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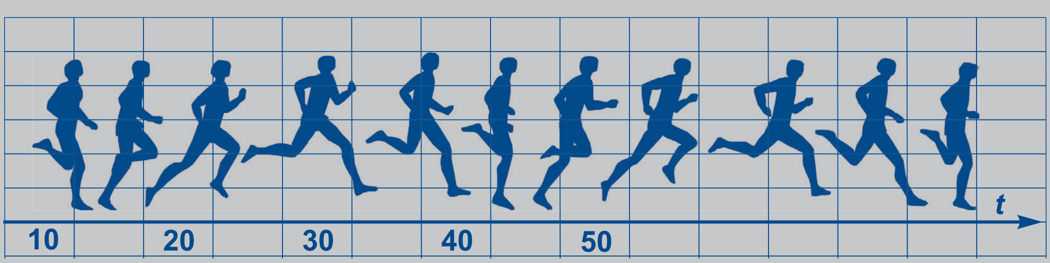

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ANALYSIS OF THE LEVEL OF AEROBIC AND ANAEROBIC FITNESS INDICES OF HANDBALL PLAYERS OF THE POLISH SUPER LEAGUE

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

Keywords: aerobic capacity, anaerobic capacity, threshold of anaerobic metabolism, body composition, handball

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Abstract:

Background: A review of the literature related to handball indicates that, in the modern game at the highest level, it is essential for the player to develop aerobic and anaerobic capacity. Given the above data and the paucity of scientific reports describing the level of aerobic and anaerobic capacity in handball players with a high level of sports skills, it was considered expedient to study these problems of capacity in the men's Super League team.

Methods: The purpose of the study was to analyze selected indices of aerobic and anaerobic capacity, and somatic components of the body, of handball players of Super League playing at different positions. Study subjects: 14 men from the Polish Super League handball team. The mean age of the participants was 25.8±3.4 years, the mean body height was 191.9±12.8 cm, and the mean body weight was 98.0±7.2 kg. Body composition was assessed using a Tanita SC 330 analyzer. The evaluation of selected indices of aerobic capacity was performed based on the direct method, the progressive ergospirometric test (cardio-pulmonary exercise test). To assess anaerobic potential, an exercise test was applied in the form of 6 repetitions of efforts lasting 10 seconds each, separated by intervals of 30 seconds on a Monark 824E cycle ergometer.

Results: The mean value of maximum oxygen uptake (VO_2max.) of the participants was 65.5±9.8 ml/kg/min, the running speed at the threshold of anaerobic metabolism (MRS at AT) was 13.2±1.7 km/h, HRmax was 180.6±7.6 bpm, and the percentage of VO_2 at the threshold of anaerobic metabolism was evaluated. The maximum power Pmax was 10.4±0.8 W/kg, the time to attain peak power was 5.0±0.9 s, and the time of maintaining power was 1.9 ±0.7 s.

Conclusion: The mean values of the body tissue components of the participants were similar to the results of national team players from other countries. The VO_2max in the athletes was at a high level but the running speed was at the threshold of anaerobic metabolism (MRS at AT) and the acquisition of VO_2max had a low value. The mean maximum power Pmax was at a low level in each of the 6 series of exercises performed.

Introduction

Handball belongs to the group of endurance and speed sports, in which the ability to perform repetitive short-duration runs of maximum intensity is of critical importance [1-3]. During the game, the exercise load is characterized by repetitive short efforts of high intensity, such as running, jumping, and throwing, separated by efforts of low intensity [3,4]. Of particular importance in the training process of a handball player is the development of aerobic and anaerobic fitness [3]. Both of these mechanisms of energy production serve to systematically reproduce adenosine triphosphate (ATP), the substrate necessary for muscle work, and their activity depends on the duration and intensity of exercise [5]. Skeletal muscle work during intense exercise relies on anaerobic processes, which are the predominant source of energy [4,5]. Scientific studies have shown that the ability to perform repetitive high-intensity efforts depends on the phosphocreatine stores in muscles and the rate of their resynthesis [6]. The rate of phosphocreatine resynthesis depends on aerobic metabolism, which suggests that athletes characterized by higher VO_2max are capable of more efficient resynthesis of this compound [7]. In addition to the maximum oxygen consumption (VO_2max), in the course of changes in physiological indicators induced by the exercise of gradually increasing intensity, two characteristic points (so-called thresholds) concerning both lactate concentration and respiratory volume of the lungs are observed. These thresholds are the aerobic threshold and the anaerobic threshold [8]. The farther the anaerobic threshold (AT) is shifted with increasing exercise intensity, the higher levels of the ability to perform intense efforts in the athlete's aerobic capacity zone. Physiological parameters of exercise observed at the anaerobic threshold (AT) provide important information in a diagnostic and predictive sense regarding the programming of training loads [9]. The ability of muscles to perform subsequent intense efforts depends, at least in part, on the rate of phosphocreatine resynthesis and the rate of hydrogen ion elimination. PCr stores are replenished quickly (30-60 s), while H+ elimination takes much longer (5-10 min) [10]. In modern handball, an important component of the match load structure is anaerobic capacity [11]. Studies of the structure of the match load by Czerwinski [12,13] and Norkowski [14,15] have shown that in the case of handball, 30-45% of the game time occurs in the zone of anaerobic efforts. Therefore, the proportion of efforts that characterize anaerobic metabolism, and their structure and proportions encourage the implementation of training contents consistent with the physiological characteristics of the game of handball. In the available domestic and foreign literature, there is little data on aerobic and anaerobic capacity in handball players at a high level of sports skills [15,16]. Body composition measurements are important in assessing nutritional status, and assessing the risk of developing diseases associated with abnormal body fat [17]. Physically active individuals, such as athletes, enjoy the important health benefits of normalizing body weight and maintaining a proper ratio of lean body mass to body fat [18,19]. Information on body fat and water content can provide some guidance when designing a diet, training program, and fluid intake [20]. The purpose of the present study was to evaluate the levels of selected indices of aerobic and anaerobic capacity and body tissue components in handball players at a high level of sports skills playing in different positions. An additional aim of the study was to compare the results with players of elite handball teams. Based on the available literature, it can be concluded that these players are characterized by a high level of aerobic and anaerobic capacity.

Materials and methods

The study included players who practice handball at the level of the Polish Super League. The team was the leading team in the above-mentioned league, where it held third place. The team participated in Cup competitions at the European level. It consisted of players from national teams from different countries. The average professional experience was 12.4 years. The study was conducted in December 2019 in the laboratory of the Verandki Center for Diagnostics and Physiotherapy of the Nałęczów Health Resort and the laboratory of the Center for Physical Culture of the Maria Curie-Skłodowska University in Lublin. According to the study schedule, the aerobic capacity test was performed first on day 1 and followed by an anaerobic capacity test four days later. The tests were carried out in the second part of the competitive period of the 2019/2020 season on 2 and 5 December 2019.

The characteristics of the participants are presented in Table 1.

Table 1. Characteristics of the study group

N=14	Age [years]	Body weight [kg]	Body height [cm]	BMI [kg/m^2]	FAT [%]	TBW [%]
x	**25.84**	**97.99**	**191.89**	**25.85**	**12.92**	**60.94**
SD	3.36	7.18	12.82	1.91	3.27	1.99
Min.	19	82.90	177	23.9	7.78	58.10
Max.	34	119.40	203	29.97	18.42	62.90

Notes:
BMI - body mass index; FAT% – body fat % ; TBW% - total body water %.

The study was conducted based on the following methods of assessing selected physiological parameters:

1. Body Composition Assessment

Body composition was assessed by the bioelectrical impedance method, using a body composition analyzer from Tanita SC 330, (Japan). Fat-free mass (FFM%) and body fat content (FAT%) were determined and BMI was calculated [21].

2. Assessment of aerobic capacity

Assessment of VO2max was performed based on the direct method - ergospirometric test CPET (Cardio-Pulmonary Exercise Test). A Cortex Metamax-3B ergospirometer was used as the test tool. The test was performed until exhaustion on a Woodway-Slat Flex System treadmill [22]. To assess the aerobic capacity of handball players, a laboratory exercise test with progressively increasing load was used, in which the participant performed a running effort on a moving treadmill, with the initial speed of 8 km/h increased by 2 km/h every 3 minutes. The participant's task was to maintain the preset running intensity at each exercise level until he or she refused to continue. The participants participated in a familiarization session, and, before starting the test, they participated in a 5-minute warm-up with a fixed, individually selected load. It was assumed that reaching VO_2max will be evidenced by the following criteria: reaching a plateau in VO_2 despite the increasing load, respiratory quotient RER $\geq$ 1.1, post-exercise maximum blood lactate concentration [La-] max > 8 mmol L-1, and reaching HRmax (for reaching HRmax, the criterion of HR $\pm$ 5 bpm from the estimated HRmax for a specific age group was adopted). The anaerobic threshold (AT) was determined in a non-invasive way, based on the analysis of changes in respiratory exchange rates in relation to exercise load. During the trial, the following were recorded: maximal running speed (MRS), current oxygen consumption (VO_2), ventilation value (VE), and heart rate (HR) [23]. Based on the recorded values we determined maximal oxygen consumption (VO_2max), maximal oxygen consumption at anaerobic threshold (VO_2max at AT), percent oxygen consumption at anaerobic threshold relative to VO_2max (% VO_2 at AT), maximal running speed at anaerobic threshold (MRS at AT), maximum running speed at VO_2max (MRS at VO_2max), percentage of maximum running speed at anaerobic transition threshold relative to maximum speed at VO_2max (% MRS VO_2max at AT), and the value of maximum heart rate level of VO_2max (HR VO_2max).

3. Anaerobic capacity assessment

For a comprehensive assessment of anaerobic potential, one of the exercise tests was used in the form of six repeated bouts of exercise lasting 10 (s) each, separated by passive intervals of 30 (s) [24]. The test was performed after a 5-minute warm-up on a cycle ergometer followed by a 5-minute rest. A Monark 824 E cycle ergometer (Sweden), connected to an IBM PC Pentium computer, with the computer program MCE_v_5.1 [25] was used for the test. RPM sensors were attached to the flywheel. During one rotation of the pedals, the flywheel made 3.70 rotations, which corresponded to a distance of 6m. The exercisers performed the test in the sitting position, starting the test from a stationary position. The test used an individual load of 0.075 of the tested body's mass. Using the MCE_v_5.1. program, the following measurements and calculations were made: peak power (W/kg), average power (W/kg), time to attain peak power (s), and time of maintaining power (s) [25,26].

4. Statistical analysis of the results

The results were processed statistically using descriptive statistics, and arithmetic means (x), standard deviations (SD), and minimum (min) and maximum (max) values and percentages were calculated. All calculations were performed using SPSS v. 22 software [27,28].

Results

Table 2. Mean values, standard deviations, and maximum and minimum values of aerobic capacity parameters of the tested athletes.

N=14	VO_2max [ml/kg/min]	VO_2 at AT [ml/kg/min]	%VO_2max at AT [%]	MRS at AT [km/h]	MRS at VO_2max [km/h]	% MRS VO_2max at AT [%]	HR VO_2max [bpm]
x	**65.5**	**53.1**	**82.1**	**13.2**	**15.5**	**85.3**	**180.6**
SD	9.8	5.8	9.9	1.7	1.6	4.7	7.6
Max.	84	60	100	16,3	17,9	92	197
Min.	48	42	69	10,7	13,4	77	171

Notes:

VO_2max – maximal oxygen consumption; VO_2max at AT – maximal oxygen consumption at anaerobic threshold; % VO_2 at AT – percent oxygen consumption at anaerobic threshold relative to VO_2max; MRS at AT – maximal running speed at anaerobic threshold; MRS at VO_2max. – the maximum running speed at VO_2max; % MRS VO_2max at AT – the percentage of maximum running speed at anaerobic transition threshold relative to the maximum speed at VO_2max; HR VO_2max – the value of maximum heart rate level of VO_2max.

Table 2 shows the values of selected parameters of the aerobic capacity of the participants. The average value of maximum oxygen consumption VO_2max of the handball players was 65.5 ml/kg/min. Oxygen consumption at the threshold of anaerobic metabolism (AT) was at 53.1 ml/kg/min, which was 82.1% relative to maximal oxygen uptake. The maximum running speed at the AT threshold (MRS on AT) was 13.2 km/h, while at VO_2max, it reached an average of 15.5 km/h. The percentage of MRS at AT relative to MRS at VO_2max was 85.3%. The heart rate (HR) value at VO_2max was 180.6 beats per minute.

Table 3. Mean values and standard deviations of aerobic capacity parameters of the players playing in different positions

	Position in the game	Body weight [kg]	Body height [cm]	VO_2max [ml/kg/min]	%VO_2max at AT [%]	MRS at AT [km/h]	MRS at VO_2max [km/h]	HR VO_2max [bpm]
x	Goalkeepers	**96.5**	**198.5**	**64.0**	**83.5**	**13.4**	**15.5**	**173.5**
SD	N=2	0.71	2.12	1.41	14.85	1.34	1.20	3.54
x	Playmakers	**100**	**195**	**68.5**	**79.5**	**13.3**	**15.6**	**182**
SD	N=6	11.9	5.2	7.8	5.4	1.7	11.6	7.9
x	Wingers	**91**	**187.5**	**67.3**	**81.3**	**14.3**	**16.1**	**182.8**
SD	N=4	7.8	5.8	14.5	13.5	1.7	1.9	9.6
x	Pivot	**119**	**198**	**54.5**	**90.5**	**11.00**	**13.8**	**179.5**
SD	N=2	1.4	2.8	9.2	13.4	0.3	0.1	3.7

VO_2max – maximal oxygen consumption; % VO_2 at AT – percent oxygen consumption at anaerobic threshold relative to VO_2max; MRS at AT – maximal running speed at anaerobic threshold; MRS at VO_2max – maximum running speed at VO_2max; HR VO_2max – the value of maximum heart rate at VO_2max.

Table 3 shows the mean values and standard deviations of selected parameters of aerobic capacity of players playing in different positions. The highest value of the index of VO_2ma. was obtained by playmakers (68.5 ml/kg/min), while the lowest value was obtained by pivot players (54.5 ml/kg/min). The highest percentage of VO_2max at the threshold of anaerobic metabolism was obtained by players in the position of a pivot (90.5%), while the lowest - by playmakers (79.5%). The highest work expressed as the maximum running speed at the threshold of anaerobic metabolism (MRS at AT), was found in players in the wingman position (14.3 km/h), while the lowest value was obtained by pivot players (11.0 km/h). Similar proportions of the value of work performed were observed in these players when achieving VO_2max. The highest value of maximum heart rate in the HR max test was obtained by the wingmen (182.8 bpm).

Table 4. Mean values and standard deviations of selected indices of anaerobic capacity of the athletes obtained in the 6x10 s test with an interval of 30 s on a cycle ergometer.

N=14	Effort 1	Effort 2	Effort 3	Effort 4	Effort 5	Effort 6
			P peak [W/kg]			
x	**10.4**	**10.1**	**9.4**	**8.8**	**8.5**	**8.6**
SD	0.8	0.7	0.5	0.7	0.8	0.7
			P avg [W/kg]			
x	**9.1**	**8.5**	**8.0**	**7.6**	**7.2**	**7.1**
SD	0.7	0.9	0.5	0.5	0.6	0.5
			Ta P peak [s]			
x	**5.0**	**4.0**	**3.9**	**4.1**	**3.8**	**3.9**
SD	0.9	0.7	0.6	1.0	0.7	0.1
			Tm P [s]			
x	**1.9**	**1.5**	**1.0**	**1.0**	**0.9**	**0.7**
SD	0.7	0.6	0.4	0.6	0.5	0.6

P peak – peak power; P avg – average power; Ta P peak – time to attain power peak; Tm P – time of maintaining power.

To analyse the mean values of the anaerobic capacity parameters, it is necessary to relate them to the norms developed by Norkowski [24]. The value of maximum and average power is at the very weak level in each of the six series. The time to attain power peak in the range of 3.7-4.0 s is a good result. In contrast, the time of maintaining power in each series is poor.

Table 5. Mean values and standard deviations of the maximum power of the tested players playing in different positions, obtained in the 6x10 s test; with an interval of 30 s on the cycle ergometer.

N=14	Effort 1	Effort 2	Effort 3	Effort 4	Effort 5	Effort 6
		P. peak [W/kg]		Goalkeepers N=2		
x	**9. 7**	**9.6**	**8.9**	**8.3**	**8.0**	**7.8**
SD	0.7	0.6	0.3	0.1	0.1	0.2
		P. peak [W/kg]		Playmakers N=6		
x	**10.4**	**10.1**	**9.4**	**9.1**	**8.7**	**8.5**
SD	0.7	0.6	0.4	0.6	0.6	0.6
		P. peak [W/kg]		Wingmans N=4		
x	**11.1**	**10.6**	**9.7**	**8.8**	**8.2**	**8.2**
SD	0.7	0.6	0.5	0.9	1.1	0.8
		P. peak [W/kg]		Pivot players N=2		
x	**10.0**	**9.6**	**9.1**	**8.5**	**8.2**	**8.1**
SD	0.3	0.01	0.1	0.1	0.1	0.1

P peak – peak power

Table 5 illustrates the average values of maximum power obtained by the tested players playing in different positions. The data show that the highest value of anaerobic power was achieved by players in the positions of winger in the range of 11.1 - 8.2 W/kg and playmakers in the range of 10.4 - 8.5W/kg. The lowest values of maximum power were achieved by: goalkeepers and pivots. When considering the ranges of power loss between the first and sixth efforts, it was found that with low values of this indicator in all participants, the greatest differences occurred in wingers 26.5 %. In players playing in other positions, the decrease in peak power ranged from 21 to 24%. A large difference between the power in the first and sixth series indicates a low ability for repeated anaerobic efforts.

Discussion

Based on the assumption that any attempt at a comprehensive physiological characterization of handball players will not be reliable without a detailed analysis of aerobic and anaerobic capacity indices, it was deemed necessary to compare the results of the present study with studies by other authors dealing with this issue.

Relating the mean VO_2max level in the group studied (65.5 ml/kg/min) to the data quoted in the available literature [29-32], it was found to be higher than that of the representatives of France (58.7 ml/kg/min), Tunisia (52.8 ml/kg/min), Croatia (53.2 ml/kg/min), and U-21 players from Serbia (40.0 ml/kg/min). However, the results documented by the above authors, except for those obtained for the Croatian representatives, did not include information about the speeds reached by each group at the threshold of anaerobic metabolism, which reduces the cognitive and diagnostic value of the study presented.

The comparison of VO_2max values in the context of the nominal playing positions of the participants and Croatian players playing in analogous positions showed significant differences in favour of the players studied in this study, i.e. 64.0 vs. 53.4 ml/kg/min (difference of +16.6%) for goalkeepers, 68.5 vs. 53.7 (+21.6%) for playmakers, 67.3 vs. 56.0 (+16.7%) for wingers, and 54.5 vs. 50.8 (+6.8%) for pivots.

In the analysis of an important aspect of aerobic capacity, i.e. running speed at successive metabolic thresholds, it was found that the participants were characterized by a high level of VO_2max, 65.5 ml/kg/min but their maximum running speeds were 13.2 km/h (3.7 m/s) at the threshold of anaerobic metabolism (MRS at AT) and 15.5 km/h (4.3 m/s) at the level of obtaining VO_2 max, which should be regarded as low values when compared with the data reported by Ronikier [33]. The above values indicate that the participants have a low level of running performance both at the threshold of anaerobic metabolism (MRS at AT) and at the level of VO_2max. The percentage of MRS AT at the anaerobic threshold (AT) relative to MRS at VO_2max showed a mean value of 85.3%. which means that the participant reached the anaerobic threshold (AT) at a relatively low level of workload. Based on the above analyses, it can be concluded that the participants did not meet the criteria for high levels of athletic performance in terms of aerobic and anaerobic capacity. The thesis of the low level of performance in the study group is consistent with the results presented in a study by other authors [29], who found that Croatian representatives obtained an average running speed at the threshold of anaerobic metabolism MRS at AT of 16.6 km/h (4.6 m/s) with a lower value of VO_2max. 54 ml/kg/min. A comparison of the average values of running speed at the anaerobic transition threshold (MRS at AT) of both groups showed clear differences in favour of the elite Croatian players, i.e. 15.6 km/h vs. 13.4 km/h, (difference of +14.4%) for goalkeepers, 17.5 vs. 13.3 (+24.17%) for playmakers, 16.7 vs. 14.3 (+14.5%) for wingers, and 16.5 vs. 11.0 (+33.3%) for pivot players. The above data, when juxtaposed with the average values of heart rate at VO_2max, with Croatian athletes reaching an average of 191.2 bpm and those studied in the present paper (180.6 bpm) indicate that the elite Croatian athletes in this sport are characterized by a high level of athletic performance, which is reflected in significantly higher aerobic power.

Evaluation of the anaerobic capacity of the handball players in the context of the energy requirements of the game [13,15,34] and against the background of the norms developed by Norkowski [24] reveals that the level of this trait is insufficient, as evidenced by the fact that the average values of maximum power developed in the anaerobic capacity test on a cycle ergometer were at a poor and very poor level. The low level of anaerobic capacity in handball players was also confirmed by the results of Rannou, Prioux, and Zouhal [32] on athletes in particular playing positions, who found that maximum power values were lower than those in sprinters and higher than in endurance athletes. When considering the results obtained in relation to the nominal playing positions, it should be noted that the power values were higher in field players than in goalkeepers [29,35], which was confirmed by the present study. In conclusion, it should be stated that the handball players in this study, with a high level of VO_2max, were not adapted to performing anaerobic efforts. They were characterized by a lack of tolerance to performance under conditions of increasing oxygen debt, which was manifested by rapidly increasing fatigue during short, 10-second repeated efforts of maximum intensity performed with incomplete rest breaks, which are characteristic of match loads. In light of the knowledge of exercise physiology, there is no doubt that a high tolerance to match effort characterized by a predominance of anaerobic loads is always better in athletes with a high VO_2max. and a high running speed at the anaerobic threshold. Therefore, constant monitoring of aerobic and anaerobic fitness levels is recommended. The available studies show that a reduction of these indices below a value of 54 ml/kg/min for aerobic capacity and below 10.8 W/kg for anaerobic capacity creates significant limitations for specialised training and effective participation of the handball player [36,23]. Researchers dealing with handball also indicate that a reliable assessment of players' morphological and fitness predispositions in terms of playing in particular positions can be of great importance in recruitment and selection for the sport [30]. An additional aspect of the study presented in this paper is the mean values of body composition components indicating that FAT%, TBW%, and BMI were similar in the respondents and the listed national teams [31]. While looking for the causes of the low level of aerobic and anaerobic capacity in the analysed group of handball players in the light of available studies on methods, training effects, and different aspects of physical endurance [11,22,37,38], it is possible to formulate a thesis that the exercise stimuli used in the training of the analysed group were characterised by too low intensity, which made them inadequate for energy requirements of the competitive effort and did not stimulate improvement in the athletic performance of the participants. The tested players were characterized by a lower level of performance parameters compared to the players of elite handball teams.

Conclusions

1. The capacity for maximal oxygen uptake as determined by the VO_2max value of the tested athletes was at a high level.
2. The tested athletes were characterized by low running speed both at the threshold of anaerobic metabolism and at the level of VO_2 max.
3. The anaerobic capacity indices of the tested athletes against the norms for handball players were at a low level.
4. The body tissue components resulting from the compositional analysis were within the reference range of results and similar to those obtained by players from the national teams of other countries.
5. There are differences in the physical and physiological characteristics of players who play in different positions.

Conflicts of Interest: The authors declare that they have no conflict of interest.

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Institutional Review Board Statement: All procedures were carried out in accordance with the 1964 Declaration of Helsinki and its subsequent amendments.

Informed consent statement: The participants and their legal guardians were informed about the research protocol in detail and gave their written informed consent to participate in the study.

Data availability statement: The data presented in this study are available on request from the corresponding author.

References:

[1] Buchheit M. Repeated-sprint performance in team sport players: associations with measures of aerobic fitness, metabolic control and locomotor function. Int. J. Sports Med. 2012;33:230-239.
[2] Gibala MJ, Little JP, Van Essen M, Wilkin GP, Burgomaster KA, Safdar A, et al: Short-term sprint interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance. J. Physiol. 2006;575: 901-911.
[3] Czerwiński J. Handball selected elements of theory and training. ZPRP. 2018:82-88.
[4] Villa H, Manchado C, Rodriguez N, Abraldes JA, Alcaraz PE, Ferragut C. Anthropometric profile, vertical jump, and throwing velocity in elite handball players by playing positions. J. Strength Cond. Res. 2012;26:2146-2155.
[5] Chmura J. Bioenergetics of a football player's effort during a match. Performance Sport No. 10, 1997.
[6] Bishop D, Spencer M. Determinants of repeated-sprint ability in well-trained team-sport athletes and endurance-trained athletes. J. Sports Med. Phys. Fitness. 2004;44:1-7.
[7] Bishop D, Girard O, Mendez-Villanueva A. Repeated-sprint ability - part II. Recommendation for training. Sports Med. 2011;41:741-756.
[8] Terjung R.L, Koerner J,E. Biochemical adaptations in skeletal muscle of trained thyroidectomized rats. Am. J. Physiol. 1976;230:1194 -1197.
[9] Jaskólski A, Jaskólska A. Ways of assessing exercise capacity. Studia i Monografie AWF we Wrocławiu, 2005;75:199-228.
[10] Christmass MA, Dawson B, Arthur PG. Effect of work and recovery duration on skeletal muscle oxygenation and fuel use during sustained intermittent exercise. Eur J Appl Physiol Occup Physiol. 1999; 80(5):436-47.
[11] Norkowski H, Buśko K. Changes in power output under the influence of sprint training in handball players. Acta Bioengin. Biomech. 2004;6: 89-99.
[12] Czerwiński J. Method of evaluation of players' adaptation to training tasks in handball. Gdańsk; 1982. p. 18.
[13] Czerwiński J. Characteristics of the handball game. Gdańsk; 1996.
[14] Norkowski H. Proposed evaluation of selected features of the anaerobic potential of Polish handball players. Trening nr 1. 2001;(49):87-93.

