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Article

Acute Effects of Handball Game on the Retinal Vessel Diameters and Blood Circulation in Professional Handball Players

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Abstract

Proper planning of athletes' workload during training, especially in preparation for championships or other important competitions, is crucial to avoid serious health complications. Athletes are exposed to significant physical, emotional and psychological stress during training and competitions. The assessment of athletes' physiological parameters before and after training is important not only for their athletic performance but also for their general health, both during active participation in sport and later in life. **The aim of this study** was to determine anthropometric characteristics and changes in the retinal vessel diameters, arterial blood pressure, heart rate, cerebrospinal fluid pressure and blood oxygenation in all handball players before and after competitive training and to relate these parameters to the most important modifiable cardiovascular risk factors. **Methods.** The study took place as part of training sessions in training centers. The test subjects were instructed to abstain from sport and alcohol for 24 hours, not to consume any caffeinated or carbonated drinks for 6 hours and not to eat for at least 2 hours before the measurements. Baseline measurements were carried out on all handball players. The experiments began at 18:00. On arrival, physical activity was assessed, and anthropometric measurements were taken. Participants were then asked to rest in a seated position. After a 10-minute rest, arterial blood pressure, heart ratio and blood oxygenation were measured. The retinal fundus of professional handball players was imaged immediately before and after a competitive match using a non-mydratic fundus camera. **Results.** 13 handball players took part in the study. After training, the average weight of the subjects decreased by 0.515 (0.41) kg, systolic blood pressure by 3.85 (15.15) mmHg, diastolic by 4.85 (9.045) mmHg, MAP by 4.565 (7.87) mmHg, CSFP by 0.79 (1.44) mmHg, SpO₂ by 1.15 (1.625) %. After training, only the average heart rate increased by 38.23 (36.33) bpm. Mean retinal arterial diameter decreased slightly in both eyes, whereas mean venous diameter increased. **Conclusions.** We found a significant increase in mean heart rate after training, but a slight decrease in the other parameters analyzed: systolic blood pressure, diastolic blood pressure, MAP, CSFP, SpO₂ and weight. We would attribute the decrease in these indicators to insufficient recovery of fluid balance. Venous measurements exhibited greater inter-individual variability than arterial measurements, with a non-significant trend toward post-exercise arterial narrowing and venous widening.

Keywords: systolic blood pressure; diastolic blood pressure; retinal vessel diameters; physiological parameters; heart rate; cerebrospinal fluid pressure and blood oxygenation; mean arterial pressure

1. Introduction

Handball is a sport that is played in many European countries [1]. Handball is an Olympic team sport that is divided into two periods (each 30 minutes long) and consists of a high level of physical contact and predominantly aerobic activities separated by anaerobic units such as sprints, jumps, throws, changes of direction in attack (counterattack and attack build-up) and defense [2,3]. Handball is a team sport characterized by repeated sprints of high intensity and short duration with partial breaks. Handball players need more speed, power, strength, endurance, agility and flexibility to compete [4]. Nowadays, handball players require greater aerobic capacity and higher repetitive sprinting ability [5]. Proper planning of athletes' workload during training, especially in preparation for championships or other important competitions, is crucial to avoid serious health complications. Athletes are exposed to significant physical, emotional and psychological stress during training and competitions, so thorough health assessment and monitoring is essential throughout the sports season. The assessment of athletes' physiological parameters during exercise is important not only for their athletic performance but also for their general health, both during active participation in sport and later in life. These analyses are valuable not only for athletes, but also for coaches and sports physicians [6,7]. Physical overuse can have a negative impact on various body systems, particularly the cardiovascular system [8,9], the nervous system, the musculoskeletal system and mental health [10]. In addition, physiological indicators such as body mass index, fat mass and muscle mass undoubtedly influence athletes' performance. Therefore, monitoring anthropometric indicators during the preparation phase for competitions is crucial [4,11,12].

Therefore, athletic performance depends not only on the physical readiness of each player, which includes strength, running ability, agility, dexterity and player position, but also on the physiological indicators, health status and anthropometric characteristics of each player [6,13–16]. During a match, players cover about 4-6 km and their heart rate increases to 140-180 beats per minute or about 90% of maximum heart rate [8,10,17]. According to other authors, players run about $4,370 \pm 702.0$ meters during a match. Approximately 80% of the total time consists of standing ($43.0 \pm 9.27\%$) and walking ($35.0 \pm 6.94\%$), and only $0.4 \pm 0.31\%$ is fast running [18]. There are five motor dimensions in handball: Throwing power, accuracy, speed of movement with the ball, ball handling and speed of movement without the ball [18,19]. Handball is a physically demanding intermittent sport with considerable aerobic components, but also with phases of high intensity with anaerobic energy release [12].

Recently, it has become increasingly known that young top athletes worldwide are dying prematurely or have serious health problems. Dynamic (running) exercises significantly alter cardiac activity and cerebral blood flow. During static exercise (weightlifting) systolic blood pressure can rise to 450-380 mmHg, leg press can reach up to 320/250 mmHg, and single arm curls can lead to 255/190 mmHg. Heart rate during static exercise can increase to 166 beats per minute or more. These changes can lead to cerebral hemorrhage, impaired cardiac function and sudden death [20,21]. To develop effective interventions to reduce cardiovascular risk factors and mortality, it is important to investigate the influence of different dynamic endurance exercises on arterial blood pressure, cardiac ratio and blood oxygenation in all handball players during handball training. As retina is known like a window to systemic circulation, retinal vessels measurements were analyzed as well.

