Int. J. Morphol.,
41(6):1653-1659, 2023.

Cardio-Physiological and Anthropometric Profile of Elite International Handball Players from Top Ranking Macedonian Teams

Perfil Cardiofisiológico y Antropométrico de Jugadores Internacionales de Balonmano de Élite de Equipos Macedonios de Primer Nivel

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GLIGOROSKA, J. P.; MOMCHILOV, M. & GEORGIEV, G. Cardio-physiological and anthropometric profile of elite international handball players from top ranking Macedonian teams. *Int. J. Morphol., 41(6)*:1653-1659, 2023.

SUMMARY: Monitoring of body composition and cardiophysiological parameters are main part of the general health status of handball players and significant indicators of their physical fitness. The assessment of body components, especially skeletal muscle mass and body fat mass are important because of their influence on sport performance. The aim of this study is to determine the body composition and cardiophysiological characteristics of elite handball players from Republic of North Macedonia. 27 male HB players from two top ranking teams from RNM were tested ergometrically with Bruce protocol for determination of maximal oxygen consumption; body analysis was made with bioelectrical impedance analyzer, InBody 720. Anthropometric parameters were as follows: mean height was 190.4±7.8 cm and weight 96.3±15.5 kg, skeletal muscle mass (SMM)=47.11±6.69 kg; BMI=26.38±3.1; BF%=15.04±6.01 and WHR=0.9±1.8. The result of ergometrical test produce mean VO2 max=43.92 ml/kg/min which is 100.46 % of reference value. The body composition of elite international handball players from the top handball teams in Republic of North Macedonia showed similar body components as other European handball players. The obesity diagnose parameters were negatively associated with exercise time and maximal oxygen consumption.

KEY WORDS: Handball players; Body composition; Heart rate; Bruce test.

INTRODUCTION

The premises of successful sport performance are ideal morphological features and body composition, in combination with optimal physiological and psychological characteristics. There are huge scientific and empirical proofs about positive relationship between certain anthropometric features and sport performance (Ghobadi *et al*., 2013; Massuca & Fragoso, 2015; Saavedra, 2018).

In handball body size is of great importance for throwing in attacks or blocking in defense. Isometric strength of limbs, especially upper limbs, has strong positive effect on throwing performance in handball players. Specific morphological traits of upper limbs, such as longitudinal dimensions of forearm and hand are found in elite handball players (Massuca & Fragoso, 2015). It is generally accepted among the expert and scientific community that anthropometric characteristics, especially height and fat free mass are the basic physical determinants to play higher level handball (Martínez-Rodríguez *et al*., 2021). The assessment of body components is valuable for monitoring health and nutritional status of athlete, emphasizing the quantification of the muscle and fat mass. The body shape and body structure varied and also made adaptations to achieve the optimal performance in different sport activities. Athletes involved in high sport levels are characterized by body proportions that determine biomechanical features conducive to optimizing the structure of movements important in handball (Lijewski *et al*., 2021).

The muscle mass is executive tissue in sport activities which provides strength for high intensity movements and higher muscle mass has direct association to better sport outcomes in intermittent team sports (Ramos-Campo *et al*., 2014). The best handball players are able to maintain a high throwing velocity in different tactical

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Received: 2023-07-22 Accepted: 2023-08-20

situations. This valuable skill is a result of specific anthropometric characteristics of upper limbs which are mostly genetically conditioned and non-modifiable by training.

The nature of the handball game imposes the dynamics and intensities of the movements which made the handball intermittent type of sport (Martínez-Rodríguez *et al*., 2020). The knowledge of body composition and physical characteristics of athletes and its relationship to cardio and hematological parameters could give the coach information about the physiological capacities of players and could help coaches select players for specific playing positions (Karcher & Buchheit, 2022).

The purpose of this study was twofold. The primary aim was to determine the body composition, hematological and cardio-physiological parameters of elite handball players from professional teams in RN Macedonia. The secondary aim was to analyze the relationship between anthropometric characteristics and cardio-physiological parameters.