[15] Norkowski H. Anaerobic capacity of handball players depending on nominal positions in the field. Physical Education and Sport. 2001;3:383-388.
[16] Chaouachi A, Bughelli M, Levin G, Baudhina NBB, Cronin J. Anthropometric physiological and performance characteristics of elite team-handball players. Journal of sport sciences. 2009; 27(2):151-157.
[17] Kęska A, Tkaczyk J, Czajkowska A, Wiśniewski A, Norkowski H, Smolarczyk M, et al: Adipose tissue content of young adults assessed by skinfold measurements and body composition analyser indications. Pediatric Endocrinology, Diabetes and Metabolism. 2012;18(1):33-36.
[18] Biela U, Pająk A, Kaczmarczyk-Chałas K, Głuszek J, Tendera M, Waśkiewicz A, et al: Prevalence of overweight and obesity in women and men aged 20-74 years. Results of the WOBASZ programme. Kardiol Pol. 2005;63(6;4):1-4.
[19] Chernichov S, Kengne AP, Huxley RR, Batty GD, de Galan B, Grobbee D,et al: Comparison of waist-to-hip ratio and other obesity indices as predictors of cardiovascular disease risk in people with type-2 diabetes: a prospective cohort study from ADVANCE. Eur J Cardiovasc Prev Rehabil. 2011;18(2):312-9.
[20] Grandjean PW, Oden GL, Crouse SF, Brown JA, Green JS. Lipid and lipoprotein changes in women following 6 months of exercise training in a work-site fitness program. J Sports Med Phys Fitness. 1996;36(1):54-59.
[21] Kamińska O, Szymańska-Parkieta K. Structure and functions of adipose tissue and methods of its determination. Katowice; 1995. (Zeszyty metodyczne nr 7).
[22] Straburzyńska-Migaj E. Ergospirometric tests in clinical practice. Warsaw; 2010.
[23] Wrześniewski S. Struktura obciążeń treningowych w rocznym cyklu szkolenia a wydolność fizyczna i efektywność gry piłkarzy ręcznych [Doctoral dissertation at AWF Warsaw]. Warsaw; 2009.
[24] Norkowski H, Noszczak J. Handball, collection of tests. Wyd. Związek Piłki Ręcznej w Polsce. 2012. s. 45-55.
[25] Staniak Z. Informatyczna system do wspomagania wydolnościowych testów prowadzone na cykloergometrach. Trening. 1994;1(21):3-8.
[26] Zdanowicz R, Wojcieszak I, Wojczuk J. Cykloergometric test of anaerobic capacity, In: Wydolnościowe testy specjalnego--wdrożenia, Instytut Sportu Warszawa. 1985;5-24.
[27] Stupnicki R. Biometrics-short outline. Wyd. MARGOS. Warsaw, 2000.
[28] Stupnicki R. Podstawy biostatystyki (Principles of Biostatistics). Wyd. AWF Warszawa. Warsaw, 2015.
[29] Sporiś G, Vuleta Jr, Milanović D: Fitness profiling in handball physical and physiological characteristics of elite players. Collegium anthropologicum. 2010; 34, (3): 1009-1014.
[30] Chaouachi A, Bughelli M, Levin G, Baudhina NBB, Cronin J: Anthropometric physiological and performance characteristics of elite team-handball players. Journal of sport sciences. 2009; 27(2): 151-157.
[31] Ilic V, Ranisavljev I, Stefanovic D, et all. Impact of Body Composition and Vo2 Max on the Competitive Success in Top-Level Handball Players. Coll. Anthropol. 39 (2015) 3: 535-540.
[32] Rannou F, Prioux J, Zouhal H, Gratas-Delamarche A, Delamarche P: Physiological profile of handball players. J Sports Med Phys Fitness. 2001; Sep;41(3):349-53.
[33] Ronikier A. Exercise physiology in sport, physiotherapy and recreation. Biblioteka trenera. Warsaw; 2008. p. 101
[34] Norkowski H., Śledziewski D, Perkowski K. Kuder A. The structure of effort intensity of handball players at different playing positions during game. Rocznik Naukowe Wyższej Szkoły Wychowania Fizycznego i Turystyki w Białymstoku. 2014;10:108-112.
[35] Michalsik LB, Madsen K, Aagaard P: Physiological capacity and physical testing in male elite team handball. J Sports Med Phys Fitness. 2015; May;55(5):415-29
[36] Czerwiński J, Jastrzębski as last Z. The training process in team sports games. Uczelniane Wydawnictwo AWFiS Gdańsk; 2006.
[37] Norkowski H. Anaerobic power of handball players representing various sport levels." Journal of Human Kinetics. 2002;7:43-50.
[38] Norkowski H. Exercise load structure and the effects of intermittent training of maximum ntensity. Studia i Monografie AWF Warszawa; 2003.

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TECHNICAL AND TACTICAL PERFORMANCE OF JUDO ATHLETES OF THE TOP NATIONAL TEAMS

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

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Keywords: judo, national teams, technical and tactical performance

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Abstract:

Background: The analysis of technical and tactical training is of particular importance in sports where it is crucial to the development of the athletes' level of performance. Particularly valuable seem to be the observations aimed at determining the way the world's best athletes fight. The purpose of this study is to present a comparative analysis of the technical and tactical training of elite fighters of Japan, Georgia, and France and to determine whether the use of taxonomy methods (cluster analysis) confirms the presence of profiles of technical and tactical performance characteristic of the top national teams.

Methods: The research material was an audio and video recording of IJF World Tour tournaments covering a two-year cycle (2017-2018) of senior competitions. In the first stage, we identified 15 athletes from each national team who fought the most during the analyzed period. Their competitive activity was then analyzed. It included 369 fights by fighters from Japan, 257 from France, and 467 from Georgia. The evaluation of the technical and tactical performance of individual athletes took into account their activity (the sum of effective attacks, ineffective attacks, and provoked penalties/number of bouts), the effectiveness of their actions (the arithmetic mean of the effective and ineffective attacks), the number of different techniques, the number of different effective techniques, the number of directions of attacks, and the number of directions of effective attacks.

Results: Statistically significant differences were found in the index of activity in the second part of the fight (the highest activity occurred in Japanese athletes) and the number of different effective techniques (the highest number was found in fighters from Georgia). The cluster analysis did not confirm the technical and tactical performance specific to the national teams studied.

Conclusion: The analysis of the indices evaluated in the present study failed to confirm specific technical and tactical performance characteristics of national teams. The range of variation in the indices analyzed in the study should be a starting point in planning the long-term training of young athletes.

Introduction

The difference between martial arts and combat sports lies primarily in the value systems related to these manifestations of physical activity. The overriding value associated with martial arts is the participation in improving the body and mind (this can continue into old age). In modern professional training systems, the main task of training is to ensure a high level of sports performance. Its culmination is expected to be participation and winning in the Olympic Games.

Judo training focuses mainly on the physical preparation and technical and tactical skills of athletes. The starting point in its planning should be the identification of the model values expected at different stages and training periods.

Therefore, studies aim to evaluate aerobic and anaerobic fitness levels [1-3] and muscle strength [4,5] in judo players of different ages and sports skill levels.

Analyses of technical and tactical performance mainly concern the techniques used [6-9] and player activity and performance [10-12].

In the training of international-level players, it is essential to obtain information on how their potential opponents fight.

Individual characteristics should be used in the strategy of preparation for bouts. Group characteristics, taking sports skill level into account, are used to plan long-term training.

The purpose of this study is to present a comparative analysis of the technical and tactical performance of elite athletes from Japan, Georgia, and France, and to determine whether the use of taxonomy methods (cluster analysis) confirms the presence of profiles of this performance characteristic of the top national teams.

Materials and methods

The research material was an audio and video recording of IJF World Tour tournaments covering a cycle of senior competitions. Recordings of the bouts can be found in a collection of multimedia files at www.judobase.ijf.org and www.dartfish.tv.

The bout records analyzed in the present study were obtained from 28 tournaments held at the 2017 and 2018 World Championships and Grand Slam and Grand Prix events organized by the IJF in 2017-2018. In the first stage, we identified 15 athletes from each national team who participated in most of the bouts in the period of competition studied.

Their competitive activity was then analyzed based on 1093 videos, with 730 technical actions recorded (456 of which were successful).

The following indices were calculated for each player:
activity in the first part of the bout (WA1), activity in the second part of the bout and the extra time (WA2), effectiveness in the first part of the bout (WS1), and effectiveness in the second part of the bout and extra time (WS2). Furthermore, the number of different techniques, the number of different effective techniques, the number of directions of attacks, and the number of directions of effective attacks performed by the athlete were taken into account.

During the analysis of the individual tournament bouts we recorded the techniques used by the athletes using *Microsoft Excel*. The database was copied into *STATISTICA PL*, where most of the analyses were performed.

The first stage involved verification of the reliability of the observations. The intraobserver correlation coefficient (high-level judo coaches) was 0.997; 95% for WA (CI: 0.991-0.999) and 0.9579 for WS (CI: 0.852-0.9884). The intraclass ICC correlation coefficient for the same observer was 0.998 for WA (CI: 0.993-0.999) and 0.989 for WS (CI: 0.961-0.997). The standard error of measurement (SEM) for the same observer for WA and WS was 1.5% and 1.9%, respectively. The above results indicate a high reliability of observations.

The activity index was used in the activity assessment, calculated from the following formula:

$$\text{Activity index (WA)} = \frac{\Sigma A}{NW}$$

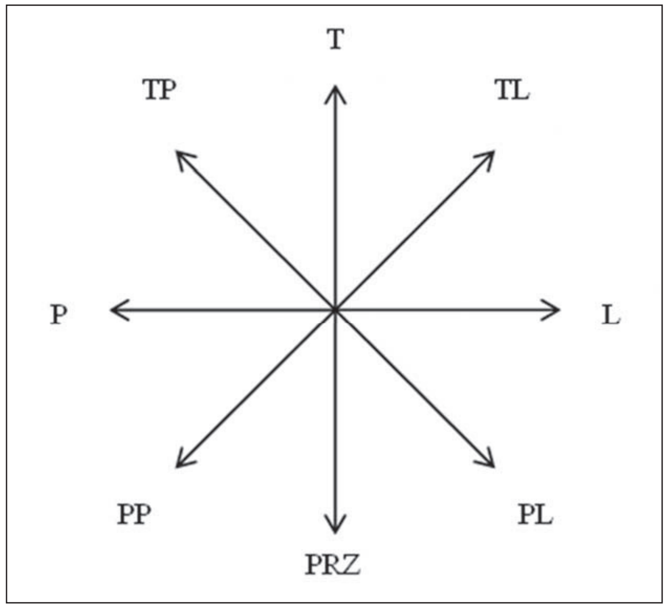
where:
ΣA – the sum of activity: effective attacks, ineffective attacks, and provoked penalties for the opponent. An attack was classified as ineffective if there was an apparent loss of balance and a fall and the judges did not award points for this action.
NW – the number of bouts fought by each athlete.
The effectiveness index is the arithmetic mean ($\bar{x}$) of the referee assessment of the technical actions recorded. It is expressed by the following formula:

$$\text{Effectiveness index (WS)} = \frac{\textit{sum of points obtained}}{\textit{number of technical actions performed (effective and ineffective)}}$$

The opportunity of using throws in eight directions was taken into account: backward, backward-left, left, forward-left, forward-right, right, and backward-right (Figure 1).

The analysis of variance was based on the F-test or Kruskal-Wallis H-test, depending on the distribution and homogeneity of variance. The Tukey's RIR test and Mann-Whitney U-test were used to test differences between group means. The Mann-Whitney U-test included the Bonferroni correction, which involves dividing the significance level of p=0.05 by the number of comparisons [13]. The Shapiro-Wilk W-test was employed to examine the normality of distributions. The homogeneity of variance was verified using the Levene's test [14].

The k-means method was used to identify athletes with a similar profile of technical and tactical performance indices. It belongs to the methods of ordering and classification of objects (taxonomy). The method allows the creation of k clusters that differ from each other as much as possible. For calculation, this method can be approached as the inverse of the analysis of variance [15]. In the present study, statistical analysis was carried out for k=3.



The symbols denote:

T – backward; TL – backward left; L – left; PL – forward left; PRZ – forward; PP – forward right; P – right; TP – forward right

Figure 1. Possible throwing directions in judo

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Bioethics Committee at the Regional Medical Chamber of Krakow (No. 42/KBL/OIL/2015 of 15 April 2015).

Results

Differences between technical and tactical performance indices

Table 1 illustrates the characteristics of the analyzed indices of technical and tactical performance in the national teams. Statistically significant differences were found for WA2 and NRTS.

Table 1. Mean values of indices of technical and tactical performance in the national teams

	Japan			Georgia			France			Test value	p
Variable	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max		
WA1	1.69	0.48	2.56	1.39	0.33	2.11	1.44	1.06	2.29	H=3.8	0.1457
WA2	2.5	0.8	3.47	1.84	0.21	2.92	2.08	1.4	3	F=4.2	0.0214
WS1	2.49	1.05	4.38	3.08	1.62	5.17	2.47	0.78	3.78	F=2.1	0.1425
WS2	2.84	1.63	5.07	3.57	1.41	4.95	3.06	1.13	4.5	F=2.3	0.1086
NRT	14.93	9	19	19.4	9	34	14.33	10	26	H=5.9	0.0528
NRTS	9.33	4	12	13	4	25	8.07	3	19	H=9.1	0.0107
NKA	4.93	4	7	4.53	3	7	4.73	4	6	H=1.0	0.6043
NKAS	3.6	2	5	3.6	2	4	3.73	2	5	H=0.3	0.8710

Based on multiple comparisons of mean WA2 values it was found that a homogeneous group was formed by the values of the index in athletes from Japan and France, and from Georgia and France. A comparison of means revealed the highest values in Japanese players, which differed significantly from the mean in athletes from Georgia, where it was the lowest (Table 2).

Table 2. Significance levels of the Tukey RIR test calculated between the teams studied; variable: WA2

		(1)	(2)	(3)
JPN	(1)		0.167591	0.017529
FRA	(2)	0.167591		0.568236
GEO	(3)	0.017529	0.568236	

Based on multiple comparisons of mean NRTS (Table 3), two homogeneous groups were formed by the values of the variable in the groups of athletes from Japan and France, and from Japan and Georgia. Comparison of the means revealed the highest values of the variable in athletes from Georgia, and they differed significantly from those recorded in players from France.

Table 3. Mann-Whitney U-test values and significance levels calculated between the teams studied; variable: NRTS

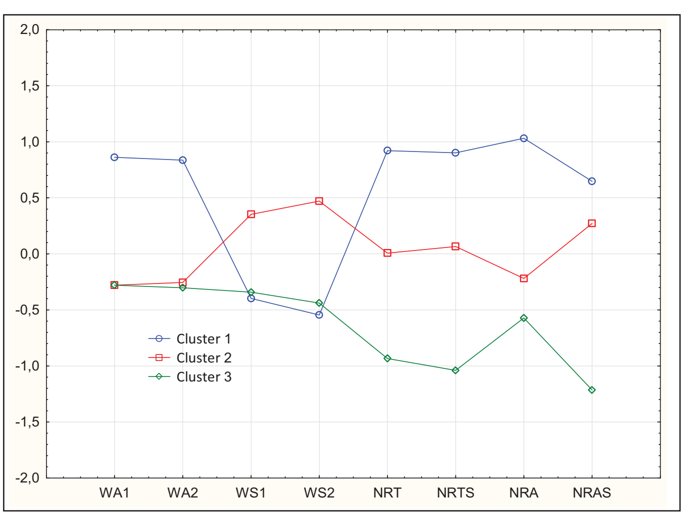
	Test value	p
JPN-FRA	1.845774	0.064926
JPN-GEO	-1.82503	0.067997
FRA-GEO	-2.59238	0.009532

Cluster analysis

All indicators except WS1 played a significant role in the process of grouping the athletes. Figure 2 illustrates the standardized means for each cluster. Based on this procedure, 11 athletes qualified for the first cluster, 23 for the second, and 11 for the third (Table 4). The first cluster included 5 athletes from Japan, 1 from France, and 5 from Georgia. In the second cluster, there were 8 athletes from Japan, 8 from France, and 7 from Georgia. The third cluster included 2 athletes from Japan, 6 from France, and 3 from Georgia.

Table 4. Number of athletes from the teams studied in each cluster

Cluster No	JPN	FRA	GEO	Total
1	5	1	5	11
2	8	8	7	23
3	2	6	3	11
Total	15	15	15	45



WA1 – activity during the first part of the bout
WA2 – activity during the second part of the bout
WA1 – effectiveness during the first part of the bout
WA2 – effectiveness during the second part of the bout
NRT – number of different techniques
NRTS – number of different effective techniques
NKA – number of directions of attacks
NKAS – number of directions of effective attacks

Figure 2. Standardised means of each cluster

Discussion

A comparison of the activeness of the athletes showed an increase in its levels in each national team in the second part of the bout, but the largest increase was found for the Japanese team members. Statistically significant differences were recorded only in the second part of the bout, with the lowest values recorded for athletes from Georgia.

No statistically significant differences were found for effectiveness. However, higher values of this index were observed in the Georgian team members. Therefore, it can be expected that with significantly lower activeness, there is a tendency for them to use scored attacks (which have a direct impact on the result of the bout) more often.

Interestingly, also in the case of this index, its higher values in the teams studied were recorded in the second part of the bout.

From a tactical point of view, the more techniques a fighter has mastered, the greater number of different situations in a fight he or she can resolve to their advantage. This finding is supported by research in the field of this sport [16]).

Elite athletes from the national Poland team performed between 19 and 26 different effective techniques [17]. In characterizing their technical performance, the author found that these athletes used 3 basic techniques, five to six auxiliary techniques, combined with the basic ones to support the activity, six to seven situational techniques, and five to eleven techniques which were described as occasional or random techniques. A large number of techniques (20 and 22, respectively) were also successfully performed during bouts by top Polish female athletes [18,19].

The results of our research indicate that the athletes have mastered from 9 to 34 different techniques at a level that allowed them to be used in the bout. A comparison of the mean revealed the highest values in the athletes from Georgia [4,19] and lower in those from France and Japan (14.33 and 14.93, respectively). However, these differences were not statistically significant.

In the case of the number of different effective techniques, the highest values of the variable were found in athletes from Georgia [13] and they differed significantly from those recorded in players from France [3], which were the lowest.

In the above mentioned study [16], the author showed that, in addition to the number of different techniques, the number of directions of attack is also related to the place won at international championships. The winners of these events can use attacks in more directions than competitors with lower levels of achievement. According to Sikorski [20], when considering the tactics of a bout in terms of the technical performance of an athlete, he or she should be prepared to attack the opponent in four basic directions, i.e. right forward right back, left forward, and left back. From a theoretical point of view, an athlete with this range of techniques is able to win with any opponent. The technical and tactical performance of a two-time Olympic champion from the national Poland team who executed effective attacks in all main directions can be considered exemplary [21].

In this study, in addition to the basic directions [20], intermediate directions (front, back, right, and left) are also included. It was noted that players made attacks in between four and seven different directions. The mean values of this index in athletes from Japan, Georgia, and France were 4.9, 4.5, and 4.7, respectively, and were not statistically significantly different.

For the number of directions of effective attacks, the minimum value was found to be 2 and the maximum value was 4. The mean values of this index in athletes from Japan, Georgia, and France were 3.6, 3.6, and 3.7, respectively, and were also not statistically significantly different.

The k-means method has already been used to search for characteristic fitness profiles of judo players of different ages [22].

In the present study, the method was applied to see if there were technical and tactical performance profiles specific to the teams studied. The distributions of players in the individual clusters do not support the conclusion that there is no technical and tactical performance profile typical of a team. Cluster 3 was dominated by players from France, but there was no specific technical and tactical performance profile for this national team since most of its members (8 players) were assigned to Cluster 2.

A weakness of the k-means method is that it is based on quantitative indices only. The analysis therefore did not take into account the type of techniques used by the athletes or the gripping methods used. Perhaps, with more variables taken into account, its application would lead to forming groups with the dominance of athletes from each national team. This may also be supported by the fact that a greater number of differences and correlations were observed for the comparison of all the fights of the athletes of the national teams included in the study [23].

Conclusion

The analysis of the indices evaluated in the present study failed to confirm specific technical and tactical performance characteristics of national teams. The range of variation in the indices analyzed in the study should be a starting point in planning the long-term training of young athletes.

Conflicts of Interest: The authors declare that they have no conflict of interest.

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Institutional Review Board Statement: All procedures were carried out in accordance with the 1964 Declaration of Helsinki and its subsequent amendments.

Informed consent statement: The participants and their legal guardians were informed about the research protocol in detail and gave their written informed consent to participate in the study.

Data availability statement: The data presented in this study are available on request from the corresponding author.

References:

[1] Pałka T, Lech G, Tyka A, Tyka A, Sterkowicz-Przybycień K, Sterkowicz S et al. Differences in the level of anaerobic and aerobic components of physical capacity in judoists at different age. Arch. Budo 2013;9(3):195-203.
[2] Sbriccoli P, Bazzucchi I, Di Mario A, Marzattinocci G, Felici F. Assessment of maximal cardiorespiratory performance and muscle power in the Italian Olympic judoka. J Strength Cond Res. 2007 Aug;21(3):738-44. doi: 10.1519/R-20245.1. PMID: 17685696.
[3] Borkowsky J, Faff J, Starczewska-Czapowska J. Evaluation of the aerobic and anaerobic fitness in judoists from the Polish national team. Biol Sport 2001;18:107-11.s
[4] Franchini E, Nunes AV, Moraes JM, Del Vecchio FB. Physical fitness and anthropometrical profile of the Brazilian male judo team. J Physiol Anthropol. 2007 Mar;26(2):59-67. doi: 10.2114/jpa2.26.59. PMID: 17435345.
[5] Lech G, Chwała W, Ambroży T, Sterkowicz S. Muscle torque and its relation to technique, tactics, sports level and age group in judo contestants. J Hum Kinet. 2015 Apr 7;45:167-75. doi: 10.1515/hukin-2015-0017. PMID: 25964820; PMCID: PMC4415829.
[6] Witkowski K, Jarosław Maśliński J, Tomasz Kotwica T. Analysis of fighting actions of judo competitors on the basis of the men's tournament during the 2008 Olympic Games in Beijing. Journal of Combat Sports and Martial Arts, 2012;3:121-129. DOI:10.5604/20815735.1047659 Corpus ID: 56046429.
[7] Sterkowicz S, Sacripanti A, Sterkowicz-Przybycień K. Techniques frequently used during London Olympic judo tournaments: A biomechanical approach. Arch. Budo 2013; 9(1): 51-58.
[8] Boguszewski D. Technical fitness training of judokas – finalists of top world tournaments in the years 2005-2008. Journal of Combat Sports and Martial Arts. 2010;1:109-114.
[9] Miller GA, Collins NA, Stewart MJ, Challis DG. Throwing Technique and Efficiency in the 2013 British Judo Championships. International Journal of Performance Analysis in Sport. 2015;15(1):53-68, DOI: 10.1080/24748668.2015.11868776.
[10] Sterkowicz S, Lech G, Almansba R. The course of fight and the level of sports achievements in judo. Arch. Budo 2007;3:72-81.
[11] Boguszewski D, Boguszewska K. Dynamics of judo contests performed by finalists of European Championships (Rotterdam 2005). Arch. Budo 2006;2:40-44.
[12] Adam M, Tabakov S. Błach Ł, Smaruj M. Characteristics of the Technical-Tactical Preparation of Male and Female Judo Competitors Participating in the Olympic Games – London 2012. Ido Movement for Culture. Journal of Martial Arts Anthropology. 2013;13(2):75-88. DOI: 10.14589/ido.13.2.6.
[13] Wilcox R. New statistical procedures for the social sciences. Modern solutions to basic problem, Hillsdale, N.J.: L. Erlbaum Associates; 1987.
[14] Stanisz A. Przystępny kurs statystyki. Tom I. Kraków, StatSoft Polska; 1998.
[15] Stanisz A: Przystępny kurs statystyki. Tom III. Analizy wielowymiarowe: Kraków, StatSoft Polska; 2007.
[16] Franchini E, Sterkowicz S, Meira CM, Gomes FR, Tani G. Technical variation in a sample of high level judo players. Percept Mot Skills. 2008 Jun;106(3):859-69. doi: 10.2466/pms.106.3.859-869. PMID: 18712208.
[17] Adam M. *Effectiveness of Techniques Performed by Outstanding Judo Competitors.* Balt J Health Phys Act. 2007:13(2): 216-220.
[18] Adam M, Majdan J. A Profile of Joanna Majdan's Individual Technical-Tactical Preparation. Balt J Health Phys Act. 2011; 3(4): 269-276. doi: 10.2478/v10131-011-0026-0.

[19] Adam M. A Profile of Adriana Dadci's Individual Technical-Tactical Preparation. Balt J Health Phys Act. 2012; 4(1): 35-43.. doi: 10.2478/v10131-012-0005-0.
[20] Sikorski W. [Aktualne problemy treningu i walki sportowej w judo]. Warszawa, Prace i Materiały Instytutu Sportu; 1985. Polski.
[21] Adam M, Smaruj M, Laskowski R. (). A Technical and Tactical Profile of the Double Olympic Judo Champion: A Case Study. International Journal of Sports Science & Coaching. 2014;9(1):123–138. https://doi.org/10.1260/1747-9541.9.1.123.
[22] Lech G, Chwała W, Tyka A, Pałka T, Jaworski J, Pilch W at al. The use of k-means method for assessment of training and differences in motor abilities indices in judo contestants at different age. Arch Budo 2015;11:319-328.
[23] Szczepanik K, Lech G, Witkowski K, Jaworski J, Pałka T, Piepiora P. Differences in technical and tactical training of the world's leading national teams in judo tournaments in 2017-2018. Arch. Budo 2023;19:1-9.

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SELF-ASSESSMENT OF PHYSICAL ACTIVITY AND SELECTED ASPECTS OF NUTRITIONAL BEHAVIOUR AND HEALTH STATUS AMONG SENIOR WOMEN

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

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Keywords: physical activity, consumption of product groups, somatic indices, functional fitness, self-assessment of health

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Abstract:

Introduction: A healthy lifestyle is one of the key factors determining holistically defined health. The aim of the study is to assess the relationship between the declared level of PA and dietary choices, somatic characteristics, functional fitness, and self-assessment of women's health.

Methods: The study was conducted in a group of 181 women aged 60 to 85 years using the CHAMPS, KomPAN, and EuroQoL questionnaires as well as the Fullerton Functional Fitness Test and tools for assessing somatic features. The relationships between the variables were assessed using Spearman's R correlation.

Results: The highest percentage of women declared average (60.2%) levels of PA, less often low (24.3%) and high (15.5%) levels. A significant positive correlation was noted between the declared level of PA and energy expenditure needed for PA ($p<0.01$). Statistical analysis indicated that with the increase in the level of PA, the frequency of consuming certain product groups decreased, including white and red meat ($p<0.01$). Furthermore, some somatic characteristics decreased along with the increase in the level of PA, including BMI ($p<0.05$), body fat ($p<0.01$), thickness of subscapular skinfold ($p<0.05$), and that on the arm ($p<0.01$), and waist circumference ($p<0.01$). It was also shown that with the increase in the level of PA, some areas of functional fitness increased, including flexion of the loaded arm and forward bend in the seated position ($p<0.05$). Positive self-assessment of health also increased ($p=0.001$).

Conclusion: Higher levels of physical activity, positively correlated with energy expenditure, are partly associated with healthy food choices and selected positive indices of health in older women.

Introduction

A healthy lifestyle is a basic factor in improving health, holistically defined as the integration and balance of all dimensions constituting a human being, including those biological and psycho-social [1]. Physical activity with the characteristics of health training and a varied and balanced diet, rich in products with high nutritional density, and limiting products with high energy density (e.g. Mediterranean diet) are behaviours positively related to health. They contribute to improving health potential, reducing the incidence of chronic diseases and delaying involutionary changes, and lead to, among others, the optimisation of body mass and composition while increasing functional efficiency [2-7]. This is particularly important during older adulthood, because in this period of ontogeny, *inter alia*, changes in body composition as well as decreased functional fitness are observed, and they limit the safe and effective performance of activities of daily living while negatively affecting the quality of life and subjective assessment of health [8-10].