The aim of this study was to determine anthropometric characteristics and changes in arterial blood pressure, heart rate, cerebrospinal fluid pressure, blood oxygenation and retinal vessels diameters in all handball players before and after competitive training and to relate these parameters to the most important modifiable cardiovascular risk factors.

2. Materials and methods

2.1. Subjects

The study examined 13 male handball players who took part in competitions. The age of the men ranged from 19 to 25 years. The criteria for inclusion were: 1) young age (18-30 years); 2) regular physical activity of approximately 90 minutes per day, 3-4 times per week for at least 3 years; 3) no medication that could influence the experimental variables; 4) no evidence of autonomic dysfunction, metabolic and cardiovascular disease. This level of physical activity is in line with current World Health Organization guidelines for aerobic activity, which apply to all healthy adults aged 18 to 64 years [22].

The study was approved by the Ethics Committee of the Kaunas Regional Biomedical Research Commission (No. BE-2-77, 2021-06-06) and was conducted in accordance with the requirements of the Declaration of Helsinki. Participants were fully informed about all experimental procedures and written informed consent was obtained from all of them. A questionnaire was used to collect information on participants' date of birth, duration of exercise practice, use of dietary supplements, smoking and alcohol consumption.

2.2. Procedures

The study took place as part of training sessions in training centers. The test subjects were instructed to abstain from sport and alcohol for 24 hours, not to consume any caffeinated or carbonated drinks for 6 hours and not to eat for at least 2 hours before the measurements. Baseline measurements were carried out on all handball players. The experiments began at 18:00. On arrival, physical activity was assessed, and anthropometric measurements were taken. Participants were then asked to rest in a seated position. After a 10-minute rest, arterial blood pressure, heart ratio and blood oxygenation were measured.

The exercise duration was 90 minutes:

- (1) 20 min low intensity zone (warm-up);
- (2) 35 min. main aerobic zone (~70-80% of the player's maximum heart rate);
- (3) 15 min. high intensity zone (80-90% of maximum heart rate);
- (4) ~20 min moderate intensity zone with transition to low intensity (70-50% of maximum heart rate).

All handball players completed a pre-match warm-up program consisting of 20 minutes of low-intensity running, stepping and stretching. A handball match was played on a rectangular court with a playing area of 800 m² (40 × 20 m) (a handball court the size of). The average ambient temperature during the game was 22 °C. A match consisted of 35 minutes of main aerobic zone and 15 minutes of high-intensity zone. Immediately after handball training, arterial blood pressure, heart rate and blood oxygenation were measured. Body weight was then measured.

2.3. Measurements

2.3.1. Anthropometry and Body Composition

Height (Leicester Height Meter; Invicta Plastics, Leicester, UK) and weight were estimated while subjects wore only underwear and were barefoot. Body mass index was calculated using the weight/height² formula and categorized according to the WHO classification for BMI.

2.3.2. Blood Pressure, Heart Ratio and Cerebrospinal Fluid Pressure

Arterial blood pressure was measured with a semi-automatic blood pressure monitor (Microlife BP A80; Micro-life AG, Widnau, Switzerland). Mean arterial pressure (MAP) was calculated according to the formula $MAP = DP + 1/3 \times (SP - DP)$, where DP is the diastolic blood pressure and SP is the systolic blood pressure [15,21,23]. CSF pressure (CSFP) was calculated using the formula

CSFP = $0.44 \times \text{BMI (kg/m}^2 + 0.16 \times \text{DBP (mmHg)} - 0.18 \times \text{age (years)} - 1.91$ [24]. The heart rate was recorded before and after training.

2.3.3. Peripheral Oxygen Saturation

Peripheral oxygen saturation (SpO₂) was measured twice with Jerry-f fingertip pulse oximeter (Shanxi Jerry Medical Instrument Co., Ltd., Shanxi, China) on the right index finger for at least 3 seconds. The average of the 2 measurements was computed and used for the analysis.

2.3.4. Retinal Vessel Imaging and Analysis

The retinal fundus of professional handball players was imaged immediately before and directly after a competitive match using an Aurora Optomed IQ non-mydriatic fundus camera. Retinal arteries and veins were measured using Automated Retinal Image Analysis (ARIA), a MATLAB-based image processing program. Measurements were taken at a standardized location along the inferior margin of the optic nerve head to ensure consistency across pre- and post-exercise images.

2.4. Statistical Analysis

The data was analyzed using IBM SPSS Statistics Version 27.0.1.0. Descriptive statistics were used to calculate the mean, standard deviation and percentage of the data. The results were also checked for a normal distribution (Gaussian distribution) to enable an appropriate choice of comparative statistics method. The Kolmogorov-Smirnov test was used ($p > 0.05$). In this way, statistical comparisons were made between the two groups of respondents and correlations between the variables were sought. If there was a normal distribution, the One-Way Anova test was used ($p < 0.05$), and if the results were not normally distributed, the non-parametric Independent Samples Test was used, and the Mann-Whitney criterion was assessed ($p < 0.05$).

3. Results

13 handball players took part in the study. The basic anthropometric characteristics of the study participants are summarized in Table 1. The average age was 20.92 (1.85) years, the average height was 188.62 (7.56) cm, the average duration of active sports participation was 11.38 (1.98) years, and the BMI was 24.86 (3.81) kg/m (Table 1). Six (46.15%) of the players were smokers, and 11 (84.615%) occasionally consumed alcohol.

