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Physical Activity, Nutritional Status, Physical Fitness

Edited by
Andrzej Tomczak

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Editor

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Contents

About the Editor . . . . **vii**

Preface to ”Physical Activity, Nutritional Status, Physical Fitness” . . . . **ix**

Andrzej Tomczak, Anna Anyżewska, Jerzy Bertrandt, Tomasz Lepionka, Artur Kruszewski and Agata Gaździńska
Assessment of the Level of Physical Activity and Body Mass Index of Soldiers of the Polish Air Force
Reprinted from: *Int. J. Environ. Res. Public Health* **2022**, *19*, 8392, doi:10.3390/ijerph19148392 . . . **1**

Jerzy Bertrandt, Anna Anyżewska, Roman Łakomy, Tomasz Lepionka, Ewa Szarska, Andrzej Tomczak, Agata Gaździńska, Karolina Bertrandt-Tomaszewska, Krzysztof Kłos and Ewelina Maculewicz
Assessment of Energy Expenditure of Police Officers Trained in Polish Police Schools and Police Training Centers
Reprinted from: *Int. J. Environ. Res. Public Health* **2022**, *19*, 6828, doi:10.3390/ijerph19116828 . . . **13**

Anna Anyżewska, Roman Łakomy, Tomasz Lepionka, Ewelina Maculewicz, Ewa Szarska, Andrzej Tomczak, Izabela Bolczyk and Jerzy Bertrandt
Association between Diet, Physical Activity and Nutritional Status of Male Border Guard Officers
Reprinted from: *Int. J. Environ. Res. Public Health* **2022**, *19*, 5305, doi:10.3390/ijerph19095305 . . . **25**

Tomasz Lepionka, Anna Anyżewska, Ewelina Maculewicz, Krzysztof Klos, Roman Lakomy, Ewa Szarska, Andrzej Tomczak, Agata Gaździńska, Katarzyna Skuza and Jerzy Bertrandt
Assessment of the Body Composition and Bone Calcification of Students of Police Schools and Police Training Centers in Poland—A Cross-Sectional Study
Reprinted from: *Int. J. Environ. Res. Public Health* **2022**, *19*, 7161, doi:10.3390/ijerph19127161 . . . **39**

Agata Gaździńska, Paweł Jagielski, Marta Turczyńska, Łukasz Dziuda and Stefan Gaździński
Assessment of Risk Factors for Development of Overweight and Obesity among Soldiers of Polish Armed Forces Participating in the National Health Programme 2016–2020
Reprinted from: *Int. J. Environ. Res. Public Health* **2022**, *19*, 3069, doi:10.3390/ijerph19053069 . . . **51**

Megan Sax van der Weyden, Michael Toczko, Marcie Fyock-Martin and Joel Martin
Relationship between a Maximum Plank Assessment and Fitness, Health Behaviors, and Moods in Tactical Athletes: An Exploratory Study
Reprinted from: *Int. J. Environ. Res. Public Health* **2022**, *19*, 12832, doi:10.3390/ijerph191912832 . **63**

Anna Keska, Anna Pietrzak and Dagmara Iwańska
Use of the Dietary Inflammatory Index to Assess the Diet of Young Physically Active Men
Reprinted from: *Int. J. Environ. Res. Public Health* **2022**, *19*, 6884, doi:10.3390/ijerph19116884 . . . **77**

Anna Mazur and Elżbieta Bartoń
The Structure of the Relationship between Physical Activity and Psychosocial Functioning of Women and Men during the COVID-19 Epidemic in Poland
Reprinted from: *Int. J. Environ. Res. Public Health* **2022**, *19*, 11860, doi:10.3390/ijerph191911860 . **89**

Tadeusz Ambroży, Łukasz Rydzik, Amadeusz Kwiatkowski, Michał Spieszny, Dorota Ambroży, Aneta Rejman, Agnieszka Koteja, Jarosław Jaszczur-Nowicki, Henryk Duda and Wojciech Czarny
Effect of CrossFit Training on Physical Fitness of Kickboxers
Reprinted from: *Int. J. Environ. Res. Public Health* **2022**, *19*, 4526, doi:10.3390/ijerph19084526 . . . **111**

Aleksandra Romanowska, Agnieszka Morawiak, Catherine Woods, Liam Kelly, Kevin Volf, Peter Gelius, Sven Messing, Sarah Forberger, Jeroen Lakerveld, Nicolette R. Den Braver, Enrique García Bengoechea and Joanna Żukowska
Health Enhancing Physical Activity Policies in Poland: Findings from the HEPA PAT Survey
Reprinted from: *Int. J. Environ. Res. Public Health* **2022**, *19*, 7284, doi:10.3390/ijerph19127284 . . . **125**

Ewelina Maculewicz, Agata Leońska-Duniec, Andrzej Mastalerz, Ewa Szarska, Aleksandra Garbacz, Tomasz Lepionka, Roman Łakomy, Anna Anyżewska and Jerzy Bertrandt
The Influence of *FTO, FABP2, LEP, LEPR,* and *MC4R* Genes on Obesity Parameters in Physically Active Caucasian Men
Reprinted from: *Int. J. Environ. Res. Public Health* **2022**, *19*, 6030, doi:10.3390/ijerph19106030 . . . **139**

About the Editor

Andrzej Tomczak

Andrzej Tomczak is a habilitated doctor of medical and health sciences in the discipline of physical culture science and a doctor of social sciences in the discipline of security studies. He is also a master of physical education and a graduate of the academy officer school. His main research areas are: the fitness and physical activity of soldiers, coordination motor abilities, the training of soldiers (survival; SERE), nutritional status, and security education. He is the author of two monographs and above 100 research papers.

Preface to ”Physical Activity, Nutritional Status, Physical Fitness”

The Special Issue “Physical fitness, nutritional status, physical activity” is mainly devoted to the environment of uniformed services. This is justified by the strong correlation between national security and the fitness of soldiers and tactical athletes. It is a fact that the ability to make physical effort is an important factor enabling the performance of official tasks by soldiers and officers of uniformed services. The level of physical fitness depends on the level of physical activity and proper nutritional status. Knowledge of the relationship between physical fitness and physical activity and nutritional status is essential for physical education specialists, military doctors, as well as soldiers, policemen, and border guards. This Special Issue is especially targeted at these people.

The first five articles mainly refer to the physical activity and nutritional status of Polish soldiers, policemen, and border guards. These works were carried out as part of a research project of the National Health Program. The Special Issue also includes articles on overweight and obesity in the civilian environment. There are also two articles on the physical fitness of athletes (kickboxers) and American soldiers.

This Special Issue, titled ”Physical fitness, nutritional status, physical activity”, is the result of the work of scientists from Poland, the USA, Ireland, Germany, and the Netherlands. They are recognized specialists in their scientific disciplines. At this point, I would like to thank the authors of the articles and reviewers whose valuable comments contributed to the high substantive level of the published articles.

Andrzej Tomczak
Editor

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Article

Assessment of the Level of Physical Activity and Body Mass Index of Soldiers of the Polish Air Force

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Abstract: Level of physical activity positively affects health condition, correlates highly with level of physical fitness and contributes to the efficient performance of military tasks. The aim of the study was to assess the level of physical activity and body mass index of the Polish Air Force soldiers. A total of 543 professional soldiers (men) doing military service in military units of the Polish Air Force underwent the examination. The average age of examined soldiers amounted to 34.8 ± 9.0 years. In order to carry out the research, the long version of the International Physical Activity Questionnaire was used. Out of the total of 477 questionnaires that qualified for the analysis, a high level of physical activity was found among 81.1% of subjects, moderate 10.5% and low 8.4%. Average MET values were obtained in the following: job-related, relocation (transportation), housekeeping, recreation (leisure activities and sport). The average MET values were 4173 ± 5306 MET; 2371 ± 2725 MET; 2455 ± 4843 MET; 2421 ± 2802 MET, respectively. The average level of body mass index amounted to 25.98 ± 3.38 kg/m^2. The tested Air Force soldiers were generally characterized by a high and moderate level of physical activity. Generally, there was no difference in the level of physical activity between the flight crew and the ground staff.

Keywords: IPAQ; soldiers; military pilots; physical activity; BMI

1. Introduction

It is generally believed that level of physical activity (PA) largely reflects state of health, as reflected in the saying "healthy body, healthy mind". Numerous studies have proven that, among other things, lack of physical activity contributes to the occurrence and development of many diseases [1–4]. Therefore, much attention is paid to promoting physical activity and pro-health lifestyles in society for everyone, from children to older people. Deficiencies in physical activity caused by civilization should be reduced by conscious participation in physical activities.

In the uniformed services, a high level of physical fitness is very desirable in the aspects of professional preparation and efficient fulfilling of service tasks (e.g., a soldier on the battlefield, a policeman during an intervention or a firefighter during a rescue operation) [5,6]. The way to achieve the desired level of physical fitness for a soldier (an officer of a particular formation) is participation in various forms of physical activity during work and leisure time. This should be reflected in a high level of physical activity. Soldiers, as part of their professional work, should participate in obligatory physical education classes, diversified by the number of hours depending on military specialty [7].

The group of soldiers in the Air Force includes soldiers of various specialties, most of which specialties are also in both the Navy and the Land Forces. These specialties are, for example, administration or logistics. Even such specialties as ground service of aviation equipment (engineering and aviation service) occurs in other branches of armed forces. In the Air Force there are particular specialties typical of military air services, like that of a supersonic airplane pilot. There is the main division of the flight crew and ground staff. The main differences are the environment of performing official tasks (air, land) and the way of logging in to perform them [8]. These differences also apply to physical preparation, in terms of the volume of classes and means of physical education (i.e., physical exercises).

In the literature, we can find many papers on the physical fitness of soldiers [9–11]. So far, not much work has been published regarding the assessment of the physical activity level of Polish soldiers, and those from other countries. In Poland, comparative research has been conducted among soldiers of military administration, special units, soldiers of the Land Forces Training Center, soldiers of the Land Forces and among soldiers of the special unit of the Military Police, and there have been assessments of physical activity level carried out among candidates seeking to become professional soldiers [12–16]. In general, a high level of physical activity was revealed for soldiers. However, a small percentage of soldiers also revealed a low level of it, which is not a good predictor of efficient performance of service duties. Mierzejewski conducted research on the level of physical activity among soldiers of land troops qualified for the Officer's Study. He stated that 79.0% of the respondents presented a high level of physical activity and 21.0% a moderate level [14]. In turn, Tomczak et al. conducted research using the International Physical Activity Questionnaire (IPAQ) tool among Polish soldiers of the Military Police. Based on the research, they found that 84.6% of the respondents were characterized by a high level of physical activity, 7.7% were moderate, and 7.7% were low [15]. Comparative research on the physical activity among soldiers of the National Reserve Force was carried out by Szettler-Degler [17]. She concluded that the level of metabolic equivalent (MET) was similar between men and women. Łyżwiński, on the basis of his own study, found that 80.0% of the surveyed Polish soldiers of the land forces perceived there to be a relationship between physical fitness and better performance of official tasks. More than half of the respondents revealed that they undertook physical activity outside of business hours and that they assessed their physical fitness as very good [13]. In many works, attention is paid to the need to raise awareness of the necessity to undertake physical activity and to motivate people to undertake physical activity [15,18,19].

The main aim of the research presented here was to assess the level of physical activity and the body mass index (BMI) of soldiers of the Polish Air Force. The specific objectives were to identify differences in the levels of physical activity and BMI between flight crew and ground staff and age groups (up to 30 years of age, 31–40 years of age and a group over 40). We hypothesized that the flight crew would reveal a higher level of physical activity than ground staff and that a higher level of physical activity would be presented by younger soldiers. Our hypothesis regarding flight crew versus ground staff was justified by the fact that flight crew participate in more compulsory physical education and recreation classes than other soldiers.

2. Materials and Methods

2.1. Study Design and Participations

A total of 543 professional soldiers (men) doing military service in military units of the Polish Air Force underwent the examination. The subjects were selected randomly. The soldiers performed professional military service in 35 military units of the Air Force. The research sample accounted for about 3% of the population of soldiers of the Air Force. The average age of examined soldiers amounted to 34.8 $\pm$ 9.0 (19–59) years old. Due to the failure to meet the criteria of credibility, 66 questionnaires did not qualify for further studies. The percentage of questionnaires that qualified for the analysis was 87.8%.

The results of the research were presented in two basic groups, i.e., flight crew 37.49 ± 7.54 (21–59) years old and ground staff 32.70 ± 9.57 (19–59) years old. The flight crew included military pilots, on-board technicians, and on-board navigators, whereas the ground staff included ground service of the aircraft, engineers, technicians, and staff soldiers. The justification for such division was the environment of performing main official tasks (flight crew—in the air; ground staff—on the ground). Subsequently, the research material was divided into the following age groups: up to 30 years old, 31–40 years old and a group over 40 years old. The age of the respondents was determined based on date of birth.

The research was carried out in 2017–2018 as part of the National Health Program research project. The permission of the Bioethics Committee of the Military Institute of Hygiene and Epidemiology in Warsaw (Poland) was obtained for conducting the research (No 01/2016). All procedures were performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. All participants provided informed consent.

2.2. Physical Activity Assessment

In order to carry out the research, the long version of IPAQ was used. In the introduction to the questionnaire a vigorous physical activity and moderate physical activity were defined in a way accessible for everybody. Vigorous physical activity is understood as heavy physical exercise that forces strong, increased breathing, and, therefore, accelerated heart rate. Moderate physical activity is understood as an average effort with slightly increased breathing and a little accelerated heart action [20,21]. The first part of the questionnaire dealt with physical efforts related to professional work (Part 1: Job-related PA). Three types of efforts were distinguished, i.e., vigorous, moderate and walking. The second part dealt with physical efforts related to relocating (walking, cycling; Part 2: Transportation (relocation) physical activity). In the third part, subjects were asked about the time they spent on taking physical activity related to housework, general housekeeping and for family care (Part 3: Housework, house maintenance, and caring for family). The fourth part of the questionnaire was connected with recreation, sport and physical activity in leisure time (Part 4: Recreation, sport, and leisure-time physical activity). The fifth part contained questions related to time spent sitting, divided into weekend and week days (Part 5: Time spent sitting).

Based on the number of days, time spent on given physical activity and MET rate determined for a given physical activity, a total energy expenditure for each type of physical exercise was calculated. 1 MET corresponds to the average energy expenditure during rest (in a sitting position). It is equivalent to the consumption of oxygen in a sitting position of a person weighing 70 kg, which is 3.5 mL O_2/min/kg [22].

2.3. Somatic Measurements

The measurement of basic morphological features was based on the analysis of the following values of somatic measurements, which were measured according to the Martin technique, body height, and body mass [23]. Body height was measured with an anthropometer (Holtain, UK) to the nearest 1 mm, in a standing upright position, without shoes. Body mass was measured using a Charder MS 4202L electronic weight floor scale (measurement accuracy < 50 g). Each measurement was performed under the same test conditions (in the morning, about 30 min before the first meal). The respondent was wearing sports clothes and barefoot. The same measuring equipment was used during all stages of the research, the accuracy of which was checked periodically. Measurements were made by people who graduated in physical education.

Based on these data, the BMI was calculated (BMI = body mass/height^2 [kg/m^2]). The scale of BMI classification reported by the World Health Organization (WHO) was accepted [24].

2.4. Statistical Analysis

Descriptive statistics were means (±standard deviations), medians, quartiles 1 and 3, as well as interquartile range. Normality checks were done with the Shapiro–Wilk test. To compare groups, we used the Mann–Whitney test, as well as the Kruskall-Wallis test. The Chi-square test, to relate nominal data, and the Spearman correlation, and its 95% CI, were also used. Effect sizes were calculated (partial eta square, and Cramer's V). These analyses were done in Statistica v.13.3 (Statsoft, Kraków, Poland), and the significance level was set at 5%. Further sample size estimation was done with the G*Power v. 3.1. software (Heinrich-Heine-Universität, Düsseldorf, Germany).

3. Results

The calculations using the G*Power test were made a posteriori. The minimum sample size should be 220 subjects for the Chi-square test (effect size = 0.3; power = 0.95). The minimum sample size should be 252 subjects for the Kruskal–Wallis test (effect size = 0.25; power = 0.95). In our research we met these requirements with a significant surplus, as 477 questionnaires were qualified for the analysis.