MATERIAL AND METHOD

Study design: A cross-sectional experimental design was conducted to analyze the body composition and cardio-physiological parameters of professional handball players. Prior to participation, the experimental procedures were explained to all the participants, who gave their voluntary written informed consent.

Participants. Data were collected from 27 male handball players, members of two highest ranked teams in R.N. Macedonia (HC Vardar and HC Metalurg). Participants were tested during their routine medical examinations (check-ups) at the Laboratory for Sports Medicine at the Institute of Physiology, Faculty of Medicine in Skopje. All participants underwent ergo-metrical testing (Bruce protocol), bioelectrical impedance analysis of body mass composition and biochemical analysis (blood count). The ethical guidelines for human investigation are followed in accordance with Helsinki Declaration and the approval of Ethical Committee of Medical Faculty in Skopje is obtained.

Measures and procedures

Anthropometric measures. Height was assessed to the nearest 0.001 m, using a stadiometer (Holtain Ltd., Crymych, UK). Body mass was measured to the nearest 0.1 kg, using an electronic scale (Seca Instruments Ltd., Hamburg, Germany).

Body composition analysis. Body composition was assessed with a segmental multifrequency bioimpedance analyzer (InBody 720, Biospace Co. Ltd., Seoul, South Korea). In order to carry out the tests, the participants stood upright on foot electrodes on the instrument platform, with legs and thighs apart and arms not touching the torso. They were barefooted and without excess clothing. Four-foot electrodes were used, two of which were oval-shaped and two heel-shaped, and prior to testing both the skin and the electrodes were cleaned and dried. Participants were asked to grip the palm and thumb electrodes (two of each electrode per athlete). The following parameters were analyzed: body mass (kg), height (cm), body mass index (BMI) (kg/m^2), skeletal muscle mass (SMM - kg), body fat (BF - kg) and body fat percent (BF%).

Ergometrical testing. Analysis of cardiovascular adaptations to physical effort was made with the standard treadmill exercise testing according to the Bruce protocol sub-maximal treadmill test in line with the ACSM guidelines. During the ergometric testing heart rates are registered at rest, before the test has started (HRRest), at the end of each minute during the first ten minutes of exercise duration (HR1, HR2, HR3 until HR10) and at the end of recovery phase, HRRec3.

Statistical analysis. Statistical analysis of the obtained results was made using the SPSS (v20.0; SPSS, Inc., Chicago, IL, USA). Descriptive statistics including mean values, standard deviation, and ±95 confidence interval, minimum and maximum values were used for series with numerical attributes. Analysis of variance was used (F; p) for inferential statistics. The significance level was set at $p<0.05$. Pearson correlation test was used to test the relationships between different groups of parameters: anthropometric, cardiophysiologic and hematological.

RESULTS

Descriptive statistics of the anthropometric measurements and obesity diagnose parameters derived from bioelectrical impedance analysis are presented in Table I. The mean values of height (190.4±7.8 cm) and weight (96.3±15.5 kg) showed remarkable numbers, but minimal and maximal values revealed a very wide range of data. The average BMI is slightly higher than upper normal reference limit, which is mainly a result of extensively developed skeletal muscle mass (SMM). Average body fat percent (BF%=15.04) was optimal for healthy active population. Average WHR of 0.9 according WHO reference value is classified at upper limit of normal values.

Regarding the BMI 15 athletes (54 %) showed values in range 25 - 30, which is classified as overweight for sedentary population. Two (7 %) athletes from our investigation had BMI higher than 30. Body fat mass expressed as percent of whole body mass (BF%) is estimate by bioelectrical impedance analyzer, and reference values for this method are between 10 to 20 % for sedentary healthy people. In our research, 19 (68 %) athletes had optimal body fat percent (between 10 and 15 %), 3 (10 %) of them had slightly higher BF% (15-20 %); 4 (14 %) of them had BF% between 20-25 %, and 2 of them had BF% higher than 30 %. Regarding the WHR, 68 % of participants (19 athletes) had normal values, lower than 0.9. In the group with low healthy risk, between 0.9 – 0.95 were 3 (10 %) athletes; 6 of them were in the group with moderate health risk (0.95-1.0) and 1 handball player had extremely high WHR=1.74. The InBody analyzer calculates individual ideal body weight, and eventual need for fat and muscle control. Nine handball players (32 %) got recommendation to loose fat mass while the rest of them (68 %) had ideal weight. All handball players show optimal amount of skeletal muscle mass, and none of them have been recommended to increase the muscle mass.