Table 1. Anthropometric characteristics.

<i>Handball players (N=13)</i>	<i>Age</i>	<i>Height (cm)</i>	<i>BMI, kg/m²</i>	<i>Duration of sports activity</i>
<i>X</i>	20.92	188.62	24.86	11.38
<i>SD</i>	1.85	7.56	3.81	1.98
<i>Min</i>	18	179	19.5	8
<i>Max</i>	24	207	33.3	15

Before the training, the average weight of the test subjects was 88.67 (16.13) kg, the BMI 24.86 (3.81) kg/m. Three subjects weighed over 100 kg. Four participants were found to be overweight, and one of them had grade I obesity. The average heart rate of the subjects was 73.62 (9.83) bmp. The average systolic blood pressure of the subjects was 137.69 (8.94) mmHg, but the systolic blood pressure of one athlete was 151 mmHg and the systolic blood pressure of nine athletes was 130 mmHg or more. The average diastolic blood pressure of the subjects was 76.46 (6.995) mmHg, but the diastolic blood pressure of one athlete was 93 mmHg and that of 2 athletes was more than 80 mmHg. The average MAP of the subjects was 96.92 mmHg (6.44), SpO₂ 98.54 (0.78) %, CSFP 17.56 (2.075) mmHg (Table 2).

Table 2. Baseline characteristics of study participants before and after training.

<i>Handball players (N=13)</i>	<i>X</i>		<i>SD</i>		<i>Min</i>		<i>Max</i>	
	<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>	<i>Before</i>	<i>After</i>
<i>Weight, kg</i>	88.67	88.15	16.13	16.08	70.5	70.1	118.8	118.6
<i>HR, bmp</i>	73.62	116.77	9.83	26.38	57	86	90	174
<i>Systolic BP, mmHg</i>	137.69	133.85	8.94	18.24	124	112	151	178
<i>Diastolic BP, mmHg</i>	76.46	71.62	6.995	6.12	65	62	93	84
<i>MAP, mmHg</i>	96.92	92.36	6.44	7.99	86.67	81.33	110.67	107.33
<i>SpO₂, %</i>	98.54	97.38	0.78	1.45	97	95	99	100
<i>CSFP, mmHg</i>	17.56	16.78	2.075	2.27	14.23	14.43	21.64	22.12

After training, the average weight of the test subjects was 88.15 (16.08) kg, whereby the weight remained unchanged in two athletes, decreased by more than 1 kg in two others and varied between 0.2 and 0.9 kg in the others. After exercise, the subjects’ average heart rate was 116.77 (26.38) bmp, one athlete’s heart rate was 174 bmp and one athlete’s heart rate was 152 bmp, and three athletes’ heart rates were 130-131 bmp. The average systolic blood pressure of the subjects was 133.85 (18.24) mmHg, but the systolic blood pressure of one athlete was 178 mmHg and that of two athletes was 150-154 mmHg. The average diastolic blood pressure of the subjects was 71.62 (6.12) mmHg, but the diastolic blood pressure of one athlete was 84 mmHg. The average MAP of the subjects was 92.36 (7.99) mmHg, SpO₂ 97.38 (1.45) %, CSFP 16.78 (2.27) mmHg.

The differences in the characteristics of the study participants before and after training are shown in Table 3. After training, the average weight of the subjects decreased by 0.515 (0.41) kg, systolic blood pressure by 3.85 (15.15) mmHg, diastolic by 4.85 (9.045) mmHg, MAP by 4.565 (7.87) mmHg, CSFP by 0.79 (1.44) mmHg, SpO₂ by 1.15 (1.625) %. After training, only the average heart rate increased by 38.23 (36.33) bmp.

Table 3. Characteristics’ difference of study participants before and after training.

<i>Handball players (n=13)</i>	<i>Before training (mean (standard deviation))</i>	<i>After training (mean (standard deviation))</i>	<i>Difference (mean (standard deviation))</i>
<i>Weight, kg</i>	88.67 (16.13)	88.15 (16.08)	0.515 (0.41) *
<i>SpO₂, %</i>	98.54 (0.78)	97.38 (1.45)	1.15 (1.625) *
<i>Systolic BP, mmHg</i>	137.69 (8.94)	133.85 (18.24)	3.85 (15.15)
<i>Diastolic BP, mmHg</i>	76.46 (6.995)	71.62 (6.12)	4.85 (9.045) *
<i>MAP, mmHg</i>	96.92 (6.44)	92.36 (7.99)	4.565 (7.87) *
<i>Heart ratio, bmp</i>	73.62 (9.83)	116.77 (26.38)	43.15 (28.6) *
<i>CSFP, mmHg</i>	17.56 (2.075)	16.78 (2.27)	0.79 (1.44) *

Table notes. *p<0.05, compared with before; SpO₂, peripheral oxygen saturation; BP, blood pressure; MAP, mean arterial pressure; CSFP, cerebrospinal fluid pressure.

Twelve handball players underwent retinal vessel measurements before and immediately after exercise. Mean retinal arterial diameter decreased slightly in both eyes, from 13.64 ± 2.06 to 12.05 ± 2.31 in the right eye (OD) and from 14.79 ± 1.95 to 14.07 ± 1.93 in the left eye (OS). In contrast, mean retinal venous diameter increased from 20.23 ± 3.49 to 22.44 ± 4.19 in OD and from 21.53 ± 2.81 to 22.71 ± 2.83 in OS. Paired t-tests revealed no statistically significant differences between pre- and post-exercise measurements. Venous measurements showed greater inter-individual variability compared to arterial measurements. Overall, the results indicate a non-significant trend toward arterial narrowing and venous widening following exercise in this cohort (Table 4).