Out of the total of 477 questionnaires which qualified for the analysis, a high level of physical activity was found among 81.8% (n = 390) of subjects, a moderate level in 10.2% (n = 50) and low in 8.0% (n = 40). Taking into account only the flight crew, it was found that a high level of physical activity characterized 80.9% of the soldiers, moderate 11.9%, and low 7.2%. In the ground staff, the following results were obtained: 82.4%, 9.0% and 8.6%, respectively (Table 1).

Table 1. Summary of the levels of physical activity of the Air Force soldiers according to the IPAQ classification.

	Level of Physical Activity					
Variables	**High**	**Moderate**	**Low**	χ^2	***p*-Value**	**V**
All Air Force soldiers (n = 477)	81.8% (390)	10.2% (49)	8.0% (38)			
All flight crew (n = 210)	80.9% (170)	11.9% (25)	7.2% (15)	1.63	0.442	0.06
All ground staff (n = 267)	82.4% (220)	9.0% (24)	8.6% (23)			
Flight crew for years 30 (n = 44)	81.8% (36)	9.1% (4)	9.1% (4)	1.86	0.761	0.07
Flight crew 31–40 years old (n = 96)	83.3% (80)	10.4% (10)	6.3% (6)			
Flight crew above 40's (n = 70)	77.1% (54)	15.8% (11)	7.1% (5)			
Ground staff for years 30 (n = 110)	90.0% (99) $_b$	7.3% (8) $_a$	2.7% (3) $_a$	12.38	0.015	0.15
Ground staff 31–40 years old (n = 92)	78.3% (72) $_a$	7.6% (7) $_a$	14.1% (13) $_b$			
Ground staff above 40's (n = 65)	75.4% (49) $_a$	13.8% (9) $_a$	10.8% (7) $_{a,b}$			

The values in a given column not sharing a letter index between rows differ at the $p < 0.05$ (Bonferroni correction). Legend: V—effect size.

Table 1 presents the results of the Chi-square test for the levels of physical activity depending on the type of specialization and the age of the respondents. The analysis showed no association between specialization and the level of physical activity. The relationship between age and the level of physical activity among flight crew also turned out to be insignificant. A significant association of low strength was noted between the level of physical activity and the age of ground staff. In the age group under 30, the percentage of soldiers with a high level of physical activity was significantly higher than in the other two age groups (90.0% vs. 78.3% and 75.4%). The percentage of soldiers up to 30 years of age with a low level of physical activity was significantly lower than among soldiers aged 31–40 (2.7% vs. 14.1%).

BMI was calculated for professional role and in terms of age groups of the soldiers (Table 2). The average BMI for all Air Force soldiers was 25.98 kg/m^2, for flight crew 26.65 kg/m^2, and for ground staff 25.46 kg/m^2. Normal body weight was revealed by 40.5% of all soldiers of the Air Force (flight crew 34.3%, ground staff 45.4%). Overweight was found in 46.5% of soldiers (flight crew 46.7%, ground staff 46.4%). On the other hand, obesity was revealed by 12.8% of all soldiers of the Air Force (flight crew19.0%, ground staff 7.9%), while underweight was diagnosed in one soldier (ground staff). Among the flight crew, the highest percentage of soldiers with normal body weight was found in soldiers under 30 (52.2%). The highest percentage of overweight soldiers was found among soldiers in the 31–40 age group (56.7%). On the other hand, soldiers in the age group over 40 showed the highest percentage of obesity (28.6%). The same tendency was found in the group of ground staff: normal body weight had the highest percentage among the youngest soldiers (68.2%), the highest percentage of overweight soldiers was in the 31–40 age group (58.7%), and obese soldiers were in the age group above 40 (16.9%).

Table 2. Summary of the BMI of the subjects [kg/m^2].

BMI for:	Age						H	*p*-Value	η^2
	<30 Years		31–40 Years		>40 Years				
	Me	IQR	Me	IQR	Me	IQR			
All Air Force soldier	24.19_a	3.31	26.26_b	3.73	26.83_b	4.94	76.74	<0.001	0.16
Flight crew	24.71_a	4.35	26.25_b	3.64	27.07_b	5.58	13.77	<0.001	0.06
Ground staff	23.96_a	3.11	26.24_b	3.72	26.57_b	4.10	58.07	<0.001	0.21

The values in a given column not sharing a letter index between rows differ at the $p < 0.05$ (Bonferroni correction). Legend: IQR—interquartile range; Me—median; H—Kruskal-Wallis test statistic; η^2—effect size.

In each age group of flight crew, a higher percentage of obese soldiers was found (statistically significant difference). Statistically significant differences in BMI values were found between the flight crew and ground staff. The following regularity was observed, BMI increases with the age of the subjects. The highest BMI was found in the group of flight crew who were over 40 (BMI = 27.67 kg/m^2).

In the next stage of the analysis of the research results, the total MET value, and the MET value for individual types of physical activity, were calculated (in accordance with the parts listed in IPAQ). It was found that the overall MET level in the group of ground staff was higher than that of the flight crew (12,333 MET vs. 10,262 MET; $p < 0.05$). For the activity from Part 1: Job-related PA, a statistically significant difference in MET values between the flight crew and ground staff was found (respectively: 3367 MET vs. 4807 MET). In the remaining parts of the listed activities, i.e., transportation of PA, housework, leisure-time PA, no statistically significant differences were found (Table 3).

Table A1 presents the results of the studies on the total MET value for each age group. In the group of flight crew, the highest total MET value (10,625 MET) was disclosed by soldiers over 40. However, in the group of ground staff, the highest MET value was for soldiers aged 31–40 (13,045 MET). The MET values calculated for the physical activities listed in the parts of the questionnaire (job-related PA, transportation PA, housework, leisure time) in individual age groups were also subjected to detailed analysis (Tables A2–A5). Taking into account the total number of Air Forces soldiers, the highest MET values related to professional work, transportation (relocation) and housework were revealed by soldiers of the age group up to 30 (respectively: 5059 MET; 2653 MET; 2959 MET) (Tables A3–A5). Flight crew over 40 received the highest MET value related to leisure time (2559 MET) (Table A5). A comparison was also made between the groups of flight crew and ground staff, MET values for intensive efforts, MET values for moderate efforts and MET values for walking. The flight crew obtained 3100 MET for intensive efforts, while the ground staff attained 3900 MET. For moderate efforts, 3214 MET was obtained by the flight crew and 3534 MET by the ground staff. For walking the results were, respectively: 4008 MET and 4871 MET (all statistically significant differences).

Table 3. Summary of MET values in flight crew and ground staff according to IPAQ criteria.

Variable	All Flight Crew (n = 210)		All Ground Staff (n = 267)				
	X ± SD	Median	X ± SD	Median	Z	p-Value	r_g
Total MET	10,262 ± 10,330 #	7456	12,333 ± 9841	10,770	−3.05	p = 0.002	0.14
MET total work (part 1)	3367 ± 4334 #	1893	4807 ± 5892	3270	−2.69	p = 0.007	0.12
MET total relocation (part 2)	2160 ± 2300	2160	2539 ± 3011	1512	−0.91	p = 0.361	0.04
MET total homework (part 3)	2648 ± 6116	1167	2303 ± 3539	2303	0.37	p = 0.712	0.02
MET total leisure time (part 4)	2087 ± 2119	1596	2684 ± 3219	1600	−1.17	p = 0.243	0.05

statistically significant differences on the level $p < 0.05$. part 1, 2, 3, 4—parts of IPAQ; r_g—effect size.

There were no statistically significant differences between the surveyed groups of soldiers in the variables "time spent sitting on a weekday" and "time spent sitting on a weekend". It was calculated that the flight crew spends 258 min per weekday and 211 min per weekend sitting (ground staff: 235 min and 219 min, respectively).

In order to determine which variables had the greatest impact on BMI, correlations were calculated and the level of statistical significance was determined. No correlations were found in the group of All Air Force soldiers (Table 4). Taking into account the total number of All flight crew, a statistically very weak negative correlation was found between BMI and total MET, MET work, MET transportation (relocation) and walking. In the group of ground staff only one correlation was found, between BMI and MET work (<30 years).

Table 4. Correlation of BMI with other variables related to IPAQ.

BMI [kg/m^2]:	All Flight Crew (n = 210)			All Ground Staff (n = 267)		
	r	CI 95%	p-Value	r	CI 95%	p-Value
Total MET	−0.23	−0.35; −0.09	<0.001			
	−0.42#	−0.64; −0.13	0.005	-		
MET total work (IPAQ part 1)	−0.16	−0.29; −0.02	0.020	0.27 #	0.08; 0.44	0.004
	−0.31 #	−0.56; −0.002	0.050			
MET total transportation (IPAQ part 2)	−0.14	−0.17; 0.004	0.027			
MET walking	−0.19	−0.32; −0.05	0.006			

Legend: # only soldiers in the age group for 30 years old; part 1, 2—parts of IPAQ; CI—confidence intervals.

4. Discussion

It was hypothesized that a higher level of physical activity would be revealed by soldiers belonging to the group of flight crew. The premise for such a hypothesis was the fact that more attention is paid to physical preparation in the flight crew. This was manifested in an increased number of physical education classes (flight crew at least 6 h per week, ground staff at least 4 h per week), and the fact that the flight crew participated once a year in three-week training and fitness camps [25]. On working days during training and fitness camps, a minimum of 6 h of physical education, sports and recreation classes were carried out. Wider educational and promotional activities in the field of a healthy lifestyle were also undertaken in relation to the flight crew. The Military Institute of Aviation Medicine plays a leading role in this aspect. Based on the results of the studies, the hypothesis was rejected. It turned out that it was the ground staff who represented a higher level of physical activity (expressed as total MET). Another surprising result was the disclosure of the fact that 8% of the Air Force soldiers were classified in a group with a low level of physical activity. This is a worrying percentage as this occupational group is expected to have a high, or at least moderate, level of physical activity. It turned out that a similar percentage of soldiers with low levels of physical activity occurred in the group of flight crew and ground staff (7.2% and 8.6%, respectively). A similar result was obtained by Tomczak et al. (2011) in studies conducted among military police soldiers (7.7%) [15]. In turn, Mierzejewski, in the research carried out at the Land Forces Training Center, did not find any soldier with a low level of physical activity [14]. This may suggest that as long as soldiers participate in military training in barracks, they are ensured an adequate level of physical activity by participation in varied military training. However, after returning to military units and everyday life, the issues of physical activity become less important.

Analyzing the levels of physical activity in individual age groups, a disturbing phenomenon was observed. In accordance with the general trend, it was assumed that younger soldiers and flight crew would be characterized by a higher level of physical activity. This assumption was also not confirmed. Among flight crew aged up to 30, a lower percentage of soldiers with a high level of physical activity was revealed than in the age group up to 30 of ground staff (81.8% and 90.0%, respectively). The highest percentage of soldiers with low levels of physical activity was also revealed among flight crew up to the age of 30 (9.1%) and ground staff (2.7%).

The level of physical activity is related to the value of BMI, greater physical activity is one of the factors influencing the reduction of body mass [26]. Assuming the BMI criteria, all the Air Force soldiers were revealed to be slightly overweight (25.98 kg/m^2). BMI increased with the age of the respondents. Higher BMI was found in the flight crew (Table 2). However, BMI should be interpreted with great caution in relation to athletes (strength competitions), as well as physically active people who regularly practice strength exercises, because then we may have to deal with the so-called muscle overweight [27]. Interesting information is provided by a comparative analysis of the currently obtained BMI results of flight crew with the results of research conducted fifteen years ago by Henrykowska and Tomczak, also among the polish flight crew [28]. At that time, the level of BMI of flight crew was 25.43 kg/m^2, which was 1.22 units lower than at present. For soldiers in the group up to 30 years old, the BMI level was 23.50 kg/m^2 (it was lower by 1.55 units), for soldiers in the group 31–40 years old, 24.41 kg/m^2 (it was lower by 1.65 units), and for the group of soldiers over 40, 27.99 kg/m^2 (it was lower by 0.32 units) [28]. Definitely higher values currently occur in the group of respondents up to the age of 30 and in the group aged 31–40. These research results show an unfavorable trend taking place, not only in the military environment [29].

Many researchers have studied the influence of BMI level on injuries suffered by soldiers [30]. There is insufficient scientific evidence for BMI in general as a modifiable risk factor. However, there is strong scientific evidence for obesity, for being overweight and underweight, as a modifiable risk factor for musculoskeletal injuries [31–33]. It was also found that soldiers who were older had higher BMIs, ran longer distances during unit physical training, and had lower cardiovascular endurance as measured by the two-mile run and were at a higher risk of a running-related injury [33].

A result worth analyzing is the MET value during professional work (IPAQ Part I). A significantly higher MET value was found for the ground staff compared to the flight crew (4807 MET and 3367 MET, respectively). The flight crew is generally believed to perform heavier work when performing tasks in the air. However, this was not confirmed by the conducted surveys. Such a result was most likely influenced by an increase in the degree of technicality of military equipment and the associated change in the manner of performing work (loads, performance of activities). As noted in the modern world, coordination skills are more important than fitness skills [34,35]. In spite of these changes, the ground staff, which consisted of technicians operating aircraft, performs many activities requiring effort (moving equipment, lifting, moving as walking or cycling).

The present considerations lead to a reflection that educational errors, related to the promotion of a healthy lifestyle, may have occurred in military units. Kaiser and Sokołowski stated that the army as a total institution has a significant impact on the lifestyle (pro-health attitudes) of soldiers. Therefore, it would be advisable to modify the existing military school programs by taking into account the issues of health education, so that the superiors not only acquire command skills, but also become model health educators [12]. Mullie et al. (2013), on the other hand, indicated that the army, instead of relying on civilian actions in the field of public health, should develop its own specific methods of preventing weight gain, improving physical fitness and influencing attitude to smoking [36].

Limitations

As stated by the Polish researchers, the respondents' self-completion of the questionnaires led to some overestimation of the type and duration of efforts [37]. So, this seems to be the biggest limitation of our research. However, it should be emphasized that the respondents were instructed in detail before filling in the questionnaires. When filling in the questionnaires, the respondents had the opportunity to ask the interviewer questions. Another limitation reported by researchers is the use of the long version of IPAQ instead of the short version. The respondent is forced to spend a longer time completing the questionnaire. In our opinion, it does not seem that the time needed to complete the IPAQ was long enough to discourage respondents from filling in the questionnaire diligently. Moreover, the long version of the IPAQ is recommended in scientific research, especially when one of the forms of physical activity is carefully analyzed [38]. In our research, we tried to carefully analyze various forms of physical activity in different professional roles and age groups.

5. Conclusions

In general, the Air Force soldiers represented a high and moderate level of physical activity. However, every fifteenth respondent revealed a low level of physical activity. There were no differences in the level of physical activity between flight crew and ground staff. Moreover, the BMI of the examined soldiers indicated overweight tendencies, and a comparative analysis with the results of research from many years ago revealed that the largest increase in BMI occurred in the group of soldiers aged 19 to 30. In the Air Force, educational programs on health promotion specific to the Air Force and individual military specialties should be introduced. Preventive programs to date have not contributed to an increase in care regarding the correct level of body weight, and to an increase in level of awareness regarding the positive aspects of physical activity. The above statements were particularly strongly confirmed by the results of research on soldiers of the youngest age (up to the age of 30). It is therefore all the more necessary to undertake immediate educational interventions.

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Appendix A

Table A1. Comparison of the total MET (professional work, transportation, housework, leisure time).

No.	Variables	Mean ± SD	Median	Q1; Q3 (Quartile Deviation)	Coef. Var.
1	Air Force soldiers for years 30 (*n* = 154)	13,175 ± 11,660	10,224	5282; 17,538 (6128)	88
2	Air Force soldiers 31–40 years old (*n* = 188)	10,367 ± 8642	8714	3727; 14,214 (5243)	83
3	Air Force soldiers above 40's (*n* = 135)	10,889 ± 8642	8586	4905; 14,096 (4596)	91
4	Flight crew for years 30 (*n* = 44)	10,541 ± 11,376	7641	4941; 12,354 (3706)	108
5	Flight crew 31–40 years old (*n* = 96)	9870 ± 8514	7378	3727; 13,077 (4675)	86
6	Flight crew above 40's (*n* = 70)	10,625 ± 11,933	7432	4287; 12,195 (3954)	112
7	Ground staff for years 30 (*n* = 110)	12,871 ± 9624	10,864	6447; 16,000 (4776)	75
8	Ground staff 31–40 years old (*n* = 92)	13,045 ± 10,709	11,740	4237; 21,403 (8583)	82
9	Ground staff above 40's (*n* = 65)	10,415 ± 8760	8202	3012; 16,730 (6859)	84

Table A2. Summary of total MET related to professional work.