Studies conducted to date in the senior population have shown the prevalence of nutritional mistakes and a decrease in physical activity with age [11-15]. One form of activating seniors was the Healthy Active Senior programme implemented at the University of Physical Education in Kraków (Poland) between 2019 and 2022. Our previous research in this area found, among others, relationships between eating habits and women's quality of life [16], relationships of BMI with eating behaviours and functional fitness [17], and life satisfaction vs. eating behaviours, body composition, and functional fitness [18].

The authors of the study found it interesting to undertake research regarding the predictive role of declared physical activity on dietary choices and selected positive health indices. Therefore, research was carried out to analyse the relationship between self-assessment of physical activity level and the frequency of consuming selected product groups, somatic indices of nutritional status, functional fitness, and the subjective assessment of health among senior women.

Materials and methods

Participants

The research was conducted in a group of 181 women aged 60 to 85 years (66.3±5.4) at the stage of recruitment for the Healthy Active Senior programme, implemented at the University of Physical Education in Kraków between 2019 and 2022. The group was dominated by women with higher (57%) and secondary education (37%), living in Kraków (89%). The characteristics of the programme have already been presented in previous research [16-18].

Instruments

The following research tools were used in the study:

1) Physical Activity Questionnaire for Older Adults CHAMPS [19] in the Polish adaptation, with confirmed reliability (intraclass correlation coefficients of the one-week test-retest ranged from 0.79 to 0.85) [20] to evaluate energy expended on physical activity per week during the month preceding examination
2) Kom-PAN Questionnaire of Eating Behaviour [21], with confirmed reliability [22], to evaluate the frequency of consuming product groups on a scale from 1 to 6, i.e. 'never' (1), 'occasionally' (2), 'once a week' (3), 'several times a week' (4), 'once a day' (5), 'several times a day' (6), and the declared level of physical activity on a scale from 1 to 3, i.e. 'low' (1), 'moderate' (2) and 'high' (3)
3) tools for the measurement of somatic indices and body composition: the HOLTAIN anthropometer, TANITA SC-330ST, used to measure body mass and composition, circumferences (waist, hips, and thighs), and skinfolds (on the arm, under the lower angle of the scapula and on the abdomen above the iliac crest)
4) Fullerton Functional Fitness Test, used to evaluate individual components of functional fitness: 30-Second Arm Curl, Seated Bow, the so-called 'Safety Pin', the 30-Second Chair Stand, 2.44-Metre Timed Up and Go, and the 2-Minute Step in Place [8]
5) EuroQoL Quality of Life Questionnaire (EQ-5D), the Visual Analogue Scale part, for subjective assessment of health on a scale from 0 ('worst possible health state') to 100 ('best possible health state') [23].

Statistical analyses

Descriptive statistics were presented. Correlations between variables were assessed using Spearman's R rank correlation coefficients in the IBM SPSS 21 program, assuming a significance level of $p<0.05$.

Results

The distribution of data on self-assessment regarding the level of physical activity shows that the largest percentage of women declared average (60.2%) levels of physical activity, less often low (24.3%) and high (15.5%) levels. The average energy expenditure on physical activity per week during the month preceding the study was 4,663.3±3,021.5 kcal (Me=3,961.4 kcal, Min-Max: 506.0-16,796.8 kcal/week). Statistical analysis confirmed a significant positive correlation between self-assessment of the level of physical activity and energy expended on physical activity (R=0.21; p=0.004).

The assessment of the consumption of product groups showed that women most often, i.e. several times a day (Me=6), drank water, and once a day (Me=5) they ate fruit, vegetables, and wholemeal bread. They consumed several times a week (Me=4) butter, vegetable oils, milk, yogurts and kefirs, fromage fais, eggs, and potatoes. On average, once a week (Me=3), their diet included regular pasta and white rice, groats, and oat flakes, yellow cheese, cold cuts, white meat, fish, legumes, and sweets. Less frequently, i.e. occasionally (Me=2), they consumed white bread, fried foods, red meat, canned vegetables, fruit, vegetable juices, and alcohol. They never (Me=1) consumed products such as fast food, lard, instant soups, canned meat, sweetened beverages, or energy drinks (Table 1).

Table 1. Frequency of consuming selected product groups in the studied group of women (descriptive statistics)

Products *	N	Mean	Median	Min.	Max.	Q25	Q75	SD
White bread	176	2.7	2.0	1.0	6.0	1.0	4.0	1.6
Wholemeal bread	179	4.2	5.0	1.0	6.0	4.0	5.0	1.3
White rice, regular pasta	180	2.8	3.0	1.0	5.0	2.0	3.5	1.0
Groats, oat flakes	180	3.3	3.0	1.0	6.0	2.0	4.0	1.2
Fast food	179	1.1	1.0	1.0	3.0	1.0	1.0	0.4
Fried products	180	2.3	2.0	1.0	6.0	1.5	3.0	1.1
Butter	179	3.8	4.0	1.0	6.0	2.0	5.0	1.8
Lard	178	1.3	1.0	1.0	5.0	1.0	1.0	0.9
Oils, olive oil	180	4.0	4.0	1.0	6.0	4.0	5.0	1.1
Milk	180	3.2	4.0	1.0	6.0	1.0	5.0	1.7
Yoghurt, kefir	181	3.8	4.0	1.0	6.0	3.0	5.0	1.2
Fromage fais	181	3.6	4.0	1.0	6.0	3.0	4.0	1.1
Yellow cheeses	180	3.0	3.0	1.0	5.0	2.0	4.0	1.2
Cold-cuts, sausages	179	3.1	3.0	1.0	6.0	2.0	4.0	1.3
Red meat	181	2.5	2.0	1.0	5.0	2.0	3.0	1.0
White meat	181	3.2	3.0	1.0	5.0	3.0	4.0	0.9
Fish	181	2.7	3.0	1.0	5.0	2.0	3.0	0.8
Eggs	180	3.4	4.0	1.0	5.0	3.0	4.0	0.9
Legumes	181	2.7	3.0	1.0	5.0	2.0	3.0	0.9
Potatoes	181	3.3	4.0	1.0	6.0	3.0	4.0	1.1
Fruit	179	5.2	5.0	1.0	6.0	5.0	6.0	0.9
Vegetables	180	5.0	5.0	1.0	6.0	5.0	6.0	0.9
Sweets	181	3.2	3.0	1.0	6.0	2.0	4.0	1.3
Instant soups	179	1.2	1.0	1.0	5.0	1.0	1.0	0.6
Canned meats	179	1.1	1.0	1.0	3.0	1.0	1.0	0.3
Canned vegetables	180	2.3	2.0	1.0	6.0	1.0	3.0	1.2
Fruit juices	180	2.6	2.0	1.0	6.0	1.0	4.0	1.3

Vegetable juices	180	2.7	2.0	1.0	6.0	2.0	4.0	1.4
Sweetened hot beverages	181	2.8	1.0	1.0	6.0	1.0	5.0	2.1
Sweetened carbonated beverages	180	1.2	1.0	1.0	5.0	1.0	1.0	0.6
Energy drinks	181	1.1	1.0	1.0	6.0	1.0	1.0	0.4
Water	181	5.5	6.0	1.0	6.0	5.0	6.0	1.1
Alcohol	181	1.9	2.0	1.0	6.0	2.0	2.0	0.8

*products listed according to Kom-PAN questionnaire

Assessment of the analysed health indices showed that the women had an average BMI of 27.4 kg/m^2, with body characterized by 25.5 kg of fat mass and 44.7 kg of fat-free mass. The average waist circumference was 82.9 cm, and the skinfold over the iliac crest was the thickest (36.4 mm). In terms of functional fitness, women performed, on average, 15.1 repetitions of the 30-Second Chair Stand test and 17.1 repetitions of the 30-Second Arm Curl test. In the Seated Bow test, the participants obtained a score of 6.4 cm, and in the Back Scratch ('Safety Pin') test, the result was -0.8 cm. Furthermore, for the 2.44-Metre Timed Up and Go test, they achieved a result of 4.9 seconds, while for the 2-Minute Step in Place, the result was 109.3 steps. The subjective assessment of health on a 100-point scale was 76.9 points (Table 2).

Table 2. Analysed indices of health: somatic characteristics, functional fitness, and self-assessment of health among females studied (descriptive statistics)

Variables (somatic, functional fitness and self-assessment)	N	Mean	Median	Min.	Max.	Q25	Q75	SD
BMI (kg/m^2)	180	27.4	26.9	18.7	40.2	24.2	30.1	4.3
FAT (%)	180	35.5	36.1	9.7	50.4	31.7	40.0	6.5
FAT Mass (kg)	180	25.5	25.2	5.6	51.9	19.4	31.0	8.3
FFM (kg)	180	44.7	43.9	34.8	67.3	41.0	48.2	5.2
TBW (kg)	180	32.8	32.1	25.5	49.3	30.0	35.3	3.8
Arm skinfold (mm)	181	26.9	27.0	7.2	85.0	21.2	31.4	8.5
skinfold under shoulder blade (mm)	181	25.8	24.8	7.8	57.0	18.8	32.8	10.2
Abdominal skinfold (mm)	181	36.4	36.0	7.4	62.0	31.4	41.0	9.6
Waist circumference (cm)	181	82.9	81.0	60.5	113.0	74.0	91.0	11.9
Hip circumference (cm)	181	97.1	96.5	14.0	124.0	91.0	103.0	10.3
Thigh circumference (cm)	181	53.7	53.5	23.0	69.5	50.0	57.0	5.8
30-Second Chair Stand (repetitions)	180	15.1	15.0	8.0	23.0	13.0	17.0	2.8
30-Second Loaded Arm Curl (repetitions)	181	17.1	17.0	7.0	28.0	15.0	19.0	3.3
Seated Forward Bow (cm)	181	6.4	7.0	-24.0	31.0	-3.0	17.0	13.4
Back Scratch / 'Safety Pin' (cm)	181	-0.8	1.0	-50.0	13.0	-4.5	4.0	7.9
Timed Up and Go - 2,44 m (sec)	181	4.9	4.9	3.3	9.9	4.4	5.3	0.8
2-Minute Step in Place (number of steps)	180	109.3	110.5	29.0	158.0	101.0	118.5	15.1
Self-assessment (pts)	181	76.9	80.0	30.0	100.0	70.0	90.0	14.3

Statistical analysis showed that as the level of physical activity increased, the frequency of consuming certain product groups decreased, including white bread (p=0.046), potatoes (p=0.042), white meat (p=0.007), and red meat (p=0.002) (Table 3).

Table 3. Correlations between the level of physical activity and frequency of consuming food groups in the study group (Spearman's R)

Physical activity & Food products	N	Spearman's R	t(N-2)	*p*-value
White bread	176	-0.15	-2.01	0.046
Wholemeal bread	179	0.05	0.67	0.502
White rice, regular pasta	180	-0.07	-0.92	0.356
Coarse groats, oat flakes	180	0.06	0.75	0.454
Fast food	179	0.02	0.23	0.815
Fried products	180	-0.09	-1.25	0.215
Butter	179	-0.11	-1.45	0.148
Lard	178	-0.03	-0.36	0.716
Oils, olive oil	180	0.02	0.27	0.790
Milk	180	0.01	0.10	0.920
Yoghurt, kefir	181	0.06	0.77	0.442
Fromage fais	181	-0.01	-0.09	0.926
Yellow cheeses	180	-0.04	-0.50	0.615
Cold-cuts, sausages	179	-0.12	-1.62	0.106
Red meat	181	-0.23	-3.20	0.002
White meat	181	-0.20	-2.71	0.007
Fish	181	-0.00	-0.05	0.960
Eggs	180	-0.09	-1.25	0.213
Legumes	181	0.13	1.71	0.089
Potatoes	181	-0.15	-2.05	0.042
Fruit	179	0.07	0.92	0.357
Vegetables	180	-0.03	-0.37	0.710
Sweets	181	-0.02	-0.31	0.757
Instant soups	179	0.05	0.66	0.510
Canned meats	179	-0.05	-0.62	0.538
Canned vegetables	180	-0.02	-0.24	0.808
Fruit juices	180	-0.01	-0.15	0.882
Vegetable juices	180	0.03	0.40	0.690
Sweetened hot beverages	181	-0.03	-0.44	0.658
Sweetened carbonated beverages	180	-0.08	-1.01	0.313
Energy drinks	181	-0.10	-1.32	0.188
Water	181	-0.02	-0.25	0.800
Alcohol	181	-0.14	-1.92	0.056

It was also shown that the BMI (p=0.023) and some somatic features decreased with the increase in the level of physical activity, including the amount of fat tissue expressed as a percentage of body mass (p=0.005) and as weight in kg (p=0.008), thickness of skinfolds at the lower angle of the scapula (p=0.047) and on the arm (p=0.007), and waist (p=0.009) and hip circumference (p=0.009). It was also noted that as the level of physical activity increased, certain domains of functional fitness also increased, including range of the Loaded Arm Curl (p=0.019) and the Seated Bow (p=0.036) test. Positive self-assessment of health also increased (p=0.001) (Table 4).

Table 4. Correlations between the level of physical activity and somatic characteristics, functional fitness, and subjective self-assessment of health in the study group (Spearman's R)

Physical activity & Somatic indices / Functional fitness / Self-assessment	N	Spearman's R	t(N-2)	*p*–value
BMI (kg/m²)	180	-0.17	-2.29	0.023
FAT (%)	180	-0.21	-2.87	0.005
FAT Mass (kg)	180	-0.20	-2.70	0.008
FFM (kg)	180	-0.03	-0.40	0.693
TBW (kg)	180	-0.03	-0.38	0.704
Skinfold on arm (mm)	181	-0.20	-2.72	0.007
Skinfold under lower angle of shoulder blade (mm)	181	-0.15	-2.00	0.047
Skinfold fat above iliac bone plate (mm)	181	-0.15	-1.96	0.051
Waist circumference (cm)	181	-0.19	-2.63	0.009
Hip circumference (cm)	181	-0.19	-2.62	0.009
Thigh circumference (cm)	181	-0.14	-1.95	0.052
30-Second Chair Stand (repetitions)	180	0.14	1.92	0.057
30-Second Loaded Arm Curl (repetitions)	181	0.17	2.37	0.019
Seated Bow (cm)	181	0.16	2.12	0.036
Back Scratch / 'Safety Pin' (cm)	181	0.03	0.41	0.681
2.44-Metre Timed Up and Go (sec)	181	-0.03	-0.37	0.715
2-Minute Step in Place (steps)	180	0.05	0.64	0.520
Well-being (pts)	181	0.24	3.33	0.001

Discussion

The present study showed that senior women who signed up for the Healthy Active Senior programme promoting an active lifestyle mostly declared an average level of physical activity. We showed nutritional mistakes, increased values of some somatic indices (including BMI), and an average level of functional fitness. In relation to the aim of the study, it was found that the level of physical activity declared by women was positively correlated with energy expenditure on physical activity, significantly correlated with some dietary choices and some indices of holistically defined health, including anthropometric indices of nutritional status, functional fitness, and subjective self-assessment of health.

The statistically significant positive relationship demonstrated between the subjective assessment of physical activity (based on Kom-PAN) and energy expenditure (based on CHAMPS) indicates that the declared physical activity can be perceived as an element of assessing physical activity levels in senior women. Other studies on the relationship between self-assessment and measured physical fitness in older women also demonstrated a positive correlation between both of these variables (i.e. declared and actual level of physical fitness) [24], which corresponds to the results of the authors' research in a similar area.

The study also indicated significant relationships between the level of physical activity and some positive dietary choices, because as physical activity increased, the frequency of consuming products with a high glycaemic index (white bread and potatoes) and meat (including red meat) decreased. Excess meat, especially red and processed meats, is not recommended due to the content of saturated fatty acids and cholesterol, as well as unfavourable substances added to food (preservatives) and those generated during thermal processing such as frying and smoking, including lipid peroxides and protein pyrolysis products [25-27]. Excessive consumption of high-glycaemic, low-fibre products and processed meat may increase health risks, including the development of cardio-metabolic and cancer diseases [28,29]. In this context, it can be assumed that higher physical activity was associated with more rational dietary choices among women (although such a situation only concerned several groups of food products). The trends demonstrated in this respect correspond to the research results of other authors. A review of the literature shows that people with more rational diets are also more involved in physical activity [30]. American studies conducted as part of the National Health and Nutrition Examination Survey programme in 2007-2014 also demonstrated associations between healthier diets and a greater frequency of physical activity among people aged 60+ [11]. A systematic review of the literature also confirmed the importance of high-quality diets for physical fitness among seniors, including physical performance [31].

The present study showed that with an increase in the level of physical activity, the values of some anthropometric indices related to nutritional status decreased, including body mass index (BMI), the amount of adipose tissue in the body composition, the thickness of skinfolds (under the shoulder blade and on the arm) and circumference (waist and hips), which further indicates a positive correlation between physical activity and the normalisation of somatic features as well as a lower degree of body fat. This is important for the prevention of obesity and its complications, especially since the results obtained indicate above-normal BMI values and an increased amount of adipose tissue in the body composition of senior women. Therefore, the results confirm the positive impact of physical activity in terms of optimising body mass and composition, which may reduce the risk of developing chronic diseases, including cardio-metabolic diseases, which was also pointed out by other authors [32,33]. The demonstrated trends towards more beneficial health values of several somatic features (anthropometric indices of nutritional status) in women with higher physical activity are consistent with the results of other authors. In this respect, research conducted by authors from the Czech Republic also confirms the positive impact of physical activity on body mass and composition indices, thus contributing to reducing the risk of obesity in older women [34]. Research from Canada, in turn, confirmed the importance of various training forms (high-intensity interval training and moderate-intensity continuous training) for optimising body composition, cardiometabolic profile, and physical capacity of older women [35]. Subsequent studies have confirmed the effect of vigorous physical activity on reducing body circumference (waist, hips, calves) in elderly people from Brazil [36]. A lower risk of excess body mass and increased BMI was also established in physically active women from various countries compared to sedentary women, which indicates the validity of promoting an active lifestyle in order to prevent obesity and maintain the health of older women from various European countries [37]. Also, among middle-aged people (40-69 years) from the UK, it was found that physical activity was inversely correlated with BMI and body fat content [38].

The present research also showed that as the level of physical activity of the women increased, certain components of their functional fitness also increased, including the number of 30-Second Loaded Arm Curls and the depth of Seated Bow tests. This indicates a positive relationship between physical activity and improved functional fitness, especially in terms of muscle strength of the upper body (upper limb) and flexibility of the lower body. Improving functional fitness leads to an increase in the efficiency of performing activities of daily living and thus, improving the quality of life of seniors [8]. The demonstrated trends towards better functional fitness in women with higher physical activity correspond to the results of studies by other authors, including new ones conducted in the German population [39]. Research by authors from Spain and Portugal also presented an indirect effect of physical activity (of at least moderate intensity) on components of physical fitness, in particular, on lower body strength, dynamic balance, and aerobic endurance in older women [40]. Subsequent studies in Canada conducted among older females confirmed the positive impact of physical activity on dynamic balance [41], limb muscle strength, flexibility, dynamic balance, and cardiorespiratory endurance [42]. Furthermore, a meta-analysis showed a positive effect of yoga on components of functional fitness, including strength, balance, and flexibility in older people [43].

The research also found that as the level of physical activity improved, the positive self-assessment of health increased, which confirms the significance of physical activity for a modern definition of health. The holistic concept of health assumes the subjectivity of health feelings, as indicated by theorists of health psychology [44]. The tendencies towards higher self-assessment of health among women with higher physical activity demonstrated in this study are consistent with the results of research obtained by other authors. For example, in other Polish studies, the importance has been demonstrated of personalised physical activity for healthy aging among seniors, preferably in the form of moderate-to-vigorous exercise, including improved physical health, overall well-being/self-assessment, and higher satisfaction with life [45]. In Polish studies, lower self-assessment of health has been indicated in older women with chronic diseases [46]. Korean studies also confirm the predictive significance concerning the frequency of vigorous physical activity (and the use of medical services) for the subjective self-assessment of health among married postmenopausal women [47]. The previously cited American studies conducted under the National Health and Nutrition Examination Survey from 2007 to 2014 also exhibited associations between high physical activity and better self-assessment of health in older people [11]. Similarly, a meta-analysis confirmed the positive impact of physical activity (in the form of yoga) on the self-assessment of mental and physical health in older people [43].

The presented work generally fits into the trend of research on behavioural determinants of health, taking the subjectivity of health into account and pointing to the importance of individual responsibility for health and high-ranking health behaviours undertaken for improving health potential during aging. Physical activity, in addition to rational dietary choices, is an important element of a healthy lifestyle, which is a key determinant of health and quality of life at every stage of ontogenesis. Some of the health indices are somatic features, such as anthropometric indices of nutritional status and functional fitness, and subjective perception of health. With this approach, the results indicate the positive impact of physical activity on other aspects of a healthy lifestyle and health status, thus referring to the conclusions drawn from research conducted by other authors, who have indicated that physical activity is a significant factor in improving the health of seniors [5,48,49].

The limitations of this study are mainly related to the self-report nature of some research tools, including those concerning physical activity and nutrition. Moreover, the results can only be interpreted in relation to the group covered by the research and cannot be generalised because they concern women who reported joining the programme that promoted health through physical activity. The failure to include men is another limitation of the work. Further studies could include additional verification of the level of physical activity using objective measures of energy expenditure and also take men and a broader spectrum of lifestyle elements into account, including coping with stress, sleep hygiene, etc.

Conclusions

1. Higher levels of physical activity, positively correlated with energy expenditure, are partially associated with healthier dietary choices, certain somatic indices of nutritional status, higher functional fitness, and better self-assessment of health in older women.
2. The obtained results suggest partial predictive significance regarding the declared level of physical activity for some positive indices of lifestyle and health status of senior women.
3. Promoting physical activity should help improve various aspects of lifestyle and the holistically defined health of senior women.

Conflicts of Interest: The authors declare that they have no conflict of interest.

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Institutional Review Board Statement: The research project was approved by the Bioethics Committee of the District Medical Chamber 166/KBL/OIL/2018).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

References:

[1] Grey M. Lifestyle determinants of health: Isn’t it all about genetics and environment? Nurs Outlook. 2017; 65(5): 501-505. https://doi.org/10.1016/j.outlook.2017.04.011.
[2] Locke A, Schneiderhan J, Zick SM. Diets for Health: Goals and Guidelines. Am Fam Physician. 2018; 97(11): 721-728.
[3] Bangsbo J, Blackwell J, Boraxbekk C-J, Caserotti P, Dela F, Evans AB, et al. Copenhagen Consensus statement 2019: physical activity and ageing. Br J Sports Med. 2019; 53(14): 856-858. doi: 10.1136/bjsports-2018-100451.
[4] Sherrington C, Fairhall N, Kwok W, Wallbank G, Tiedemann A, Michaleff ZA, et al. Evidence on physical activity and falls prevention for people aged 65+ years: systematic review to inform the WHO guidelines on physical activity and sedentary behaviour. Int J Behav Nutr Phys Act. 2020; 17(1): 144. doi.10.1186/s12966-020-01041-3.
[5] Lewis CB, Laflin M, Gray DL. Exercise as Medicine for Older Women. Clin Geriatr Med. 2021; 37(4): 639-650. doi: 10.1016/j.cger.2021.05.009.
[6] Stojanović MDM, Mikić MJ, Milošević Z, Vuković J, Jezdimirović T, Vučetić V. Effects of Chair-Based, Low-Load Elastic Band Resistance Training on Functional Fitness and Metabolic Biomarkers in Older Women. J Sports Sci Med. 2021; 20(1): 133-141. doi: 10.52082/jssm.2021.133.
[7] Scoditti E, Tumolo MR, Garbarino S. Mediterranean Diet on Sleep: A Health Alliance. Nutrients. 2022; 14(14): 2998. doi: 10.3390/nu14142998.