Table 4. Changes in retinal vascular diameter before and after training.

<i>Handball players (n=13)</i>	<i>Vessel type</i>	<i>Baseline vessel diameter</i>	<i>Post-exercise vessel diameter</i>	<i>p-value</i>
<i>Right eye (OD)</i>	<i>Artery</i>	13.64 ± 2.06	12.05 ± 2.31	0.103
	<i>Vein</i>	20.23 ± 3.49	22.44 ± 4.19	0.172
<i>Left eye (OS)</i>	<i>Artery</i>	14.79 ± 1.95	14.07 ± 1.93	0.398
	<i>Vein</i>	21.53 ± 2.81	22.71 ± 2.83	0.336

4. Discussion

Successful monitoring of training and match load provides a better picture of individual training tolerance, which is influenced by numerous factors such as age, previous experience, fitness level, nutrition and recovery practices of the player. The data obtained thus provides a solid basis for optimal training periodization and consequently for maximizing athletic performance, reducing the risk of injury and avoiding overload and overtraining syndromes [25]. The assessment of physiological and anthropometric parameters and their changes in elite athletes is essential for achieving peak performance. We found no articles analyzing the changes in physiological and anthropometric parameters of handball players before and immediately after training. The articles tended to look for a relationship between anthropometric parameters and athletic performance or the player’s position.

The aim of this study was to determine the anthropometric characteristics and the changes in arterial blood pressure, cardiac ratio, blood oxygenation and cerebrospinal fluid pressure in all handball players during competitive training and to relate these parameters to the main modifiable cardiovascular risk factors (body mass index (BMI), heart rate and blood pressure (BP)).

In most studies, the age and anthropometric characteristics of the subjects and the duration of active participation in sport were like those of our subjects. In our subjects, age was 20.92±1.847 (18-24) years, height was 188.62±11.29 (179-207) cm, weight was 88.67±16.13 (70.5-118.8) kg, and experience in professional sports was longer than 11.24±3.095 years.

The 93 elite male handball players from the first handball league of Kosovo were included in the study, age (mean (SD)) 22 (1) years, height 184.0 (7.83) cm, weight 84.10 (13.74) kg, and with 8 (4) years of professional playing experience [14]. Lijevski and co-authors (2021) studied 36 professional handball players aged 26.1 ± 6.44 years. The players had a previous experience of 14.4 ± 6.89 years in handball, i.e., a slightly longer duration than our subjects. The subjects’ height was 1.86±0.67, weight 89.27±11.47 kg and BMI 25.64±2.49 [26]. Gurkan and co-authors (2012) studied 12 Turkish Super league handball players who were older than our sub-subjects and had a longer duration of exercise. Their mean age was 29.3±4.1 years, duration of active participation was 15.2±3.2 years, height was 189±6.6 cm and weight were 96.2±13.3 kg [13]. nine experienced handball players at national level with 21.0 (18.1; 21.9) years, 181.0 (178.0; 184.0) cm and 78.4 (72.6; 84.2) kg, training 5.1 (4.4; 5.8) h/week, participated in the study [8]. Fourteen male handball players (mean ± SD: age 23.8 ± 4.4 years, range 19–34 years; body mass 84.0 ± 7.4 kg; height 1.88 ± 0.06 m) from the same team playing in the French professional handball league voluntarily participated in this study. Their training background was 12.4 ± 4.2 years in handball. The test period was conducted in the second half of the competitive season. In the five months prior to the start of the study, each participant had trained on average seven times per week [27]. Jakovlevic and co-authors (2016) investigated the relationship between body composition and athletic performance in handball players and rowers. 20 handball players took part in the study. Their average age was 23.7±3.72 years, height was 189±4.15 cm, weight was 91.6±8.14 kg and the duration of active sports participation was 9.55±3.93 years. The researchers found that specific body composition and morphometric parameters, along with technique and sports experience, can be considered an important factor in an athlete’s performance. These physiological characteristics can be used to identify talent and develop more specific assessment methods in elite sport. In addition, they can help coaches or sports scientists to develop a training program that raises and improves all essential attributes to the level required for success [12].

Heart rate (HR) is one of the easily available physiological indicators. Today, it is one of the most frequently used and exceptionally reliable load intensity analysis methods, but it is also considered to be a reliable benchmark for the assessment of load intensity [38]. Before training the average HR of our subjects was 73.62 (9.83) bpm and after training 116.77 (26.38) bpm. HR max before training was 90 bpm, HR max after training was 174 bpm.