No.	Variables	Mean ± SD	Median	Q1; Q3 (Quartile Deviation)	Coef. Var.
1	Air Force soldiers for years 30 (*n* = 154) ^	5059 ± 6786	2833	1.0; 7371 (3685)	134
2	Air Force soldiers 31–40 years old (*n* = 188)	3523 ± 4436	1879	99; 4830 (2365)	126
3	Air Force soldiers above 40's (*n* = 135)	4068 ± 4301	3150	693; 5760 (2533)	106
4	Flight crew for years 30 (*n* = 44)	3424 ± 3920	2607	346; 4665 (2159)	114
5	Flight crew 31–40 years old (*n* = 96)	3412 ± 4749	1488	313; 4581 (2134)	139
6	Flight crew above 40's (*n* = 70)	3268 ± 4030	1980	537; 4476 (1965)	123
7	Ground staff for years 30 (*n* = 110)	5413 ± 6800	4116	1485; 7518 (3016)	126
8	Ground staff 31–40 years old (*n* = 92)	4569 ± 5223	2617	1.0; 7612 (3806)	114
9	Ground staff above 40's (*n* = 65)	4120 ± 5067	2160	0.0 ± 5850 (2925)	123

^ The difference at a statistically significant level between the groups No 1–2 ($p < 0.05$).

Table A3. Summary of total MET related to relocate in different groups.

No.	Variables	Mean ± SD	Median	Q1; Q3 (Quartile Deviation)	Coef. Var.
1	Air Force soldiers for years 30 (n = 154) ^	2653 ± 2932	1758	495; 3600 (1552)	111
2	Air Force soldiers 31–40 years old (n = 188)	2245 ± 2830	1350	396; 3492 (1548)	126
3	Air Force soldiers above 40's (n = 135)	2228 ± 2290	1638	495; 2988 (1246)	103
4	Flight crew for years 30 (n = 44)	2181 ± 2472	1386	396; 3130 (1367)	113
5	Flight crew 31–40 years old (n = 96)	2058 ± 2070	1386	448; 3501 (1526)	101
6	Flight crew above 40's (n = 70)	2287 ± 2508	1674	318; 2952 (1254)	110
7	Ground staff for years 30 (n = 110)	2730 ± 3397	1592	693; 3483 (1741)	124
8	Ground staff 31–40 years old (n = 92)	2696 ± 3040	2065	144; 3742 (1799)	113
9	Ground staff above 40's (n = 65)	1994 ± 2116	1116	396; 2799 (1201)	160

^ The difference at a statistically significant level between the groups No. 1–3 ($p < 0.05$).

Table A4. Summary of total MET related to housework.

No.	Variables	Mean ± SD	Median	Q1; Q3	Coef. Var.
1	Air Force soldiers for years 30 (n = 154)	2959 ± 6403	1260	330; 4020	216
2	Air Force soldiers 31–40 years old (n = 188)	2346 ± 2801	1440	390; 3400	119
3	Air Force soldiers above 40's (n = 135)	2033 ± 5006	810	0.0; 2460	246
4	Flight crew for years 30 (n = 44)	3088 ± 9574	990	422; 2415	310
5	Flight crew 31–40 years old (n = 96)	2356 ± 2815	1305	435; 3240	120
6	Flight crew above 40's (n = 70)	2773 ± 6708	1080	180; 3060	242
7	Ground staff for years 30 (n = 110) ^	1742 ± 1956	940	90; 3240	112
8	Ground staff 31–40 years old (n = 92)	2981 ± 5200	1590	0.0; 3690	174
9	Ground staff above 40's (n = 65)	2294 ± 2436	1380	360; 4200	106

^ The difference at a statistically significant level between the groups No. 7–8 ($p < 0.05$).

Table A5. Summary of total MET related to leisure time.

No.	Variables	Mean ± SD	Median	Q1; Q3 (Quartile Deviation)	Coef. Var.
1	Air Force soldiers for years 30 (n = 154)	2504 ± 2929	1440	438; 3531 (1546)	117
2	Air Force soldiers 31–40 years old (n = 188)	2253 ± 2890	1555	305; 3063 (1379)	128
3	Air Force soldiers above 40's (n = 135)	2559 ± 2524	1986	546; 3828 (1641)	99
4	Flight crew for years 30 (n = 44)	1848 ± 2081	1278	313; 2754 (1220)	113
5	Flight crew 31–40 years old (n = 96)	2044 ± 2017	1645	519; 2790 (1135)	99
6	Flight crew above 40's (n = 70)	2296 ± 2284	1765	206; 3744 (1769)	99
7	Ground staff for years 30 (n = 110) ^	2986 ± 3468	1815	914; 4273 (1680)	116
8	Ground staff 31–40 years old (n = 92)	2798 ± 3225	1551	148; 4470 (2161)	115
9	Ground staff above 40's (n = 65)	2007 ± 2674	1116	1.0; 3051 (1525)	133

^ The difference at a statistically significant level between the groups No. 7–9 ($p < 0.05$).

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Assessment of Energy Expenditure of Police Officers Trained in Polish Police Schools and Police Training Centers

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Abstract: Knowledge of the energy expenditure related to the training of policemen allows for assessment of the intensity of the work performed and is an indispensable element of planning and implementing nutrition. This study on energy expenditure comprised a total of 280 persons, students of two Polish police schools and two police training centers. The energy expenditure of policemen was determined based on measurements of the heart rate using Polar RC3 GPS heart rate monitors. The energy expenditure of policemen associated with the training process in the police schools and training centers ranged from 1793 to 3043 kcal/8 h and amounted to 2314 ± 945 kcal/8 h during training on average. The values of energy expenditure related to a typical training day in Polish institutions conducting police training are diverse and depend on the specificity and nature of the training. According to the criteria for assessing the burden of work, the work performed by police officers can be classified as hard work and very hard work.

Keywords: energy expenditure; police schools; police officers; physical activity; hardness of work

1. Introduction

Many studies have concluded that physical inactivity is a primary cause of most chronic diseases [1–3]. The benefits of physical activity for maintaining health have been well documented, especially in the prevention and treatment of chronic diseases such as certain cancers, type 2 diabetes, and cardiovascular diseases [4,5]. This is especially important in the police force, as law enforcement officers are often required to adapt quickly from sedentary, passive functions to hostile environments where maximum body effort is needed [6]. In this context, accurate measurement of energy expenditure is essential for both epidemiological studies and assessment of human nutritional needs [7,8].

Total energy expenditure is the energy required by the body during a 24-h period and is determined by the sum of three components: basal energy expenditure, diet-induced thermogenesis, and physical activity [9]. Determination of energy expenditure is important to adjust the nutritional habits of individual people and must take into account the energy requirements for physical activity and specific health conditions. To date, no research has been conducted in Poland on the energy burden associated with the service and training of officers studying at police schools and trained at police training centers. In the Polish uniformed services, such research was conducted only among students of various types of military schools and fire schools. These studies indicate that students at military universities were burdened with an energy expenditure of 3339 to 4121 kcal/d, while students at fire schools—from 3735 to 4745 kcal/d [10–13]. According to the workload classification by Lehman, they performed medium to very heavy work [14].

The issues related to energy expenditure, the energy value of food, and, consequently, the systemic energy balance are of particular importance in the uniformed services. Knowledge of the physical burden connected with the specificity of the service performed should be an indispensable element of food planning, which must cover the energy needs of the body and provide all necessary nutrients in the right amounts and proportions. The police are a uniformed and armed formation serving the public and intended to protect human security and to maintain public safety and order. Knowledge of the energy expenditure related to the training of police officers allows for assessment of the severity of work performed and provides a possibility to quantify it and forms the basis for establishing nutrition standards. The heaviness of work, the measure of which is the value of energy expenditure, is an indispensable element of an assessment of physical load in accordance with psychophysical capabilities, while the physical load is a relation between the requirements of work based on physical effort and the capabilities of the body.

The aim of this study was to determine the energy expenditure of students at police schools and police training centers in relation to the specificity and nature of the training to assess degree of intensity of their work.

2. Materials and Methods

2.1. Participants

The research on energy expenditure covered 270 students at four police training institutions: two police schools, a police training center, and a police prevention department.

The examination of energy expenditure covered 280 persons trained in 2 Polish police schools and 2 police training centers. The research involved 60 students at the police academy, including 50 men and 10 women; 113 students, all men, trained on specialist courses at the police training center; 47 students at the police school; and 60 policemen trained at the police prevention department.

Due to the small number of women studying in police schools and police training centers, only men took part in the research. Thus, the study covered 50 students of the police academy, 113 students trained in specialist courses at the police training center, 47 students at the police school, and 60 students at the police prevention department. Among the 113 students of the police training center, 74 people were trained on a specialist course for police officers intervening against aggressive and dangerous persons, 18 participated in training for future police dog handlers, and 21 were trained to work in the water police. All students participated in the same theoretical classes and classes on the use of weapons, while the other specialist classes took into account the specificity of the future service in the police.

The research on the students of the police academy and the police school was conducted during typical training activities included in the training plan and covered both theoretical classes in the form of lectures and those related to high physical activity, such as tactics or shooting.

The research was conducted in accordance with the Helsinki Declaration of the World Medical Association and was approved by the Ethics Committee of the Military Institute of Hygiene and Epidemiology (no. 1/XXI 95/2016). Participants received an information sheet about the details of the study, the purpose, and the procedures used as well as potential risks and benefits of their participation.

2.2. Measurement of Height and Weight

Body height (without shoes) was measured using a portable stadiometer (TANITA HR-001, Tanita Corporation, Tokyo, Japan). Body weight was measured using a bioelectrical impedance analysis (BIA) with the TANITA MC-780 103 device (Tanita Corporation, Tokyo, Japan), with an accuracy of 0.1 kg, according to the procedure specified in the instruction manual (lightly dressed, without shoes). All measurements were performed according to the procedure specified in the instruction manual and without any metal objects.

2.3. Measurement of Energy Expenditure

The method of analyzing heart rate changes was used to measure energy expenditure. The energy expenditure study included heart rate measurements with a Polar RC3 GPS heart rate monitor (Polar Electro Oy, Kempele, Finland). The values of energy expenditure of the activities performed by the policemen constitute the average value of at least three measurements. The obtained results were the basis for determining the energy demand of policemen in relation to the specificity and nature of training and/or service, as well as for the assessment of the intensity of work, in accordance with the classification given by Lehman (Table 1) [14].

Table 1. Classification of work severity on the basis of energy expenditure values for an 8-h working day [6].

Severity of Work	Energy Expenditure during an 8-h Working Day			
	Male		Female	
	kcal	kJ	kcal	kJ
Very light	<300	<1256	<200	<837
Light	300–800	1256–3350	200–700	837–2930
Moderate	800–1500	3350–6280	700–1000	2930–4187
Hard	1500–2000	6280–8374	1000–1200	4187–5024
Very hard	>2000	>8374	>1200	>5024

2.4. Statistical Analyses

All statistical analyses were performed using the program R (The R Foundation for Statistical Computing v2.0–1. https://cran.r-project.org, accessed on 20 September 2021). Anthropometric data are shown as mean values ± standard deviation, and differences among experimental groups were analyzed with Student's *t*-test, which were statistically significant when $p < 0.05$. To check the compliance of the variables with the normal distribution, the Shapiro–Wilk test was used, and Levene's test was used for verification of the homogeneity of variance. The differences in the values of energy expenditure of students at individual universities and training centers were calculated using the chi-square test. The data spread is presented in interquartile range (IQR) values.

3. Results

3.1. Characteristics of the Studied Groups

The characteristics of the studied groups are given in Table 2.

In the police academy, the research included students of the police service preparation course.

The group of people trained in the police prevention department was the youngest, which resulted from the student selection criteria, while students at the police school were characterized by the highest body weight.

3.2. Energy Expenditure of Police Academy Students

The study of students' energy expenditure was carried out during the implementation of tasks in the study program at the police academy. It included measurements both during typical theoretical classes and in field conditions, during which students learned how to use weapons, arrest procedures, chase, etc. The results of the energy expenditure of police officers carrying out typical training tasks during 8 h of training are presented in Table 3.

Table 2. Characteristics of police officers.

	Students of the Police Academy	Students of the Police Training Center	Students of the Police School	Policemen Trained in the Police Prevention Department
Sex	Male—50	Male—113	Male—47	Male—60
Age (years)	38.0 ± 6.7 (IQR = 4.0)	39.8 ± 9.8 (IQR = 9.0)	40.2 ± 6.6 (IQR = 11.0)	36.1 ± 6.6 * (IQR = 8.0)
Height (cm)	178.3 ± 8.3 (IQR = 7.0)	179.4 ± 8.6 (IQR = 11.0)	180.4 ± 6.9 (IQR = 9.0)	180.3 ± 6.5 (IQR = 9.0)
Weight (kg)	81.7 ± 13.3 (IQR = 16.5)	87.7 ± 13.6 (IQR = 19.6)	93.8 ± 15.3 * (IQR = 15)	83.7 ± 12.5 (IQR = 16.0)

* Statistically significant difference at $p < 0.05$. IQR—interquartile range.

Table 3. Average energy expenditure of men studying in the police academy during an 8-h training day.

N = 50	Lectures, Tactics Classes, Detention (Handcuffing), Physical Education Classes							
		X	±	SD	Median	Min	Max	IQR
Energy expenditure	Time (h)	9.5	±	2.5	9.4	5.6	25.2	0.8
	kcal/h	279	±	68	261	141	441	92
	kcal/min	4.65	±	1.13	4.35	2.35	7.35	1.5
	kcal/h/kg bw	3.3	±	0.9	3.2	1.3	5.4	1.1
	kcal/min/kg bw	0.055	±	0.014	0.052	0.022	0.09	0
	kcal measured	2646.8	±	1007.7	2602.5	1461	5117	1016
Pulse	Max	169.4	±	24.7	170.5	93	220	32.0
	Min	59.5	±	11.8	61	47	77	11.0
	Average	92.6	±	8.2	94	68	108	12.0
Average	**kcal/8 h**	**2233**	±	**546**	**2247**	**1127**	**3527**	**736**

IQR—interquartile range.

Analysis of the obtained results showed that the average energy load of police officers carrying out training tasks at the basic course in the police academy amounted to 2233 ± 546 kcal/8 h and varied depending on the activities performed. This value, according to Lehman's classification of workload, allows to classify the work performed as very heavy work [6].

3.3. Energy Expenditure of Students at the Police Training Center

3.3.1. Energy Expenditure of Students Trained on Specialist Courses for Police Officers

The research on energy expenditure covered 74 men, all students at the police training center trained on specialist courses for police officers intervening against aggressive and dangerous people and for instructors of police shooting in anti-terrorist police units. The mean body weight and mean height of the officers were 90.4 ± 13.8 kg and 179.7 ± 7.8 cm, respectively. The energy expenditure of police officers trained for the above-mentioned specialist courses included both training tasks of a theoretical nature (lectures) and those related to high physical activity, e.g., preparation and implementation of shooting. The results of the energy load of officers in relation to the training process are summarized in Table 4.

It was shown that the average energy expenditure of an officer associated with a typical 8-h day of program training was 2458 ± 723 kcal, which places the work performed in the category of very heavy work. It should be emphasized that there is a large variation in the results of energy load related to the implementation of various types of training. Theoretical training resulted in a low energy load of students, amounting to 1.75 kcal/min, which was characteristic of light work, while during intensive tactical classes, it amounted to 7.67 kcal/min, indicating the performance of hard work.

Table 4. Energy burden related to implementation of training at specialist courses at the police training center.