[8] Rikli RE, Jones CJ. Development and validation of criterion-referenced clinically relevant fitness standards for maintaining physical independence in later years. Gerontologist. 2013; 53(2): 255-267. doi.10.1093/geront/gns071.
[9] Li Z, Lai Q, Benedict RJ, Yang T, Zhang X. Age and residential differences in functional fitness of Chinese older women. Australas J Ageing. 2022; 41(4): e379-e386. doi: 10.1111/ajag.13037.
[10] Tian Y, Shi Z. Effects of Physical Activity on Daily Physical Function in Chinese Middle-Aged and Older Adults: A Longitudinal Study from CHARLS. Clin Med. 2022; 11(21): 6514. doi: 10.3390/jcm11216514.
[11] Xu F, Cohen SA, Lofgren IE, Greene GW, Delmonico MJ, Greaney ML. Relationship between Diet Quality, Physical Activity and Health-Related Quality of Life in Older Adults: Findings from 2007-2014 National Health and Nutrition Examination Survey. J Nutr Health Aging. 2018; 22(9): 1072-1079. doi: 10.1007/s12603-018-1050-4.
[12] Stoś K, Ołtarzewski M, Rychlik E. Dietary patterns of Polish seniors in retirees` households. Rocz Panstw Zakl Hig. 2021; 72(4): 393-401. doi.10.32394/rpzh.2021.019.
[13] Ishikawa-Takata K, Nakae S, Sasaki S, Katsukawa F, Tanaka S. Age-Related Decline in Physical Activity Level in the Healthy Older Japanese Population. J Nutr Sci Vitaminol (Tokyo). 2021; 67(5): 330-338. doi: 10.3177/jnsv.67.330.
[14] Visser M, Schaap LA, Wijnhoven HAH. Self-Reported Impact of the COVID-19 Pandemic on Nutrition and Physical Activity Behaviour in Dutch Older Adults Living Independently. Nutrients. 2020; 12(12): 3708. doi.10.3390/nu12123708.
[15] Ricardo AM, Damaris HG, Daniel LG, Marta LM. Nutritional Status, Dietary Habits, and Physical Activity in Older Adults from Manta, Manabí. Foods 2022; 11: 3901. https://doi.org/10.3390/ foods11233901.
[16] Gacek M, Kosiba G, Majer M, Gradek J, Kucia K, Koteja A, et al. Nutritional Habits, Self-Rated Health, and Quality of Life of Women Participating in the Healthy Active Senior Programme. J Kinesiol Exerc Sci. 2023; 101(33): 1-9. DOI: 10.5604/01.3001.0016.2225.
[17] Gacek M, Wojtowicz A, Kosiba G, Majer M, Gradek J. Body Mass Index, Functional Fitness and Nutritional Behaviours of Senior Women from the Kraków Population. Rocz Panstw Zakl Hig. 2023; 74(1): 31-40. doi.org/10.32394/rpzh.2023.0240.
[18] Gacek M, Wojtowicz A, Kosiba G, Majer M, Gradek J, Koteja A, Czerwińska-Ledwig O. Satisfaction with Life and Nutritional Behaviour, Body Composition and Functional Fitness of Women from the Kraków Population Participating in the “Healthy Active Senior” Programme. Int J Environ Res Public Health. 2023; 20: 1877. https:// doi.org/10.3390/ijerph20031877.
[19] Stewart A, Mills KM, King AC, Haskell WL, Gillis D, Ritter PL. CHAMPS Physical Activity Questionnaire for Older Adults: Outcomes for Interventions. Med. Sci Sports Exerc. 2001; 33(7): 1126-1141.
[20] Król-Zielińska M, Ciekot-Sołtysiak M, Szeklicki R, Zieliński J, Osiński W, Kantanista A. Validity and Reliability of the Polish Adaptation of the CHAMPS Physical Activity Questionnaire. Biomed Res Int. 2019; 6187616. doi: 10.1155/2019/6187616.
[21] Gawęcki J (Ed.). Dietary Habits and Nutrition Beliefs Questionnaire and the Manual for Developing of Nutritional Data. Polish Academy of Sciences, Olsztyn 2014, Poland.
[22] Kowalkowska J, Wądołowska L, Czarnocińska J, Człapka-Matyasik M, Galiński G, Jeżewska-Żychowicz M, et al. Reproducibility of a Questionnaire for Dietary Habits, Lifestyle and Nutrition Knowledge Assessment (KomPAN) in Polish Adolescents and Adults. Nutrients 2018; 10: 1845. doi: 10.3390/nu10121845.
[23] Balestroni G, Bertolotti G. EuroQol-5D (EQ-5D): an instrument for measuring quality of life. Monaldi Arch Chest Dis. 2012; 78(3): 155-159. doi: 10.4081/monaldi.2012.121.
[24] Kasović M, Štefan L, Zvonar M. Self-Reported vs Measured Physical Fitness in Older Women. Clin Interv Aging. 2020; 15: 425-430. doi: 10.2147/CIA.S240156.
[25] Givens DI. Review: Dairy foods, red meat and processed meat in the diet: implications for health at key life stages. Animal. 2018; 12(8): 1709-1721. doi: 10.1017/S1751731118000642.
[26] Wiseman MJ. Nutrition and cancer: prevention and survival. Br J Nutr. 2019; 122(5): 481-487. doi: 10.1017/S0007114518002222.
[27] Grosso G, La Vignera S, Condorelli RA, Godos J, Marventano S, Tieri M, et al. Total, red and processed meat consumption and human health: an umbrella review of observational studies. Int J Food Sci Nutr. 2022; 73(6): 726-737. doi: 10.1080/09637486.2022.2050996.
[28] Fuller S, Beck E, Salman H, Tapsell L. New Horizons for the Study of Dietary Fiber and Health: A Review. Plant Foods Hum Nutr. 2016; 71(1): 1-12. doi: 10.1007/s11130-016-0529-6.
[29] Stoś K, Rychlik E, Woźniak A, Ołtarzewski M. Red and Processed Meat Consumption in Poland. Foods. 2022; 11(20): 3283. doi: 10.3390/foods11203283.
[30] Ari Y, Çakır E. Correlation between participation in physical activity and healthy nutrition: An example of a sports science faculty. Balt J Health Phys Activ. 2021; 13(3): 37-45. doi.10.29359/BJHPA.13.3.05.
[31] Bloom I, Shand C, Cooper C, Robinson S, Baird J. Diet Quality and Sarcopenia in Older Adults: A Systematic Review. Nutrients. 2018; 10(3): 308. doi.10.3390/nu10030308.
[32] Gallardo-Alfaro L, Bibiloni MDM, Mateos D, Ugarriza L, Tur JA. Leisure-Time Physical Activity and Metabolic Syndrome in Older Adults. Int J Environ Res Public Health. 2019; 16(18): 3358. doi: 10.3390/ijerph16183358.
[33] Figueiró TH, Arins GCB, Santos CESD, Cembranel F, Medeiros PA, d’Orsi E, Rech CR. Association of objectively measured sedentary behavior and physical activity with cardiometabolic risk markers in older adults. PLoS One. 2019; 14(1): e0210861. doi: 10.1371/journal.pone.0210861.

[34] Sofková T, Přidalová M. Assessment of changes in somatic characteristics based on the level of physical activity in women who undertook weight reduction course. Cent Eur J Public Health. 2018; 26(3): 223-227. doi: 10.21101/cejph.a4678.
[35] Boukabous I, Marcotte-Chénard A, Amamou T, Boulay P, Brochu M, Tessier D, et al. Low-Volume High-Intensity Interval Training (HIIT) versus Moderate-Intensity Continuous Training on Body Composition, Cardiometabolic Profile and Physical Capacity in Older Women. J Aging Phys Act. 2019; 27(4): 879-889. doi: 10.1123/japa.2018-0309.
[36] de Oliveira DV, Branco BHM, Jesus MC, Sepúlveda-Loyola V, Gonzáles-Caro H, Morais Freire GL, et al. Relationship between vigorous physical activity and body composition in older adults. Nutr Hosp. 2021; 38(1): 60-66. doi: 10.20960/nh.03254.
[37] Molina-Garcia P, Medrano M, Pelclová J, Zając-Gawlak I, Tlučáková L, Přidalová M. Device-Measured Physical Activity, Sedentary Behaviors, Built Environment, and Adiposity Gain in Older Women: A Seven-Year Prospective Study. Int J Environ Res Public Health. 2021; 18(6): 3074. doi: 10.3390/ijerph18063074.
[38] Bradbury KE, Guo W, Cairns BJ, Armstrong MEG, Key TJ. Association between physical activity and body fat percentage, with adjustment for BMI: a large cross-sectional analysis of UK Biobank. BMJ Open. 2017; 7(3): e011843. doi: 10.1136/bmjopen-2016-011843.
[39] Albrecht BM, Stalling I, Recke C, Doerwald F, Bammann K. Associations between older adults' physical fitness level and their engagement in different types of physical activity: cross-sectional results from the OUTDOOR ACTIVE study. BMJ Open. 2023; 13(3): e068105. doi: 10.1136/bmjopen-2022-068105.
[40] Zymbal V, Carrasco L, Sañudo B, Luís D, Baptista F. Mediating effect of muscle power on the relationship of physical activity with physical fitness and physical function in older women. Exp Gerontol. 2022; 158: 111660. doi: 10.1016/j.exger.2021.111660.
[41] Buckinx F, Peyrusqué E, Granet J, Aubertin-Leheudre M. Impact of current or past physical activity level on functional capacities and body composition among elderly people: a cross-sectional analysis from the YMCA study. Arch Public Health. 2021; 79(1): 50. doi: 10.1186/s13690-021-00573-9.
[42] Syue SH, Yang HF, Wang CW, Hung SY, Lee PH, Fan SY. The Associations between Physical Activity, Functional Fitness, and Life Satisfaction among Community-Dwelling Older Adults. Int J Environ Res Public Health. 2022; 19(13): 8043. doi: 10.3390/ijerph19138043.
[43] Sivaramakrishnan D, Fitzsimons C, Kelly P, Ludwig K, Mutrie N, Saunders DH, Baker G. The effects of yoga compared to active and inactive controls on physical function and health related quality of life in older adults- systematic review and meta-analysis of randomised controlled trials. Int J Behav Nutr Phys Act. 2019; 16(1): 33. doi: 10.1186/s12966-019-0789-2.
[44] Sęk H, Heszen I. Psychologia zdrowia [Health psychology]. Wyd. PZWL, Warszawa 2012. (Polish)
[45] Żurek G, Lepsy E, Żurek A, Radajewska A, Ptaszkowski K, Golachowska M. The relationship between the level of physical activity, independence in daily activities, and life quality and satisfaction in women over 80 living in rural areas - a pilot study. Rocz Panstw Zakl Hig. 2020; 71(2): 171-180. doi: 10.32394/rpzh.2020.0112.
[46] Knapik A, Brzęk A, Famuła-Wąż A, Gallert-Kopyto W, Szydłak D, Marcisz C, Plinta R. The relationship between physical fitness and health self-assessment in elderly. Medicine (Baltimore). 2019; 98(25): e15984. doi: 10.1097/MD.0000000000015984.
[47] Kim EJ, Nho J-H. Trajectories of subjective health status among married postmenopausal women based on the ecological system theory: a longitudinal analysis using a latent growth model. Korean J Women Health Nurs. 2022; 28(2): 123-133. doi: 10.4069/kjwhn.2022.05.24.
[48] Bethancourt HJ, Rosenberg DE, Beatty T, Arterburn DE. Barriers to and facilitators of physical activity program use among older adults. Clin Med Res. 2014; 12(1-2): 10-20. doi: 10.3121/cmr.2013.1171.
[49] Lim H-S, Yoo J-J. Association between Health Indicators and Health-Related Quality of Life according to Physical Activity of Older Women. Healthcare (Basel). 2020; 8(4): 507. doi: 10.3390/healthcare8040507.

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EFFECT OF TRAINING AND SELECTION ON ISOMETRIC HANDGRIP STRENGTH AND ITS CORRELATIONS WITH SPORTS SKILL LEVEL IN JUDOKAS AGED 11 TO 14 YEARS

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A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

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Abstract:

Background: Handgrip strength development is a very important component of training in combat sports, especially wherever throws and grips are used to limit the movements of the opponent. The main aim of this study was to compare isometric handgrip strength (IHS) values between athletes of different ages to determine the effect of training and selection on its level, and to analyse the relationship between IHS and the level of achievement.

Methods: The study group consisted of 23 judokas aged 11 to 13 years with 52 non-athlete peers and 19 judokas aged 13 to 14 years with 38 non-athlete peers. Examinations of judokas were conducted during regional championships. The level of achievement was determined based on the place taken in the tournament.

Results: Comparison of IHS values between judokas and their peers in both groups revealed statistically significant differences in relative values. In the group of children, the absolute mean IHS value for the dominant limb was significantly higher in judo practitioners. Comparison of the mean IHS values between judokas of different ages showed statistically significant differences for absolute handgrip strength for the dominant limb, non-dominant limb, and their total. A very high correlation in the group of children was found between the level of achievement and the handgrip strength of the dominant and non-dominant limbs. A high correlation was observed for the level of achievement and the strength of the non-dominant hand.

Conclusions: Training and selection has a significant impact on higher (mainly relative) IHS values. As the person gets older, the absolute IHS values increase, but their effect on the players' level of achievement decreases.

Introduction

Handgrip strength determines the activities of daily living connected with lifting and carrying objects, and performing basic and instrumental activities [1]. In most sports where upper limbs are used during competition, handgrip strength has an effect on the level of players' achievement through its connection with technical training. Therefore, training optimization needs measurement of its level and broadly understood analysis. Research of this type has been conducted, among others, in team sports games [2-4], gymnastics [5], or rock climbing [6]

Handgrip strength development is a very important component of training in combat sports, especially wherever throws and grips are used to limit the movements of the opponent. High level of handgrip strength allows for utilization of the strength of the muscles of the entire athlete's body [7]. The importance of handgrip strength is demonstrated, among others, by its significantly higher values compared to athletes practising sports where competition consists in performing blows and kicks [8,9].

A special case of this kind of combat sport is judo. This uniqueness is related to the strict rules related to clothing (Japanese name: judogi). A judogi consists of loose pants and a jacket with wide sleeves, tied with a belt. When applying standing techniques (Japanese: tachi-waza), competitors can grip an opponent's uniform from the belt upwards (belt, sleeves, collar, back cloth), whereas during performance of prone techniques (Japanese name: ne-waza), it is also allowed to grip pants. It is therefore possible to use a large number of different grips, whose main objective is to maximise the use of the athlete's own potential while limiting the potential of the opponent. While recognising the importance of isometric handgrip strength (IHS) during the judo fight, the authors have often focused on this problem in scientific publications. The topic of their studies was mostly to evaluate IHS in players at different age. Only few studies have attempted to determine the effect of training and selection on its value [Dias et al. 2012] and an analysis of the correlation with the sports skill level of judokas [11]. In addition, they apply to older age groups. Therefore, the authors examined judo players and their non-athlete peers aged 11-12 years and 13-14 years.

The primary aim of this research is:

- to compare HGS values between players at different chronological age;
- to determine the effect of training and selection on its level;
- to analyse the relationship between the IHS and the level of achievement. Describe the general perspective of the article, include a review of the relevant literature that motivates the research question and a full description of the experimental aims and hypotheses.

Materials and Methods

The study group consisted of 23 judo athletes aged 11 to 13 years with 52 non-athlete peers, and 19 youth judokas aged 13 to 14 years with 38 non-athlete peers. Examinations of judokas were conducted during regional championships. It was performed on the day of the competition after the official weigh-in. Participation in the study was voluntary. The examinations were conducted according to the Declaration of Helsinki. All participants were informed about the aim of the study and could withdraw from further examinations at any time without giving any reason. The test had to be approved by the coach, who was the legal guardian of the participant during the competition.

These included the measurement of handgrip strength of the right and left hand, the measurement of body height, body weight, and body composition analysis.

The EH 101 handgrip tester with the option to adjust the grip to the size of the palm of the hand was used to measure the handgrip strength. The measurements were taken in the standing position with the upper limb held along the body. The result was recorded in kgf.

Body weight and composition were determined using a Tanita TBF-551 body composition analyser.

Body height (BH) was measured by means of a Martina anthropometer (USA) with accuracy of 0.1 cm.

The study also used a questionnaire, which included questions about age, training experience, and dominant upper limb.

The level of achievement was determined based on the place taken in the tournament, using the following pattern: 1st place: 9 points; 2nd place: 7 points; 3rd place: 5 points: 3rd place: 3.5 points; 7th place: 1.5 points; 9th place: 0.5 points.

The comparison group consisted of students from schools in the Lesser Poland Voivodeship. Persons whose height and body weight were approximately within the range of variability of these indices in groups of judokas were included in the study.

Tables 1 and 2 show the characteristics of age, training experience and somatic built of study participants in two age categories.

Table 1. Age, training experience and somatic built of study participants in the group of children (aged 11 to 12 years)

Variable	Judo competitors					Non-athlete peers						
	N	Mean	Min.	Max.	SD	N	Mean	Min.	Max.	SD	Test value	P
Age	23	11.43	11.00	12.00	0.51	52	11.60	11.00	12.00	0.50	U=-1.10	0.270
Body height	23	149.57	141.00	164.00	5.73	52	151.38	141.00	163.00	5.56	t=-1.29	0.202
Body mass	23	40.28	30.30	47.80	5.31	52	40.72	28.90	49.90	6.14	U=-0.37	0.709
Lean body mass	23	35.44	26.66	42.06	4.67	52	35.84	25.43	43.91	5.40	U=-0.37	0.709
% FAT	23	17.13	9.50	27.30	5.10	52	17.15	6.80	34.60	6.81	U=0.4	0.692
Training experience	23	4.43	1.00	7.00	1.73							
Level of achievement	23	3.96	0.00	9.00	2.95							

Table 2. Age, training experience and somatic built of study participants in the group of youth athletes (aged 13 to 14 years)

Variable	Judo competitors					Non-athlete peers						
	N	Mean	Min.	Max.	SD	N	Mean	Min.	Max.	SD	Test value	p
Age	19	13.42	13.00	14.00	0.51	38	13.18	13.00	14.00	0.39	U=1.44	0.150
Body height	19	163.55	149.00	176.50	6.71	38	163.54	144.00	181.00	7.76	t=0.01	0.995
Body mass	19	54.82	43.10	74.70	8.08	38	56.31	33.60	80.20	11.36	t=-0.51	0.612
Lean body mass	19	48.24	37.93	65.74	7.11	38	49.55	29.57	70.58	10.00	t=-0.51	0.612
% FAT	19	16.35	6.60	26.30	4.71	38	18.44	9.70	33.00	6.09	t=-1.31	0.195
Training experience	19	6.05	4.00	10.00	1.61							
Level of achievement	19	2.66	0.00	9.00	3.13							

Cross-tabulation was used to characterize the research material. Depending on the distribution and homogeneity of variance, means were compared using the Student's t-test for unrelated samples and the Mann-Whitney U test. The homogeneity of variance was evaluated by means of the Levene's test. The assumption of normal distribution was verified by means of the Shapiro-Wilk W-test.

In the case of comparison of children practising judo with their non-athlete peers, the sample size provided very good power for a large effect size (94%), much smaller for a medium effect size (63%), and very small for a small effect size (2%).

When comparing youth judokas and their non-athlete peers, the sample size ensured very good power for the large effect (88%), smaller for a medium size effect (55%), and very small for a small size effect (1.7%).

In comparisons between judo practitioners (children and youth athletes), the sample size also ensured very good power for the large effect size (81%), smaller for the medium effect size (48%), and very small for the small effect size (1.6%).

Results

Table 3 presents the values of handgrip strength for children practising judo and their non-training peers. Comparison of absolute values revealed significant differences only for the mean handgrip strength of the dominant limb. A higher mean was found in judokas. It was 21.34 and 18.99 in the second group.

More significant differences were observed in the indices expressed in relative units per kilogram of body weight and per kilogram of lean body mass. In the case of these indices, differences were found for the dominant upper limb, non-dominant upper limb, and in their total values. In all cases, higher mean values were found in judokas.

In the age group of youth athletes, statistically significant differences concerned the maximum handgrip strength of the dominant and non-dominant limbs, and their sum expressed in relative units (per kilogram of body weight and kilogram of lean body mass). Significantly higher means were found in all cases in the group of judokas.

Table 3. Handgrip strength in children (11-12 years old) practising judo and their non-athlete peers

Isometric handgrip strength / unit	Judo competitors				Non-athlete peers				Test value	p
	Mean	Min.	Max.	SD	Mean	Min.	Max.	SD		
Dominant upper limb (kgf)	**21.34**	**14.20**	**30.70**	**4.10**	**18.99**	**10.60**	**30.80**	**4.38**	**U=2.01**	**0.044**
Non-dominant upper limb (kgf)	19.81	14.40	28.40	3.57	17.73	9.00	27.70	4.01	U=1.83	0.068
Total (kgf)	41.15	32.30	59.10	7.28	36.72	19.60	58.50	7.94	U=1.92	0.055
Dominant upper limb (kgf/kg)	**0.53**	**0.37**	**0.71**	**0.09**	**0.47**	**0.23**	**0.75**	**0.11**	**t=2.26**	**0.027**
Non-dominant upper limb (kgf/kg)	**0.50**	**0.32**	**0.61**	**0.08**	**0.44**	**0.19**	**0.64**	**0.10**	**t=2.37**	**0.021**
Total (kgf/kg)	**1.03**	**0.71**	**1.26**	**0.16**	**0.91**	**0.42**	**1.32**	**0.20**	**t=2.46**	**0.016**
Dominant upper limb (kgf/kg LBM)	**0.61**	**0.42**	**0.81**	**0.10**	**0.54**	**0.26**	**0.85**	**0.13**	**t=2.27**	**0.027**
Non-dominant upper limb (kgf/kg LBM)	**0.56**	**0.36**	**0.70**	**0.09**	**0.50**	**0.22**	**0.73**	**0.11**	**t=2.37**	**0.021**
Total (kgf/kg LBM)	**1.17**	**0.80**	**1.43**	**0.18**	**1.04**	**0.48**	**1.51**	**0.22**	**t=2.46**	**0.016**

Table 4. Handgrip strength in youth judokas (aged 13 to 14 years) and their non-athlete peers

Isometric handgrip strength / unit	Judo competitors				Non-athlete peers				Test value	p
	Mean	Min.	Max.	SD	Mean	Min.	Max.	SD		
Dominant upper limb (kgf)	30.66	21.40	39.10	5.22	28.33	16.20	42.70	6.59	t=1.34	0.185
Non-dominant upper limb (kgf)	29.19	23.00	38.30	5.00	26.53	15.00	41.70	6.27	t=1.61	0.114
Total (kgf)	59.84	45.90	75.60	9.93	54.86	33.70	84.30	12.62	t=1.0	0.139
Dominant upper limb (kgf/kg)	**0.56**	**0.42**	**0.76**	**0.08**	**0.51**	**0.32**	**0.69**	**0.09**	**t=2.1**	**0.041**
Non-dominant upper limb (kgf/kg)	**0.54**	**0.37**	**0.78**	**0.09**	**0.48**	**0.31**	**0.68**	**0.09**	**t=2.52**	**0.015**
Total (kgf/kg)	**1.10**	**0.83**	**1.53**	**0.17**	**0.98**	**0.65**	**1.38**	**0.17**	**t=2.39**	**0.020**
Dominant upper limb (kgf/kg LBM)	**0.64**	**0.48**	**0.86**	**0.09**	**0.58**	**0.36**	**0.79**	**0.11**	**t=2.1**	**0.041**
Non-dominant upper limb (kgf/kg LBM)	**0.61**	**0.42**	**0.88**	**0.11**	**0.54**	**0.36**	**0.77**	**0.10**	**t=2.52**	**0.015**
Total (kgf/kg LBM)	**1.25**	**0.94**	**1.74**	**0.20**	**1.12**	**0.73**	**1.56**	**0.20**	**t=2.39**	**0.020**

The table presents the values of handgrip strength for children and youth judokas. Comparison of the mean IHS values revealed statistically significant differences in absolute handgrip strength for the dominant limb, non-dominant limb, and their total. A higher mean was found in all cases in the group of young judo athletes.

No statistically significant differences were recorded in the case of indices expressed in relative units.

When analysing the relationship between handgrip strength and the level of achievement in competitions, significant correlations were observed only in the group of children (Table 6). All the correlations concerned absolute values of specific indices. A very high correlation was found between the level of achievement and the handgrip strength of the dominant and non-dominant limbs. Furthermore, a high correlation was observed in the level of achievement and the strength of the non-dominant hand.

Table 5. Handgrip strength in children and youth judokas

Isometric handgrip strength / unit	Children				Youth athletes				Test value	p
	Mean	Min.	Max.	SD	Mean	Min.	Max.	SD		
Dominant upper limb (kgf)	**21.34**	**14.20**	**30.70**	**4.10**	**30.66**	**21.40**	**39.10**	**5.22**	**U=-4.69**	**0.000**
Non-dominant upper limb (kgf)	**19.81**	**14.40**	**28.40**	**3.57**	**29.19**	**23.00**	**38.30**	**5.00**	**U=-4.88**	**0.000**
Total (kgf)	**41.15**	**32.30**	**59.10**	**7.28**	**59.84**	**45.90**	**75.60**	**9.93**	**U=-4.88**	**0.000**
Dominant upper limb (kgf/kg)	0.53	0.37	0.71	0.09	0.56	0.42	0.76	0.08	t=-1.07	0.292
Non-dominant upper limb (kgf/kg)	0.50	0.32	0.61	0.08	0.54	0.37	0.78	0.09	t=-1.67	0.111
Total (kgf/kg)	1.03	0.71	1.26	0.16	1.10	0.83	1.53	0.17	t=-1.41	0.165
Dominant upper limb (kgf/kg LBM)	0.61	0.42	0.81	0.10	0.64	0.48	0.86	0.09	t=-1.07	0.292
Non-dominant upper limb (kgf/kg LBM)	0.56	0.36	0.70	0.09	0.61	0.42	0.88	0.11	t=-1.63	0.111
Total (kgf/kg LBM)	1.17	0.80	1.43	0.18	1.25	0.94	1.74	0.20	t=-1.41	0.165

Table 6. Statistically significant correlations between handgrip strength and the level of achievement in the group of children

Pairs of variables	N	R	p
Level of achievement & dominant upper limb (kgf)	23	0.720126	0.000
Level of achievement & non-dominant upper limb (kgf)	23	0.666382	0.001
Level of achievement & total (kgf)	23	0.754760	0.000

Discussion

As mentioned in the Introduction section, the maximum handgrip strength is an important aspect of strength and conditioning. Franchini [13] examined a large group of adult athletes from Brazil and demonstrated that the absolute value of the maximum handgrip strength depends on the weight category and adopts mean values for the right upper limb ranging from 43±7 (60 kg category) to 61±11 (+100 kg); for the left limb, this range was from 42±8 to 60±11. There was an inverse correlation in relative values (kgf/kg), with the highest results obtained by competitors from the lightest weight category. For the right upper limb, the mean values ranged between 0.49±0.09 (+100 kg category) and 0.73±0.12 (60 kg category). For the left limb, the values ranged from 0.49±0.09 to 0.70±0.13, respectively.

In the group of juniors, the maximum handgrip strength was 52.0±8.3 for the right hand and 50.6±8.5 for the left. In cadets, this was 39.8±12.7 and 39.4±10.0 kgf [14], respectively.

In the present study, the maximum handgrip strength in the group of youth athletes was 30.66±5.2 for the dominant limb and 29.2±5 kgf for the non-dominant limb, and differed significantly from the mean recorded for children. In the group of children, the mean for the right and left hands was 21.34±4.1 and 19.81±3.6, respectively. Significant differences with the same pattern of means were also noted for the total of the handgrip strength for the right and left hands. Therefore, it can be seen that the absolute values of the handgrip strength increase with the transition of the athletes to the next age groups.

Dias [11] compared HGS indices between Brazilian judo athletes (age=22.54; SD=3.86) and their non-athlete peers and found no significant differences in maximum force and time to achieve this force. The differences in favour of judo players concerned only strength endurance.

In our study, in the group of children practising judo, higher values were observed compared to the control group in the case of absolute handgrip strength of the dominant hand. Higher relative values, both kgf/kg and kgf/kg LBM, were found in the groups of judokas for the right and left limbs, and the total of their values.

Higher values of the analysed variables expressed only in relative values were also documented in the group of youth athletes.

Relative measures of static strength represent more objective indices of the actual strength potential of an individual than absolute strength. Their importance has been emphasized in many sports, especially those with weight categories, such as judo. The dynamometric measurement of handgrip strength can especially depend on the size of the body. The actual level of strength potential can be evaluated based on presentation in relative values [15]. Therefore, body weight and LBM belong to the most important strength abilities. The results obtained in our study support these findings. They clearly indicate that training and selection in this sport has an effect on higher values of handgrip strength in these age groups.

While attempting to determine the effect of handgrip strength on the athletes' sports skill level, we examined its differentiation in groups of individuals with different sports skill level. Bonith-Gongora [16] failed to demonstrate differences in the maximum handgrip strength between male elite athletes (medallists of the Portuguese, Swedish, and Danish championships aged up to 17 years) and non-elite athletes (participants who did not win any medal during the Spanish U17 championships). On the other hand, the non-elite group needed more time to reach the maximum force of the isometric handgrip. Gutiérrez-Sanchez et al. [12] examined athletes age of 15 to 19 years and also did not find any differences in the HGS level between those ranked at different places of the podium. Interestingly, a differentiation was observed in the group of women.

In this study, using correlation analysis, a correlation was found in the youngest age group between the level of achievement and the absolute values of the handgrip strength of the dominant and non-dominant upper limbs, and the total of their values. No such dependencies were documented in the older group of athletes.

These results seem to confirm previous findings which showed that with the transition to higher age groups, the correlations of motor skills and the course of fights and the sports skill level of the athletes disappear [17].