Vala et al. (2022) investigated the heart rate of female handball players in different positions during competition. The mean maximum heart rate independent of the player's position during competition was 175.6 ± 15.5 bpm [28]. Povoas and co-authors (2012) included 30 female handball players in their study. Their average age was 25.2 ± 3.59 years, their weight 87.7 ± 8.96 kg and their height 186.5 ± 7.92 cm. After exercise, their heart rate was 191 ± 8.6 bpm [18]. Yasin and co-authors (2020) investigated physiological parameters during training in players from different handball leagues. They found that heart rate increased similarly during training in both leagues, ranging from 191.6 ± 7.3 to 192.1 ± 9 bpm in anaerobic energy supply mode. However, the heart rate dynamics in the recovery phase were statistically significantly different. In the Major League handball players, the heart rate dropped to 119.5 ± 6.4 bpm in the first three minutes, while it only reached 124.9 ± 10.9 bpm in the Super League athletes. They explain these results by the fact that the age of the Super League handball players (16-17 years) influences the type of recovery processes. After the anaerobic exercises, their working capacity recovered faster than in the adult Super League handball players (17-21 years). The anaerobic exchange of heart rate, where the body switches from aerobic to anaerobic mechanisms of energy supply, correlates directly with physical fitness level and age. For Major League handball players, the anaerobic threshold HR was 179.4 ± 8.1 bpm and for Super League players it was 176.4 ± 8.8 bpm. This is since junior handball players have a higher anaerobic replacement threshold than senior handball players [29]. Chittibabu (2013) selected twelve male university handball players. The selected handball players were 22.12 ± 3.22 years old, 174.50 ± 7.83 cm tall and 65.62 ± 7.79 kg in weight. The results show that the peak heart rate of the handball players was significantly affected during the handball game. The peak heart rate of handball players decreased dramatically in the last 15 minutes of the first and second half of the handball game: in the first half after 15 minutes 187.75 ± 7.59 bpm, after 30 minutes - 179.50 ± 12.04 bpm, in the second half after 45 minutes - 180.08 ± 13.58 bpm and after 60 minutes - 179.42 ± 11.38 bpm. The data on the average heart rate of the handball players was 165.58 ± 15.79 beats after 15 minutes, 157.83 ± 11.08 beats after 30 minutes, 161.42 ± 14.63 beats after 45 minutes and 157.08 ± 14.94 beats after 60 minutes [5]. Heart rate and exercise time were analyzed in elite female handball players (U19) during six competitive matches. The average age of the participants was 17.9 ± 0.3 years, the average weight was 65.4 ± 6.9 kg and the average height was 169.6 ± 6.9 cm. The average heart rate of the players was 183.7 ± 7.3 bpm. The results of this study show that handball is an intermittent high-intensity sport. The physiological profile shows that the players spent more than 83% of the playing time per game in the high-intensity zone ($>85\%$ HRmax). On this basis, training focusing on anaerobic exercise and interval training methods is recommended [30]. Povoas et al. (2018) studied 33-55-year-old former male team handball players. The participants had played team handball for 15 ± 8 years and trained on average 2-7 times per week and a total of 7 ± 4 hours per week, despite having no regular physical activity in the previous 14 ± 6 years. The handball training for recreational teams was conducted for 12 weeks. During this period, the THG participants completed 2-3 training sessions of 75 minutes per week, consisting of a standardized 10-minute warm-up followed by 60 minutes of recreational team handball games. During the team handball games, which lasted an average of 60 ± 3 min, the field players covered a total distance of ~ 6.5 km (6410 ± 416 m), of which ~ 1 km involved high-intensity movements (934 ± 426 m). In the field players, the mean heart rate during the games was 145 ± 15 bpm/min and the maximum heart rate was 165 ± 14 bpm/min [31]. In another study, Povoas and co-authors (2012) found that the maximum heart rate in handball players during a match was 185 ± 9.6 bpm. The participants had at least 5 years of experience in the top Portuguese professional handball league. The teams analyzed regularly participated in European club championships. HR analyses were performed on 30 male outfield players (10 from each outfield player position: wings, backs and pivots) [18]. The aim of the study by

Madsen et al. (2019) was to compare the activity pattern and heart rate, technical participation and subjective perception in U13 boys and girls playing team handball in five game formats. The physiological response to training (mean heart rate) was high for both genders with heart rates between 167 and 184 beats per minute in all game formats. The mean heart rate during pre-match handball games is only a medium intensity activity, but handball is a continuous game with many high intensity actions, as shown by peak heart rates between 192 and 202 beats per minute [33]. Fifteen participants (13 field players and 2 goalkeepers; 42.0 ± 7.1 years; height 179.4 ± 7.3 cm; body weight 98.3 ± 9.6 kg; systolic blood pressure 131 ± 11 mmHg; diastolic blood pressure 75 ± 10 mmHg; 62 ± 8 bpm HR at rest; 177 ± 10 bpm HRmax) agreed to participate in this study. They had been playing team handball for 19 ± 3 (12–22) years and exercised on average 2–7 times, totaling 8 ± 3 (2–14) hours per week, but had no record of regular PA in the last 13 ± 7 (4–26) years. Peak HR during games was 167 ± 13 bpm and mean HR was 148 ± 14 bpm for outfield players. [33]. Bauer et al. (2019) enrolled 30 male professional handball players (mean age 27 ± 4 years). Their participants were (just like our participants) experienced elite athletes with a mean professional training history of 10 years, which may have had an influence on their results. At rest, the heart rate of the handball players was 53 ± 7 bpm, the brachial blood pressure was 123 ± 8 mmHg systolic and 61 ± 9 mmHg diastolic in the athletes. The mean maximum heart rate during the strenuous exercise test was 172 ± 10 bpm in the athletes, the systolic brachial blood pressure was 189 ± 17.5 mmHg, and the maximum diastolic blood pressure was 89.9 ± 8.5 mmHg [34]. In this study, an increase in heart rate was also found, but in contrast to our study, the authors also found an increase in systolic and diastolic pressure. The average systolic blood pressure of our subjects after exercise was 133.85 (18.24) mmHg, the average diastolic blood pressure - 71.62 (6.12) mmHg, the average MAP of the subjects was 92.36 (7.99) mmHg. The reduction in systolic and diastolic blood pressure after exercise observed in our study is consistent with the results of the study by Hornstrup (2019), who observed low systolic and diastolic blood pressure in subjects aged 20-30 years after 12 weeks of handball training [35]. Similar results were obtained by Randers et al. (2018) in a study with basketball players [36]. In both studies, however, the blood pressure of professional athletes was not measured immediately after training, but only after a certain period of training.