N = 74		**Police Training Center**						
		X	±	**SD**	**Median**	**Min**	**Max**	**IQR**
Energy expenditure	Time	6.3	±	1.1	6.3	1.8	7.6	0.47
	kcal/h	299.9	±	74.4	299.6	105.2	460.6	96.14
	kcal/min	4.99	±	1.24	4.99	1.75	7.67	1.60
	kcal/h/kg bw	3.4	±	1	3.1	1.4	6.3	1.31
	kcal/min/kg bw	0.056	±	0.016	0.052	0.023	0.102	0.02
	kcal measured	1889.8	±	964.7	1884.5	656	3402	683
Pulse/min	Maximum	166	±	28	170	47	232	34
	Minimum	61	±	103	52	32	89	11
	Average	97.1	±	9.3	94	83	125	12
Average	**kcal/8 h**	**2458**	±	**723**	**2242**	**1010**	**4546**	**769.1**

IQR—interquartile range.

3.3.2. Energy Expenditure of Officers Trained as Future Service Dog Handlers

Another assessment concerned the energy expenditure of officers trained as future service dog handlers. The study involved 18 officers, aged 34 ± 4.3 years, of an average body weight of 83.2 ± 16.0 kg and body height of 174.0 ± 7.0 cm. The training included training of patrol dogs and dogs for special tasks such as searching for drugs or explosives. The results of the energy expenditure of service dog handlers are summarized in Table 5.

Table 5. Energy load related to the training of officers—future service dog handlers.

N = 18		**Training Center for Service Dog Handlers for the Police**						
		X	±	**SD**	**Median**	**Min**	**Max**	**IQR**
Energy expenditure	Time (h)	5.3	±	1.3	5.6	0.8	6.1	0.5
	kcal/h	263.8	±	104.2	263.7	1388.4	448.7	213.87
	kcal/min	4.39	±	1.73	4.39	2.30	7.47	3.56
	kcal/h/kg bw	3.10	±	1.00	3.10	1.60	5.60	1.34
	kcal/min/kg bw	0.052	±	0.017	0.052	0.026	0.092	0.02
	kcal measured	1422	±	727	1299	212.0	2737	1441
Pulse/min	Maximum	56.4	±	24.4	152,0	126.0	228.0	37
	Minimum	60.0	±	11.0	63.0	39.0	75.0	13
	Average	94.0	±	9.8	96.0	78.0	109.0	19
Average	**kcal/8 h**	**2111**	±	**834**	**2110**	**1107**	**3590**	**857.98**

IQR—interquartile range.

The energy expenditure related to the training of service dog handlers amounted to 2111 ± 834 kcal/8 h, which puts the severity of work performed in the category of very heavy work.

3.3.3. Energy Expenditure of Police Officers Who Perform Tasks on Waters

The police training center trains, among others, police officers who perform tasks on waters and in surrounding areas. During these courses, students acquire skills related to performing specialized tasks in the preventive service on water; rescuing and searching for people, property, and floating equipment; and maneuvering a boat in difficult and extreme weather conditions. They also acquire skills in organizing rescue operations, handling specialized rescue and navigation equipment, and learning to use modern means of transport, including water scooters, while on patrol. The training process takes place mainly on water and concerns driving and operating motorboats and navigation and rescue operations in water areas.

The study of energy expenditure of police officers connected with the specificity of this training covered 21 male officers, aged 34.5 ± 6.6 years, with an average body weight of 89.5 ± 10.9 kg and height of 184.5 ± 4.5 cm. The values of energy load associated with the training are summarized in Table 6.

Table 6. Energy burden of officers related to the training of policemen performing tasks on water.

N = 21		Training of Policemen Performing Tasks at the Water Areas						
		X	**±**	**SD**	**Median**	**Min**	**Max**	**IQR**
Energy expenditure	Time (h)	6.0	±	0.0	6.0	6.0	6.0	0.13
	kcal/h	221.7	±	69.1	230.9	108.7	415.8	63.14
	kcal/min	3.69	±	1.73	3.84	1.81	6.93	1.05
	kcal/h/kg bw	2.5	±	0.9	2.5	1.3	5.1	1.07
	kcal/min/kg bw	0.042	±	0.014	0.041	0.021	0.085	0.02
	kcal measured	1433.6	±	441.9	1470.0	712.0	2668.0	387
Pulse/min	Maximum	144.7	±	20.8	143.0	113.0	192.0	23
	Minimum	60.0	±	10.0	58.0	43.0	81.0	11
	Average	85.4	±	10.7	87.0	65.0	107.0	9
Average	**kcal/8 h**	**1973**	**±**	**553**	**1847**	**870**	**3326**	**505.12**

IQR—interquartile range.

It was shown that an 8-h day of training resulted in an energy load of 1973 ± 553 kcal, indicating that they were performing heavy work. The relatively low energy expenditure of the water police trainees compared to those participating in other courses results from the specificity of patrolling water areas on motorboats, which is related to their low physical activity. Analysis of the average values of energy expenditure incurred by officers during the 8-h training process in the three centers included in the police training center showed that officers were burdened with different levels of energy expenditure, which resulted from the specificity of the training. The highest value of energy load related to the 8-h training day was found in officers trained on specialist courses and during the training of service dog handlers, which qualified the work as very hard work, while officers trained on water performed heavy work.

3.4. Energy Expenditure of Policemen Trained in the Police School

The police school specializes in training prevention police officers, i.e., those whose service has a direct impact on public order and the sense of security of citizens. Among other things, the school provides basic vocational training that every police officer admitted to the service must undergo. It prepares them for the implementation of tasks in basic executive positions (e.g., in patrol and intervention services, in police prevention units, or in a convoy service). Students gain knowledge and skills in the fields of law, crime prevention, forensics, intervention tactics and techniques, psychology, social communication, ethics, human rights, first aid, shooting training, and operation of IT and communication equipment. They learn how to perform patrol intervention and convoy protection services as well as the specifics of work as a district policeman and unit officer on duty.

A total of 47 male officers with an average body weight and height of 93.8 ± 15.3 kg and 180.4 ± 6.9 cm, respectively, were included in this energy expenditure study.

The results of the research on the energy load of officers during the 8-h training day are summarized in Table 7.

The results of the research on the energy expenditure of officers trained in the police school show that the work performed during the training is very hard work.

3.5. Energy Expenditure of Policemen Trained in the Police Prevention Unit

Police prevention units are designed mainly for team activities within compact subunits. The main tasks of these units include the following:

- Protection of public security and order during legal gatherings and mass events;
- Restoring public order in the event of collective violation of the law;

- Protection of public order in the event of constitutionally defined states of emergency as well as catastrophes and natural disasters;
- Pursuit of dangerous criminals.

The study involved 60 officers with an average body weight of 83.7 ± 12.5 kg and an average body height of 180.3 ± 6.5 cm. The research included activities carried out on a typical training day, including combat tactics, drills, and shooting.

The obtained results are summarized in Table 8.

Table 7. Energy expenditure of male officers trained at the police school.

N = 47		Training of Policemen at the Police School						
		X	±	SD	Median	Min	Max	IQR
Energy expenditure	Time (h)	7.0	±	2.70	6.5	2.5	24.0	1.5
	kcal/h	283.0	±	118.0	292.0	54.0	552.0	166.6
	kcal/min	4.71	±	1.96	4.86	0.90	9.20	2.8
	kcal/h/kg bw	3.0	±	1.2	2.8	0.7	5.7	2.0
	kcal/min/kg bw	0.050	±	0.020	0.047	0.011	0.095	0
	kcal measured	1976.0	±	947.0	1982.0	345.0	4930.0	1248
Pulse/min	Maximum	159.6	±	27.8	155.0	115.0	224.0	28
	Minimum	66.2	±	11.2	66.0	27.0	83.0	16
	Average	92.9	±	11.4	93.0	66.0	116.0	16
Average	**kcal/8 h**	**2267**	±	**942**	**2334**	**936**	**4415**	**1332.6**

IQR—interquartile range.

Table 8. Energy expenditure of officers trained in the police prevention unit.

N = 60		Training of Policemen at Police Prevention Unit						
		X	±	SD	Median	Min	Max	IQR
Energy expenditure	Time (h)	5.7	±	1.0	6.0	2.6	7.0	0.88
	kcal/h	380.0	±	164.0	381.0	92.0	678.0	267
	kcal/min	6.33	±	2.73	6.35	1.53	11.3	4.45
	kcal/h/bw	4.6	±	1.9	4.9	1.3	8.2	3.43
	kcal/min/bw	0.076	±	0.031	0.082	0.021	0.138	0.06
	kcal measured	2171.0	±	1013.9	2170.0	244.0	4464.0	1412
Pulse/min	Maximum	172.4	±	26.1	179.0	115.0	226.0	42
	Minimum	62.9	±	11.1	64.0	44.0	78.0	15
	Average	102.7	±	16.8	106.0	62.0	134.0	26
Average	**kcal/8 h**	**3043**	±	**1308**	**3048**	**937**	**5427**	**2136**

IQR—interquartile range.

It should be noted that in all examined police units, there was a large variation in the results, from low values of 1463.0 ± 339.0 kcal/8 h in the case of women's training up to high values of 3043 kcal/8 h, which was connected with the specificity, conditions, and nature of the training and service performed. The average values of energy expenditure of the police officers trained for 8 h in all divisions are summarized in Table 9.

The analysis of the obtained values of energy load of the examined students in relation to the training processes showed that their energy expenditure from the implementation of individual training tasks was similar and ranged from 0.42 to 0.71 kcal/min/kg bw (Table 10). Although the largest energy expenditure related to the implementation of individual training activities, as well as that related to the 8-h training process, was observed in the students of police prevention units, it was not a statistically significant difference. On the other hand, the lowest energy expenditure related to the training was observed in the water police.

Table 9. Average values of energy expenditure of the police officers trained within 8 h.

N = 280		The Average Values of Energy Expenditure Related to the Training of Police Officers						
		X	±	SD	Median	Min	Max	IQR
Energy expenditure	Time (h)	7.0	±	2.5	6.8	0.8	25.6	1.52
	kcal/h	297.0	±	118.0	287.0	54.0	678.0	146.6
	kcal/min	4.95	±	1.96	4.78	0.90	11.3	2.44
	kcal/h/bw	3.50	±	1.40	3.20	0.70	8.20	1.76
	kcal/min/kg bw	0.058	±	0.023	0.053	0.011	0.136	0.03
	kcal measured	2035.0	±	910.1	1954.0	212.0	5117.0	1118
Pulse/min	Maximum	165.4	±	25.4	165.5	93.0	232.0	38
	Minimum	62.2	±	11.2	63.0	47.0	89.0	14
	Average	95.7	±	12.6	94.5	62.0	137.0	17
Average	**kcal/8 h**	**2314**	±	**945**	**2294**	**736**	**5427**	**1173**

IQR—interquartile range.

Table 10. Differences in the value of energy expenditure related to the process and specificity of training students at police schools and training centers.

Energy Expenditure	Students at the Police Academy	Students at the Police Training Center			Students at the Police School	Policemen Trained in the Police Prevention Department
		Specialist Courses	Dog Handlers	Water Police Training		
kcal/min/kg bw	0.055 ± 0.014	0.056 ± 0.016	0.052 ± 0.017	0.042 ± 0.014 *	0.050 ± 0.020	0.076 ± 0.031
Daily energy expenditure kcal/8 h	2223 ± 546	2458 ± 723	2111 ± 834	1973 ± 553 *	2267 ± 942	3043 ± 1308
Classification of the severity of work	Very hard work	Very hard work	Very hard work	Hard work	Very hard work	Very hard work

* Statistically significant difference at $p < 0.05$.

4. Discussion

Poland is one of the few countries where determination of the energy expenditure of workers on tasks at work is required by law. Information on how physically demanding work is (a measure of energy expenditure) at each workstation is essential not only for comparison with applicable regulations concerning maximum allowable values for regular work activity but also for work planning and taking proactive action to reduce the adverse health effects of work.

The value of energy expenditure related to an 8-h work shift should be taken into account when planning work, planning breaks, and allocating preventive meals and drinks by the employer. Heavy workload increases the risk of musculoskeletal system dysfunction, which is one of the causes of accelerated degenerative changes (especially of the spine) and an accelerated decline in exercise capacity. Hard physical work should also be considered a risk factor for cardiovascular disorders such as high blood pressure and ischemic heart disease. The assessment of energy expenditure, and thus the severity of work performed, allows to quantify the physical load of an employee according to his/her endurance capabilities.

Law enforcement is a highly stressful occupation that is prone to increasing the prevalence and incidence of cardiovascular disease. Evidence indicates that the prevalence of traditional cardiovascular risk factors among police officers is high (often higher than in the general population). Police work creates exposure to risk factors for the development of cardiovascular disease and diabetes and results in increased mortality rates [15–17]. Epidemiological studies suggest that police officers and related public security personnel develop an increased risk of cardiovascular morbidity and mortality. Currently employed police personnel have a high prevalence of traditional risk factors, including hypertension, hyperlipidemia, metabolic syndrome, smoking, and a sedentary lifestyle. Moreover, low physical activity of policemen leads to a positive energy balance and, consequently, to obesity [18,19]. Obesity may be more common among police officers compared with civilians, whereas diabetes is present less frequently. Law enforcement personnel are also exposed to occupational risk factors such as sudden physical exertion, acute and chronic psychological stress, shift work, and noise [16]. Obesity not only affects the ability of police officers to perform their work-related duties, but consequently, it may also impact public safety.

In the available literature, there are few works concerning the energy expenditure of students at police schools and police officers trained in police training centers. The values of energy expenditure obtained in the present study indicate that the energy loads of students and trainees participating in training programs in Polish police schools and police training centers range from 1973 ± 553 to 3043 ± 1308 kcal/8 h of work. These values place their work in the category of very hard work.

Studies in police schools can be compared to studies from fire service schools. The results of earlier research revealed that the values of energy expenditure during typical activities from the training program prepared for students at the Main School of Fire Service were diverse and ranged from 1.49 to 10.66 kcal/min. According to Christensen's classification of work severity, the work performed by students can be classified as light work to very heavy work [20]. The average daily energy load of students at the Main School of Fire Service on a typical day of training on the training ground was 4745 ± 1181 kcal/d, which means that the work performed should be considered, according to the obligatory classification of work intensity, as very heavy [11].

Previous studies on the energy load of students at the National Fire Service Aspirants School showed that their daily energy expenditure from the training process amounted to 3735.5 kcal, while during 8 h of program classes, students expended only 1289.5 kcal [12].

Historical studies on the energy burden of 30 male and 10 female police cadets, randomly selected from the Singapore Police Force, showed that the value of daily energy expenditure associated with duty and training tasks was 3028 and 1752 kcal, respectively [21].

A study on the energy expenditure of 28 healthy police officers working in shifts showed that the energy expenditure was 3062 kcal/d during night shifts, amounted to 2647 kcal/d during day shifts, and was the lowest on holiday duty, when it amounted to 2310 kcal/d [22].

An assessment of the service-related daily energy expenditure of Malaysian police officers showed that males expended 2639.6 ± 229.4 kcal/d and females 2268.9 ± 203.5 kcal/d [23].

The values obtained in the present study on energy expenditure associated with studies and training in Polish police schools and police training centers confirm the results of previous research, indicating that both studies and police training as well as police service are characterized by work that falls into the category of heavy work.

5. Conclusions

1. Assuming that the average value of men's energy expenditure during the training process in Polish police schools and the police training center, as well as in the prevention unit, amounts to 2314 ± 945 kcal/8 h of training, it should be concluded that the work performed by police officers belongs to the category of very hard work.
2. The energy expenditure related to the implementation of the study and training program depends on the type of university or training center as well as the specificity of the performed training activities.
3. The energy value of the daily food ration used in the nutrition of police officers trained in Polish police schools and police training centers should be adjusted to their energy expenditure.

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Article

Association between Diet, Physical Activity and Nutritional Status of Male Border Guard Officers

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Abstract: The main factors that determine the effectiveness and reliability of duties and tasks performed by border guard officers, are very good health and maintaining a high level of psychophysical fitness that depend mainly on adequate diet and physical activity and thus, nutritional status. The aim of the study was to verify the correlations between dietary habits, physical activity level and selected nutritional status indicators. One hundred and sixty-nine male border guard officers participated in the study. A 61-item food frequency questionnaire (FFQ) was used to assess dietary habits and a long-form International Physical Activity Questionnaire (IPAQ) was used to assess physical activity. Fat mass was determined by bioelectrical impedance analysis (BIA) and bone calcification was assessed by the dual energy X-ray absorptiometry (DXA). Many correlations between dietary habits, as well as the physical activity of officers and body mass index (BMI), fat mass index (FMI) and visceral fat level (VFL) were found, while bone mineral density (BMD T-score) negatively correlated only with two food groups and 6 out of 61 products but did not correlate with physical activity. The results also confirmed many poor dietary habits and abnormalities in nutritional status. Thus, there is a need for nutritional education and further monitoring of health-related behaviors, as well as monitoring the nutritional status of border guard officers.