Despite the observed differences (compared to non-athlete peers and in the group of judokas), it is obvious that intentional development of the IHS should be scheduled for later periods of the development of sports skills. In rational training, the development of strength abilities must be preceded by the development of coordination skills and technique. Planning of training in younger age groups should primarily take into account the biological developmental patterns.

Conclusions

1. In young judo practitioners, the absolute values of handgrip strength of the dominant limb, non-dominant limb, and the total of their values were significantly higher than in the group of children.
2. Compared to the non-athlete peers, children and young judo athletes were characterized by significantly higher handgrip strength expressed in relative units. Furthermore, in the group of children, the absolute mean IHS for the dominant limb was significantly higher in judokas.
3. A very high correlation in the group of children was found between the level of achievement and the handgrip strength of the dominant and non-dominant limbs. Furthermore, a high correlation was observed for the level of achievement and the strength of the non-dominant hand.
4. Intentional IHS training should be implemented later in the development of the sports skill level (junior and senior athletes).

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Data availability statement: The data presented in this study are available on request from the corresponding author.

References:

[1] Manoharan VS, Sundaram SG, Jacob IJ. Factors affecting hand grip strenght and its evaluation: a systemic review. International Journal of Physiotherapy and Research. 2015; vol. 3 no. 6, pp. 1288-1293.

[2] Gerodimos V. Reliability of handgrip strength test in basketball players. Journal of Human Kinetics. 2012; vol. 31, pp. 25-36.

[3] Gaurav V, Singh M, Singh S, Singh and Sandeep A. A study of hand dimensions and hand grip strength between adolescent basketball and volleyball players. American International Journal of Research in Humanities, Arts and Social Sciences. 2015; vol. 3, no. 10, pp. 287-289.

[4] Marques MC, Tillaar R, Vescovi JD, González-Badillo JJ. Relationship between throwing velocity, muscle power, and bar velocity during bench press in elite handball players. International Journal of Sports Physiology and Performance. 2007;2:414-422.

[5] Ruprai RK, Tajpuriya SV, Mishra N. Handgrip strength as determinant of upper body strength/physical fitness: a comparative study among individuals performing gymnastics (ring athletes) and gymnasium (powerlifters). International Journal of Medical Science and Public Health. 2016;5(6):1167-1172.

[6] Gürer B, Yildiz ME. Investigation of sport rock climbers' handgrip strength. Biology of Exercise. 2015;11(2):55-71.

[7] Foo LH, Zhang Q, Zhu K, Ma G, Greenfield H, Fraser DR. Influence of body composition, muscle strength, diet and physical activity on total body and forearm bone mass in Chinese adolescent girls. British Journal of Nutrition. 2007;98(6):1281-1287.

[8] Iermakov SS, Podrigalo LV, Jagiełło W. Hand-grip strength as an indicator for predicting the success in martial arts athletes. Archives of Budo. 2016;12:179-186.

[9] Zaggelidis G. Maximal Isometric Handgrip Strength (HGS) in Greek Elite Male Judo and Karate Athletes. Sport Science Review. 2016; 25(5-6):321-344.

[10] Franchini E, Del Vecchio FB, Matsushigue KA, Guilherme G. Artioli GG. Physiological Profiles of Elite Judo Athletes. Sports Medicine. 2011;41(2):147–166.

[11] Dias AJ, Wentz M, Külkamp W, Mattos D, Goethel M, Júnior BN. Is the handgrip strength performance better in judokas than in non-judokas. Science & Sports. 2012;27: e9-e14.

[12] Gutiérrez-Sánchez Á, Soria-Domínguez A, Pérez-Turpin JA, Cortell Tormo JM, Concepción Suárez Llorca CS. Importance of hand-grip strength as an indicator for predicting the results of competitions of young judokas. Archives of Budo. 2011; vol. 7 no. 3, pp. 167-172.

[13] Franchini E, Schwartz J, Takito MY. Maximal isometric handgrip strength: comparison between weight categories and classificatory table for adult judo athletes. Journal of Exercise Rehabilitation. 2018;14(6):968-973.

[14] Little N.G.. Physical performance attributes of junior and senior women, juvenile, junior and senior men judokas. Journal of Sports Medicine and Physical Fitness. 1991;31: 510–520.

[15] Szopa J, Mleczko E, Żak S. Podstawy antropomotoryki. Kielce; 1999.

[16] Bonitch-Góngora JG, Almeida F, Padial P, Bonitch-Domínguez JG, Feriche B. Maximal isometric handgrip strength and endurance differences between elite and non-elite young judo athletes. Archives of Budo. 2013;9 (4):239-248.

[17] Gutiérrez-Sánchez Á, Soria-Domínguez A, Pérez-Turpin JA, Cortell Tormo JM, Concepción Suárez Llorca CS. Importance of hand-grip strength as an indicator for predicting the results of competitions of young judokas. Archives of Budo. 2011;7(3):167-172.

[18] Lech G, Pałka T, Tyka A, Jaworski J, Chwała W, Sterkowicz S, Ambroży T. Effect of motor abilities on the course of fight and achievement level in judokas at different age. Archives of Budo Science of Martial Arts and Extreme Sports. 2015; 11:169-179.

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SELECTED TARGETED FITNESS PARAMETERS IN YOUTH HANDBALL PLAYERS AS PART OF THE OSPR PROJECT IMPLEMENTED IN 2018-2021

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

Keywords: handball, targeted fitness, fitness tests, control of training effects, handball training centres

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Abstract:

Introduction: handball is a team game in which the level of physical fitness plays a very important role with regard to the ability to perform training tasks and the course and final outcome of a competition. The aim of the study was to evaluate the targeted fitness parameters of young handball players as part of the Handball Training Centres project and to quantify the young people who achieve the best results in the targeted fitness parameters.

Methods: the participants of the study were 1,943 girls and 2,075 boys practising handball in 16 voivodeship handball training centres between 2018 and 2021. Mean values for weight, height, age, and competitive experience are given in the body of this study.

Results: the mean values of the 30m run ranged from 4.92 to 5.29s in girls and from 4.50 to 5.29s in boys. The mean values for envelope runs with ball dribbling were 27.24-29.86s in girls and 25.41-27.30s in boys. The mean value of the distance run in the Beep Test was 1022.4-1359.44m in girls and 1261.18-1877.94m in boys. Other results are presented in detail further in the text.

Conclusion: based on the result of the Beep Test, it is possible to select the individuals who perform best in other tests of targeted fitness. About 19.7% of girls and 21.0% of boys achieved the best results in the targeted fitness parameters. The worst results were obtained for the 30m run and the envelope run with ball dribbling, while the best results were found in the vertical jump test and the push-up test.

Introduction

Handball is a game based on natural human movements such as running, jumping, and throwing, and is an excellent tool for the all-round development of children and young people's motor skills. In assessing the nature of the game at a professional level, it should be considered as an extremely varied, highly emotional game under constantly changing conditions that requires a variety of actions from the player during the sports competition. The demands of the game require players to be prepared in a multifaceted way. They refer to the ongoing development of strength and conditioning as well as technical and tactical potential, on which the sports performance largely depends.

In modern training, it is essential to manage the process efficiently to achieve the set objectives [1]. Therefore, for proper management of the training process, a constant supply of information about the effects of the activity and the adaptive changes of the athlete's body as a response to the applied loads is necessary. These objectives are met by a control system integrated into the training process, from the programming stage throughout the planning stages [2].

The principle of control of training effects assumes a systematic, ongoing, and periodic control of the outcomes of the applied training loads. The principle of the efficiency of the impact is based on providing immediate and reliable information about the quality of the tasks performed and the state of the athlete's body [1]. The control of general and special fitness includes current control – providing immediate information on the training or game effects, operational control – providing information on the effects of work over a longer period (1-3 months), and periodic control - taking into account several important components of biological, motor, mental, and technical development [1].

Assessment by means of tests plays a very important role in terms of its control, diagnostic, prognostic, informational, motivational, didactic, and social functions. During the training process, student-athletes are subjected to ongoing and staged control. The task of the former is to determine the direct effect of the training process on selected psychophysical parameters. The task of stage control is to determine the dynamics of the progression of the somatic, physiological, motor, pedagogical, and psychological parameters [3]. Whether training on the court, in the pool, or the gym, an athlete must eventually specialise in his or her sport. Sport-specific training should result in physiological adaptations appropriate to the specific movement pattern, metabolic requirements, mode of strength development, type of muscle contraction, and pattern of muscle recruitment [4].

Special preparation of an athlete determines his or her ability to play a particular sport. Studies of athletes using measurable forms of motor and technical performance assessment (tests) are helpful in accurately determining training measures. These tests also play a controlling role, which is why the use of tests assessing the level of motor fitness and technique has become a necessity in the modern training of athletes, from the level of children to that of professional sports [5]

The aim of the study was to evaluate the targeted fitness parameters of young handball players as part of the Handball Training Centres (Ośrodki Szkolenia w Piłce Ręcznej – OSPR) project, and to quantify (in percentage terms) the participants who achieve the best results in the targeted fitness parameters.

For the purposes of this study, the following questions were formulated:

1. What values did the participants obtain in the targeted fitness tests?
2. What percentage of participants achieved reference values?
3. In which trials of the targeted fitness test is there the highest number of scores rated as high?

Materials and methods

The participants of the study were girls and boys who practised handball, in 16 voivodeship handball training centres in 2018-2021 according to the training program guidelines of the Polish Handball Association [6]. Training classes were held three times a week for 90 minutes each for a year. The examinations were carried out during voivodeship consultations, which took place twice a year, in spring and autumn.

The methods used in the study included measurements based on the targeted fitness test (RSU) developed for the implementation of the OSPR Programme [6]:

1. 30m run. Starting from a standing position at the signal. Measurement of the running time with a stopwatch with an accuracy of 0.01s. The test was performed twice and the better result was recorded.
2. Countermovement jump. Measurement of the difference between the highest point marked by the fingers of one hand on the measurement plate and the reach of the fingers of that hand in a standing position. Measurement with an accuracy of 0.5cm. The test was performed twice and the better result was recorded.
3. Envelope run (3m x 5m envelope) with ball dribbling. Time measurement by stopwatch with an accuracy of 0.01s. The test was performed twice and the better result was recorded.
4. Push-ups (at tempo). For boys, feet and hands resting on 2 benches, and for girls, hands resting on the bench and feet resting on the ground. Measurement of the number of full arm flexion (push-ups) performed correctly (with head, torso, buttocks, and lower limbs in line). Tempo: one push-up repetition per second. The test was performed once.
5. Aerobic capacity (Beep Test) Estimation of maximal oxygen consumption (VO_2max) was performed using an indirect method based on Beep Test (Norwegian version) The test consisted of a maximum number of shuttle runs performed over a distance of 20 metres in a sports hall. The rhythm and running pace were provided by the acoustic signal test programme (Beep Test, Norwegian version) from the CD. The participant completed the test by 'refusal' or failing to run to the 20m line twice at the signal. The last section allowed the determination (from the table) of the distance in (m) and the estimated VO_2max level (in ml/kg/min) [7,8]. The test was performed once.

Statistical analysis was conducted using the SPSS v. 21 software. For the purpose of the study, descriptive statistics was used to calculate arithmetic means, maximum and minimum values, standard deviations, and percentages [9].

Results

Table 1 shows the mean values of the results of the test trials performed during the 2018-2021 OSPR voivodeship consultations by girls. It should be noted that the first consultation in 2018 involved young people one year older, so their results in the individual test trials are better than the others. A comparison of the results from the other consultations reveals that the best results in the 30m run and the envelope run with ball dribbling were achieved by the young people in autumn 2020. Furthermore, the participants achieved their best results in the push-up test and the Beep Test in autumn 2018.

Table 1. Mean values and standard deviations of the scores obtained by girls in the RSU test trials performed during voivodeship consultations in 2018-2021

Consultation, girls	Age [years]	Training experience [years]	Body height [cm]	Body mass [kg]	30m run [s]	Counter-movement jump [cm]	Envelope run with ball dribbling [s]	Push-ups [n]	Beep Test [m]
Spring 2018, N=301	15	6	166.53±6.03	57.48±8.71	4.92±0.32	38.44±675	27.24±2.07	13.65±8.72	1359.44±310.15
Autumn 2018 N=244	14	5	164.557.14±	54.789.06±	5.110.35±	37.436.80±	28.41±2.82	9.23±7.43	1274.88±349.36
Spring 2019 N=306	14	5	163.48±7.11	53.52±9.08	5.15±0.41	37.25±6.47	28.76±2.74	8.95±7.38	1117.35±389.43
Autumn 2019 N=302	14	5	161.79±7.88	51.16±10.11	5.12±0.33	34.74±6.10	29.86±2.75	7.19±6.61	1174.29±372.46
Spring 2020 N=197	14	5	163.13±6.58	52.94±9.51	5.1±0.30	36.5±6.37	29.1±3.35	9.3±7.31	1150.79±311.25
Autumn 2020 N=309	14	5	164.26±9.40	55.29±10.95	5.05±0.35	37.03±6.02	28.06±2.48	8.61±6.71	1264.58±294.38
Spring 2021 N=284	14	5	164.09±6.98	53.94±9.83	5.29±2.17	36.41±6.60	28.95±3.29	6.83±6.16	1022.49±326.48

Notes:

RSU – targeted fitness test/report,

Table 2 shows the mean values of the results of the test trials performed during the 2018-2021 OSPR voivodeship consultations by boys. It should be noted that the first consultation in 2018 involved young people one year older, so their results in the individual test trials are better than the others. A comparison of the results from the other consultations reveals that the best results in the 30m run and the Beep Test were achieved at the 2019 consultation in the spring. Furthermore, the best scores in the envelope run with ball dribbling and push-up tests were achieved during the 2018 autumn consultation.

Table 2. Mean values and standard deviations of the scores obtained by boys in the RSU test trials performed during voivodeship consultations in 2018-2021

Consultation, boys	Age [years]	Training experience [years]	Body height [cm]	Body mass [kg]	30m run [s]	Counter-movement jump [cm]	Envelope run with ball dribbling [s]	Push-ups [n]	Beep Test [m]
Spring 2018, N=304	15	6	181.10 ±7.72	70.69±10.35	4.50±0.32	49.57±8.26	25.41±1.91	23.04±9.86	1877.94±334.98
Autumn 2018 N=273	14	5	179.49±7.08	69.78±10.28	5.29±2.17	48.56±14.62	25.92±2.05	20.21±9.84	1585.95±613.03
Spring 2019 N=329	14	5	176.25±7.99	66.05±11.09	4.59±0.32	48.11±8.09	26.31±1.82	17.42±9.71	1635.29±365.99
Autumn 2019 N=315	14	5	172.49±8.94	61.04±11.70	4.65±0.34	44.82±8.42	26.87±2.31	13.57±9.53	1542.52±438.88
Spring 2020 N=225	14	5	168.58±9.29	57.78±11.47	4.93±0.40	41.04±8.49	27.30±3.01	13.57±10.15	1261.18±381.64
Autumn 2020 N=297	14	5	172.72±8.64	61.38±11.62	4.68±0.38	43.50±7.38	26.46±2.35	16.28±9.26	1572.27±378.36
Spring 2021 N=332	14	5	168.20±8.78	57.55±12.12	4.92±0.45	41.81±7.69	27.24±2.05	12.17±8.57	1334.24±406.66

Notes:

RSU – targeted fitness test/report,

Table 3 shows the percentages of the number of girls with scores in the ‘high’ category in each consultation. The largest number of participants scored ‘high’ during the autumn consultation in 2019. In contrast, the lowest number of participants scored ‘high’ during the spring consultations in 2018, 2020, and 2021. The lowest percentages of results obtained in the “high” category were found for the 30m run and the envelope run with ball dribbling. Furthermore, the highest scores were obtained in the countermovement jump and push-up test. The number of girls who scored in the “high” category in the Beep Test is at an average of 18.3%. While referring to the VO_2max values of the participants, it should be noted that the highest values were observed during the 2018 consultation and the autumn consultation in 2020. The BMI of the participants was at a similar level, between 19.5 and 20.8.

Table 3. The percentages of the number of girls who scored in the ‘high’ category in the RSU test trials at each consultation, and the mean VO_2max and BMI of the study participants

Consultation, girls	Age [years]	Training experience [years]	VO_2 max [ml/kg/min]	BMI [kg/m²]	30m run [s]	Countermovement jump [cm]	Envelope run with ball dribbling [s]	Push-ups [n]	Beep Test [m]
					%	%	%	%	%
Spring 2018, N=301	15	6	41.8±8.2	20.8±1.7	2	22	6	34	17
Autumn 2018 N=244	14	5	40.5±9.2	20.2±1.9	8	31	11	27	19

Spring 2019 N=306	14	5	37.7±9.9	20.0 ±1.8	8	42	10	33	18
Autumn 2019 N=302	14	5	38.8±9.7	19.5±1.7	13	42	7	29	24
Spring 2020 N=197	14	5	38.4±9.2	19.9±1.8	4	37	5	35	13
Autumn 2020 N=309	14	5	40.2±8.6	20.5±1.7	9	33	10	25	25
Spring 2021 N=284	14	5	36.2±9.9	19.91.9	8	38	10	22	12

Table 4 shows the percentages of the number of boys with scores in the 'high' category in each consultation. The largest number of participants scored 'high' during the autumn consultation in 2019 and 2020. In contrast, the lowest number of participants scored 'high' during the spring consultations in 2019, 2020, and 2021. The lowest percentages of results obtained in the "high" category were found for the 30m run and the envelope run with ball dribbling. Furthermore, the highest scores were obtained in the countermovement jump and push-up test. The number of boys who scored in the "high" category in the Beep Test is at an average of 18.1%. While referring to the VO_2max values of the participants, it should be noted that the highest values were observed during the 2018 consultation and in spring 2019 and autumn 2020. The BMI of the participants ranged from 20.4 to 22.5.

Table 4. The percentages of the number of boys who scored in the 'high' category in the RSU test trials at each consultation, and the mean VO_2max and BMI of the study participants

Consultation, girls	Age [years]	Training experience [years]	VO_2max. [ml/kg/min]	BMI [kg/m²]	30m run [s]	Countermovement jump [cm]	Envelope run with ball dribbling [s]	Push-ups [n]	Beep Test [m]
					%	%	%	%	%
Spring 2018, N=304	15	6	48.6±9.1	21.6±2.0	9	57	3	42	23
Autumn 2018 N=273	14	5	45.5±18.2	21.7±1.9	8	52	5	38	21
Spring 2019 N=329	14	5	45.8±10.9	21.3±1.8	11	51	0	31	10
Autumn 2019 N=315	14	5	44.9±12.5	22.5±2.1	14	44	2	22	23
Spring 2020 N=225	14	5	40.2±12.1	20.4±1.7	7	29	3	23	14
Autumn 2020 N=297	14	5	45.2±10.2	20.6±1.9	16	34	5	31	20
Spring 2021 N=332	14	5	41.5±12.2	20.4±1.8	10	33	2	23	16

Discussion

The final result in handball is influenced by many factors, with their level significantly affecting the results of the game. These include the level of morphological characteristics, general physical fitness, technical and tactical skills used in the game, strength and conditioning, and psychological and pedagogical factors related to the sports competition [3,5,10,11]. The training process needs to be monitored on a regular basis to continuously adjust the load to the current exercise capacity. The lack of constant optimisation of loads and ongoing control of effects usually leads to exceeding functional adaptive capacity, which in turn can negatively affect biological development and inhibit the development of desired skills [12-14].

Based on the results obtained from the tests it is possible to identify the athletes scoring in the "high" category. The criterion for this division is to reach the best performance in the tests. In boys, 21.0% of the players scored in the 'high' classification. The fewest, with only 12% of 'high' scores, were obtained in the 30m run and the envelope run with ball dribbling. This is not a good predictor as the speed of movement and the technique of handling the ball with a change of direction are very important elements of individual technique from the point of view of effectiveness. Similar tendencies were found in the results of girls. In this group, the lowest number of 'high' scores was also found in these two tests. The participants performed best on two tests: the countermovement jump and the push-up test. The results of the Beep Test, which evaluates aerobic capacity, were at a high level by 18.1% of girls and 18.3% of boys. Similar results in the 30m run and Beep Test were obtained by boys in studies in Greece and Germany, with average sprint scores ranging from 4.79 to 5.05s and 20m shuttle run (Beep Test) scores of 44.55 to 49.93 VO_2max [15,16]. The mean value of BMI was at a similar level in boys (21.2 kg/m^2) and adolescents from Greece and Germany (22.85 kg/m^2 and 22.32 kg/m^2, respectively). [15]. In a 2019 study by Saavedra J et al, the mean scores in boys were 4.37s for the 30m run and 22.48 kg/m^2 for BMI [17]. In girls, lower results were observed than those obtained by previous authors [17]. The mean VO_2max and BMI in girls were 40.1 ml/kg/min and 20.1 kg/m^2, respectively, and in girls from Greece, they were 47.34mL/kg/min and 21.10 kg/m^2, respectively. In the 30m run test, mean values of 5.1s were observed in the girls and 5.19s in the Greek girls [16].

The results of the research presented in this study and the results of other authors confirm that stage-based control or selection control using tools such as motor tests makes it possible to assess the performance of adolescents in a diagnostic and prognostic sense [15-20]. The results presented can to some extent add to the knowledge base in this field of research. They can also serve as reference points in the process of handball training at the youth training stage.

Conclusions

The analysis of the results obtained in the study leads to the following conclusions:

1. More attention needs to be paid to the effectiveness of developing speed in training programs for both girls and boys.
2. Training programmes should be modified by implementation of more training measures to develop individual ball handling technique.
3. The best results were achieved by the participants for the countermovement jump, push-up test, and Beep Test.
4. The score obtained in the Beep Test is an excellent tool in the assessment of comprehensive targeted fitness of youth handball players.
5. For the purpose of achieving specific training goals, the training process should be monitored and adjustments should be made to training programs.

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Informed consent statement: The participants and their legal guardians were informed about the research protocol in detail and gave their written informed consent to participate in the study.

Data availability statement: The data presented in this study are available on request from the corresponding author.

References:

[1] Sozański H. Podstawy teorii treningu sportowego. COS Warszawa, 1999.
[2] Sozański H, Zaporożanow W. Kierowanie jako czynnik optymalizacji treningu. RCMSzKFiS Warszawa, 1993.
[3] Czerwiński J. Piłka ręczna wybrane elementy teorii i treningu. ZPRP Warszawa, 2014.
[4] Bompa TO, Haff GG. Periodyzacja teoria i metodyka treningu. COS Warszawa, 2010.
[5] Czerwiński J. Piłka ręczna wybrane elementy teorii i technologii treningu. ZPRP Warszawa, 2018.
[6] Nowiński W, Kulik J. Materiały metodyczno-szkoleniowe OSPR. ZPRP Warszawa, 2015.
[7] Norkowski H, J. Noszczak. Piłka ręczna, zbiór testów. Wydawnictwo Wydziału Szkolenia ZPRP, 2010.
[8] Leger L, A, Mercier D, Godoury C, Lambert J. The multistage 20 metre shuttle run test for aerobic fitness. J Sport Sci; 6:93-1010, 1988.
[9] Stupnicki R. Biometria-krótki zarys. Wyd. MARGOS. Warszawa, 2000.
[10] Stawiarski W. Zależności sukcesów sportowych w piłce ręcznej od wieku, wzrostu, wagi oraz sprawności ogólnej i specjalnej. Biuletyn Szkoleniowo Informacyjny ZPRP nr 3, 1965.
[11] Stawiarski W. Skuteczność gry w piłkę ręczną oraz jej wpływ na wynik w zależności od poziomu sportowego i dymorfizmu płciowego. Materiały szkoleniowe ZPRP nr 4, s. 15-19, 1990.
[12] Sozański H. Kontrola treningu, jego efektów adaptacyjnych i walki sportowej. Trening 1, s. 5-11, 1996.
[13] Ważny Z. Metodologiczne problemy trafności oceny wpływu obciążeń treningowych na osiągnięcia sportowe. Sport Wyczynowy nr 7-8, str. 9-19, 1999.
[14] Zatoń M. Rodzaj bodźca treningowego i efekty adaptacyjne. Trening 1 (29) str 18-23, 1996.
[15] Galal El-Din H, Zapartidis I, Ibrahim H. A comparative study betweeen talented young Greek and German handball players in some physical and antropometric characteristics. Biol. Sport; 28;245-248, 2011.
[16] Zapartidis I, Vareltzis I, Gouvali M. Physical fitness and antropometric charakteristics in different levels of young team handball players. The Open Sports Journal, 2; 22-28, 2009.
[17] Saavedra Jose M, Halderson K, Kristjandottir H, Porgeirsson S, Sveinsson G. Antropometric characteristics, physical fitness and the prediction of throwing velocity In young men handball players. Kinesiology 51/2; 253-260, 2019.
[18] Fieseler G, Hermassi S, Schwesig R. Differences in anthropometric characteristics in relation to throwing velocity and competitive level in professional male team handball: a tool for talent profiling. Medicine The Journal of sports medicine and physical fitness,2017.
[19] Hammami R, Sekulic D, Chaouachi A. Analysis of maturity status as a determinant of the relationships between conditioning capacities and pre-planned agility in young handball athletes. Journal of Strength and Conditioning Research, 2018.
[20] Visnapuu M, Jürimäe T. Relations of anthropometric parameters with scores on basic and specific motor tasks in young handball players. Psychology, Medicine Perceptual and motor skills, 2009.

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ANAEROBIC CAPACITY IN MEN AND WOMEN IN RELATION TO SELECTED COMPONENTS OF BODY POSTURE

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A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

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Abstract:

Background: To improve the health of society and a specific professional group such as physiotherapists, one should take into consideration, for complementary diagnosis, the assessment of the level of anaerobic capacity to select training loads for regular physical activity and a diagnosis of a body posture. The aim of the present study was to identify selected components of body posture in relation to the level of anaerobic power in men and women.

Methods: The tested group included 91 students, 45 women and 46 men aged 20 to 21 years. In accordance with the objectives of the present study, selected somatic features, body posture, and anaeorobic power were performed using the WinGate test.

Results: In the study group, in the significant proportion, hollow feet, abnormal depths physiological curvatures of spine and the scoliotic posture, and to a lesser extent, laterally flat feet and pelvis sprain. The level of physical capacity shows a statistically significant corrlation with the body weight in women and men. A statistically significant correlation between anaerobic power and fat-free body mass in women and body mass and the body fat percentage in men were found. Significant correlation was noted between maximum aerobic power and lateral deviation of the spine, the maximum power with the total scope of mobility in the sagittal plane and the motility from the extension to the flexion (women), and in men between an angle kyphosis as well as between the the position of the spine in sagittal plane. In terms of tested relations, sexual dimorphism is not exposed with the exception of the level of longitudinal arch and the surface of loaded feet, lateral deviation of the spine as well as the mobility range of the spine in the sagittal and frontal planes. The level of anaerobic power the influence on the rotation of the dorsal surface and the scope of spine mobility in a bow in women and a density of adipose tissue in men have been shown.

Conclusion: Chosen elements of a body posture indicate an association with the level anaerobic power of men and women. Obtained results should find practical application, promoting a comprehensive approach in the diagnosis of the body posture and assessment of physical efficiency as determinants in the pursuit of health.