The final results of the Bruce test are shown in Table II. Interesting heart rate values were, heart rate at rest, before the test started and heart rate during recovery period, immediately after the ergometry. The shortest duration of Bruce test was 8.73 minutes (726 seconds) while the longest duration was 16.16 minutes (970 seconds). The average VO_2 max was 43.92 ml which is 100.46 % of reference value for this age group.

The general anthropometric parameters, height and weight, and all obesity diagnose parameters (BMI, BF%, WHR, fat control) showed weak negative correlation with cardio-physiological parameters (exercise time and oxygen consumption). Through the age span of our athletes (18 to 34 years) BF% and WHR showed weak positive correlations to age (0.249 and 0.259). The fat control parameter was higher in older athletes (r=0.388). Heart rates during the ergometry test (at rest and at recovery as well) were higher in older athletes (r=0.358; r=0.26; r=0.5).

Table I. Anthropometrical and obesity diagnose parameters in handball players.

	mean	SD	min	max	skewness
Age	27,48	5,50	20,00	38,00	,410
Height (cm)	190,44	7,85	177,00	208,00	,223
Weight (kg)	96,28	15,46	67,50	128,00	(,026)
SMM (kg)	47,11	6,69	33,60	60,80	(,219)
BMI	26,38	3,10	21,00	32,80	,203
BF %	15,04	6,01	3,00	29,80	,674
WHR	,904	,179	,74	1,74	4,086
Fat control (kg)	2,70	4,55	,00	18,10	2,021
Muscle control kg)	,004	,019	,00	,10	5,099

SMM – skeletal muscle mass; BMI – body mass index; BF% - body fat percent; WHR – waist to hip ratio.

Table II. Cardio-physiological parameters obtained from Bruce ergometry in handball players.

	mean	SD	min	max	skewness
HRR	85.42	14,39	65,00	125,00	(,414)
HR recovery	109,08	12,236	85,00	134,00	,379
ET (minutes)	12.10	1.84	8.73	16.16	(,133)
VO_2 ml/kg	43,92	4,58	34,00	53,00	(,564)
VO_2 %	100,46	10,48	77,00	126,00	(,245)

HRR –heart rate at rest; HRRec – hear rate at recovery; ET – exercise time; VO_2 – oxygen consumption in milliliters per kg body mass; VO_2 %- oxygen consumption as percent of predictive values.

Table III. Correlations between the anthropometric and the cardio-physiological parameters in handball players.

	ET	VO_2 max	VO_2 %	HRrest	HR1	HRRec
Height	-0.182 *	-0.220*	-0.267	-0.059	0.227 *	0.094
Weight	-0.215	-0.242	-0.295 *	-0.024	0.233	0.06
BMI	-0.181 *	-0.186 **	-0.254	-0.001	0.145 *	-0.017
BF%	-0.231*	-0.182 *	-0.156	0.100	0.111	-0.027
WHR	-0.167	-0.154 *	-0.164	-0.006	0.058	-0.067
SMM	-0.115	-0.171	-0.254*	0.06	0.199	0.058
Fat control	-0.27	-0.021	0.027	0.000	-0.137	-0.162
Muscle control	/	/	/	0.000	0.000	0.000

*p<0.01; ** p<0.05

Analysis of correlations of obesity diagnose parameters showed high positive associations between body weight and BMI, BF%, WHR and fat control (r=0.78; 0.838; 0.855 and 0.376).

The obesity diagnoses parameters showed weak negative correlations with cardio-physiological parameters. Weight, BMI, body fat percent and WHR were negatively associated with exercise time, and maximal oxygen consumption.