Keywords: diet; nutrition; physical activity; nutritional status; body mass index; fat mass index; bone mineral density; border guard officers

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1. Introduction

Very good health and maintaining high level of psychophysical fitness are the main factors that determine the effectiveness and reliability of duties and tasks performed by Border Guard officers. The main tasks include border protection and the control of border traffic [1]. Some of the border guard's duties are performed in diverse geographical conditions, such as the sea area or mountains, thus maintaining a healthy condition and psychophysical fitness are crucial. Changing circumstances, i.e., during the deployment period, may lead to modification of dietary habits and exercise routine, for example with a negative effect on body composition and physical performance [2]. Thus, it is very important to maintain good nutritional status which mainly depends on diet and physical activity.

Optimizing nutrition strategies to support health and performance is important, especially for physically active people [3] as well as tactical personnel [4]. The recommendations, for example position stands developed by the International Society of Sports Nutrition, such as nutrient timing [5], protein and exercise [6] can be also applied as some of the nutrition recommendations for uniformed forces. Nevertheless, the basic principles of healthy diet and implementing a balance and diverse diet with high nutritional density are crucial, especially considering the poor dietary habits observed in these populations [4,7–10]. Diet quality, eating styles, and macronutrient composition influence body composition [11]. Too low an energy intake can lead to weight loss, especially a decrease in muscle mass, or decrease in bone density, which may negatively affect psychophysical performance, prolong recovery time and increase injury risk [2,12]. On the other hand, too high an energy intake may cause weight gain, and thus indirectly increase the risk of obesity that might result in difficulties in fulfilling service tasks. These abnormalities might be also the reason for early service eliminations because of health concerns.

The second factor that significantly affects body composition is physical activity. It not only leads to increasing physical performance and muscle mass, but also, as the most variable component of daily energy expenditure, determines energy balance [13]. Lifelong exercise delays the onset of 40 chronic diseases, such as coronary (ischemic) heart diseases, hypertension, obesity, insulin resistance, metabolic syndrome, osteoporosis, depression, and anxiety [14]. The evidence for the notion of "exercise is medicine" is strong, and physical activity has been used in both the prevention and treatment strategies for various diseases [15]. It is also an interaction between physical activity and other factors, for example diet and genetics that increases disease risk factors.

Since physical inactivity is considered as the biggest public health problem of the 21st century [16], the growing trend of people with overweight and obesity is also observed in the general population [17,18], as well as among uniformed service officers [19–25]. According to the last study, the prevalence of overweight and obesity in the Polish Army Forces (50% and 17% of men) [10] is similar to that in the general population of Poland (52% and 16% of men) [18]. Border guard officers, like other uniformed services, attend physical education classes and are obligated to complete annual physical fitness test [26,27]. Nevertheless, it has been observed that not all of border guard officers attend sport classes [28–30]. It has been shown that both occupational and leisure time physical activity are associated with body composition in police officers [31], thus it is necessary to assess the level of physical activity including both physical activity during work and physical activity as sport and leisure time.

Proper diet, regular physical activity, and thus nutritional status are extremely important for uniformed forces, affecting their physical fitness and their suitability for service. However, the literature on these associations between lifestyle factors and body composition among tactical personnel is relatively scarce, especially there has been a lack of research carried out among border guard officers. Therefore, the aim of the study was to verify the correlations between dietary habits, physical activity level and selected nutritional status indicators: body mass index (BMI), fat mass index (FMI), visceral fat level (VFL), bone mineral density (BMD T-score) and muscle mass index (MMI) in border guard officers from Poland.

2. Materials and Methods

The study was carried out with the participation of 169 male border guard officers from Poland. Informed consent was obtained from all subjects involved in the study. The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Military Institute of Hygiene and Epidemiology (1/XXI/2016).

2.1. Eating Meals, Food Consumption Frequency Assessment and Dietary Patterns

A two-part questionnaire was used to assess diet. The first part contained questions about the regularity of eating five meals with three possible answers to choose: every day, not every day, never. The second part was the evaluated 61-item food frequency questionnaire (FFQ) [32], slightly modified by adding two new categories of answers in this questionnaire, as in an earlier study [9].

Border guard officers were asked, included in the FFQ, how often they had consumed 61 food products in the past 12 months. For each product they could choose one of the eight answers regarding food consumption frequency: 1—never or almost never, 2—once a quarter or less often, 3—once a month or less often, 4—a few times a month, 5—once a week, 6—several times a week, 7—every day, 8—several times a day.

Reported frequencies were calculated into daily frequencies (time/day), as follows: never or almost never—0.003 (1/365), once a quarter or less often—0.01 (4/365), once a month or less often—0.03 (1/30), a few times a month—0.08 (2.5/30), once a week—0.14 (1/7), several times a week—0.57 (4/7), every day—1, several times a day—2. Converted frequencies were also summed within the main food groups, that were identified as:

1. Fruits, vegetables, and potatoes.
2. Seeds of legumes.
3. Cereal products.
4. Dairy products and eggs.
5. Meat products and fish.
6. Fats, nuts, and grains
7. Sweets and snacks.
8. Soft drinks.
9. Alcoholic beverages.

Converted frequencies of the main food groups were used to obtain dietary patterns.

2.2. Physical Activity Assessment

A long-form International Physical Activity Questionnaire (IPAQ) was used to assess physical activity level [33]. Officers were asked to answer 27 questions about physical activity during work/job, transportation, homework, house maintenance, and caring for family, recreation, sport, and leisure-time, as well as time spent sitting. Then results were calculated as metabolic equivalent (MET-minutes/week) according to the scoring protocol [34].

2.3. Nutritional Status Assessment

The TANITA HR-001 stadiometer (Tanita Corporation, Tokyo, Japan) was used to measure height. The head was aligned in the Frankfort horizontal plane [35]. Body weight and body composition (fat mass, visceral fat level, muscle mass) were evaluated using the TANITA MC-780 analyzer (Tanita Corporation, Tokyo, Japan). All measurements were performed in accordance with the procedures from the instruction manuals. Three additional indicators were calculated: body mass index (BMI), fat mass index (FMI) and muscle mass index (MMI):

BMI = body weight/height^2 [kg/m^2],
FMI = fat mass/height^2 [kg/m^2],
MMI = muscle mass/ height^2 [kg/m^2].

The scale of BMI classification reported by the World Health Organization (WHO) [36] and the scale of FMI described by Kelly et al. [37] were accepted.

Bone mineral density (BMD) was measured in the forearm bone of the nondominant hand, using Dual Energy X-ray Absorptiometry (DEXA) densitometric method, with an EXA 3000 analyzer (OsteoSys, Seoul, Korea). The results were interpreted in accordance with the WHO standards for BMD T-score: osteoporosis: BMD T-score ≤ -2.5, osteopenia: $-2.5 <$ BMD T-score ≤ -1.0, standard: BMD T-score > -1.0 [38].

2.4. Statistical Analysis

The PS IMAGO PRO (IBM SPSS Statistics, Armonk, NY, USA) program was used for all statistical analyses. Shapiro–Wilk test was used to verify the compatibility of variable distribution with normal distribution. Due to noncompliance of analyzed variables with normal distribution, Spearman's correlation was conducted to assess the associations among dietary habits, physical activity and five nutritional status indicators (BMI, FMI, VFL, BMD T-score, and MMI). Two dietary patterns were identified using the K-means cluster analysis. Input variables were converted to standardized scores. Logistic regression was used to assess the relationship between excess fat mass and potential risk factors. For all analysis the significant level of $\alpha = 0.05$ was assumed.

3. Results

The study was conducted among 169 male border guard officers aged 37 ± 6 years. The average length of service was 13 ± 7 years. About 1/3 of the subjects lived in a city of over 100 thousand inhabitants (32%), 35% in a city of up to 100 thousand inhabitants, and the rest lived in the country (33%). Almost 3/4 of officers were higher educated (71%), while others were secondary educated (29%). Nearly 2/3 of subjects assessed the physical level of work as light (27%) or performed while sitting (38%). According to 30% of officers, their work was moderate, and for others it was hard (5%).

3.1. Eating Meals, Food Consumption Frequency and Dietary Patterns

The meals that were most often eaten every day were dinner (84%), breakfast (83%) and supper (66%) (Table 1). Lunch was eaten every day only by 30%, afternoon snack by 18%, and supper by 66% of officers.

Table 1. Frequency of eating meals by border guard officers.

Percentage of Answers (%)	Breakfast	Lunch	Dinner	Afternoon Snack	Supper
Every day	83	30	84	18	66
Not every day	14	36	16	27	26
Never	3	34	0	55	8

Fruits (all types) were eaten every day by only 30% of subjects, out of which barely 3% ate them several times a day (Table S1). About half of officers (51%) ate fruits several times a week. The most common fruits consumed were apples and pears (eaten more than once a week by 61% of subjects), and bananas (eaten more than once a week by 43% of subjects), while avocado, olives and other tropical fruits (not including kiwi fruit and citrus) were the least often consumed. Vegetables (all types) were eaten every day by only 32% of officers, including 3% of them who ate these products several times a day. Almost half of subjects (49%) ate vegetables several times a week. Tomatoes were the most often consumed vegetable (eaten more than once a week by 73% of officers), while leafy green vegetables and crucifers were the least often consumed (eaten more than once a week by 31% and 33 % of officers). So-called dark bread (wholemeal or with grains) was eaten every day by only 26%, while so-called white bread by 33%. Most of the officers consumed all dairy products, as well as eggs, less than daily. Meat products, especially high-quality cold-cuts and sausages were much more popular than fish—both lean and oily fish were eaten less than once a week by most of the officers (69% and 75%). Although nuts were more popular than grains, only 21% and 10% of subjects ate these products more than once a week. Sweets were more popular than salty snacks. More than half of officers (53%) never or almost never consumed energy drinks, while sweetened sodas such as beer were consumed more than once a week by 23% and 28% of subjects. Two major dietary patterns were identified using the K-means cluster analysis. The first one Dietary pattern 1—was a more healthy and more varied diet, while Dietary pattern 2 was a less healthy and less varied diet. Barely 24% of border guard officers were classified in the more healthy diet group (Dietary pattern 1). The differences between these two dietary patterns are described in Table 2.

Table 2. The frequency of food consumption by dietary pattern groups.

Dietary Pattern/Groups of Products	Dietary Pattern 1		Dietary Pattern 2		*p*
	X ± SD	Me	X ± SD	Me	
Fruits, vegetables, and potatoes	8.21 ± 3.50	8.07	4.69 ± 2.14	4.63	<0.001 **
Seeds of legumes	0.32 ± 0.30	0.16	0.13 ± 0.16	0.11	<0.001 **
Cereal products	2.66 ± 0.99	2.79	1.49 ± 0.70	1.35	<0.001 **
Dairy products and eggs	3.29 ± 1.52	3.25	1.63 ± 0.92	1.64	<0.001 **
Meat products and fish	2.90 ± 1.27	2.93	1.61 ± 0.78	1.53	<0.001 **
Fats, nuts, and grains	2.69 ± 1.04	2.70	1.61 ± 0.88	1.54	<0.001 **
Sweets and snacks	2.35 ± 1.32	2.33	1.22 ± 0.87	1.09	<0.001 **
Non-alcoholic beverages	1.18 ± 0.83	1.03	0.46 ± 0.46	0.26	<0.001 **
Alcoholic beverages	0.51 ± 0.46	0.42	0.33 ± 0.33	0.24	0.041 *
Selected products					
Fruits, vegetables, and potatoes					
Fruits together—all types	0.89 ± 0.46	1.00	0.56 ± 0.32	0.57	<0.001 **
Stone fruits	0.41 ± 0.39	0.36	0.19 ± 0.22	0.08	<0.001 **
Kiwi fruit and citrus	0.49 ± 0.41	0.57	0.17 ± 0.24	0.08	<0.001 **
Other tropical fruits	0.20 ± 0.34	0.08	0.09 ± 0.15	0.03	0.001 **
Bananas	0.57 ± 0.44	0.57	0.29 ± 0.30	0.14	<0.001 **
Apples and pears	0.60 ± 0.43	0.57	0.38 ± 0.28	0.57	0.002 **
Avocado	0.06 ± 0.13	0.01	0.05 ± 0.12	0.01	0.185
Olives	0.09 ± 0.17	0.03	0.08 ± 0.16	0.03	0.787
Dried fruits	0.18 ± 0.29	0.08	0.11 ± 0.20	0.03	0.107
Sweet fruit preserves and candied fruits	0.18 ± 0.25	0.08	0.09 ± 0.18	0.03	0.014 *
Vegetables—all types	0.89 ± 0.41	1.00	0.58 ± 0.36	0.57	<0.001 **
Crucifers	0.39 ± 0.36	0.57	0.22 ± 0.23	0.14	0.002 **
Yellow–orange vegetables	0.56 ± 0.35	0.57	0.28 ± 0.22	0.14	<0.001 **
Green leafy vegetables	0.44 ± 0.27	0.57	0.21 ± 0.24	0.08	<0.001 **
Tomatoes	0.71 ± 0.37	0.57	0.48 ± 0.31	0.57	0.001 **
Vegetables: fresh cucumbers, squash, zucchini, pumpkin, eggplant	0.59 ± 0.36	0.57	0.33 ± 0.28	0.14	<0.001 **
Root vegetables and others	0.50 ± 0.28	0.57	0.27 ± 0.24	0.14	<0.001 **
Potatoes in various forms	0.58 ± 0.38	0.57	0.40 ± 0.30	0.57	0.005 **
Seeds of legumes					
Fresh seeds of legumes and canned ones	0.22 ± 0.22	0.08	0.08 ± 0.10	0.08	<0.001 **
Dry seeds of legumes	0.10 ± 0.12	0.08	0.05 ± 0.07	0.03	<0.001 **
Cereal products					
Wholemeal or with grains, so-called dark bread	0.75 ± 0.58	0.57	0.47 ± 0.40	0.57	0.006 **
Refined bread, so-called white bread	0.81 ± 0.57	0.79	0.54 ± 0.47	0.57	0.004 **
Unrefined groats coarse	0.39 ± 0.27	0.57	0.19 ± 0.22	0.08	<0.001 **
Refined cereal grain	0.39 ± 0.25	0.57	0.17 ± 0.19	0.08	<0.001 **
Ready-to-eat breakfast cereal products	0.32 ± 0.33	0.14	0.12 ± 0.20	0.03	<0.001 **
Dairy products and eggs					
Milk and milk drinks	0.82 ± 0.59	0.57	0.40 ± 0.36	0.57	<0.001 **
Sweetened milk drinks	0.45 ± 0.43	0.57	0.19 ± 0.24	0.08	<0.001 **
Cottage cheese	0.58 ± 0.29	0.57	0.29 ± 0.27	0.14	<0.001 **
Flavored cottage cheese	0.26 ± 0.32	0.08	0.08 ± 0.14	0.03	0.004 **
Cheese	0.63 ± 0.37	0.57	0.34 ± 0.31	0.14	<0.001 **
Eggs and egg dishes	0.54 ± 0.28	0.57	0.33 ± 0.26	0.14	<0.001 **
Meat products and fish					
Sausages. different types	0.68 ± 0.41	0.57	0.37 ± 0.29	0.57	<0.001 **
High-quality cold cuts	0.72 ± 0.31	0.57	0.47 ± 0.30	0.57	<0.001 **
Sausage products and offal	0.26 ± 0.30	0.14	0.11 ± 0.16	0.08	<0.001 **
Red meat	0.36 ± 0.40	0.14	0.17 ± 0.20	0.08	0.001 **