Povoas and co-author (2012) found that body weight loss during the games was 0.8 ± 0.52 (0.0–1.4) kg, which corresponds to 0.9 ± 0.34 (0.0–1.3) % of their body mass. The participants had at least 5 years of experience in the top Portuguese professional handball league. The mean weight of the subjects before training was 88.67 (16.13) kg (min. 70.5 kg, max. 118.8 kg), while the mean weight after training decreased statistically significantly by 0.515 (0.41) kg to 88.15 (16.08) kg (min. 70 kg, max. 118.6 kg). The weight loss could be explained by the loss of fluid during training, as the subjects did not consume any fluid during training [18].

Using MRI, Tarumi et al. (2021) found that absolute CSFP flow rate decreased but arterial blood pressure and heart rate increased in young subjects (men and women) during rhythmic handgrip exercise. In our subjects, the mean CSFP before exercise was 17.56 (2.075) mmHg columns, while the mean CSFP after exercise decreased statistically significantly to 16.78 (2.27) mmHg columns [37].

Analysis of retinal vessel parameters before and immediately after handball training revealed a slight decrease in retinal arterial diameter and an increase in retinal venous diameter. Venous measurements exhibited greater inter-individual variability than arterial measurements; however, these differences did not reach statistical significance in our study cohort.

Nussbaumer and co-authors (2014) investigated changes in retinal vessel diameters in response to acute dynamic exercise of different intensities in healthy seniors (median age 68) and in healthy young adults (mean age 26). They found that maximal and submaximal exercise intensities induced a significant dilation in central retinal arteriolar and central retinal venular diameters [38].

Nie and Feng (2025), in a meta-analysis, reported that physical activity interventions significantly improved retinal arterial and venular calibers in children and adolescents. In contrast, alterations in retinal microvasculature—characterized by arteriolar narrowing and venular widening—have been associated with increased cardiovascular disease risk [39].

In addition, Cui et al. (2023) examined associations between physical activity, retinal thickness, and vascular structure. Their findings suggested a protective role of recreational physical activity against retinal microvascular alterations in an elderly Chinese population [40].

Ikemura et al. investigated the effects of acute dynamic exercise on retinal vascular stiffness in healthy older and younger men (69 ± 3 and 23 ± 3 years, respectively). In this study, retinal arteriolar blood flow decreased following exercise. Moreover, the effects of acute exercise on vascular stiffness differed between conduit arteries and retinal arterioles, potentially reflecting regional differences in vascular tone regulation and vessel function [41].

5. Conclusions

The aim of the study was to investigate the effects of intensive sporting activity on physiological parameters in athletes. Since it is not possible to examine athletes during a competition, we decided to use intensive training. The tests were performed immediately after the training session and therefore only non-invasive tests were used. We found a significant increase in mean heart rate after training, but a slight decrease in the other parameters analyzed: systolic blood pressure, diastolic blood pressure, MAP, CSFP, SpO2 and weight. We would attribute the decrease in these indicators to insufficient recovery of fluid balance. Venous measurements exhibited greater inter-individual variability than arterial measurements, with a non-significant trend toward post-exercise arterial narrowing and venous widening. To the best of our knowledge, this study represents the first comprehensive assessment of retinal vascular structure and circulation in professional handball players. Future research should broaden the scope of this investigation to encompass larger and more diverse cohorts of athletes from multiple sporting disciplines, thereby enabling comparative analyses in relation to the intensity and nature of physical exertion.

Author Contributions: All authors conceived and designed the experiments. The all authors performed the experiments, and analyzed the data. The authors D.I. and G.I. performed the statistical analysis and drafted the initial manuscript. All authors have read, contributed to, and approved the final version of the manuscript.

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References

1. Póvoas SC, Ascensão AA, Magalhães J, Seabra AF, Krstrup P, Soares JM, Rebelo AN. Physiological demands of elite team handball with special reference to playing position. *J Strength Cond Res.* 2014 Feb; 28(2):430-42. doi: 10.1519/JSC.0b013e3182a953b1
2. Hornstrup T, Póvoas S, Helge JW, Melcher PS, Frstrup B, Andersen JL, et al. Cardiovascular and metabolic health effects of team handball training in overweight women: Impact of prior experience. *Scandinavian Journal of Medicine & Science in Sports* [Internet]. 2019 Nov 7;30(2):281–94. Available from: <https://doi.org/10.1111/sms.13563>
3. Ziv G, Lidor R. Physical characteristics, physiological attributes, and on-court performances of handball players: A review. *EJSS (Champaign, Ill)* [Internet]. 2009 Oct 28;9(6):375–86. Available from: <https://doi.org/10.1080/17461390903038470>
4. Balasubramaniana CM, Chittibabu B. Effect of handball specific aerobic training on body composition and VO2 max of male handball players. *International Journal of Physical Education, Fitness and Sports.* 2014; 3 (4): 40-47
5. Chittibabu, B. Effect of handball specific repeated – sprint training on aerobic capacity of male handball players. *International Journal of Physical Education, Fitness and Sports.* 2013; 2(4): 4-7
6. Pantović M, Joksimović M, Brkić B, Gladysheva A, Karišik S. Body Composition and Somatotype in Elite Handball Players. *Intern J of Physical Education, Fitness and Sports.* 2019; 8 (4): 97-107; www.ijpefs.com
7. Suna G, Beyleroğlu M, Hazar K. Comparison of aerobic, anaerobic power features basketball and handball team players' Niğde University. *J Phys Educ and Sport Scienc.* 2016;10(3):379-385