DISCUSSION

In the present study, physiological profile, constructed of anthropometric and cardio-physiological variables for professional handball players is presented. Regarding the nationality of the handball players almost half of the athletes, 48 % (13/27), were from Macedonia, while others are from other European or South American countries. The majority of our handball players (~70 %) showed normal obesity diagnoses parameters, and maximal oxygen consumption was 100 % of predicted values for Bruce ergometry for healthy active people.

Our hypothesis was that athletes with higher obesity i.e. athletes with higher BMI, BF% and WHR will have lower exercise time at Bruce test and consequently lower maximal oxygen consumption. Our results confirmed our hypothesis but the negative associations between the analyzed parameters were weak, which could be explained by the fact that higher obesity parameters in athletes are still close to the normal range, without serious deviations from upper limit for these parameters.

Previous studies suggest that body composition factors such as fat mass and muscle mass have significant influence on physical performance (Moncef *et al*., 2012; Hammami *et al.*, 2019; Molina-López *et al*., 2020). Therefore, the knowledge of BC and physical characteristics of athletes could give the coaches information about the performance of players and could help coaches select players depending on playing position and sport. Furthermore, this information could be considered as auxiliary element in the talents detection programs (Fieseler *et al*., 2017).

Anthropometric characteristics of handball players. Many publications reported significant positive correlations between anthropometric characteristics, body height and weight, BMI, lean body mass and throwing ball velocity. Researches found that general anthropometric characteristics were better predictors than those specific to handball. The handball players are generally very corpulent athletes, and they showed higher values for height and weight, and consequently for most of the longitudinal and circumferential measures (Gusic *et al*., 2017).

The general anthropometric characteristics of the elite handball players from our investigation showed mean values similar to other European handball teams, height= 190.44±7.85 cm and weight=96.28±3.1 kg. Comparison of anthropometric characteristics of male handball players in the 2013 World Championship showed that height of the athletes of the different national teams was in the range from 183.72±6.25 cm for players from Saudi Arabia to maximal values of mean height of 194.39±8.99cm for Croatian and 194.00±7.51cm for Denmark handball players. Comparison of 21 national team players showed that players from Asia, Africa and South America were shorter than handball players from Europe. Although Arabian players were the shortest, they had highest BMI=26.66±2.25 (Ghobadi *et al*., 2013). Our, Macedonian handball players, nine years ago, in 2013, were an average height of 189.53±4.92 cm. The Macedonian handball players were in the middle of the table regarding the height and weight. Eight years ago average height of the Macedonian national team handball players was 189.53 cm and they were weighted 92.65 kg. These values indicate that Macedonian elite players were shorter and less heavy than today, which could be a result of more foreign players in our sample.

Anthropometric characteristics of elite German handball players were as follows: height=192±0.1cm; weight=96.1±12.9 kg; BMI=25.9±1.69 (Fieseler *et al*., 2017), and these physical characteristics are very similar to our results. Professional handball players from Spain, slightly older than our participants (28.4±0.9 years) in 2014, were 191.64±1.4 cm tall and with a weight of 97.1±2.3kg, with body fat percent between 11.3 and 18.2, depending on playing position (Ramos-Campo *et al*., 2014). Tunisian elite handball players showed lower mean values for anthropometric measures: body mass=85.16±20.29 kg, height=181.83±5.82 cm, BMI=24.96±3.45; BF%=11.22 than their European colleagues (Moncef *et al*. 2012).

The handball players from our investigation had high BMI values (26.38±3.8) which is above normal reference value, but still they have normal BF% values (mean = 15.04 %). The high BMI in our handball sample is the result of significantly developed muscular mass (SMM). South American players showed very high average value for BF%=23.1, whichvaries from 14.5 % in goalkeepers to 27 % in center players (Bezerra & Simão, 2006). Asian handball players were very lean according the results of Hasan *et al*. (2007), BF%=15 %. Elite Croatian handball players showed average BF%=14.69) and Serbian elite players in 2011 BF% was 13.61 (Ilic *et al*., 2011).