Table 2. *Cont.*

Dietary Pattern/Groups of Products	Dietary Pattern 1		Dietary Pattern 2		p
	X ± SD	Me	X ± SD	Me	
Poultry and rabbit	0.51 ± 0.27	0.57	0.31 ± 0.25	0.14	<0.001 **
Wild game meat	0.05 ± 0.12	0.01	0.02 ± 0.06	0.01	0.034 **
Lean fish	0.16 ± 0.18	0.14	0.08 ± 0.09	0.08	0.003 **
Oily fish	0.16 ± 0.20	0.08	0.08 ± 0.11	0.06	0.003 **
Fats, nuts, and grains					
Oil, all kinds	0.52 ± 0.33	0.57	0.32 ± 0.26	0.14	0.002 **
Butter, all types	0.81 ± 0.43	1.00	0.52 ± 0.47	0.57	<0.001 **
Margarine, all types	0.30 ± 0.50	0.08	0.21 ± 0.35	0.03	0.073
Cream, sweet or sour cream, for food or beverages	0.30 ± 0.29	0.14	0.16 ± 0.26	0.08	0.005 **
Other animal fats	0.08 ± 0.15	0.03	0.07 ± 0.16	0.03	0.532
Mayonnaise and dressings, i.e., salad dressings—all types	0.23 ± 0.38	0.08	0.11 ± 0.15	0.08	0.035 *
Nuts	0.28 ± 0.29	0.14	0.16 ± 0.22	0.08	0.049 *
Grains	0.21 ± 0.28	0.08	0.09 ± 0.17	0.03	0.010 **
Sweets and snacks					
Sugar to sweeten beverages	0.89 ± 0.80	1.00	0.43 ± 0.58	0.08	0.003 **
Honey to sweeten food and beverages	0.24 ± 0.30	0.08	0.15 ± 0.26	0.03	0.062
Chocolate, chocolate candies, and candy bars	0.48 ± 0.33	0.57	0.25 ± 0.30	0.08	<0.001 **
Non-chocolate candies	0.22 ± 0.41	0.08	0.08 ± 0.15	0.03	0.030 *
Biscuits and cakes	0.30 ± 0.29	0.14	0.16 ± 0.20	0.08	0.004 **
Ice cream and pudding	0.08 ± 0.09	0.08	0.07 ± 0.13	0.03	0.035 *
Salty snacks	0.18 ± 0.29	0.08	0.08 ± 0.12	0.03	0.146
Soft drinks					
Fruit juices and fruit nectars	0.47 ± 0.40	0.57	0.23 ± 0.27	0.08	<0.001 **
Vegetable juices and vegetable-fruit ones	0.35 ± 0.45	0.14	0.09 ± 0.15	0.03	<0.001 **
Energy drinks	0.12 ± 0.25	0.03	0.04 ± 0.20	0.00	<0.001 **
Sweetened sodas such as Fanta, Coca-Cola, Mirinda, Sprite	0.24 ± 0.29	0.08	0.10 ± 0.17	0.03	0.034 *
Alcoholic beverages					
Beer	0.34 ± 0.30	0.14	0.20 ± 0.24	0.08	0.002 **
Wine and drinks	0.10 ± 0.19	0.03	0.08 ± 0.12	0.03	0.804
Vodka and spirits	0.07 ± 0.12	0.03	0.06 ± 0.10	0.03	0.931

U Mann–Whitney Test * $p < 0.05$; ** $p < 0.01$. X—average; SD—standard deviation; Me—median.

3.2. Physical Activity

Based on the IPAQ, the average total physical activity equaled 17,255 ± 14,152 (median: 13,692) MET-minutes per week (Table 3). The largest part of physical activity was job-related physical activity (39%). Housework, house maintenance, caring for family accounted for 22%, transportation for 20%, and recreation, sport and leisure-time physical activity for 19% of the total value of physical activity. Taking into consideration the intensity level, walking counted for 38%, moderate physical activity for 36%, and intensive physical activity for 26% of the total value of physical activity. According to the IPAQ classification, 93% officers were characterized by a high and 7% by a moderate level of physical activity. The mean time spent in the sitting position on weekdays was 4.8 ± 2.8 (median: 4.0) hours a day, and on weekends it was 3.9 ± 2.3 (median: 4.0) hours a day, however the result values ranged from 0.5 up to 14.5 h a day.

Table 3. Physical Activity according to the long-form International Physical Activity Questionnaire (IPAQ).

Characteristics	X ± SD	Me	IRQ
Physical activity (MET-minutes/week):			
total	17,255 ± 14,152	13,692	6606–24,390
job-related physical activity	6803 ± 8469	3390	480–9900
transportation	3418 ± 3802	2133	495–5148
housework, house maintenance, caring for family	3793 ± 4398	2295	660–5040
recreation, sport and leisure-time physical activity	3241 ± 4560	1680	420–3919
walking	6548 ± 6672	3861	1663–8910
moderate	6232 ± 6144	4320	2160–8550
intensive	4475 ± 5737	2160	480–6400
Time spent sitting (h/d):			
weekdays	4.8 ± 2.8	4.0	3.0–6.0
weekend	3.9 ± 2.3	4.0	2.0–5.0

X—average; SD—standard deviation; Me—median; IRQ—interquartile range.

3.3. Nutritional Status

Nutritional status indicators varied among the examined border guard officers (Table 4). Body weight ranged from 62.5 to 114.9 kg and height ranged from 165.6 to 199.3 cm. According to the BMI classification, normal weight was observed in only 32% of officers, while 67% officers were overweight (53%) or obese (14%). However, normal fat was found in 54% of officers, and excess fat in 39%. Additionally, in the group with BMI higher than 25 kg/m^2, 58% of the officers were normal fat, and only 42% were classified as excess fat. Almost all of participants (96%) had a healthy level of visceral fat, according to the Tanita classification. Sufficient bone mineral density was observed in 87% of the subjects, osteopenia—12%, and osteoporosis—1%.

Table 4. Anthropometry and nutritional status.

Characteristics	X ± SD	Me
Height (cm)	179.3 ± 6.3	179.0
Weight (kg)	85.7 ± 11.4	84.4
BMI (kg/m^2)	26.6 ± 3.2	26.2
FMI (kg/m^2)	5.6 ± 1.9	5.4
MMI (kg/m^2)	20.0 ± 1.4	19.9
	Percentage of classifications	
BMI (kg/m^2)	Underweight < 18.5 18.5 ≤ Norm < 25.0 25.0 ≤ Overweight < 30.0 Obesity > 30.0	1 32 53 14
FMI (kg/m^2)	Fat deficit <3 3 ≤ Normal fat ≤ 6 Excess fat >6	7 54 39
VFL	Healthy level	96
	Excess level	4
BMD T-score	Osteoporosis ≤ −2.5 −1.0 ≥ Osteopenia > −2.5 Standard > −1.0	1 12 87

X—average; SD—standard deviation; Me—median; BMI—body mass index; FMI—fat mass index; MMI—muscle mass index; VFL—visceral fat level; BMD T-score—bone mineral density expressed in relation to a reference population in standard deviation units.

Since there were no associations between age and BMI, FMI, BMD (t-score) and MMI, age was positively correlated with VFL (Table 5). The nutritional status indices were correlated with each other.

Table 5. Correlations between selected nutritional status indices.

Nutrtional Status Indices		Age	BMI	FMI	VFL	BMD T-Score
BMI	Rho	0.097				
	p	0.207				
FMI	Rho	0.058	0.931 **			
	p	0.456	<0.001			
VFL	Rho	0.334 **	0.899 **	0.944 **		
	p	<0.001	<0.001	<0.001		
BMD T-score	Rho	−0.087	0.345 **	0.254 **	0.222 **	
	p	0.258	<0.001	0.001	0.004	
MMI	Rho	0.096	0.87 **	0.650 **	0.648 **	0.419 **
	p	0.216	<0.001	<0.001	<0.001	<0.001

Spearman's correlation; ** $p < 0.01$. BMI—body mass index; FMI—fat mass index; VFL—visceral fat level; BMD T-score—bone mineral density expressed in relation to a reference population in standard deviation units; MMI—muscle mass index.

3.4. Associations among Diet, Physical Activity and Nutritional Status

Twelve negative correlations between the main food groups consumption frequency and BMI (fruits, vegetables, and potatoes; seeds of legumes; dairy products and eggs; fats, nuts, and grains), FMI (fruits, vegetables, and potatoes; seeds of legumes; dairy products and eggs) VFL (fruits, vegetables, and potatoes; seeds of legumes; dairy products and eggs) and BMDT-score (fruits, vegetables, and potatoes; dairy products and eggs) were found (Table S2). Out of the selected 61 products negative correlations were observed between BMI and 18 products (fruits together—all type; other tropical fruits; bananas; sweet fruit preserves and candied fruits; vegetables—all types; yellow–orange vegetables; leafy green vegetables; fresh seeds of legumes and canned ones; potatoes in various forms; unrefined groats coarse; refined cereal grain; ready-to-eat breakfast cereal products; milk and milk drinks; butter; nuts; grains; honey; vegetable juices and vegetable-fruit ones). FMI negatively correlated with almost all of products from the first group, including fruits, vegetables, and potatoes (14 of 18), and with seeds of legumes, unrefined groats coarse; refined cereal grain; ready-to-eat breakfast cereal products; milk and milk drinks; lean fish; nuts; grains; honey; vegetable juices and vegetable-fruit ones. Positive correlation was observed only between FMI and sweetened sodas such as Fanta, Coca-Cola, Mirinda, Sprite. VFL negatively correlated with 20 out of 61 analyzed foods. The BMD T-score negatively correlated with six products (yellow–orange vegetables; tomatoes; potatoes; cottage cheese; eggs; honey).

It was found that officers with more healthy dietary habits (dietary pattern 1) had significantly lower BMI ($p = 0.001$), FMI ($p < 0.001$) and VFL ($p < 0.001$) than officers from the less healthy diet group (Table 6).

No associations between the total amount of physical activity and BMI, FMI, VFL, and BMD T-score were observed (Table 7). However, correlations were found between several categories of physical activity and BMI, FMI and VFL. Recreation, sport and leisure-time physical activity negatively correlated with BMI (Rho = −0.182; $p = 0.018$), FMI (Rho = −0.277; $p < 0.001$) and VFL (Rho= −0.228; $p = 0.003$), while waking negatively correlated only with BMI (Rho = −0.156; p = 0,043). Time spent sitting at the weekend positively correlated with FMI (Rho = 0.198; $p = 0.014$) and VFL (Rho = 0.172; $p = 0.034$). Only one correlation was found between muscle mass expressed as MMI and walking (Rho= −0.186; $p = 0.015$).

Table 6. Nutritional status indices and physical activity by dietary pattern groups.

Characteristics	Dietary Pattern 1		Dietary Pattern 2		p
	X ± SD	Me	X ± SD	Me	
BMI [kg/m^2]	25.4 ± 2.9	24.7	27.0 ± 3.2	27.0	0.001 **
FMI [kg/m^2]	4.6 ± 1.6	4.5	5.8 ± 2.0	5.8	<0.001 **
VFL	6.03 ± 2.58	6.00	7.85 ± 2.87	8.00	<0.001 **
BMD T-score	−0.11 ± 0.85	−0.15	0.10 ± 1.00	0.05	0.214
MMI [kg/m^2]	19.7 ± 1.5	19.3	20.1 ± 1.4	20.1	0.027 *
Physical activity (MET-minutes/week):					
total	22,554 ± 16,079	19,638	15,704 ± 13,149	12417	0.007 **
job-related physical activity	8815 ± 10,529	5667	6212 ± 7683	2925	0.215
transportation	4087 ± 4033	2772	3232 ± 3726	2014	0.249
housework, house maintenance, caring for family	5320 ± 5626	4020	3335 ± 3856	2170	0.030 *
recreation, sport and leisure-time physical activity	4331 ± 5087	2573	2926 ± 4359	1587	0.056
walking	7916 ± 6967	6584	6161 ± 6559	3663	0.201
moderate	9104 ± 7636	7410	5373 ± 5338	3540	0.002 **
intensive	5534 ± 6409	4560	4169 ± 5514	1920	0.188
Time spent sitting (h/d):					
weekdays	4.4 ± 2.3	4.5	5.0 ± 3.0	4.0	0.483
weekend	3.9 ± 1.9	4.0	4.0 ± 2.4	4.0	0.678

U Mann–Whitney Test * $p < 0.05$; ** $p < 0.01$. X—average; SD—standard deviation; Me—median; BMI—body mass index; FMI—fat mass index; VFL—visceral fat level; BMD T-score—bone mineral density expressed in relation to a reference population in standard deviation units; MMI—muscle mass index.

Table 7. Relationships between physical activity (IPAQ) and body mass index (BMI), fat mass index (FMI), visceral fat level (VFL) and bone mineral density (BMD T-score).

Physical Activity	BMI		FMI		VFL		BMD T-Score	
	Rho	p	Rho	p	Rho	p	Rho	p
Physical activity [MET-minutes/week]:								
total	−0.100	0.198	−0.122	0.114	−0.123	0.112	−0.048	0.534
job-related physical activity	−0.030	0.697	−0.014	0.861	−0.058	0.456	0.020	0.794
transportation	−0.080	0.303	−0.042	0.584	−0.024	0.761	−0.063	0.418
housework, house maintenance and caring for family	0.007	0.927	−0.020	0.792	0.014	0.859	−0.019	0.806
recreation, sport and leisure-time	−0.182 *	0.018	−0.277 **	<0.001	−0.228 **	0.003	−0.108	0.161
walking	−0.156 *	0.043	−0.117	0.131	−0.132	0.087	−0.140	0.070
moderate	−0.028	0.722	−0.086	0.266	−0.031	0.685	−0.006	0.941
intensive	−0.073	0.343	−0.122	0.113	−0.140	0.070	0.043	0.578
Time spent sitting [h/d]:								
weekdays	0.051	0.532	0.084	0.299	0.062	0.449	0.050	0.536
weekend	0.147	0.070	0.198 *	0.014	0.172 *	0.034	−0.090	0.270

Spearman's correlation; * $p < 0.05$; ** $p < 0.01$. BMI—body mass index; FMI—fat mass index; VFL—visceral fat level; BMD T-score—bone mineral density expressed in relation to a reference population in standard deviation units.

It was found that both dietary pattern (OR = 2.98) and physical activity: sport and recreation (OR = 0.57) are associated with the risk of excess fat mass (Table 8).

Table 8. Logistic regression model for excess fat mass index probability ($p < 0.001$).

Variable	B	Standard Error	p	OR	95% CI
Dietary pattern	1.093	0.441	0.013	2.98	1.26–7.08
IPAQ—sport and recreation	−0.560	0.240	0.020	0.57	0.36–0.91
Constant	−2.446	0.823	0.003		

B—regression coefficient; Dietary pattern: 1—more healthy, 2—less healthy.

4. Discussion

Our results confirm that there are some relationships between diet, physical activity and nutritional status indicators assessing body mass, fat mass, visceral fat mass and bone mineral density among border guard officers. Many irregularities in dietary habits (i.e., insufficient meals inadequate consumption of some food groups) as well as in nutritional status were also observed.

Poor eating habits resulted in abnormalities in officers' nutritional status. The strongest correlations (negative) were found between BMI, FMI and VFL, and nuts, fruit and vegetables, and dairy products frequency consumption. The frequency of the consumption of these products was not compatible with the current recommendations. Barely 1/3 of officers ate fruits and vegetables daily, but only 3% ate these products a few times a day. Our finding are worrying and in line with the general tendency of decreasing fruit and vegetable consumption in past years, that has been observed in household budget surveys by Statistics Poland [39]. Between 2000 and 2018, the average monthly consumption per capita of fruit decreased from 4.1 kg to 3.7 kg, and the average monthly consumption per capita of vegetables decreased from 13.3 to 7.9 kg. Similar dietary mistakes, i.e., consuming less than the recommended 4–5 meals a day, insufficient consumption of fruit, vegetables, nuts, diary, were also observed in the general population in Poland [40], as well as among soldiers [7,9] and other physically active groups, i.e., athletes [41]. Poor dietary habits may result in a worse body composition and can lead to obesity [11]. In a recent study, Gaździńska et al. observed that consumption of sweetened beverages was higher in soldiers with BMI $\geq$ 30 as compared to normal weight soldiers, while there were no differences in the number of meals during the day, snacking between meals, or fast-food consumption [10]. However, most of the surveyed declared eating sweets (80%) and fast-food (69%), and only 33% of soldiers were classified with normal weight. The authors showed that the risk of obesity increases with the age of 40, but is not limited to this, due to over consumption of food in stressful situations and lower physical activity.