8. Buchheit M, Leprêtre PM, Behaegel AL, Millet GP, Cuvelier G, Ahmaidi S. Cardiorespiratory responses during running and sport-specific exercises in handball players. *Journal of Science and Medicine in Sport* (Online) [Internet]. 2009 May 1;12(3):399–405. Available from: <https://doi.org/10.1016/j.jsams.2007.11.007>
9. Hornstrup, T., Póvoas, S., Helge, JW., Melcher, PS., Fristrup, B., Andersen, JL., Møgelvang, R., Hansen, PR., Nybo, L., Krstrup, P. Cardiovascular and metabolic health effects of team handball training in overweight women Impact of prior experience. *Scand J of Med and Sc in Sport*. 2020 February; 30(2):281-294. DOI: 10.1111/sms.13563 Publication date: 2020
10. Kumar R, Bhat RA. Comparative study of aerobic and anaerobic capacity between basketball and handball players Ge-Intern. *J of Management*. 2014; 2 (9): IF-3.142 ISSN: (2321-1709)
11. Ersoy N, Ersoy G, Kutlu M. Assessment of hydration status of elite young male soccer players with different methods and new approach method of substitute urine strip. *J Int Soc Sports Nutr*. 2016;13:34
12. Karaba-Jakovljević D, Jovanović G, Erić M, Klašnja A, Slavić D, Lukač D. Anthropometric characteristics and functional capacity of elite rowers and handball players. *Medicinski Pregled* [Internet]. 2016 Jan 1;69(9–10):267–73. Available from: <https://doi.org/10.2298/mpns1610267k>
13. Gürkan AC, Altunsoy M, Demirhan B, Sever O, Özcan M, Gökdemir K. Anthropometric Features and Balance Among Elite Handball Players. *Ovidius University Annals, Series Physical Education and Sport/Science, Movement and Health*. 2012; 12(2), ISSUE 2, Romania
14. Karaba-Jakovljević D, Jovanović G, Erić M, Klašnja A, Slavić D, Lukač D. Anthropometric characteristics and functional capacity of elite rowers and handball players. *Medicinski Pregled* [Internet]. 2016 Jan 1;69(9–10):267–73. Available from: <https://doi.org/10.2298/mpns1610267k>
15. Manchado C, Tortosa-Martínez J, Suárez HV, Ferragut C, Platen P. Performance factors in women's team handball. *Journal of Strength and Conditioning Research* [Internet]. 2013 Jun 1;27(6):1708–19. Available from: <https://doi.org/10.1519/jsc.0b013e3182891535>
16. Nikolaidis PT, Ingebrigtsen J, Physical and physiological characteristics of elite male handball players from teams with a different ranking, *Journal of Human Kinetics*. 2013; 38:115-124
17. Loftin M, Anderson P, Lytton L, et al. Heart rate response during handball singles match-play and selected physical fitness components of experienced male handball players. *J Sports Med Phys Fitness*. 1996;36(2):95–9
18. Póvoas SC, Seabra AF, Ascensão AA, Magalhães J, Soares JM, Rebelo AN. Physical and physiological demands of elite team handball. *J Strength Cond Res*. 2012; 26(12):3365-75. doi: 10.1519/JSC.0b013e318248ae4e
19. Pavlović S, Talović M, Kazazović E, Lakota L. Analysis and Differences in the Basic Motor and Situational Motor Abilities between Female Handball Players in the Bih First Federal League and the First League of the Republika Srpska. *Sportlogia* [Internet]. 2013 Dec, 31; 9 (2): 129-133. Available from: <https://doi.org/10.5550/sgia.130902.en.008p>
20. Dickerman RD, McConathy WJ, Smith GH, East JW, Rudder L. Middle cerebral artery blood flow velocity in elite power athletes during maximal weight-lifting. *Neurol Res*. 2000 Jun;22(4):337-40
21. MacDougall JD, Tuxen D, Sale DG, Moroz JR, Sutton JR. Arterial blood pressure response to heavy resistance exercise. *Appl Physiol*. 1985 Mar; 58(3):785-90
22. World Health Organization. Information sheet: global recommendations on physical activity for health 18 - 64 years old. 2011. <http://www.who.int/dietphysicalactivity/physical-activity-recommendations-18-64years.pdf>. Accessed 4 July 2018
23. DeMers D, Wachs D. Physiology, mean arterial pressure. 2023. [https://www.ncbi.nlm.nih.gov/books/NBK538226/#:~:text=A%20common%20method%20used%20to,%2B%201%2F3\(PP\)](https://www.ncbi.nlm.nih.gov/books/NBK538226/#:~:text=A%20common%20method%20used%20to,%2B%201%2F3(PP))
24. Fleischman D, Bicket AK, Stinnett SS, Berdahl JP, Jonas JB, Wang NL, Fautsch MP, Allingham RR. Analysis of cerebrospinal fluid pressure estimation using formulae derived from clinical data. *Invest Ophthalmol & Vis Sc*. 2016; 57(13): 5625-30
25. Marić D, Gilić B, Foretić N. Monitoring the Internal and External Loads of Young Team Handball Players during Competition. *Sport Mont (Štampano Izd)* [Internet]. 2021 Feb 1;19(1):19–23. Available from: <https://doi.org/10.26773/smj.210204>