Introduction

Body posture changes are closely related to human motor behaviour. Assuming that the human body is a 'biomachine,' the dysfunction of one component affects the others, mainly the neighbouring ones. Therefore, all structural problems are reflected in the functioning of the body and there is a need for an accurate assessment of the capacity in conjunction with body posture. Body posture diagnosis is of interest to many researchers worldwide [1-4], and its important elements are accuracy and precision. While analysing the results presented in the literature, one can point out that although there are many methods and tools for assessing body posture, it is difficult to find a perfect method for the whole body.

Considering the multifaceted nature of body posture, one should also consider the high probability of the occurrence of faulty postures and postural defects correlated with lifestyle in different social groups, as confirmed in the analysis performed by Woynarowska and Oblacińska [5]. The authors show that in 1999–2009, there was a deterioration in physical fitness and an increase in body adiposity in the age group of 9–19 years. A large regression in muscle strength, endurance, and flexibility was also observed, which may be related to segmental spine mobility. The condition of the musculoskeletal system, closely related to the body build, influences the body posture, which depends, among others, on an efficient and correctly formed musculoskeletal system, mobility, and stability within particular spine segments, an efficient osteoligamental system, and a compatible nervous system [6]. Body posture determines health and physical and mental well-being. These are also to a large extent determined by an individual's immunity, defence and compensatory mechanisms, and adaptive capabilities. A significant percentage of disorders are due to lack of physical activity and eating disorders, associated not only with food quality or quantity but also with numerous food intolerances.

The notion of physical capacity is identified with the ability to undertake long-lasting efforts of moderate intensity [7–12]. Not without significance is the physiological response of the body to a given effort, which depends, among others, on the increase in energy demand, the level of training, or the temperature of the environment. The adaptive capacity of organs, mainly the cardiovascular system, blood oxygen capacity, and the efficiency of cellular biochemical mechanisms related to energy acquisition are responsible for the efficiency of the abovementioned processes. According to the U.S. Department of Health and Human Services [13], there is a direct relationship between physical activity and life expectancy, and researchers indicate that populations engaging in physical activity live longer. In diagnosing the physical capacity of active people, it is necessary to consider the indices of the aerobic and anaerobic components of physical capacity. The anaerobic capacity of the body, i.e. the ability to undertake short-term physical efforts of very high intensity, is assessed most frequently based on work volume or average power [14–16]. Both indices highly correlate with maximal anaerobic capacity, regarded as the main measure of anaerobic capacity [15].

The study was to assess the relationship between anaerobic capacity and selected body posture indices. The following research questions were posed:

1. Does maximal anaerobic capacity exhibit a relationship with selected body build and posture indices?
2. Is there any dimorphism in the above relationships?
3. Is the occurrence of the analysed body posture defects the same in participants with high and low maximal anaerobic capacity?

Materials and methods

Study group

The study involved 91 participants: 45 females and 46 males aged 20–21 years and was conducted at the Podhale State College of Applied Sciences in Nowy Targ, Poland. The participants were informed about the study conditions and provided their written consent to participate, with the possibility to withdraw at any stage without giving any reason. The research was supervised by a paramedic. The inclusion criteria involved declared good health, no contraindications, and blood pressure not exceeding 140/90 mm Hg. The individuals entered the tests in sportswear, in the afternoon, at least 2 hours after a light meal. The purpose and procedure of the research were explained. The participants were instructed on the execution of the particular test immediately before their commencement.

Methods

Selected somatic traits, body posture, and anaerobic capacity indices were determined. The first stage of the study comprised the measurement of arterial blood pressure and basic body build indices: body height, determined with a Martin anthropometer (USA) with 0.5-cm accuracy, body weight, measured with Sartorius F150S-DZA scales (Germany), and body mass index. Body composition was estimated with the 8-electrode bioelectrical impedance method, in accordance with the methodology specified by the device manufacturer (Jawon Medical, certificate CE0197) and the criteria by Hattori et al. [17]. The investigated indicators were body fat percentage, body fat mass, and lean body mass [18,19]. Following the guidelines presented by Dehghan and Merchant [18], the participants came from one ethnic group, did not suffer from any diseases affecting water-electrolyte balance, did not undertake physical effort 2–3 hours before the bioelectrical impedance analysis, and had their fluid and food intake times controlled. For the assessment of body height, body mass, body mass index, and the results in the feet area, comparisons were made between our results and those obtained by Lizis [20]. Body mass index analysis was based on the World Health Organization classification [21].

The assessment of foot arches and load distribution was performed with a FreeMed Posture set, consisting of a computer podoscope (2D scanner) and a tensometric mat. Plantocontourogram area values were calculated with an accuracy of 1.0 mm^2 [22]. The following indices were used: right and left foot surface (cm^2), right and left forefoot and hindfoot surface (cm^2), right and left foot load (%), right and left forefoot and hindfoot load (%). From the indices of foot structure, the following values were calculated using a computer program: right and left foot length and width (mm), the surface of the soles of the feet (cm^2), load distribution on the sole side (cm^2), longitudinal arches of the right and left foot – with Clarke's angle (°), and transverse arches of the right and left foot – determined by Wejsflog W index. The spine and body posture analysis employed the DIERS Formetric III 4D and the MediMouse systems. The former allowed to evaluate the pelvic tilt (mm), pelvic torsion (°), thoracic kyphosis angle (°), lumbar lordosis angle (°), lateral deviation VPDM (mm) (rms, root mean square), back surface rotation (mm) (rms). The latter served to determine spine deviation from the anatomical axis in the frontal plane (°), range of spinal mobility in the frontal plane (°), and range of spinal mobility in the sagittal plane in the tested positions: relaxed position – forward bend (°), relaxed position – backward bend (°), forward bend – backward bend (°).

In the anaerobic capacity assessment, with maximal anaerobic capacity as the main measure, the Bar-Or test was applied [15]. The proper effort was preceded by a 5-minute warm-up on a cycle ergometer at an individually selected intensity of 50.0% of maximal oxygen uptake and a pedalling frequency of 60 revolutions · min^{-1}, with three 5-second maximal accelerations at the 2nd, 4th, and 5th minute. Two minutes after completing the warm-up, the participants performed a 10-second maximal physical effort with a load of 7.5% of body mass for men and 7.0% of body mass for women [14,15]. During this effort, among others, we recorded maximal anaerobic capacity and time to reach maximal anaerobic capacity. The anaerobic test was performed on a Monark 875E cycle ergometer (Sweden).

Statistical analysis

The results were processed with the Statistica software, ver. 13. The Shapiro-Wilk test determined whether the variables in each group approximated a normal distribution. Correlation between variables was investigated with Pearson's *r* correlation and Spearman's rho correlation tests. The test choice depended on whether the examined variables had a near-normal distribution and whether they were ordinal or ratio variables. When the distribution was close to normal and the variable was a ratio, Pearson's *r* correlation test was used; otherwise, Spearman's rho correlation test was applied. A stepwise multiple regression analysis determined the set of investigated characteristics that influenced capacity in men and women. In all analyses, effects for which the probability value *P* was less than the adopted significance level of $\alpha = 0.05$ were assumed significant ($P < 0.05$).

Results

First, descriptive statistics for the participants' basic somatic traits and maximal anaerobic capacity were presented. Then, we provided the results of correlation analyses aiming to determine the relationships between maximal anaerobic capacity and body posture. The final stage was to present the results of the stepwise multiple regression analysis, which established the relationships between selected body posture components and maximal anaerobic capacity.

Mean body height was 166.6 ± 5.70 cm in women and 179.0 ± 5.50 cm in men. As for body mass, the mean values equalled 61.6 ± 8.60 kg in women and 80.5 ± 10.90 kg in men (Table 1).

With regard to the maximal anaerobic capacity measurement (Table 2), a weak index was recorded in 22.22% of women and 13.04% of men. Sufficient maximal capacity was found in 13.33% of women and 28.26% of men. Overall, 22.22% of women and 34.78% of men were classified below the average, whereas average values of the index were reached by 40.00% of women and only 15.22% of men. Only 2.22% of women and 6.52% of men were above the average. A very good level of maximal capacity was not achieved by any of the participants, with only 1 person (male) with the value of the index at the elite level (Figure 1).

Table 1. Descriptive statistics for basic somatic characteristics and body composition

Variable	Women		Men	
	M	SD	M	SD
BH (cm)	166.60	5.70	179.0	5.50
BM (kg)	61.60	8.60	80.50	10.90
BMI (kg · m^{-2})	18.80	2.70	22.60	2.80
LBM (kg)	44.60	4.27	62.75	6.28
BFM (kg)	16.72	4.72	17.09	6.22
BFP (%)	26.97	5.27	20.89	5.44

BH – body height, BM – body mass, BMI – body mass index, LBM – lean body mass, BFM – body fat mass, BFP – body fat percentage

Table 2. Descriptive statistics for maximal anaerobic capacity

Variable	Women		Men	
	M	SD	M	SD
Maximal anaerobic capacity (W · kg^{-1})	8.77	0.79	11.00	1.46

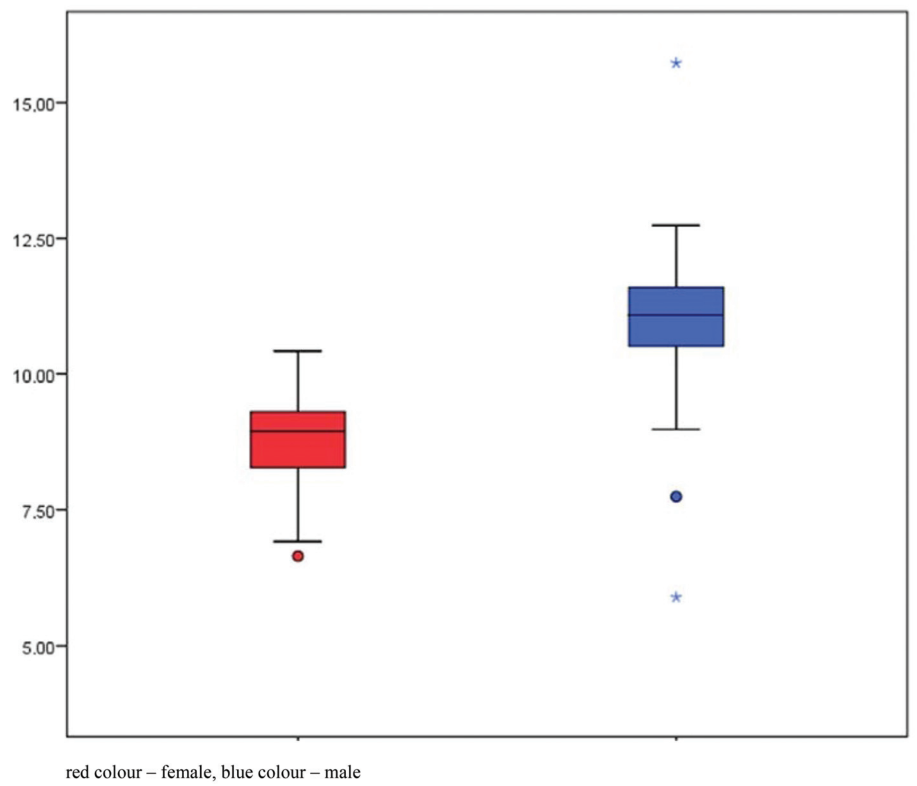

Figure 1. Graphical representation of maximal anaerobic capacity results

In the male group, a statistically significantly high correlation was observed between maximal oxygen uptake and body fat mass (r = –0.531; P > 0.001) and body fat percentage (r = –0.613; P > 0.001). Men with higher body fat percentage exhibited higher anaerobic capacity. In the female group, no significant correlations were found (P > 0.05) (Table 3).

Table 3. Results of Pearson's *r* correlation test of relationships between maximal anaerobic capacity and selected somatic traits

Variable		Women ($n = 45$)	Men ($n = 46$)
		MAP	MAP
BH	*r*	–0.040	0.194
	P	0.793	0.195
BM	*r*	0.019	–0.176
	P	0.901	0.242
BMI	*r*	0.038	–0.204
	P	0.803	0.173
LBM	*r*	0.023	0.143
	P	0.883	0.342
BFM	*r*	–0.065	–0.531*
	P	0.671	0.000
BFP	*r*	–0.086	–0.613*
	P	0.576	0.000

MAP – maximal anaerobic capacity, BH – body height, BM – body mass, BMI – body mass index, LBM – lean body mass, BFM – body fat mass, BFP – body fat percentage

* correlation significant at the level of 0.01 (two-sided)

In the female group, the analysis indicated a statistically significant positive average correlation between maximal anaerobic capacity and right foot surface ($r = 0.312$; $P = 0.037$). This means that higher values of maximal capacity were recorded among women with a larger load-bearing area of the right foot. There was also a trend ($0.1 > P > 0.05$) implying a positive weak relationship between left foot surface and maximal capacity ($r = 0.273$; $P = 0.070$). This means that women with higher left foot load-bearing area were likely to have higher maximal anaerobic capacity (Table 4).

Table 4. Results of Pearson's *r* correlation test examining relationships between maximal anaerobic capacity and foot load indices

Variable		Women ($n = 45$)	Men ($n = 46$)
		MAP	MAP
Left foot surface	*r*	0.273	–0.156
	P	0.070	0.301
Right foot surface	*r*	0.312*	–0.120
	P	0.037	0.426
Left foot percentage load	*r*	–0.142	–0.119
	P	0.353	0.431
Right foot percentage load	*r*	0.142	0.119
	P	0.353	0.431

MAP – maximal anaerobic capacity

* Correlation significant at 0.05 (two-sided)

For the analyses of the correlation of pelvic tilt and pelvic torsion with anaerobic capacity, the non-parametric Spearman's rho correlation test was used due to the smaller numbers of participants (resulting from the deviations to the left or right side). The results did not indicate statistically significant relationships between these variables ($P > 0.05$). In the male group, there was a trend suggesting a correlation between maximal capacity and pelvic tilt to the left ($r_s = -0.376$; $P = 0.077$) and pelvic torsion to the right ($r_s = 0.352$; $P = 0.066$).

In the female group, Pearson's *r* correlation test revealed a significant relationship between maximal anaerobic capacity and back surface rotation ($r = 0.323$; $P = 0.030$). There were no significant correlations for the other variables in the female group (Table 5).

Table 5. Relationships between maximal anaerobic capacity and pelvic position, angle of spinal kyphosis and lordosis, and body posture indices

Variable		Women ($n = 45$)	Men ($n = 46$)
		MAP	MAP
Pelvic tilt to the right[a]	r_s	–0.168	–0.114
	P	0.601	0.699
Pelvic tilt to the left[a]	r_s	–0.171	–0.376
	P	0.394	0.077
Pelvic torsion to the right[a]	r_s	–0.192	0.352
	P	0.337	0.066
Pelvic torsion to the left[a]	r_s	–0.238	–0.150
	P	0.358	0.579
Kyphosis angle	*r*	0.037	0.044
	P	0.811	0.773
Lordosis angle	*r*	–0.224	0.062
	P	0.138	0.682
Back surface rotation	*r*	0.323*	–0.095
	P	0.030	0.528
Lateral deviation VPDM	*r*	0.129	–0.143
	P	0.399	0.342

MAP – maximal anaerobic capacity

[a] Spearman's rho correlations calculated for participants with pelvic tilt/torsion

* Correlation significant at the level of 0.05 (two-sided)

In the female group, a statistically significant positive weak correlation was found between maximal anaerobic capacity and forward bend ($r = 0.378$; $P = 0.010$), which means that individuals with a greater range of forward bend were characterized by higher maximal anaerobic capacity. There was also a statistically significant positive correlation of maximal anaerobic capacity with the range of mobility in the sagittal plane, i.e. from extension to bend ($r = 0.342$; $P = 0.022$), implying that participants with a greater range of mobility presented higher maximal anaerobic capacity.

The results obtained in the female group also showed a statistically significant positive weak correlation of maximal anaerobic capacity with the total range of mobility in the sagittal plane ($r = 0.375$; $P = 0.011$), suggesting that women with a greater range of mobility are likely to have higher maximal anaerobic capacity (Table 6).

Table 6. Results of Pearson's *r* correlation test of relationships between maximal anaerobic capacity and the spinal range of mobility in the sagittal and frontal planes

Variable		Women ($n = 45$)	Men ($n = 46$)
		MAP	MAP
Pelvic tilt to the right[a]	r_s	–0.168	–0.114
	P	0.601	0.699
Pelvic tilt to the left[a]	r_s	–0.171	–0.376
	P	0.394	0.077

Pelvic torsion to the right[a]	r_s	–0.192	0.352
	P	0.337	0.066
Pelvic torsion to the left[a]	r_s	–0.238	–0.150
	P	0.358	0.579
Kyphosis angle	r	0.037	0.044
	P	0.811	0.773
Lordosis angle	r	–0.224	0.062
	P	0.138	0.682
Back surface rotation	r	0.323*	–0.095
	P	0.030	0.528
Lateral deviation VPDM	r	0.129	–0.143
	P	0.399	0.342

MAP – maximal anaerobic capacity

[a] Spearman's rho correlations calculated for participants with pelvic tilt/torsion

* Correlation significant at the level of 0.05 (two-sided)

Due to the small sizes of the investigated groups, the set of independent variables (somatic determinants of maximal anaerobic capacity) included the following variables correlated with maximal anaerobic capacity: right foot Clarke's angle, right foot surface, back surface rotation, forward bend range of mobility in the female group; and body fat percentage in the male group.

The following variables were not included in the regression model despite their correlation with maximal anaerobic capacity:

- body fat mass (male group) – because of a strong correlation with body fat percentage;
- range of spinal mobility in forward bend (female group) – because of a very strong correlation with the range of mobility in forward bend from relaxed position;

Table 7. Stepwise multiple regression of maximal anaerobic capacity in relation to right foot Clarke's angle, right foot surface, back surface rotation, and forward bend range of mobility in the female group

Model	Variable	*B*	Standard error	β	*t*	*p*
1	Constant	12.033	1.585		7.594	0.000
	Right foot Clarke's angle	–0.061	0.030	–0.300	–2.064	0.045
	Multiple correlation coefficient: $R = 0.300$ Multiple determination coefficient: $R^2 = 0.069$ Equation significance: $F = 4.262$; P = 0.045					
2	Constant	11.061	1.602		6.905	0.000
	Right foot Clarke's angle	–0.054	0.029	–0.262	–1.854	0.071
	Back surface rotation	0.157	0.077	0.289	2.040	0.048
	Multiple correlation coefficient: $R = 0.415$ Multiple determination coefficient: $R^2 = 0.133$ Equation significance: $F = 4.368$; P = 0.019					
3	Constant	8.895	1.873		4.750	0.000
	Right foot Clarke's angle	–0.033	0.030	–0.160	–1.100	0.278
	Back surface rotation	0.149	0.074	0.275	2.011	0.050
	Forward bend range of mobility	0.011	0.005	0.296	2.045	0.047
	Multiple correlation coefficient: $R = 0.499$ Multiple determination coefficient: $R^2 = 0.194$ Equation significance: $F = 4.527$; P = 0.008					

- range of spinal mobility in backward bend (female group) – because of a very strong correlation with the range of mobility in backward bend from relaxed position.

Variables that were included in the regression equation but the distributions of their results were not close to normal were logarithmically transformed to satisfy the condition of distribution normality. The first analysis focused on the results for women (Table 7).

Two variables were significant in the regression equation. In the female group, maximal anaerobic capacity was influenced by back surface rotation ($\beta = 0.275$; P = 0.050) and forward bend range of mobility ($\beta = 0.296$; P = 0.047). The β coefficient was positive for these two variables, which, with the assumption of a linear dependence, would indicate a directly proportional relationship. The multiple determination coefficient was 0.194 (model 3), which implies that ca. 19% of the variation in maximal anaerobic capacity can be explained based on these variables. This variation is best described by back surface rotation (model 2 – 1 difference: $R^2 = 0.064$), followed by bend range of mobility (model 3 – 2 difference: $R^2 = 0.061$). Clarke's angle in models 2 and 3 did not reach a significance level below $\alpha = 0.05$. Right foot surface was excluded from the above regression equation ($t = 1.904$; P = 0.064) (Table 7).

One variable is significant in the regression equation. In the male group, maximal anaerobic capacity was influenced by body fat percentage ($\beta = -0.613$; P < 0.001). The β coefficient was negative, which, with the assumption of a linear dependence, would indicate an inversely proportional relationship. The multiple determination coefficient was 0.362, which implies that ca. 36% of the variation in maximal anaerobic capacity can be explained based on body fat percentage (Table 8).

Table 8. Stepwise multiple regression of maximal anaerobic capacity in relation to body fat percentage in the male group

Model	Variable	*B*	Standard error	β	*t*	*p*
1	Constant	14.441	0.690		20.943	0.000
	Body fat percentage	–0.165	0.032	–0.613	–5.148	0.000
	Multiple correlation coefficient: $R = 0.613$ Multiple determination coefficient: $R^2 = 0.362$ Equation significance: $F = 26.502$; P < 0.001					

Discussion

Correct body posture requires a static and dynamic balance of muscle tone, and the relaxed posture can be corrected by consciously tensing relevant muscle groups, which is a forced state and therefore temporary and often impossible to achieve. The body tries to reduce the impact of faulty posture and postural defects through compensatory mechanisms, which also affect the function of internal organs. Scoliosis, for example, adversely affects the function of the circulatory and respiratory systems. Bioenergetic processes and neurohumoral activity are also impaired [23]. Children with postural defects are characterized by decreased aerobic glycolysis with an increased proportion of anaerobic glycolysis. They also exhibit hypoxaemia, reduced maximal oxygen uptake indices, and decreased total physical capacity measured in PWC170 and PWC150 tests. Moreover, the hyperventilation syndrome is observed, consisting in an increased frequency of respiratory movements and raised respiratory minute ventilation, which are treated as a compensatory reaction aimed at eliminating hypoxia (oxygen deficiency in the tissues) and hypoxaemia (oxygen deficiency in the blood) [23]. One can therefore conclude that the more advanced the scoliotic process, the greater the child's disorders in this area.

Pujszo et al. [24] investigated the relationships between body posture control and anaerobic capacity in women and concluded that anaerobic physical effort interfered with body posture control and that the physiological state of the body interfered with body posture, i.e. balance. Furthermore, the authors observed that a disturbance of body posture control by maximal anaerobic effort was highly correlated with a disturbance of body posture control by a series of rolls (rotational movements), which might imply an identical mechanism of labyrinth interference.

In the present study, maximal anaerobic capacity, in accordance with the classification by Zupan et al. [25], was 8.77 W kg^{-1} in women and 11.00 W kg^{-1} in men. The indicator was weak in 22.22% of women and 13.04% of men, and sufficient in 13.33% of women and 28.26% of men. Overall, 22.22% of women and 34.78% of men were classified below the average, whereas average values of the indicator were reached by 40.00% of women and only 15.22% of men. Only 2.22% of women and 6.52% of men were above the average. A very good level of maximal capacity was not achieved by any participant, with only 1 person (male) showing the index at the elite level. In the study group, a high correlation was revealed between maximal capacity and body fat mass (r = –0.531; P > 0.001) and body fat percentage (r = –0.613; P > 0.001). These correlations show that men with lower body mass and body fat percentage exhibit higher anaerobic capacity.

In analysing the relationships between somatic characteristics of the feet and anaerobic capacity in the examined women, one should point at a statistically significant negative average correlation between maximal anaerobic capacity and right foot Clarke's angle (r = –0.300; P = 0.045). Females with a greater Clarke's angle, reflecting right foot longitudinal arches, presented lower maximal anaerobic capacity values.

The analysis of the relationships between the foot load and anaerobic capacity in women revealed a statistically significant positive average correlation between maximal anaerobic capacity and right foot surface (r = 0.312; P = 0.037). Women with a larger loaded area of the right foot presented higher values of maximal capacity. Regarding the other variables, only a trend (0.1 > P > 0.05) was found, indicating a positive weak relationship between left foot surface and maximal capacity (r = 0.273; P = 0.070). Women with a larger loaded area of the left foot were likely to exhibit higher levels of maximal capacity.

In the male group, with regard to spine position and pelvic alignment, there was a statistically significant positive correlation between maximal anaerobic capacity and back surface rotation (r = 0.323; P = 0.030). There was also a trend (0.10 > P > 0.05) suggesting a correlation between maximal anaerobic capacity and pelvic tilt to the left (r_s = –0.376; P = 0.077) and pelvic torsion to the right (r_s = 0.352; P = 0.066).

For the range of spinal mobility in the female group, a statistically significant positive weak correlation was found between maximal anaerobic capacity and the range of mobility in the sagittal plane, i.e. from extension to bend (r = 0.342; P = 0.022), and total range of mobility in the sagittal plane (r = 0.375; P = 0.011). Women with a greater range of forward bending and total mobility in the sagittal plane exhibited higher maximal anaerobic capacity.

Maximal anaerobic capacity was influenced by back surface rotation (β = 0.275; P = 0.050) and bend range of mobility in the sagittal plane (β = 0.296; P = 0.047) in females and by body fat percentage (β = –0.613; P < 0.001) in males.

Low levels of maximal anaerobic capacity and significant abnormalities in the body posture of the study participants suggest the need to increase their activity levels, which are likely to correct their body posture and improve physical capacity. Lifestyle changes can also impact work comfort and the quality of services provided, implying the maintenance of health and well-being.

Conclusions

1. The level of maximal anaerobic capacity shows a statistically significant relationship with body mass in both sexes. In men, a statistically significant correlation was observed between anaerobic capacity and lean body mass and body fat percentage. In women, a statistically significant correlation was demonstrated between maximal anaerobic capacity and the loaded area of the right foot, spine position, and range of motion in the sagittal plane.
2. There was no dimorphism between the selected body posture components and maximal anaerobic capacity, except for the level of longitudinal arches of the feet and feet loading surface, lateral deviation of the spine, and the range of its mobility in the sagittal and frontal planes.
3. Maximal anaerobic capacity influenced back surface rotation and spinal range of motion in the forward bend in women and body fat percentage in men.

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Informed consent statement: The participants and their legal guardians were informed about the research protocol in detail and gave their written informed consent to participate in the study.

Data availability statement: The data presented in this study are available on request from the corresponding author.

References:

[1] Ludwig O, Mazet C, Mazet D, Hammes A, Schmitt E. Changes in habitual and active sagittal posture in children and adolescents with and without visual input – implications for diagnostic analysis of posture. J Clin Diagn Res. 2016;10(2):SC14–SC17. https://doi.org/10.7860/JCDR/2016/16647.7283

[2] Johnson J. Postural correction. An illustrated guide to 30 pathologies. Human Kinetics, Champaign 2018.