The level of physical activity in almost all of the border guard officers was high (93%), similar to the earlier research among soldiers [9]. No correlations between total physical activity and BMI, FMI VFL, BMD-T-score, and MMI were observed. MMI was associated only with walking (negative correlation) while only physical activity during recreation, sport, and leisure-time negatively correlated with BMI and FMI. Similar relationships between LTPA and body composition were also observed in police officers [31,42]. Police officers with higher physical activity level had lower fat mass. It was also reported that police officers who were physically active and had a low level of body fat had better reaction times [43]. In another study it was observed that high level of body fat was associated with low level of physical performance [44]. In our study, time spent sitting positively correlated with FMI, and this was also observed by other authors [45,46].

During physical education classes border guard officers attend classes such as swimming and water rescue, water sports, martial arts, and training of the use of firearms. In previous studies it was shown that in a group of 55 female border guard officers almost 2/3 practiced sports (5% competitive, and 69% recreational), but 26% did not perform any leisure-time physical activity [28]. In another study, in another group of 53 male and female border guard officers only 36% were physically active in their spare time [30]. However, in a different study with a larger surveyed group (121 female and 338 male) the percentage of not performing any leisure-time physical activity was lower—7% of female and 4% of male [29]. According to the IPAQ classification the level of physical activity in border guard officers from their own research was higher than in the last study performed by Łyżwiński (93% with the high and 7% with the moderate level of physical activity vs. 58% with the high, 36% with the moderate, and 6% with the low level of physical activity) [47]

According to the BMI, excessive body mass was found in 67%, while based on FMI, excessive amount of fat mass was found in 39% of border guard officers. Our results are consistent with a recent study describing the ratio of overweight or obesity in 69% men from Poland aged 18–64 [18]. Border guard officers were more likely to have excess fat mass than soldiers from Poland [9] (39% vs. 19%), while the average BMI value was more similar (26.6 vs. 25.6 kg/m^2). High prevalence of uniformed force officers with overweight or obesity was also observed in other studies, i.e., among police officers [21,48], soldiers [9,19,20,22–25], and firefighters [49]. However, it must be highlighted that using only the BMI classification to verify overweight or obesity, especially in physically active groups may be incorrect due to usual extensive muscle mass [50]. The authors found that major discrepancy exists between obesity according to BMI (about 25%) and being diagnosed for obesity with the ICD code (12.5% of diagnosed for obesity by BMI). In our study similar differences were also observed. The average BMI was higher than the reference value for normal weight, while the average FMI was adequate. Out of 67% of the officers classified with BMI higher than 25 kg/m^2, excessive fat mass (based on FMI) was found only in less than half of them (42%). It is strongly recommended to be particularly careful when interpreting BMI values in adults with increased physical activity [51]. Moreover, some authors recommend that the optimal cut off point for interpreting obesity in active duty service members is BMI of 29 kg/m^2 in men and BMI of 26 kg/m^2 in women [52]. It means that BMI 25–29 kg/m^2 may be not useful for clearly discriminating between lean and fat mass in physically actives, especially active-duty service members [22,50]. In one of the recent studies, there was an attempt to assess adiposity in the U.S. The military based a combination of BMI + circumference-based equations, however it resulted in poor sensitivity [25].

The main limitation of our study is the relatively small group (169 officers). We conducted our research only among men, so future studies should include both men and women. The other limitation is using FFQ to assess diet. Although it is not an ideal method, it has been widely used in various studies. Some of the obtained Spearman's correlations might be difficult to interpret based on only FFQ without portions of consumed foods. Thus, in future studies comparing nutritional status with energy intake would be an additional benefit. The other limitation is using only IPAQ to assess the physical activity level. For future studies, it is recommended to use an accelerometer and add more detailed questions on the type of training (i.e., strength or endurance training). Energy as well as macronutrient intake (protein, fat and carbohydrate) and a detailed description of physical activity could be used for more detailed analyses, i.e., to assess associations between muscle mass and dietary intakes and physical activity among uniformed service officers.

5. Conclusions

Our study confirmed correlations between diet, physical activity and body mass index, fat mass index, visceral fat level, and bone mineral density in male border guard officers. Higher body mass and fat mass were correlated with poorer dietary habits, i.e., low consumption of fruit, vegetables, dairy, nuts, grains, as well as with lower leisure-time physical activity and longer time spent sitting during the day.

There is a strong need for further monitoring of health-related behaviors among border guard officers due to the many dietary mistakes and abnormalities in nutritional status that were observed. It is also necessary to provide nutritional education and encourage officers to follow dietary recommendations.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/ijerph19095305/s1, Table S1: Food consumption frequency; Table S2: Relationships between diet (FFQ) and body mass index (BMI), fat mass index (FMI), visceral fat level (V Fat L), and bone mineral density (BMD T-score).

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Assessment of the Body Composition and Bone Calcification of Students of Police Schools and Police Training Centers in Poland—A Cross-Sectional Study

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Abstract: The 21st century is considered the age of malnutrition resulting in the unprecedented frequency of civilization diseases. Among these disorders, obesity is particularly distinguished and considered an epidemic-scale disease. For this reason, conducting studies on obesity and counteracting this phenomenon is essential. Research from recent years indicates a problem of excessive body weight among officers of uniformed services, who should be characterized by good health and fitness level due to the specificity of the work. As the problem of obesity affects every fourth Pole, research in uniformed services seems to be essential from health and national security perspectives. The presented study aimed to determine the elements of nutritional status in 289 students of Polish police schools and police training centers. Body composition was determined by bioelectrical impedance analysis, and bone calcification assessment was conducted by the DXA densitometric method. Based on BMI and body fat content, body weight disorders were found in 31.8% of all examined students. Densitometric test results showed changes in bone calcification of varying severity in 26.6% of the total number of respondents. The presence of obesity in students of police schools and training centers proves that the present nutrition model is energetically unbalanced, while the demonstrated disorders of bone calcification indicate an improper condition of mineral nutrition.

Keywords: police schools; body composition; obesity; osteoporosis; osteopenia; DEXA

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1. Introduction

A multitude and variability of factors influencing food consumption necessitate their monitoring as significant for human nutritional status. Nutritional status is a component of a health condition resulting from the habitual consumption of food, the absorption and use of its nutrients, and possible pathological factors that affect these processes [1]. The purpose of nutritional status assessment is to identify people who exhibit malnourished nutritional disorders or are overweight and obese. Overweight and obesity are common health problems in 21st century societies. The prevalence of overweight and obesity in developed countries, including Poland, has steadily increased and has been one of the most common lifestyle-related health problems [2,3]. Globally, it is estimated that 44% of adults and 20% of children over five are overweight or obese. Moreover, since 1975, the number of overweight and obese people has tripled and now accounts for 4 million deaths worldwide each year, of which nearly 2/3 are due to cardiovascular disease [4]. Currently, obesity is perceived as aesthetically problematic and, primarily, as a severe medical issue and pathophysiological disorder caused by a superabundant accumulation of adipose tissue [5]. Excessive fat accumulation leads to negative consequences for the quality of life and wellbeing, life expectancy and treatment costs [6,7], and an increased incidence of chronic non-communicable diseases [8].

One of the methods of body weight monitoring is the use of body mass index—BMI—which is the quotient of body weight (measured in kilograms) and the square of the height (in meters). It is widely used in public health and clinical nutrition to quickly evaluate nutritional wellbeing, as excessive BMI is associated with increased risks of mortality, cardiovascular disease, and some cancers. According to the standards adopted by the World Health Organization (WHO), overweight is diagnosed when the BMI value is 25 or more, and obesity is diagnosed when the value of this index is 30 or more [9]. Although BMI has a significant limitation in the discrimination between adipose tissue and muscle mass, it is included in several widely used nutritional screening tools [10].

The complexity of external and innate factors influencing nutritional status is evident. The direct cause of overweight and obesity associated with the accumulation of adipose tissue is an imbalance in energy management, caused by an excessive intake of calories from food and drinks. It is favored by other factors, i.e., an inactive lifestyle, the popularity of food products with high sugar content, new technologies reducing physical effort, environmental and genetic factors, and family habits. However, it can be concluded that nutritional status results from the applied nutrition model and physical load. The nutritional status assessment indicates whether the physiological needs of the subject in relation to the nutrient requirements are met. Numerous observations of the relationship between anthropometric measurements and nutrition have shown that such values as height and weight or body fat content are reliable indicators of nutritional status. In turn, the proper nutritional status indicates that the demand for other nutrients is sufficiently covered. Moreover, the assessment of the nutritional status allows the determination of the current state of health and is a factor in forecasting the possible development of several metabolic diseases that are directly or indirectly related to nutrition.

Research conducted in the last decade shows that obesity and the ignorance of soldiers and police officers about a healthy lifestyle are severe problems for uniformed services. It should be emphasized that these are professional groups on which the state's security depends. Our previous study conducted on 479 police officers showed the presence of excessive body weight resulting from abdominal obesity in over 50% of male police officers [11]. A similar study conducted on 7000 Polish soldiers showed that cardiovascular diseases among military personnel pose a more significant threat in this group than among civilians. The prevalence of obesity and related diseases—hypertension, high cholesterol or prediabetes, and smoking—was alarming [12]. The authors emphasized the irrational nutrition model and the urgent need for nutritional education and prevention of civilization-related metabolic diseases among uniformed services. As a consequence of these studies, the National Health Program was conducted in 2016–2020, which included implementing overweight and obesity reduction programs and a comprehensive study of the diet of uniformed services employees.

In light of the above studies, assessing the components of nutritional status seems to be essential both from a health and national security perspective. The aim of the research study was to assess the frequency of abnormalities in the body composition and bone mineralization among officers of uniformed services. Based on previous research, we assumed that we would identify the irregularities mentioned earlier in a significant group of respondents, and as a consequence, individual conversations and training on the importance of leading a healthy lifestyle would be conducted. In this paper, we present the results of the studies realized as a part of the National Health Program concerning candidates and police officers studying and serving in police schools and police training centers.

2. Materials and Methods

2.1. Participants

The study on elements of nutritional status covered 289 candidates, including 48 female officers and 241 police officers. The study was designed to reflect the characteristics of the entire Police formation as well as the given training unit. Hence, the police officers trained in the Police Academy in Szczytno, Police Training Center in Legionowo, and its subordinate units (the Department of Police Cynology in Sułkowice, Water Police Training Base in Kal, and Police Prevention Department in Rzeszów) were chosen as participants of this study. The study on bone calcification covered 276 police officers trained in Police Training Center in Legionowo, Police Academy in Szczytno, and Police School in Słupsk. The field research was carried out from March to October 2019. The accepted criteria for inclusion in the study included age 18 to 60, active service in Police, and consent to the study. Women declaring pregnancy were excluded from the study.

The following parameters constituting the elements of nutritional status assessment were measured: anthropometric measurements, BMI, and the total fat content in the body. Moreover, bone density was assessed using the DEXA (Dual Energy X-ray Absorptiometry) densitometric method. In the first step, the body weight and height of each of the surveyed officers were measured and then, based on the results, the Body Mass Index (BMI) was determined. The BMI value allowed the subjects to be classified into one of the four groups (according to the WHO classification): underweight (BMI up to 18.4 kg/m^2), average body weight (BMI 18.5–24.9 kg/m^2), overweight (BMI 25.0–29.9 kg/m^2), and obesity (BMI over 30.0 kg/m^2) [13,14]. Moreover, based on the body fat content measured by multi-frequency bioelectrical impedance, the Fat Mass Index was calculated with the following equation: FMI = fat $-$ free mass/height^2 (kg/m^2). The scale of FMI classification developed by Kelly et al. was accepted, adopting FMI values between 3 and 6 as a normal fat mass, FMI < 3 as fat deficit, and FMI > 6 as excess fat [15]. Bone calcification was assessed based on the value of the T-score, in which the mean value and standard deviation in the groups of young adults were adopted as the reference range regardless of the patient's age. The T-score value -1 was accepted as the normal standard, meaning that it is not smaller than one standard deviation below the mean value. T-score values between -1 and -2.5 are typical for osteopenia, and values less than -2.5 are typical for osteoporosis [16]. The research was conducted in accordance with the 93rd Helsinki Declaration of the World Medical Society and was positively verified by the Ethics Committee of the Military Institute of Hygiene and Epidemiology (No. 1/XXI 95/2016). Participants received an information sheet on the details and the purpose of the study, the procedures used, and the potential risks and benefits of their participation.

2.2. Anthropometric Measurements

All measurements were made in accordance with the principles of good practice and procedures specified in the instruction manual by qualified researchers. Height was measured using a portable stadiometer (without shoes) (TANITA HR-001, Tanita Corporation, Tokyo, Japan). The police officers were asked to stand barefoot on the footprints, with his/her heels together and touching the backstop, keeping their legs straight, shoulders relaxed, and head in the horizontal Frankfurt plane position.

Bodyweight and fat content were measured using bioelectrical impedance analysis (BIA) using the TANITA MC-780 103 machine (Tanita Corporation, Tokyo, Japan) with an accuracy of 0.1 kg according to the procedure specified in the instruction manual (lightly dressed, without shoes) and with the use of a standard mode. The measurements were performed at room temperature, in light clothing, and under constant hydration conditions. Subjects were recommended to refrain from eating and intense physical exertion for about three hours before the study. The subjects were asked to discard any transmitting devices such as mobile phones or smartwatches that may affect the readings.

Bone mineral density was measured on the forearm of the non-dominant hand using the DEXA method with the EXA 3000 densitometer (OsteoSys Co., Ltd., Seoul, Korea).

2.3. Statistical Analysis

The obtained results are presented as arithmetic means and standard deviation (SD). There were no missing data in the presented study, as the complete set of the presented data was collected from all subjects.

Statistical analyses were performed using Statistica 12.5 software (StatSoft, Tulsa, OK, USA). The Kolmogorov–Smirnov test was used to check the normality of the variables' distribution. To compare the results between the two groups, the Student's *t*-test or, in the case of variables with a non-normal distribution, the Mann–Whitney U test was used. For variables with non-normal distribution, non-parametric tests were performed: Kruskal–Wallis test, which is a non-parametric equivalent of one-way analysis of variance, and Dunn's test, as an equivalent of post hoc tests. The value $\alpha = 0.05$ was adopted as the level of significance.

3. Results

The nutritional status assessment covered 241 officers, including 75 trained at the Police Academy, 69 at the Police Training Center, 39 at the Department of Police Cynology, and 97 at the Police Prevention Unit. The basic characteristics of all surveyed police officers are provided in Table 1, while the detailed breakdown by individual centers is presented in Table 2.

Table 1. Basic characteristics of police officers.

	Male	Female	*p*
No. of participants	241	48	
Age (years)	32.6 ± 8.3 [#]	35.3 ± 9.7 [#]	0.0471
Body height (cm)	180.2 ± 6.4 [a]	165.6 ± 5.7 [a]	0.0000
Body weight (kg)	87.8 ± 13.4 [a]	67.3 ± 12.0 [a]	0.0000
BMI Body Mass Index (kg/m^2)	27.0 ± 3.4 [a]	24.6 ± 4.7 [a]	0.0000
Body fat (%)	20.0 ± 6.4 [a]	27.2 ± 7.6 [a]	0.0000
FMI Fat Mass Index (kg/m^2)	5.56 ± 2.36 [a]	7.00 ± 3.52 [a]	0.0048

Data are presented as mean ± standard deviation. $p < 0.05$ was adopted as the critical probability value. The results marked with the same symbol ([#]) in the row showed statistically significant differences in Student's *t*-test. Variables sharing same letter ([a]) are statistically different in Mann–Whitney U test.

Table 2. Characteristics of police officers with the detailed breakdown by individual centers.

Parameter	Sex	Police Academy	Police Training Center	Department of Police Cynology	Water Police Training Base	Police Prevention Department	*p*
Body height (cm)	F	165.8 ± 6.0	166.2 ± 5.9	161.7 ± 3.9 [a]	-	168.6 ± 7.2 [a]	0.0412
	M	180.6 ± 6.3	180.5 ± 6.2	178.1 ± 6.57 [a]	184.5 ± 4.76 [a]	179.8 ± 6.0	0.0451
Body weight (kg)	F	64.9 ± 10.9	67.3 ± 12.8	71.6 ± 13.4	-	67.3 ± 12.0	n.s.
	M	83.3 ± 10.6	86.5 ± 12.2	88.9 ± 10.6	81.4 ± 9.4	92.1 ± 14.4	n.s.
Body Mass Index(kg/m^2)	F	23.6 ± 4.0	24.8 ± 5.0	26.6 ± 5.2	-	24.6 ± 4.7	n.s.
	M	25.6 ± 2.5	26.6 ± 3.0	27.4 ± 3.6	25.0 ± 2.1	28.3 ± 3.7	n.s.
Fat Mass Index(kg/m^2)	F	7.01 ± 3.55	7.10 ± 3.80	8.51 ± 4.02	-	7.01 ± 3.48	n.s.
	M	4.64 ± 1.44	5.27 ± 1.87	5.87 ± 2.14	4.49 ± 1,10	6.55 ± 2.54	n.s.