Aerobic capacity of handball players. Elite international handball players from Macedonian 1st handball league achieved average maximal oxygen consumption of 43.92±4.58 ml/kg/min which is equivalent to 100 % of expected maximal oxygen consumption for young healthy men. This "average" value which is optimal for healthy active population could be a result of the testing protocol, which was submaximal by intensity. From our experience, elite handball players usually reach lower maximal oxygen consumption than football and basketball players (Pluncevic Gligoroska *et al*., 2015). Handball is an intermittent exercise that primarily uses aerobic metabolism, interspersed by high intensity actions that greatly tax anaerobic metabolism.

A graphical presentation of the Bruce test result is the heart rate curve which is made of mean values of heart frequency for each minute, starting with heart rate during resting period, through the ten consequent minutes of the treadmill testing, until the end of 3 minutes recovery period. The average heart rate at rest in Macedonian elite handball players was 85.42, which is significantly above normal rest heart frequency, which indicates the higher arousal during preparatory state of the athletes. After the 1st minute of the test, the heart rate rapidly increased to 101.92 although the intensity of the effort is extremely low, the velocity of the treadmill is only 2.7 km/h. During the second and third stage of the test, while the intensity of acidity is moderate, heart rates was increased about 15 bpm for each stage. At the first minute of the 4th stage (10 minute of whole test) when velocity of the treadmill imposes brisk walking or light running heart rate rises abruptly. After the ending of the testing, when the athlete has reached his submaximal pulse (170 bpm), during the 3 minutes of recovery period, heart rates decreased to average 109.8 bpm, which indicates excellent capacity of cardiovascular system to adapt to rest condition.

The correlation coefficients between the heart physiological parameters and the results from the Bruce test (Table III) showed a strong negative correlation between resting heart rate and during the test (r=-0.685) and oxygen consumption (r=-0.688). Athletes with lower resting heart rate had a longer test duration and greater oxygen consumption. Similar correlation is noted between heart rate at recovery phase and oxygen consumption (r=-0.565). These correlations indicate that athletes with good cardiovascular fitness have lower heart rate before testing, they had greater endurance until reaching the submaximal heart rate and during the period of recovery their heart rates are decreasing faster. In a similar study, conducted in our laboratory with Macedonian soccer players, heart rate curve was formed with significantly lower values during all 12 time points, for example mean HR was lower for 15 beats at rest and for 12 beats at recovery period. The soccer players achieved better results on Bruce test, ET=13.79 min (*vs* 12.1 min) and VO_2max=48.89 ml/kg/min (vs 43.2 ml/min/kg) comparing to our handball players (Pluncevic Gligoroska *et al*., 2015).

Today professional handball players seem prepared to stay in the game for longer than they used to, which means that they have improved their aerobic capacity. During the game, players obtained heart rate between average values of 137±12 bpm and maximum values of 173±13 bpm (Sporis *et al*., 2010). Tunisian handball players showed average maximal oxygen consumption around 50.45 ml/kg/min (Moncef *et al*., 2012). A Brazilian handball team was tested for motoric and metabolic performance variables, showed an average height of 184.4±6.7 cm (171.8 – 198 cm), weight 89.5±10.4kg (70.2 – 105.1 kg) and body fat 15.8 % at first and 14.1 % at second evaluation. The maximal oxygen consumption was 46.5 ml/kg/min at first and 50.6±4.22 ml/kg/min (Souza *et al*., 2006).

Investigation of physical and physiologic characteristics of ninety-two elite Croatian handball players in 2010 showed average height 192.18.2 cm, weight 96.0±8.3 kg; low body fat percentage of 11.2±3.4 and maximal oxygen consumption 54.0±4.1 ml/kg/min (Sporis *et al*., 2010).

Our hypothesis was that athletes with higher body mass and higher obesity parameters will be negative with cardio-physiological parameters, i.e. athletes with higher BMI, BF% and WHR will have lower exercise time and consequently lower maximal oxygen consumption. Our results confirmed our hypothesis but the negative associations between analyzed parameters were weak, which could be explained with the optimal body composition in examined handball players. Although they are elite handball players, certain number of athletes were overweight and had high BF%, which could be a burdening factor for aerobic endurance.