[3] Maciałczyk-Paprocka K, Stawińska-Witoszyńska B, Kotwicki T, Sowińska A, Krzyżaniak A, Walkowiak J, Krzywińska-Wiewiorowska M. Prevalence of incorrect body posture in children and adolescents with overweight and obesity. Eur J Pediatr. 2017;176(5):563–572. https://doi.org/10.1007/s00431-017-2873-4

[4] Borek JM, Malak RE, Matthews-Brzozowska T, Samborski W. Posturography examination as a diagnostic tool in children – a review of the literature. J Med Sci. 2019;88(1):34–38. https://doi.org/10.20883/jms.2019.333

[5] Woynarowska B, Oblacińska A. Stan zdrowia dzieci i młodzieży w Polsce. Najważniejsze problemy zdrowotne. Studia BAS. 2014;2(38):41–64.

[6] Zwierzchowska A. Biomedyczne i pedagogiczne podstawy rozwoju i oceny dziecka specjalnych potrzeb edukacyjnych. AWF, Katowice 2015.

[7] Chmura J, Nazar K, Kaciuba-Uściłko H. Choice reaction time during graded exercise in relation to blood lactate and plasma catecholamine thresholds. Int J Sports Med. 1994;15(4):172–176. https://doi.org/10.1055/s-2007-1021042

[8] Viru A. Adaptation in sports training. CRC Press, Boca Raton 1995.

[9] Kozłowski S, Nazar K. Wprowadzenie do fizjologii klinicznej. Wydawnictwo Lekarskie PZWL, Warszawa 1999.

[10]. Bassett DR Jr, Howley ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. Med Sci Sports Exerc. 2000;32(1):70–84. https://doi.org/10.1097/00005768-200001000-00012

[11] Bompa TO, Haff GG. Periodyzacja – teoria i metodyka treningu. Centralny Ośrodek Sportu, Warszawa 2010,

[12] Nazar K. Fizjologia wysiłków fizycznych. In: Jegier A, Nazar K, Dziak A (eds) Medycyna sportowa. Polskie Towarzystwo Medycyny Sportowej, Warszawa; 2005. pp 19–27

[13] U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans. http://www.health.gov/PAGuidelines/pdf/paguide.pdf (Accessed: 16 August 2018).

[14] Dotan R, Bar-Or O. Load optimization for the Wingate Anaerobic Test. Eur J Appl Physiol Occup Physiol. 1983;51(3):409–417. https://doi.org/10.1007/BF00429077

[15] Bar-Or O. The Wingate anaerobic test. An update on methodology, reliability and validity. Sports Med. 1987;4(6):381–394. https://doi.org/10.2165/00007256-198704060-00001

[16] Górski J. Fizjologia wysiłku i treningu fizycznego. Wydawnictwo Lekarskie PZWL, Warszawa 2012.

[17] Hattori K, Tatsumi N, Tanaka S. Assessment of body composition by using a new chart method. Am J Hum Biol. 1997;9(5):573–578. https://doi.org/10.1002/(SICI)1520-6300(1997)9:5<573::AID-AJHB5>3.0.CO;2-V

[18] Dehghan M, Merchant AT. Is bioelectrical impedance accurate for use in large epidemiological studies? Nutr J. 2008;7:26. https://doi.org/10.1186/1475-2891-7-26

[19] Ackland TR, Lohman TG, Sundgot-Borgen J, Maughan RJ, Meyer NL, Stewart AD, Müller W. Current status of body composition assessment in sport: review and position statement on behalf of the ad hoc research working group on body composition health and performance, under the auspices of the I.O.C. Medical Commission. Sports Med. 2012;42(3):227–249. https://doi.org/10.2165/11597140-000000000-00000

[20] Lizis P. Sklepienie stóp oraz ich związki z wybranymi cechami morfologicznymi i funkcjonalnymi studentów. AWF, Kraków 2012.

[21] World Health Organization. Body mass index – BMI. https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi (Accessed: 16 August 2018)

[22] Demczuk-Włodarczyk E. Budowa stopy w okresie rozwoju progresywnego człowieka. AWF, Wrocław 2003.

[23] Tuzinek S, Biniaszewski T, Ratyńska A. Podstawy teorii i metodyki gimnastyki kompensacyjno-korekcyjnej. Politechnika Radomska, Radom 2010.

[24] Pujszo R, Błach W, Smaruj M, Adam M Wydolność fizyczna beztlenowa a kontrola postawy ciała kobiet. In: Rutkowska E (ed). Sport vs. wellness. NeuroCentrum, Lublin; 2008. pp 161–168

[25] Zupan MF, Arata AW, Dawson LH, Wile AL, Payn TL, Hannon ME. Wingate Anaerobic Test peak power and anaerobic capacity classifications for men and women intercollegiate athletes. J Strength Cond Res. 2009;23(9):2598–2604. https://doi.org/10.1519/JSC.0b013e3181b1b21b

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PROFILE OF SELECTED INDICES OF POSTURAL STABILITY IN MEMBERS OF THE POLAND NATIONAL BADMINTON TEAM COMPARED TO NON-ATHLETE STUDENTS

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

Keywords: postural stability, balance, badminton, elite athletes, students

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Abstract:

Background: Badminton is numbered among the fastest racket sports. Movements during a match are characterized by spatial and temporal limitations resulting from the game regulations and opponents' actions. The aim of this research was to determine the levels of selected indices of postural stability of elite badminton players compared to a non-athlete comparison group.

Methods: The study material consisted of results collected in a group of 10 members of the Poland national badminton team (age: 22.7 ± 24.64) and 29 non-athlete students (age: 21.67 ± 0.88). The scope of the study included eleven selected indices of postural stability. The examinations were conducted using a Microgate GYKO triaxial accelerometer. The Student's t-test or Mann-Whitney U test (depending on the variance and distribution) were used to evaluate the significance of differences in postural stability between the two groups. The magnitude, extent, and direction of intergroup variation in the indices of postural stability were determined by the magnitude of the normalized differences.

Results: Statistically significant differences between non-athletes and badminton players were obtained for 7 indices of postural stability. The magnitudes of the normalized differences ranged from 0.31 SD (Mean Velocity) to 2.10 SD (Length AP).

Conclusions: Badminton players showed higher levels of all analyzed indices of postural stability. These results were likely to have been caused by the nature of the sport the participants were involved in. In the training of young badminton players, special attention should be paid to exercises that improve postural stability.

Introduction

The history of badminton dates back to ancient times and has a long tradition with different versions of the game using a racket and a cork with feathers. This is evidenced by drawings and descriptions of religious rituals and playing using an item similar to a modern shuttlecock. Over time, the game has evolved, becoming a professional sport and gaining international recognition. Badminton likely originated in India in the late 19th century during British colonial rule. It became an entertainment for military officers who played the game in their leisure time. Initially, the game was known by various names, such as “poona,” “pune” and “battledore and shuttlecock.” Finally, in 1875, the name “badminton” first appeared, derived from the name of the Duke of Beaufort’s residence [1-2]. As the sport developed, the rules of the game evolved, and, in the 1940s and 1950s, badminton began to gain popularity also outside the UK and Asia. Although the sport is dominated by Asians, in recent years more and more athletes from various European and American countries have perceived its attractiveness and are developing their skills. It is estimated that more than 300 million people around the world participate in this sport at both recreational and professional levels [3]. It has become one of the most popular and dynamic sports in the world. Played by both amateur and professional athletes, badminton attracts crowds of fans who not only admire the technical and tactical skills of the players but also like the excitement of the matches played on the court. Especially in Asian countries, its popularity is even higher than of football [4]. This resulted in badminton being included in the Barcelona Olympic Games program for the first time in 1992 [2,5]. The Badminton World Federation (BWF) was founded in London on July 5, 1934, with Poland joining in 1972. BWF currently has 199 member nations [6], including Poland, which joined in 1972.

Badminton is a challenging game, requiring players to have physical fitness, a high level of strength and conditioning, and coordination, technical, and tactical skills [5,7]. Given the specific nature of the game, badminton players constantly have to adapt to dynamically changing situations on the court. Thus, the sport can be included in the categories that have the highest level of variability of movement structures [8]. The game is dominated by stimuli of external origin and open motor structures. Therefore, the badminton player has to process different types of information simultaneously. On the other hand, considering the badminton match in terms of types of loads, it was found that efforts during the match are of a speed and endurance nature. The speed effort is observed in single actions, which usually last from 6 to 12 seconds, with the shuttlecock being hit about 5 to 12 times. The endurance effort, based on aerobic exercise, is related to the total duration of the match, which usually ranges from 28 to 78 minutes [9-14]. In conclusion, during the competitions, around 60 to 70% of energy is supplied from aerobic sources, whereas the remaining 30% is generated by anaerobic sources [5]. The review of the above literature shows that the physiological determinants of badminton matches are best understood. There is also a rich literature on the level of somatic development of badminton players [5,15].

Far fewer papers have addressed the problems of the development and level of coordination motor skills in badminton players. Postural stability is also included in this group of issues. The present paper will contribute to this field of research.

The main aim of this study is to determine the level of selected indices of postural stability of badminton champions against a non-athlete control group. The following research questions were asked in the study:

- Are there statistically significant differences in the levels of selected indices of postural stability between elite badminton players and non-athlete students?
- What is the magnitude, extent, and direction of intergroup variation in the postural stability indices studied?

Materials and Methods

Characterization of the study participants

The study analysed the results collected among 10 players of the Polish badminton national team (with an average training experience of 12.80 ± 2.74 years) and 29 non-players from the University of Physical Education in Krakow, Poland. The examinations of badminton players were conducted in the final phase of the competitive period. Table 1 shows the characteristics of chronological age and basic parameters of the somatic constitution of study participants.

Table 1. Characteristics of the basic somatic features of the groups studied

Variable [unit of measurement]	Badminton players (n=10)				Non-athlete students (n=29)			
	$\bar{x}$	Min.	Max.	SD	$\bar{x}$	Min.	Max.	SD
Chronological age [years]	22.72	19.23	28.20	4.64	21.67	20.22	24.33	0.88
Body height [cm]	180.80	169.00	191.00	6.06	179.82	167.00	196.00	6.87
Body mass [kg]	74.40	67.00	83.00	5.12	75.55	63.00	92.00	7.62

Research Protocol

Postural stability tests were performed from 9:00 am to 1:00 pm using a GYKO triaxial accelerometer in a separate room providing silence and quiet. During the bipedal standing, the athletes had their feet placed straight, with no rotation in the talocrural joint. Feet were placed to the width of the hips, whereas upper limbs were freely positioned along the torso. During the test, the participant looked at a black spot marked on the wall 2 meters away. The duration of the test was 30 seconds. According to the manufacturer's recommendations, the accelerometer was placed at the T1 thoracic vertebrae level [16]. The site was determined by palpation based on the spinous processes. The data were transmitted wirelessly from GYKO to a laptop (Lenovo Yoga 500-15 i5-6200/8GB/1000/Win10).

Scope of the study

The study evaluated basic somatic parameters such as body height (b-v, measured with an anthropometer) and body weight (measured with a TANITA TBF-551 body composition analyzer). The scope of the study also included indices of postural stability: Area [mm^2], Convex Hull Area [mm2], Length [mm], Length AP [mm], Length ML [mm], Mean Distance [mm], Mean Distance AP [mm], Mean Distance ML [mm], Mean Velocity [mm/s], Mean Velocity AP [mm/s], Mean Velocity ML [mm/s]. A detailed description of the variables studied was presented in [16].

Statistical analysis

The following statistical methods were used in the study:

1. The Shapiro-Wilk W test was used to examine the normality of distributions. The homogeneity of variance was verified by means of Levene's test.
2. Basic descriptive statistics of selected indices of postural stability in the groups of students and badminton players were calculated.
3. The Student's t-test or Mann-Whitney U test (depending on the variance and distribution) was used to verify the differences between means from individual groups. Furthermore, the effect size [17] was computed and interpreted as follows: ES > 0.2 = small, > 0.5 = medium, > 0.8 = large.
4. The profiles of postural stability indices were then calculated. Standardization of the results was performed using means and standard deviations for the non-athlete participants.

The calculations were performed using the STATISTICA 13.1 PL package, and a significance level was set at $p \leq 0.05$. The effect size was calculated using the freeware program GPower 3.1, which is often used for this type of analysis [18].

Ethics

The research was conducted in accordance with the principles of the Declaration of Helsinki. Each participant provided informed consent to participate in the study and was informed of the purpose and the possibility of withdrawal from the study at any stage. The research was approved by the Bioethics Committee at the Regional Medical Chamber in Kraków, Poland (approval No. 159/KBL/OIL/2017).

Results

Tables 2 and 3 present the basic statistical characteristics of the variables analyzed in the group of badminton players and non-athlete students. As can be seen, significantly higher values of coefficients of variation were obtained in the group of non-athletes. They generally ranged from about 17.94% to as high as 74.80%. In the badminton group, the figures ranged from 22.28% to 44.36%. In both groups, the highest values of coefficients of variation were obtained for the variables Area and Convex Hull Area. In the badminton players, they were 43.36% and 44.30%, respectively. In the group of non-athlete students, these coefficients were 74.80% and 57.62%, respectively.

Table 2. Basic statistical characteristics of selected indices of postural stability in a group of non-athlete students

Variable [unit of measurement]	Non-athlete students				
	$\bar{x}$	SD	X_{min}	X_{max}	V [%]
Area [mm^2]	824.83	394.33	233.99	1678.79	74.80
Convex Hull Area [mm^2]	611.92	352.61	100.66	1836.82	57.62
Length [mm]	374.82	68.29	260.87	565.65	18.21
Length (AP) [mm]	276.78	49.62	187.53	418.76	17.92

Length (ML) [mm]	196.60	42.51	116.71	298.45	21.62
Mean Distance [mm]	10.85	3.70	4.88	18.89	34.10
Mean Distance AP [mm]	8.83	3.77	3.91	16.16	42.69
Mean Distance ML [mm]	4.73	2.12	1.20	9.35	44.82
Mean Velocity [mm/s]	12.38	2.26	8.62	18.70	18.25
Mean Velocity (AP) [mm/s]	9.14	1.64	6.20	13.84	17.94
Mean Velocity (ML) [mm/s]	6.49	1.40	3.86	9.86	21.57

Table 3. Basic statistical characteristics of selected postural stability indices in the group of badminton players

Variable [unit of measurement]	**Badminton players**				
	$\bar{x}$	**SD**	X_{min}	X_{max}	**V [%]**
Area [mm²]	447.77	194.18	103.15	673.75	43.36
Convex Hull Area [mm²]	315.57	139.81	78.24	481.98	44.30
Length [mm]	232.47	51.74	167.49	337.07	22.25
Length (AP) [mm]	172.33	41.43	119.97	267.90	24.04
Length (ML) [mm]	120.85	31.19	73.45	176.78	25.80
Mean Distance [mm]	7.68	2.00	3.16	10.35	26.04
Mean Distance AP [mm]	6.62	2.15	2.36	9.60	32.47
Mean Distance ML [mm]	2.90	0.74	1.64	3.69	25.51
Mean Velocity [mm/s]	11.62	2.59	8.37	16.85	22.28
Mean Velocity (AP) [mm/s]	8.62	2.07	6.00	13.40	24.01
Mean Velocity (ML) [mm/s]	6.04	1.56	3.67	8.84	25.82

Next, the focus of the analysis was on the evaluation of the significance of differences in the analyzed variables characterizing postural stability between badminton players and the non-athlete control group. The significance of differences between the means of the two groups was evaluated using Student's t-test for uncorrelated variables, or

Table 4. Evaluation of the significance of differences between groups with normalized values and effect size

Variable [unit of measurement]	**d**	**t /U**	**p**	**z**	**ES**
Area [mm²]	377.06	2.89	**0.01**	0.96	1.21
Convex Hull Area [mm²]	296.35	59.00^{U}	**0.00**	0.84	1.10
Length [mm]	142.35	6.00	**0.00**	2.08	2.34
Length (AP) [mm]	104.45	5.96	**0.00**	2.10	2.28
Length (ML) [mm]	75.75	5.16	**0.00**	1.78	2.03
Mean Distance [mm]	3.17	2.57	**0.01**	0.85	1.27
Mean Distance AP [mm]	2.21	105.00^{U}	0.21	0.58	1.02
Mean Distance ML [mm]	1.83	2.66	**0.01**	0.86	1.15
Mean Velocity [mm/s]	0.76	0.88	0.38	0.33	0.31
Mean Velocity (AP) [mm/s]	0.52	0.82	0.42	0.31	0.27
Mean Velocity (ML) [mm/s]	0.45	0.85	0.40	0.32	0.30

Statistically significant differences at $p \leq 0.05$ are presented in bold.

d - absolute differences between the means of the two groups; t - Student's t-test value; U - Mann-Whitney U test value (with continuity correction); z - normalized intergroup differences,

ES – effect size, > 0.2 = small, > 0.5 = medium, > 0.8 = large the Mann-Whitney U test (depending on the homogeneity of variance and normality of distribution). The respective data are presented in Table 4. Statistically significant differences between non-athletes and badminton players were obtained for 7 indices of postural stability (of 11 analyzed variables).

Regardless of the evaluation of the significance of differences in arithmetic means, absolute and normalized intergroup differences were also calculated (Table 4). This methodological approach allowed for the analysis of the differentiation within all the variables studied (expressed in different measurement units). The data in Tables 2 and 3 were used to calculate absolute and normalized intergroup differences. Analysis of the system of normalized differences revealed higher results of badminton players for all variables. Standardized intergroup differences between the two groups ranged from 0.31 SD to 2.10 SD. Significantly larger normalized differences were obtained for the length of the statokinesiogram based on the COP movement. The normalized values ranged from 1.78 to 2.10 SD. Then, normalized values of 0.96 SD and 0.84 SD were found for the area covered by the COP on the ground and the Convex Hull Area. Furthermore, the smallest values of normalized differences were obtained for Mean Velocity, Mean Velocity AP, and Mean Velocity ML. The normalized values ranged from 0.31 to 0.33 SD. From the practical point of view, in addition to the significance of intergroup differences, the effect size is also important. In our study, based on the adopted classification, a large effect size was observed for 8 variables. For the remaining 3 variables, the medium effect size was found.

Discussion

The aim of this study was to examine the level of selected indices of postural stability of badminton champions compared to a non-athlete control group. Results on postural stability indices were obtained from the GYKO triaxial accelerometer.

Comprehensive and multifaceted analysis is becoming increasingly important in the training of badminton players at both amateur and professional levels. In this training, special emphasis should be on coordination motor skills [19]. It is the high level of this group of skills that is one of the most important factors for achieving the champion level in many sports [20,21]. The highly complex nature of the game of badminton requires the processing of a lot of neurophysiological information in order to adapt to the constantly changing situations on the court [7,22-24]. Many authors have stressed the importance of coordinative motor skills in teaching playing technique [25-27].

Of the many coordination skills, balance plays a key role in badminton players due to its important effect on maintaining an upright posture, and is also essential when performing complex movements. Maintaining balance is possible with specialized neuromuscular coordination and depends on internal regulation, external factors, and the interaction between each other. This requires the cooperation of the visual organ and vestibular and somatosensory systems, controlled by the central and peripheral nervous systems. The information obtained is processed by the central nervous system and then transferred to the effector organs [28-30]. Balance disorders can result from external and internal stimuli, or pathologies in the complex balance system. Postural stability, on the other hand, is defined as the body's ability to regain a particular position once the destabilizing stimulus has ceased [31]. Balance training is an essential component of badminton training protocol, aimed at least to prevent injuries and improve performance [32]. Similar conclusions were drawn by previous authors in a review paper [33]. The authors emphasized the need for including balance exercises in training programs for athletes of various sports. They also stressed that there is no general model suitable for all sports as the specific nature and requirements of each sport must be taken into account. A review of studies published by Bellows and Wong [34] also raises similar issues. Other studies have shown that the lower limb is the area most vulnerable to badminton-related injuries [35,36]. They can account for as much as 40% to 67% of injuries in badminton players [37,38]. Therefore, in addition to improving sports performance, balance training in badminton also improves the safety of playing and reduces the risk of future ankle sprains.

Postural stability is critical in badminton as it is the ability to maintain a stable body position during a variety of movements on the court. Badminton players have to deal with sudden changes of direction, accelerations, jumps, and dynamic hitting of the shuttlecock, all of which require strong and confident posture [39]. The results of our study showed that badminton players had a significantly higher level of most variables characterizing postural stability than students from the non-athlete control group. Yüksel [40], who compared the balance of 11-year-old children came to similar conclusions. This researcher found that children who underwent badminton training had statistically significantly higher levels of this ability than their untrained peers. Furthermore, Erol [41] observed that a basic badminton training program applied to a training group of children aged 11 to 12 years had a statistically significant effect on balance levels. Research was also conducted on the level of balance between amateur badminton players and non-athletes [23]. The cited study involved 30 young adult badminton players and 33 individuals from the control group.

Badminton players showed no statistically significant differences in balance levels compared to the control group. In the context of this research, the results obtained are very interesting. As previously shown, the physical activity of non-athlete students at the University of Physical Education in Krakow was high [42]. It is generally accepted that regular physical activity has a positive effect on the level of both fitness and coordination skills (including balance). Therefore, despite the high physical activity of the students, the statistically significant differences between the groups take on additional significance.

Limitation of the study

The choice of the research sample was largely dictated by the ability to conduct balance tests in a group of athletes. This, however, limited the sample size and thus the power of the study.

It is necessary to study the effects of basic postural stability training in badminton players of different training experience and sports skill levels. Furthermore, it seems appropriate to study postural stability under various external conditions (starting positions, eyes open or closed, stable or unstable ground). Alternative balance measurement tools (stabilometric platforms, force plates) should also be considered.

Despite these limitations, we believe that our results will be used to prove the validity of the concept of the implementation of exercises aimed at improving the level of postural stability in the training process of badminton players.

Conclusion

For most of the analyzed variables of postural stability, higher values were obtained in the group of elite badminton players.

By far the largest normalized differences between the players and the control group were obtained for the length of the statokinesiogram of the COP.

These results are likely to have been caused by the nature of the sport the participants were involved in. In the training of young badminton players, special attention should be paid to exercises that improve postural stability.

Conflicts of Interest: The authors declare that they have no conflict of interest.

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References:

[1] Lim PH. The transition and transformation of badminton into a globalized game: A study of the trials and tribulations of Malaysian badminton players competing for Thomas Cup and Olympic gold medals. Shah MH, Saliha H. (eds.). MSC8 proceedings: Selected full papers. Malaysian Social Science Association. Kajang, Selangor; 2012. p. 172-187.

[2] Lim PH, Aman MS. The History of modern organized badminton and the men's team Thomas Cup Tournaments, 1948–1979. International Journal of the History of Sport. 2017;34(7-8):676-696. doi:10.1080/09523367.2017.1389904.

[3] Green R, West AT, Willems MET. Notational analysis and physiological and metabolic responses of male junior badminton match play. Sports. 2023;11(2). doi:10.3390/sports11020035.

[4] Li S, Zhang Z, Wan B, Wilde B, Shan G. The relevance of body positioning and its training effect on badminton smash. J Sports Sci. 2017;35(4):310-316. doi:10.1080/02640414.2016.1164332.

[5] Phomsoupha M, Laffaye G. The science of badminton: game characteristics, anthropometry, physiology, visual fitness and biomechanics. Sports Med. 2015; 45(4):473-95. doi: 10.1007/s40279-014-0287-2.

[6] Badminton World Federation. Available online: https://corporate.bwfbadminton.com/about/ (accessed on 27 July 2023).
[7] Jaworski J, Żak M. The structure of morpho-functional conditions determining the level of sports performance of young badminton players. J Hum Kinet. 2015;47(1):215-223. doi: 10.1515/hukin-2015-0077.
[8] Hirtz P, Starosta W. Kierunki badań koordynacji ruchowej w sporcie. Antropomotoryka. 1991;5:69-82.
[9] Abián-Vicén J, Castanedo A, Abián P, Sampedro J. Temporal and notational comparison of badminton matches between men's singles and women's singles. Int J Perf Anal Spor. 2013;13(2):310-320. doi: 10.1080/24748668.2013.11868650.
[10] Abián P, Castanedo A, Feng XQ, Sampedro J, Abián-Vicén J. Notational comparison of men's singles badminton matches between Olympic Games in Beijing and London. Int J Perf Anal Sport. 2014;14(1):42-53. doi: 10.1080/24748668.2014.11868701.
[11] Laffaye G, Phomsoupha M, Dor F. Changes in the game characteristics of a badminton match: a longitudinal study through the Olympic game finals analysis in men's singles. J Sports Sci Med. 2015;14(3):584-590.
[12] Savarirajan R. Result of heart rate, playing time and performance of Tamilnadu badminton senior ranking players. Int J Sports Sci Fitness. 2016;6(1):43–56.
[13] Valldecabres R, Benito A-M, Casal CA, Pablos C. 2015 Badminton World Championship: singles final men's vs women's behaviours. J Hum Sport Exerc. 2017;12(Proc3.):775-788. doi:10.14198/JHSE.2017.12.PROC3.01.
[14] Fu Y, Liu Y, Chen X, Li Y, Li B, Wang X, Shu Y and Shang L. Comparison of energy contributions and workloads in male and female badminton players during games versus repetitive practices. Front. Physiol. 2021;12:640199. doi: 10.3389/fphys.2021.640199.
[15] Tomaszewski P, Kęska A, Tkaczyk J, Nowicki D, Sienkiewicz-Dianzenza E. Somatic characteristics and motor fitness of elite and sub-elite Polish male badminton players. J Sports Med Phys Fitness.2018;58(10);1456-1464. doi:10.23736/S0022-4707.17.07279-6.
[16] www.gyko.it/Repower/GykoRePower_UserManual_EN.pdf (accessed on 27 July 2023).
[17] Cohen J. Statistical power analysis for the behavioral sciences (2nd edition). Hillsdale, NJ: Erlbaum Associates. 1998.
[18] Faul F, Erdfelder E, Lan AG and Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007;39(2):175-191. doi: 10.3758/bf03193146.
[19] Jaworski J, Lech G, Żak M, Madejski E, Szczepanik K. The level of selected coordination abilities in badminton players at various ages and sport skill levels as compared to non-athletes. Balt. J. Health Phys. Act. 2017;9(3):33-43.
[20] Subramanyam V, Manilal KP. The interrelationship of simple visual reaction time, choice visual reaction time and attention control among the national level players of selected disciplines of sports authority of India. Int.J. Sports Sci. Fitness. 2014;4(2): 157-164.
[21] Pion J, Segers V, Fransen J, Debuyck G, Deprez D, Haerens L, et.al. Generic anthropometric and performance characteristics among elite adolescent boys in nine different sports. Eur. J. Sport Sci. 2015;15(5):357-366. doi:10.1080/17461391.2014.944875.
[22] Kosack MH, Staiano W, Folino R, Hansen MB, Lønbro S. The acute effect of mental fatigue on badminton performance in elite players. Int J Sports Physiol Perform. 2020; 15(5):632-638. doi: 10.1123/ijspp.2019-0361.
[23] Wong TKK, Ma AWW, Liu KPY, Chung LMY, Bae YH, Fong SSM, et.al. Balance control, agility, eye-hand coordination, and sport performance of amateur badminton players: A cross-sectional study. Medicine (Baltimore). 2019;98(2):e14134. doi: 10.1097/MD.0000000000014134.
[24] Cui X, Lam WK, Gao Q, Wang X, Zhao T. Biomechanical analysis on skilled badminton players during take-off phase in forehand overhead strokes: A pilot study. Biology. 2022;11(10):1401. doi: 10.3390/biology11101401.
[25] Mooney R, Mutrie N. The effects of goal specificity and goal difficulty on the performance of badminton skills in children. Pediatr. Exerc. Sci. 2000;12(3):270-283. doi:10.1123/pes.12.3.270.
[26] Sakurai S, Ohtsuki T. Muscle activity and accuracy of performance of the smash stroke in badminton with reference to skill and practice. J. Sport Sci. 2000;8(11):901-914. doi: 10.1080/026404100750017832.
[27] Wang S, Zhang J, Yin X. A research on performance of perceptual motor skill training for badminton. Journal of Beijing Sport University. 2009;32(9):46.
[28] Singh NB, Taylor, WR, Madigan, ML, Nussbaum, MA. The spectral content of postural sway during quiet stance: Influences of age, vision and somatosensory inputs. J Electromyogr Kinesiol. 2012;22(1):131-136. doi:10.1016/j.jelekin.2011.10.007.
[29] Iwasaki S, Yamasoba T. Dizziness and imbalance in the elderly: Age-related decline in the vestibular system. Aging Dis. 2015;6(1):38-47. doi:10.14336/AD.2014.0128.
[30] Jaffri A, NewmanT, Smith B, Miller S. The dynamic leap and balance test (DLBT): a test-retest reliability study. Int J Sports Phys Ther. 2017;12(4):512-519.
[31] Błaszczyk JW. Sway ratio – a new measure for quantifying postural stability. Acta Neurobiol Exp (Wars). 2008;68(1):51-57.
[32] Malwanage KT, Senadheera VV, Dassanayake TL. Effect of balance training on footwork performance in badminton: An interventional study. PLoS One. 2022;17(11): e0277775. doi:10.1371/journal.pone.0277775.
[33] Brachman A, Kamieniarz A, Michalska J, Pawłowski M, Słomka KJ, Juras G. Balance training programs in athletes –A systematic review. J Hum Kinet. 2017;58:45–64. doi: 10.1515/hukin-2017-0088.
[34] Bellows R, Wong CK. The effect of bracing and balance training on ankle sprain incidence among athletes: A systematic review with meta-analysis. Int J Sports Phys Ther. 2018;13(3):379-388.