26. Lijewski M, Burdukiewicz A, Pietraszewska J, Andrzejewska J, Stachoń A. Asimmetry of Muscle Mass Distribution and Grip Strength in Professional Handball Players. *Int J Environ Res Public Health*. 2021; 18:1913: 2-12
27. Ravier G, Hassenfratz C, Bouzigon R, Gros Lambert, A. Physiological and affective responses of 30s– 30s intermittent small-sided game in elite handball players: A new alternative to intermittent running. *Journal of Human Sport and Exercise*. 2019; 14(3):538-548. doi:<https://doi.org/10.14198/jhse.2019.143.05>
28. Vala R, Valova M, Litschmannová M, Dráždilová P. Analysis of the load intensity of female handball players during a match. *Journal of Physical Education and Sport*. 2022; 22 (4): 1079 - 1085, DOI:10.7752/jpes.2022.04136
29. Yasin B, Saleh Aal, Eltibi SA, Nairat M, Petracheva IV. Comparison of physical and physiological indicators in handball players of various training groups. *Theory and Practice of Physical Culture*. 2020; 4:37-39
30. Belka J, Hulka k, Safar M, Weisser R, Samcova A. Analyses of time-motion and heart rate in elite female players (U19) during competitive handball matches. *Kinesiology*. 2014; 46(1):33-43
31. Póvoas S, Castagna C, Resende C, Coelho E, Silva P, Santos R, et al. Effects of a Short-Term Recreational Team Handball-Based Programme on Physical fitness and cardiovascular and metabolic Health of 33-55-Year-Old Men: a pilot study. *BioMed Research International (Print) [Internet]*. 2018 Oct 3;2018:1–11. Available from: <https://doi.org/10.1155/2018/4109796>
32. Madsen M, Ermudis G, Rago V, Surrow K, Vigh-Larsen JF, Randers MB, et al. Activity profile, heart rate, technical involvement, and perceived intensity and fun in U13 male and female team handball players: effect of game format. *Sports (Basel) [Internet]*. 2019 Apr 19;7(4):90. Available from: <https://doi.org/10.3390/sports7040090>
33. Póvoas S, Castagna C, Resende C, Coelho E, Silva P, Santos R, et al. Physical and physiological demands of recreational team handball for adult untrained men. *BioMed Research International [Internet]*. 2017 Jan 1;2017:1–10. Available from: <https://doi.org/10.1155/2017/6204603>
34. Bauer P, Kraushaar L, Most A, Hölscher S, Gondai ST, Dörr O, et al. Impact of vascular function on maximum power output in elite handball athletes. *Research Quarterly for Exercise and Sport [Internet]*. 2019 Aug 9;90(4):600–8. Available from: <https://doi.org/10.1080/02701367.2019.1639602>
35. Hornstrup T, Løwenstein FT, Larsen MAD, Helge EW, Póvoas S, Helge JW, et al. Cardiovascular, muscular, and skeletal adaptations to recreational team handball training: a randomized controlled trial with young adult untrained men. *European Journal of Applied Physiology (Print) [Internet]*. 2018 Nov 24;119(2):561–73. Available from: <https://doi.org/10.1007/s00421-018-4034-5>
36. Randers MB, Hagman M, Brix J, Christensen J, Pedersen MT, Nielsen J, et al. Effects of 3 months of full-court and half-court street basketball training on health profile in untrained men. *Journal of Sport and Health Science [Internet]*. 2018 Apr 1;7(2):132–8. Available from: <https://doi.org/10.1016/j.jshs.2017.09.004>
37. Tarumi T, Yamabe T, Fukuie M, Zhu DC, Zhang R, Ogoh S, et al. Brain blood and cerebrospinal fluid flow dynamics during rhythmic handgrip exercise in young healthy men and women. *Journal of Physiology [Internet]*. 2021 Feb 16;599(6):1799–813. Available from: <https://doi.org/10.1113/jp281063>
38. Nussbaumer, M & Donath, Lars & Fischer, M & Schäfer, J & Faude, Oliver & Zahner, Lukas & Schmidt-Trucksäss, Arno & Hanssen, Henner. Effects of acute bouts of endurance exercise on retinal vessel diameters are age and intensity dependent. *Age (Dordrecht, Netherlands)*. 2014; 36. 10.1007/s11357-014-9650-3.
39. Nie P and Feng T (2025) Meta-analysis of the effects of physical activity on ocular biometrics in children and adolescents. *Front. Public Health* 13:1615033. doi: 10.3389/fpubh.2025.1615033
40. Cui B, Zhu Y, Zhang X, He K, Shi Y, Yu J, Zhou W, Zhu Y, Yan H. Association of Physical Activity with Retinal Thickness and Vascular Structure in Elderly Chinese Population. *Ophthalmic Res*. 2023;66(1):281-292. doi: 10.1159/000527448.
41. Ikemura T, Nakamura N, Hayashi N. Impact of acute dynamic exercise on vascular stiffness in the retinal arteriole in healthy subjects. *J Appl Physiol* (1985). 2022 Feb 1;132(2):459-468. doi: 10.1152/jappphysiol.00507.2021.

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