Correlations between anthropometric and cardio-physiological parameters. Aerobic physical fitness level have traditionally been assessed by maximal oxygen uptake and generally in literature its relationship with body fat was found negative (Amani *et al*., 2010). The analysis of correlations between obesity diagnose parameters and results of Bruce test in our investigation showed weak negative correlations (between - 0.17 and -0.24) for all parameters (BMI, BF%, WHR), even for skeletal muscle mass (-0.11).

Peak oxygen uptake was significantly correlated with body fat percentage in Japanese sedentary population, in men r=-0.684 and woman r=-0.681, while peak work rate was positively correlated with lean body mass (Oda *et*

al., 2014). The study of relationship between body fat percent and maximal oxygen consumption among young adults in Malaysia found significant negative correlation - r=-0.42 (Amani *et al*., 2010).

An investigation of influence of morphological features on motor performance in Tunisian handball players found negative correlations between all anthropometric variables and motor skills (vertical jump, sprint ability, countermovement jump. Body fat mass and body fat percent showed low to moderate negative correlation to VO2max (r=-0.11 and r=-0.39) while thin mass showed strong negative correlation with VO_2max - r=-0.61 (Moncef *et al*., 2012). A strong negative correlations was found between body fat mass and maximal running speed (r=-0.68) and maximal oxygen consumption - r=-0.58 (Sporis *et al*., 2010).

CONCLUSIONS

The body composition of elite international handball players from the top handball teams in Republic of North Macedonia showed similar body components compared to other European handball players. They have high skeletal muscle mass, high BMI and average BF%. Significant percent of handball players (1⁄4 of participants) showed certain level of obesity regarding the BF% and WHR.

Cardio-physiological response to Bruce ergo metrical testing showed successful continuous adaptation with heart rates at higher level than expected for elite athletes. The maximal oxygen consumption was equivalent to 100 % of expected maximal oxygen consumption for young healthy men. The obesity diagnoses parameters were negatively associated with exercise time and maximal oxygen consumption.

Investigation of physiological profile of handball players could contribute to the monitoring of athletes health and nutritional status and for optimal construction of training and nutrition regimen to improve handball performance.

GLIGOROSKA, J. P.; MOMCHILOV, M. & GEORGIEV, G. Perfil cardiofisiológico y antropométrico de jugadores internacionales de balonmano de élite de equipos macedonios de primer nivel. *Int. J. Morphol., 41(6)*:1653-1659, 2023.

RESUMEN: El seguimiento de la composición corporal y los parámetros cardiofisiológicos son una parte principal del estado de salud general de los jugadores de balonmano y son indicadores importantes de su condición física. La evaluación de los componentes corporales, especialmente la masa muscular esquelética y la masa grasa corporal, son importantes debido a su influencia en el rendimiento deportivo. El objetivo de este estudio fue determinar la composición corporal y las características cardiofisiológicas de jugadores de balonmano de élite de la República de Macedonia del Norte. Se evaluaron 27 jugadores masculinos de HB de dos equipos de primer nivel de RNM ergométricamente con el protocolo de Bruce para determinar el consumo máximo de oxígeno; el análisis corporal se realizó con el analizador de impedancia bioeléctrica InBody 720. Los parámetros antropométricos fueron los siguientes: talla media 190,4±7,8 cm y peso 96,3±15,5 kg, masa músculo esquelética (SMM)=47,11±6,69 kg; IMC=26,38±3,1; %GC=15,04±6,01 y RCC=0,9±1,8. El resultado de la prueba ergométrica produce un VO_2 máximo medio = 43,92 ml/kg/min, que es el 100,46 % del valor de referencia. La composición corporal de los jugadores de balonmano internacionales de élite de los mejores equipos de balonmano de la República de Macedonia del Norte mostró componentes corporales similares a los de otros jugadores de balonmano europeos. Los parámetros diagnósticos de obesidad se asociaron negativamente con el tiempo de ejercicio y el consumo máximo de oxígeno.

PALABRAS CLAVE: Jugadores de balonmano; Composición corporal; Ritmo cardiaco; Prueba de Bruce.

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