at the expense of fluid and food intake to swiftly replenish glycogen because 3-4 g of water binds to 1 g of glycogen. Results from this study showed a decrease in intracellular water, which assumed that the players who applied HIIT 15 s - 15 s did not drink enough liquid and food to replenish glycogen stores within 2 hours of exercise.

The high locomotion demands of handball games impose considerable physical loads on the players' bodies; therefore, a more favorable body composition profile (e.g., less fat mass) might be beneficial for the athlete. Usually observed in excessive adipose tissue, this benefit acts as a dead weight in activities where the body mass must be repeatedly lifted against gravity during locomotion and jumping (Mala *et al*., 2015). Therefore, measured body composition gives a great insight into the current status of handball players and allows coaches to select and implement the right training volume and intensity to raise their motor capabilities (Mala *et al*., 2015). Additionally, body composition components should be constantly monitored throughout the sports season to prevent diseases such as menstrual irregularities, common in female athletes who may have low body fat levels, which are one of the risk factors for female athlete triad syndrome.

To the author's knowledge, this was the first study specifically designed to examine the effects of different training programs based on SSG in handball and HIIT 15 s – 15 s on the body composition of female handball players. Apart from the many advantages of this study, there were several study limitations. First and foremost, this study investigated only body composition, while motor performance, physiological parameters, and technical-tactical elements were neglected. The second limitation is the sample of participants consisted only of female athletes (16.11±0.93 years), as males were not included in the study. Therefore, this study cannot refer to the younger population. Thirdly, despite analyzing body composition, this study did not provide energy intake and nutritional management programs for youth athletes. Further studies are necessary to provide insight into the effects of SSG in handball in different groups of participants, such as children or adults, as well as obese individuals. Also, the effects of SSG in handball should be compared with different types of training, such as speed agility quickness training or conventional endurance training. Additionally, future research should study the effects of SSG in handball on the tactical and physiological aspects of the competition.

CONCLUSIONS

The findings of this study indicate that SSG in handball leads to greater changes in body composition in female handball players, compared to HIIT 15 s – 15 s and handball training alone. Furthermore, SSG in handball has established superior fat mass, fat-free mass, and muscle mass changes compared to HIIT 15 s – 15 s. At the same time, HIIT 15 s – 15 s achieved greater changes in intracellular and extracellular water. The SSG activates the aerobic system more, which is reflected in decreased fat mass and increased fat-free mass. Meanwhile, short-term HIIT 15 s – 15 s in our female handball players stimulated the anaerobic system, which did not lead to significant changes in fat mass, fat-free mass, and muscle mass, but it did lead to significant changes in body water. These results provide unique findings on the effect of training programs on the body composition of female handball players but also provide information about the benefits of adequate

body composition. Accordingly, handball coaches and conditioning coaches should perceive all the advantages SSG in handball brings to the female handball player.

ACKNOWLEDGMENTS. We would like to express our gratitude to the Provincial Secretariat for Higher Education and Scientific Research for funding this research. The preparation of this paper was supported by the Provincial Secretariat for Higher Education and Scientific Research, grant number (142-451-3039/2023-01); Ministry of Science, Technological Development and Innovation, Serbia (179011).

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RESUMEN: El propósito de este estudio fue comparar los efectos de diferentes programas de entrenamiento basados en juegos reducidos (SSG) y entrenamiento interválico de alta intensidad (HIIT) sobre la composición corporal de jugadoras de balonmano. Un total de 45 jugadoras de balonmano (edad: 16,13 ± 0,89 años; experiencia de entrenamiento: 6,18 ± 1,33 años) fueron asignadas a tres grupos: grupo de juego (GG; N = 15), grupo de carrera (RG; N = 15) y grupo de control (CON; N = 15). Los programas de formación duraron ocho semanas, con dos sesiones de formación por semana. El GG realizó partidos reducidos de tres contra tres en una cancha de 20 x 20 m; el RG realizó 15 s de carrera HIIT seguidos de 15 s de recuperación activa; El grupo CON mantuvo un entrenamiento regular de balonmano. Independientemente de la asignación de grupo, a todos los participantes se les midió cada una de las siguientes variables: altura corporal, masa corporal, masa libre de grasa, masa grasa, masa muscular, agua intracelular y agua extracelular. Los resultados demuestran diferencias significativas ($p<0,001$) entre los grupos que siguieron los programas de entrenamiento, en relación a masa magra, masa grasa, agua intracelular y agua extracelular, pero sin diferencias significativas ($p>0,01$) en la masa muscular. El GG mostró una mejora significativa ($p<0,001$) mayor en estas variables de composición corporal que RG y CON. Las variables de composición corporal mejoraron con GG, pasando de un 2,04 % en masa grasa a un 1,3 % en agua extracelular. En el RG, los resultados mostraron mejoras significativas ($p<0,001$) sólo en el agua intra y extracelular. El CON indicó mejoras en la masa magra, la masa muscular, el agua intracelular y el agua extracelular. En conclusión, ocho semanas de SSG en balonmano proporcionan mejores cambios en la composición corporal en comparación con el HIIT de 15 s - 15 s y el entrenamiento de balonmano solo.

PALABRAS CLAVE: Deporte de equipo; Atletas femeninas; Acondicionamiento.

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Corresponding author:
Associate Professor Dr. Damjan Jaksic
16 Lovcenska str
21000 Novi Sad
SERBIA

E-mail: damjan.jaksic@uns.ac.rs