[35] Senadheera VV. Epidemiological review of badminton related injuries among competitive badminton players. Inter Jour Sports Sci Phys Educ. 2019;4(3):41–44. https://doi.org/10.11648/j.ijsspe. 20190403.12.
[36] Pardiwala DN, Subbiah K, Rao N, Modi R. Badminton injuries in elite athletes: a review of epidemiology and biomechanics. Indian J Orthop. 2020;54(3):237-245. doi: 10.1007/s43465-020-00054-1.
[37] Marchena-Rodriguez A, Gijon-Nogueron G, Cabello-Manrique D, Ortega-Avila AB. Incidence of injuries among amateur badminton players: A cross-sectional study. Medicine (Baltimore). 2020;99(18):e19785. doi:10.1097/MD.0000000000019785.
[38] Mohd Jamali MNZ, Selvanayagam VS, Hamid MSA, Yusof A. Prevalence, patterns and factors associated with injury: comparison between elite Malaysian able-bodied and para-badminton players. Phys Sportsmed. 2022;50(4):316-322. doi: 10.1080/00913847.2021.1930241.
[39] Du Y, Fan Y. The effect of fatigue on postural control and biomechanical characteristic of lunge in badminton players. Bioengineering. 2023;10(3):301. doi: 10.3390/bioengineering10030301.
[40] Yüksel, MF. The effect of badminton training on children’s physical development in summer sports school. İnönü University Journal of Physical Education and Sport Sciences. 2017;4(3):68-82.
[41] Erol S. Investigation of the effects of badminton basic training program applied in 11-12 years old children on motor development. Spormetre The Journal of Physical Education and Sport Sciences. 2022;20 (3):182-192. doi:10.33689/spormetre.1132471.
[42] Jaworski J, Lech G, Ambrozy T, Żak M. Profile of coordination motor abilities in elite judokas and badminton players compared to non-athletes. Biomedical Human Kinetics. 2020;12(1):17-24. doi:10.2478/bhk-2020-0003.

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THE IMPACT OF COVID-19 ON AEROBIC CAPACITY IN A LONG-DISTANCE RUNNER – A CASE STUDY

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Authors' contribution:

A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
G. Funds collection

Keywords: COVID-19, SARS-CoV-2, aerobic capacity, long-distance running, case study

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Abstract:

Background: The COVID-19 pandemic caused by the SARS-CoV-2 virus has posed a significant threat to life worldwide. Prolonged quarantine and isolation from society, necessary to prevent the spread of the virus, can lead to immobilization and lack of physical activity, which in turn may affect the organs' ability to fight viral infection and increase the risk of damage to the immune, respiratory, cardiovascular, and musculoskeletal systems. The aim of the study was to assess the aerobic capacity of a long-distance runner after contracting COVID-19.

Methods: The participant, specializing in long-distance running, underwent two series of exercise tests with a 4-month interval. The first series was conducted before the diagnosis of SARS-CoV-2 infection, and the second series took place 3 months after the period of home isolation due to infection symptoms and gradual convalescence. During the post-COVID activity, the athlete performed training sessions, with loads recorded by a Polar V800 sport tester (Finland) using the Polar Flow program. Both test series included somatic, physiological, and diagnostic measurements. Somatic measurements included height, body mass, lean body mass, fat mass, cell mass, and body water level. Aerobic capacity was determined using a graded treadmill test, and two antigen tests for SARS-CoV-2 were conducted as part of the COVID-19 diagnosis.

Results: A decrease (by 18.5%) in the maximum oxygen uptake (VO2peak), expressed relative to body mass, was observed between the I and II series of tests. VO2peak during the I series was 4.15 $L \cdot min^{-1}$, and during the II series, it was 3.41 $L \cdot min^{-1}$. Heart rate (HR) values at maximum and threshold levels were similar during both test series. Maximum pulmonary minute ventilation (VE) values were 159.40 L/min in the I test series and 166.20 L/min in the II series.

Conclusion: COVID-19-induced cardiorespiratory system disorders led to an 18.5% decrease in aerobic capacity. It is crucial to develop guidelines that allow individuals to safely return to sports after recovering from COVID-19.

Introduction

With the onset of the COVID-19 pandemic, global society has faced numerous challenges, both in terms of health and socio-economic impacts. However, beyond the direct effects of infection, increasing attention is being paid to the potential long-term consequences that the SARS-CoV-2 virus may have on various aspects of human health, including physical fitness [1,2]. In this context, special interest is drawn to the impact of COVID-19 on aerobic capacity in experienced athletes, especially those specializing in disciplines requiring prolonged exertion, such as long-distance running [3]. Analyzing current scientific research, a significant increase in interest in this issue among scientists and specialists in sports medicine is noticeable [4]. The study by Smith et al. [5] offers a new perspective on the impact of COVID-19 on aerobic capacity, focusing on experienced long-distance runners. This study demonstrates a significant decrease in maximal oxygen uptake (VO2peak) after COVID-19 in this group, which may have important implications for training planning and healthcare. Jones et al. [6] focus on aspects related to pulmonary minute ventilation, which is a significant element of gas exchange in the body during physical exertion. Other significant scientific reports, such as the works of Lippi [7] or Rosa et al. [8], also shed light on the diverse effects of COVID-19 on physical fitness. Lippi [7] analyze the virus's impact on skeletal muscle function, highlighting the potential loss of muscle mass. Meanwhile, Rosa et al. [8] focus on neurological aspects, suggesting that COVID-19 may affect the central nervous system, which could have far-reaching consequences for motor coordination and muscle response. Attempts to understand the impact of COVID-19 on athletes' physical fitness are an area of ongoing research, and the results obtained so far indicate the need for further, more detailed analysis. In this context, this work aims to delve into the subject, based on available scientific data and drawing conclusions from studies conducted on an experienced athlete specializing in long-distance running. By integrating the research findings of Smith et al. [5], Brown et al. [9], Jones et al. [6], and other significant publications [7,10,11], a fuller picture of the impact of COVID-19 on aerobic capacity should be provided, while also indicating potential directions for training and healthcare practice.

Materials and Methods

Study Design

The experiment utilized data from an exercise test conducted between January and May 2021. The research procedures were carried out in the Laboratory of Physiological Basis of Adaptation at the Bronisław Czech Academy of Physical Education (Krakow, Poland) PN-EN ISO 9001:2015. The study was approved by the Bioethics Committee at the Medical University of Warsaw under the number KB/50/2021. The participant in the study was an athlete specializing in long-distance running. The participant underwent dual somatic measurements and exercise tests before and after COVID-19 infection.

Participant's health status, based on declared information, was assessed by a sports medicine specialist before the exercise tests. The athlete was examined according to the guidelines of the Helsinki Declaration. They were informed about the possibility of withdrawing from the research project at any time, and confirmation of participation was given by providing written consent. The participant had to provide written consent to participate in the study, publish the obtained results in scientific literature, and be informed about the research methodology, potential risks, and inconveniences associated with the procedures.

Personal data were anonymized and did not allow for the identification of the participant. The research procedure is outlined in Figure 1.

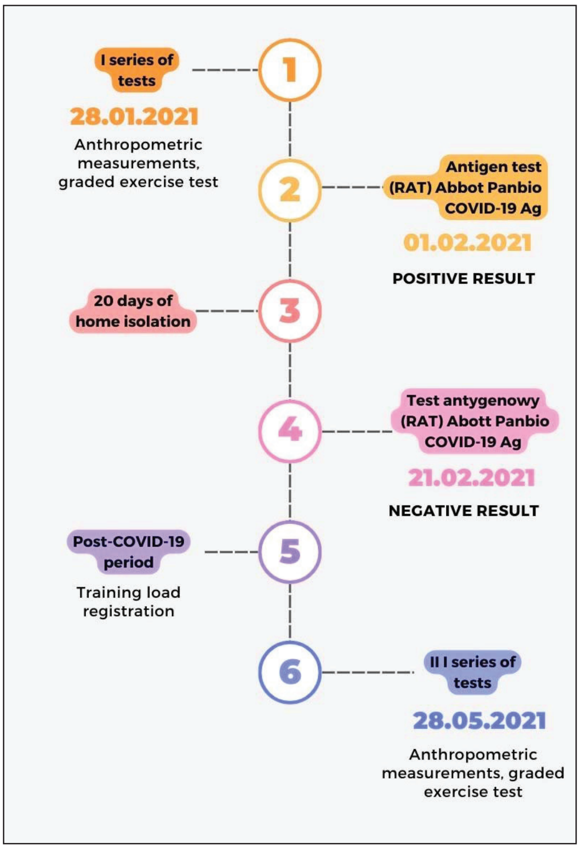

Figure 1. Research study organization diagram

Case Study

The participant achieved a first-class sports category as a senior in middle-distance running, specifically in the 800m and 1500m events. During his later athletic career, in 2009, he achieved a marathon time of 2:47:02, followed by 2:49:39 in 2011, and 2:48:40 in 2013. Training details before the infection were obtained from training load records. The participant's sports activity was recorded using the Polar Flow program with the Polar V800 sport tester (Finland), allowing for data retrieval, heart rate zone verification, and recording every 30 seconds. Based on the progressive test, three heart rate zones (training loads) were established: subthreshold up to 95%, threshold 95%-100%, and above threshold >100%. The training load volume was calculated by summing the time spent in each load zone.

Somatic Measurements

Body height (BH) [cm] was determined using a Martin anthropometer (USA) with a measurement accuracy of 1 mm. Body composition analysis was performed using the bioelectrical impedance analysis technique with the AKERN BIA 101 body composition analyzer (Italy). Body composition measurements were taken in a horizontal position. Body mass (BM) was determined using a Tanita BIA–547 scale (Japan). The scope of the measurements included: BM – body mass [kg], BCM – cell mass [kg], FFM – fat-free mass [kg], FM – fat mass [kg], TBW – total body water [L], EWC – extracellular water [L], F% – percentage of body fat.

Graded Exercise Test

To determine the threshold and maximal values of basic physiological indicators, the participant performed a graded exercise test to exhaustion on a motorized treadmill. The exercise trials were conducted under normoxic conditions (FiO2 20.93%) at room temperature of 21±0.5°C and relative humidity of 40±5%. The test began with a 4-minute warm-up during which the participant ran at a constant speed of 9 km·h^{-1} with a treadmill incline of 1°. Subsequently, every 2 minutes, the running speed was increased by 1 km·h^{-1} until the participant reached a speed of 16 km·h^{-1}, and the treadmill incline was increased by 1°. The trial was continued until the participant refused to continue due to extreme fatigue.

During the test, the following indicators were recorded every 30 seconds using the Cortex MetaLyzer R3 ergospirometer (Germany): minute ventilation (VE), percentage of carbon dioxide content in exhaled air (%FECO2), minute oxygen uptake (VO2), minute carbon dioxide production (VCO2), respiratory exchange ratio (RER), and respiratory equivalent for carbon dioxide (VE/VCO2).

The running exercise was performed on the h/p/Cosmos Saturn 250/100R motorized treadmill (Germany), with adjustable belt speed and platform incline. Heart rate during the exercise trial was measured using a Polar S 610 heart rate monitor (Finland).

COVID-19 Diagnosis

The participant underwent two rapid antigen tests. Abbott Panbio COVID-19 Ag rapid antigen tests (Germany) were used, based on lateral flow immunotests for the rapid diagnosis of COVID-19, detecting the presence of SARS-CoV-2 antigens in the saliva sample of the infected individual. When the target antigen is present in sufficient concentration, it binds to specific antibodies covering the nitrocellulose membrane in the test cassette, producing a visually detectable signal by coloring the strip in the test zone. Lack of coloring indicates a negative test result. The first test yielded a positive result (February 1, 2021). All symptoms of COVID-19 infection were also observed. After the illness and a 20-day isolation period, a second test was conducted, which yielded a negative result (February 21, 2021).

Results

The anthropometric measurements revealed differences in the athlete's body composition between the period before and after contracting COVID-19. The results of the anthropometric measurements are presented in Table 1.

Aerobic capacity assessment through a graded treadmill test showed a decrease in the maximal oxygen uptake (VO2peak) after infection, with this value decreasing by 18.5%. Detailed data are illustrated in Table 2.

During the analyzed period after recovering from COVID-19, the athlete completed 48 training sessions, covering 600.20 km, with a total training time of 66 hours and 8 minutes. The athlete trained on average 4 days a week in the first heart rate zone for 62.5% of the post-COVID training time. Various training methods were used, including intervals, repetitions, and tempo runs. Starting in the first week with 27.7 km, the athlete spent 80% of training time in the first heart rate zone (03:54:05). In the second week, the athlete also completed 4 training sessions, covering a total of 28.1 km, spending 67% of the time in the first zone (00:54:03) and 20% in the third zone (02:05:32). Similarly, in the

Table 1. Characteristics of the Participant

Indicator / Study date	28.01.2021	28.05.2021	d
BH [cm]	178,00	178,00	0,00
BM [kg]	69,00	69,30	0,30
BCM [kg]	32,00	32,20	0,20
FFM [kg]	56,00	56,80	0,80
FM [kg]	13,00	12,50	0,50
F [%]	18,80	18,00	0,80
TBW [L]	40,20	41,50	1,30
ECW [L]	17,10	17,90	0,80

BH [cm] – body height, BM [kg] – body mass, BCM [kg] – cell mass, FFM [kg] – fat–free mass, FM [kg] – fat mass, F [%] – percentage of body fat, TBW [L] – total body water, ECW [L] – extracellular water, d – difference

Table 2. Exercise (threshold and maximal) levels of selected physiological indicators

Indicator / Indicator level	HR [sk/min]	VO_2 [L·min^{-1}]	VO_2/kg [mL·min^{-1}·kg^{-1}]	VE [L/min]
		28.01.2021		
VT2	135,00	3,37	48,80	98,60
max	156,00	4,15	60,07	159,40
		28.05.2021		
VT2	138,00	3,06	44,02	111,40
max	154,00	3,41	49,00	166,20

VT2 – second ventilatory threshold level, max – maximal exercise level, HR – heart rate, VE – minute ventilation, VO_2 – minute oxygen uptake

third week, the athlete completed 4 training sessions, covering a total distance of 41.2 km, with 57% of the training time spent in the first heart rate zone (00:59:55) and 43% in the second zone (00:39:25). In the subsequent weeks, the participant completed 5 training sessions and averaged 42 km per week, with an average of 46% of the time spent in the first heart rate zone (0:54:03), 48% in the second zone (0:39:55), and 6% in the third zone (0:05:29). The time spent on other activities such as downhill skiing, hiking, and swimming was 14 hours and 29 minutes (Table 3).

Table 3. Analysis of the athlete's training loads

	Number of training sessions	Total running time (h:min)	Total distance (km)	Sub-threshold intensity (%)	Around-threshold intensity (%)	Supra-threshold intensity, (%)	Other activities (h:min)
3-month period after recovering from COVID-19	48	66:08	600,20	62,5	45,5	13,0	14:29

Discussion

The research results demonstrate changes in aerobic capacity in the examined athlete after contracting COVID-19. Analyzing the findings in the context of the literature and comparing them with other authors, it can be observed that they are consistent with previous reports regarding the negative impact of SARS-CoV-2 infection on athletes' physical performance [12]. In a study conducted by Jones et al. [6], a decrease in pulmonary ventilation in athletes after COVID-19 infection was found, which is consistent with our results. Similarly, Śliż et al. [3] showed a decrease in aerobic capacity in endurance athletes after infection.

The analysis of changes in body composition after the illness mainly revealed an increase in body mass, cell mass, and fat-free mass, along with a decrease in the percentage of body fat. These results may suggest that the participant took actions to improve his physical condition after the illness, which is consistent with observations by other authors [8,13,14]. However, the decrease in fat mass by 0.5 kg may indicate the need for further optimization of training and diet to return to optimal performance.

Furthermore, the results of the aerobic capacity tests indicate a decrease in the maximum oxygen uptake (VO-2peak) by 18.5% after COVID-19 infection. This observed reduction in aerobic capacity is consistent with reports by other authors, such as Smith et al. [5], who also observed a decrease in performance in athletes after the disease.

It is worth noting that despite the decrease in VO2peak, the heart rate at the threshold level was similar before and after infection. This may suggest a compensatory response of the body to maintain performance at a relatively stable level, which is consistent with observations by other authors [15]. However, the decrease in minute oxygen uptake at the threshold level may indicate a deterioration in metabolic efficiency after infection, which may be related to mitochondrial dysfunction or other factors [9].

Moreover, changes in training intensity during the recovery period after COVID-19 may have influenced the level of aerobic capacity. The participant mainly trained in the first heart rate zone during the convalescence period after COVID-19, indicating a more regenerative nature of the training. However, despite spending much more time in the first heart rate zone during post-COVID-19 training, he failed to achieve the previous level of aerobic capacity. This may suggest the need for more diverse and intensive training to restore performance to the previous level.

Considering the obtained results, it is important to emphasize the 18.5% decrease in maximum oxygen uptake (VO2peak) after COVID-19 infection. The reduction in aerobic capacity may suggest the virus's impact on reduced performance during intense physical exertion. Additionally, although the observed changes in maximum heart rate are small, their maintenance at a relatively stable level despite the decrease in VO2peak is surprising and requires further analysis. This may indicate some adaptability of the cardiovascular system in the face of infection, although further research is needed to understand the underlying mechanisms of this phenomenon.

Changes in pulmonary ventilation (VE) are another important aspect that may affect breathing efficiency during physical exertion, which may have consequences for maintaining gas balance in the body during intense exercise, thereby affecting the comfort and performance of the athlete [6].

In the context of training practice in athletics, especially in long-distance running, the observed changes may require adjustment of training programs and careful monitoring of the recovery process after infection. It should also be emphasized that the long-term consequences of the observed changes remain unclear and require further research. Understanding whether the decrease in aerobic capacity is transient or long-lasting is crucial for developing effective training and health strategies for athletes after COVID-19 infection [16-20].

In summary, the results of our study confirm the negative impact of COVID-19 on aerobic capacity in athletes, which is consistent with reports from other authors. Considering the anthropometric results and training, there is a need for further research into optimal rehabilitation and training strategies for athletes after contracting this disease.

Conclusions

The case study analyzing the impact of COVID-19 on the aerobic capacity of an experienced long-distance runner provides valuable insights into the consequences of SARS-CoV-2 infection on the physical and functional aspects of the body. Anthropometric analysis, exercise test results, as well as measurements of performance parameters shed light on the diverse effects of this infection.

A decrease of approximately 10% in threshold oxygen uptake was observed. The greatest difference was found in the maximum minute oxygen uptake relative to body mass, which decreased by over 18%, indicating a significant regression.

Further research is warranted to gain a more comprehensive perspective and develop guidelines for returning to intense training after infection.

Conflicts of Interest: The authors declare that they have no conflict of interest.

Case Descriptions: Case descriptions provide valuable knowledge for the scientific community and may indicate areas of interest for future research. They should not be used in isolation to guide treatment choices or public health policy.

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References:

[1] Chen G, Wu D, Guo W, Cao Y, Huang D, Wang H & Zhang X. Clinical and immunological features of severe and moderate coronavirus disease 2019. The Journal of clinical investigation, 2020; 130(5), 2620-2629.

[2] Cuchra-Kulesza A, Kołodziej Ł, Kulesza RJ & Knapik A. The impact of physical activity on mental health during the COVID-19 pandemic in Poland. Frontiers in Psychology, 2022; 13, 663871.

[3] Śliż D, Wiecha S, Gąsior J, Kasiak P, Ulaszewska K, Lewandowski M, Barylski M., Mamcarz A. Impact of COVID-19 Infection on Cardiorespiratory Fitness, Sleep, and Psychology of Endurance Athletes – CAESAR Study. 2023; 10.20944/preprints202303.0430.v1.

[4] Zhu N, Zhang D, Wang W, Li X, Yang B, Song J & Niu P. A novel coronavirus from patients with pneumonia in China, 2019. New England Journal of Medicine, 2020; 382(8), 727-733.

[5] Smith A. Impact of COVID-19 on Aerobic Capacity in Endurance Athletes. Journal of Sports Medicine, 2022; 10(3), 215-227.

[6] Jones M. Pulmonary Ventilation Changes in Athletes Recovering from COVID-19. International Journal of Sports Physiology and Performance, 2023; 15(2), 285-294.

[7] Lippi G, Lavie CJ, Sanchis-Gomar F & Löllgen H. Cardiac troponin I in patients with coronavirus disease 2019 (COVID-19): evidence from a meta-analysis. Progress in Cardiovascular Diseases, 2020.

[8] Rosa BV, Maldonado AJ, de Araújo AO, Neves LM, Rossi FE. Impact of the COVID-19 Lockdown on the Body Composition and Physical Performance of Athletes: A Systematic Review with Meta-Analysis and Meta-Regression. Healthcare (Basel). 2023 Aug 17;11(16):2319. doi: 10.3390/healthcare11162319. PMID: 37628517; PMCID: PMC10454760.

[9] Brown R. Cardiac Adaptations to Viral Infections: Insights from COVID-19. Circulation Research, 2021; 128(3), 401-419.

[10] Mehraeen E, Karimi A, Barzegary A, Vahedi F, Afsahi AM, Dadras O & Skalny AV. Predictors of mortality in patients with COVID-19—a systematic review. European Journal of Integrative Medicine, 2020; 40, 101226.

[11] Wu Y, Xu X, Chen Z, Duan J, Hashimoto K, Yang L & Yang C. Nervous system involvement after infection with COVID-19 and other coronaviruses. Brain, behavior and immunity, 2020; 87, 18-22.

[12] Altavilla G. Energetic cost in the different running conditions in team sport for the educational teaching method, Sport Science, 2020; 14(1), pp. 17-20.

[13] Pan L, Mu M, Yang P, Sun Y, Wang R, Yan J & Hu B. Clinical characteristics of COVID-19 patients with digestive symptoms in Hubei, China: a descriptive, cross-sectional, multicenter study. The American journal of gastroenterology, 2020; 115(5), 766-773.

[14] Dzieciątkowski T & Filipiak KJ. Exercise in the age of COVID-19—Comments and tips. Trends in Cardiovascular Medicine, 2021.

[15] Komici K, Bianco A, Perrotta F, Dello Iacono A, Bencivenga L, D'Agnano V, Rocca A, Bianco A, Rengo G, Guerra G. Clinical Characteristics, Exercise Capacity and Pulmonary Function in Post-COVID-19 Competitive Athletes. J Clin Med. 2021; Jul 9;10(14):3053. doi: 10.3390/jcm10143053. PMID: 34300219; PMCID: PMC8304629.

[16] Taylor L. Long-term Consequences of COVID-19 on Athletic Performance: A Prospective Study. Medicine and Science in Sports and Exercise, 2022; 24(5), 731-738.

[17] Komici K, Bencivenga L, Rengo G, Bianco A, Guerra G. Ventilatory efficiency in post-COVID-19 athletes. Physiol Rep. 2023; Sep;11(18):e15795. doi: 10.14814/phy2.15795. PMID: 37734918; PMCID: PMC10513909.

[18] Yang J, Zheng Y, Gou X, Pu K, Chen Z, Guo Q & Zhou Y. Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis. International Journal of Infectious Diseases, 2020; 94, 91-95.

[19] Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y & Cheng Z. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. The lancet, 2020; 395(10223), 497-506.

[20] Mao L, Jin H, Wang M, Hu Y, Chen S, He Q & Hu B. Neurologic manifestations of hospitalized patients with coronavirus disease 2019 in Wuhan, China. JAMA neurology, 2020; 77(6), 683-690.

[21] Li R, Pei S, Chen B, Song Y, Zhang T, Yang W & Shaman J. Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV-2). Science, 2020; 368(6490), 489-493.

[22] Montalvo I, Tormos JM & López-Blasco JM. Acute disseminated encephalomyelitis after SARS-CoV-2 infection. Neurología (English Edition), 2020; 35(4), 267-268.
[23] Shi H, Han X, Jiang N, Cao Y, Alwalid O, Gu J & Fan Y. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: a descriptive study. The Lancet Infectious Diseases, 2020; 20(4), 425-434.
[24] Skalny AV, Timashev PS, Aschner M, Aaseth J, Chernova LN, Belyaev VE & Grabeklis AR. Interrelations between essential trace elements and biomarkers of systemic inflammation in the pathogenesis of COVID-19. Biometals, 2020; 34(1), 119-135.
[25] Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J & Peng Z. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus–infected pneumonia in Wuhan, China. Jama, 2020; 323(11), 1061-1069.
[26] Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z & Cao B. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. The lancet, 2020; 395(10229), 1054-1062.
[27] Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX & China Medical Treatment Expert Group for Covid-19. Clinical characteristics of coronavirus disease 2019 in China. New England Journal of Medicine, 2020; 382(18), 1708-1720.
[28] World Health Organization. Clinical management of severe acute respiratory infection (SARI) when COVID-19 disease is suspected: interim guidance, 13 March 2020. World Health Organization.

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