Data are presented as mean ± standard deviation. $p < 0.05$ was adopted as the critical probability value. The results marked with the same letter in the row showed statistically significant differences in Dunn's test. M—male; F—female; n.s.—not significant.

The percentage of normal body weight, overweight and obese police officers in each examined group based on BMI is presented in Table 3.

Table 3. The number of police officers with normal body weight, overweight, and obesity.

Nutritional Status Parameter	Sex	Total *n* (%)	Police Academy *n* (%)	Police Training Center *n* (%)	Department of Police Cynology *n* (%)	Water Police Training Base Kal *n* (%)	Police Prevention Department Rzeszów *n* (%)
No. of patricipants	F	48	15	11	11	0	11
	M	241	70	47	27	11	86
Normal weight	F	32	10	9	6	0	7
	M	69	24	10	8	4	23
Overweight *n* (%)	F	11 (22.9)	3 (20.0)	1 (9.1)	4 (36.4)	0 (0)	3 (27.3)
	M	134 (55.6)	40 (57.1)	24 (51.1)	12 (44.4)	7 (63.6)	51 (59.3)
	Total	145 (50.2)	43 (50.6)	25 (43.1)	16 (42.1)	7 (63.6)	54 (55.7)
Obesity *n* (%)	F	5 (10.4)	2 (13.3)	1 (9.1)	1 (9.1)	0 (0)	1 (9.1)
	M	38 (15.8)	6 (8.6)	13 (27.7)	7 (25.9)	0 (0)	12 (14.0)
	Total	43 (14.9)	8 (9.4)	14 (24.1)	8 (21.1)	0 (0)	13 (13.4)
Total overweight (%)	F	33.3	33.3	18.2	45.5	0	36.4
	M	71.4	65.7	78.7	70.4	63.6	73.3
	Total	65.1	60.0	67.2	63.2	63.6	69.1

M—male; F—female; *n*—number of participants.

The basic characteristic of the examined police officers presented in Table 1 showed that examined women were significantly older than men. Moreover, the group of men was characterized by significantly higher body weight and body height, as well as by significantly higher BMI values. Examined female officers were characterized by a higher percentage of body fat.

Statistical analysis performed within the group of men and women (Table 2) revealed significant differences in body height of both men and women depending on the service unit. Trainees in the Department of Police Cynology, both women and men, were significantly shorter in height in relation to their colleagues in the Police Prevention Department and Water Police Training Base, respectively.

The analysis of the body weight and height measurements enabled the calculation of BMI and, in consequence, permitted assigning respondents to appropriate groups according to the WHO classification described in Section 2. None of the surveyed officers were underweight, while over 65% of the examined subjects had increased body weight. These abnormalities were found in one-third of the surveyed women, whereas this percentage was 71.4% in men. According to WHO criteria, 50.2% of all respondents were overweight, including 22.9% women and 55.6% men. Obesity was found in 14.9% of all surveyed officers, including 10.4% of women and 15.8% of men. Such a significant number of obese people in service is alarming since it may contribute to developing cardiovascular diseases and other metabolic civilizational diseases, resulting in their release from service.

BMI does not always provide reliable results for an assessment of body composition, especially in the case of physically active people, since its value may result from high muscle mass and not from high-fat content in the body. Therefore, finding abnormalities in body weight should be based on also on total body fat content. For this reason, we conducted a body adipose tissue measurement to calculate the FMI index. The Fat Mass Index (FMI) calculation ensures a more reliable approach as it differentiates muscle and fat mass of the total body weight. Hence, from a clinical point of view, while assessing anthropometric components of nutritional status, both BMI and FMI should be used as complementary tools. The results of the assessment of the nutritional status of police officers based on the fat content are summarized in Table 4.

Table 4. Assessment of the nutritional status of police officers based on the fat content.

Nutritional Status Parameter	Total n (%)			Police Academy Szczytno n (%)			Police Training Center Legionowo n (%)			Department of Police Cynology Sułkowice n (%)			Water Police Training Base Kal n (%)	Police Prevention Department Rzeszów n (%)		
No. of participants	Σ	F	M	Σ	F	M	Σ	F	M	Σ	F	M	M	Σ	F	M
	289	48	241	85	15	70	58	11	47	38	11	27	11	97	11	86
Normal body fat	198 (68.5)	40 (83.3)	158 (65.6)	65 (76.5)	13 (86.7)	52 (74.3)	37 (63.8)	10 (90.9)	27 (57.4)	24 (63.2)	8 (72.7)	16 (59.3)	9 (81.8)	63 (64.9)	9 (81.8)	54 (62.8)
Excessive body fat	92 (31.8)	8 (16.7)	84 (34.9)	20 (23.5)	2 (13.3)	18 (25.7)	21 (36.2)	1 (9.1)	20 (42.6)	15 (39.5)	3 (27.3)	12 (44.4)	2 (18.2)	34 (35.1)	2 (18.2)	32 (37.2)
Excessive BMI and normal body fat	96 (33.2)	8 (16.7)	88 (36.5)	31 (36.5)	3 (20.0)	28 (40.0)	18 (31.0)	1 (9.1)	17 (36.2)	9 (23.7)	2 (18.2)	7 (25.9)	5 (45.5)	33 (34)	2 (18.2)	31 (36.0)
Excessive BMI and body fat	92 (31.8)	8 (16.7)	84 (34.9)	20 (23.5)	2 (13.3)	18 (25.7)	21 (36.2)	1 (9.1)	20 (42.6)	15 (39.5)	3 (27.3)	12 (44.4)	2 (18.2)	34 (35.1)	2 (18.2)	32 (37.2)

Abbreviations: n, number of participants; BMI, body mass index; F, female; M, male; Σ, the sum of the participants of both sexes.

Total body fat content (FMI) analysis revealed the presence of excessive fat tissue in 31.8% of all subjects. Overweight and obesity resulting from high-fat content were found in 34.9% of men and 16.7% of women. Consequently, we compared the number of candidates with excess body weight according to the BMI with the measured body fat level. This comparison showed that excessive body mass in 36.5% of men and 16.7% of women results from muscle mass and is not a type of overweight that may be hazardous to health. On the other hand, all subjects with excessive body fat were characterized by abnormalities in BMI.

An adequate supply of calcium is significant for maintaining the proper structure and functioning of the human skeletal system. The content of this mineral, in addition to genetic determinants and the degree of physical activity, is an essential factor influencing bone mass. Therefore, achieving the maximum values of peak bone mass, the main prognostic factor for the risk of osteopenia or osteoporosis is essential in preventing the mentioned bone pathophysiological conditions [17].

The proper status of Police officers' bone calcification is vital due to the physical burden of the training process and the realization of specific tasks related to this training process. Maximum skeletal calcification, known as peak bone mass, occurs between 25 and 35. This age range is also the period in which most new candidates for service in the Police are admitted. Our study of Police officers' mineral nutritional status covered 276 officers, including 67 women and 209 men. Bone calcification was assessed based on the T-score value—above or below the expected value for the population of young, healthy people, according to the ranges presented in Section 2.

Densitometric tests revealed that 26.6% of the respondents suffered from disturbances in bone mineralization of varying severity, and when separated by gender, it concerned 52.3% of women and 18.7% of men (Tables 5 and 6).

Table 5. Assessment of the bone calcification of female police officers (*n* = 67).

T–Score (Bone Calcification)		Total (*n* = 67)		Police Academy Szczytno (*n* = 40)		Police Training Center Legionowo (*n* = 9)		Police School Słupsk (*n* = 18)	
		n	%	*n*	%	*n*	%	*n*	%
<−2.5	Osteoporosis	3	4.6	3	7.5	0	0	0	0
−2.5 to −1	Osteopenia	32	47.7	20	50.0	6	66.6	6	33.3
>−1	Normal	32	47.7	17	42.5	3	33.3	12	66.7

Abbreviations: *n*, number of participants.

Table 6. Assessment of the bone calcification of male police officers (*n* = 209).

T–Score (Bone Calcification)		Total (*n* = 209)		Police Academy Szczytno (*n* = 82)		Police Training Center Legionowo (*n* = 56)		Police School Słupsk (*n* = 71)	
		n	%	*n*	%	*n*	%	*n*	%
<−2.5	Osteoporosis	2	1.0	1	1.2	1	1.8	0	0
−2.5 to −1	Osteopenia	37	17.7	20	24.4	12	21.4	5	7.0
>−1	Normal	170	81.3	61	74.4	43	76.8	66	93.0

Abbreviations: *n*, number of participants.

The densitometric tests revealed the alteration of bone calcification in female officers regardless of the place of service. We found that 4.6% of the surveyed police officers had changes characteristic of osteoporosis, while bone changes characteristic of osteopenia occurred in 47.7% of the surveyed females. The most significant number of female officers (20) with altered skeletal calcification characteristic of osteopenia was found among women trained at the Police Academy, while the highest percentage (66.6%) was found among women in the Police Training Center (Table 5).

The analysis of the results of densitometric tests in male officers revealed changes in skeletal calcification in all three research sites, and it mainly concerned disorders characteristic of osteopenia (Table 6). The highest percentage of officers with bone density disorders was observed in the Police Academy and the lowest was observed in the Police School in Słupsk.

4. Discussion

Since service in the Police is considered a dangerous occupation, it is required that the potential candidate is in excellent health condition [18]. Police officers are a professional group particularly exposed to work-related stress, which may have a negative effect on the health condition. Numerous studies suggest that exposure to both chronic and work-related stress is associated with an increased risk of civilization diseases, including obesity, cardiovascular disease (CVD), and type 2 diabetes (T2DM) [19,20]. Research in this area shows a higher incidence of diseases, especially cardiovascular diseases, among police officers than in other professional groups [21]. This observation is supported by epidemiological reports showing a higher incidence of obesity among police officers in relation to non-police employees [22,23]. Hence, it seems extremely important to study the relationship between body composition and the risk of diet-related metabolic diseases as they may be essential in monitoring the health of police officers. Consequently, obtained observations and results enable the implementation of appropriate preventive measures, which is the main tenet of the National Health Program, partly presented in this paper.

The presented research studies were conducted at the places of service of police officers, which is why we based on measurements performed with mobile equipment. Body composition assessment is a valuable and accessible tool enabling the simple evaluation of physical fitness and health as it results from various factors such as diet, stress, the intensity of physical activity and other daily habits [24,25].

The assessment of nutritional status elements based on anthropometric measurements and BMI revealed excess body weight in the majority of examined Police officers. These results were different depending on the place of the research and ranged from 60.0% to 69.1%. The fact that 71.8% of all male participants and 35.4% of women are overweight is disconcerting. According to the classification of nutritional status based on BMI, 25% of the women and 56% of men were overweight, while obesity was found in 10.4% and 15.8%, respectively. These results align with observations made among uniformed services in recent years, similarly to the civilian population [26].

As we indicated earlier, the assessment of overweight and obesity based on BMI values may not be reliable for adults with increased physical activity and high muscle mass. BMI cannot distinguish between fat mass and lean mass; thus, it is advisable to determine the fat mass and calculate Fat Mass Index (FMI). This indicator assesses the degree of fatness and not the entire body weight, which in the case of a police officer may result in extensive muscle mass, increasing the BMI. The synthesis of those parameters seems to be an optimal approach as it can provide information about the actual number of obese people. The total body fat content measurement in police officers showed that 31.8% of all respondents had increased adipose tissue content. What is essential is that every subject with excessive body fat also had excessive BMI. By sex, irregularities in the body fat content of varying severity were found in 16.7% of female officers and 34.9% of female officers. In our study, the average BMI among Police male officers was above reference values, while the average % fat level and FMI were adequate in both sexes. Our previous research regarding polish soldiers confirmed similar observations [26].

The prevalence of overweight and obesity among police officers is also a significant health problem in other countries. Although the physical demands of police work suggest the importance of maintaining a healthy body weight, studies have shown that 40.5% of U.S. police officers are obese [27]. A similar result was observed in another study of 276 U.S. police officers, where the obesity rate of male police officers was 41.9% [28]. These observations are supported by a study of the nutritional status of 160 Saudi Arabian police officers, where overweight or obesity was found in 66.9% of respondents [29].

Another measure of nutritional status essential for police officers is bone mineral density (calcification). A low value of this parameter leads to osteopenia and osteoporosis. Osteoporosis is a condition that affects the bones, causing them to become weak and fragile and more likely to break (fracture). Changes in bone mass occur due to complex regulatory mechanisms based on genetic factors and the nervous and humoral systems [30]. The role of an adequate supply of calcium and its content in the body for the proper functioning of the skeletal system is indisputable. However, it should be noted that the content of this element in the body undergoes dynamic changes [31]. Therefore, it is essential to achieve the maximum values of peak bone mass, which is the main prognostic factor for the risk of osteopenia or osteoporosis and to monitor bone calcification in the prevention of osteoporosis. This is of particular importance among police officers, as it allows for the early detection of disorders and appropriate therapy and avoiding fractures, which may be the reason for dismissal from service. In the presented study, only half of the examined women revealed a proper BMD (T-score above −1); changes typical of osteopenia were found in 47.7% of subjects, while osteoporosis was found among three of 67 examined women. Significantly better results were obtained in the case of men, as bone calcification disorders concerned only about 20% of the studied population and features of osteoporosis were found in less than 1% of the respondents.

Due to the lack of similar research among police officers, the obtained results can be applied to soldiers who are also subjected to similar conditions of service and training. Our previous research on soldiers trained similarly to candidates in police schools showed that osteopenia and osteoporosis were found in 19.2% of respondents under 30 and 7.4% of soldiers over 30 [32]. On the other hand, studies performed among Polish Land Forces soldiers revealed adequate bone calcification in 75% of soldiers aged up to 30 and among 90% of soldiers aged over 30 [33]. Similarly, 77% of soldiers returning from a mission in Afghanistan, aged up to 30, and 87% of soldiers aged over 30 were characterized by an adequate bone calcification [34].

5. Strengths and Limitations

The presented research has several strengths. First, it may be considered a unique study as there are limited numbers of studies among police officers in Poland that assess the elements of the nutritional status (anthropometry, body composition, and bone calcification). Moreover, we focused on three nutritional status indicators: indicators of protein-energy status describing body size (BMI) and obesity (FMI) and indicators of mineral nutritional status (BMD T-score) that are considered essential in the evaluation of police officer's health and suitability for the service. The results of bone calcification are unique since there are no studies evaluating this aspect of nutritional status among police officers in Poland. Third, based on the body composition and densitometric analysis, we revealed significant abnormalities in Police officers' nutritional status, which clearly show the necessity to perform educational activities in the health promotion of uniformed services (Police officers). These activities should be primarily focused on nutritional prevention of nutrition-related non-communicable diseases and motivate police officers to respect the basic principles of a healthy lifestyle.

One of the study's limitations is the relatively small group (289 police officers). However, our research aimed to gain cross-sectional knowledge concerning the tested parameters of officers at their service places. Although the surveyed officers come from different units, this group is a representative sample of this uniformed formation. From the above limitation comes another one concerning using a DEXA-based apparatus for measuring body composition. We agree that this method of collecting data concerning body composition is optimal, but because the research study was carried out off-site in various places of police service throughout the country, we used devices characterized by small size and mobility. We agree that another limitation of the study is the lack of information on the other components of the nutritional status (nutrition and physical activity). However, since the presented work is part of the National Health Program project, these results will be presented in another work comparing research on diet and physical activity in different uniformed services.

6. Conclusions

The presented results on elements of the nutritional status of police officers showed the disturbing occurrence of nutritional disorders, especially obesity. This is particularly worrying as it proves an unbalanced nutrition model in terms of energy, predisposing to the development of diet-dependent metabolic civilizational diseases. Moreover, the observed bone calcification disorders in police officers indicate an improper state of mineral nutrition, predisposing them to an increased bone fractures.

The reported abnormalities and disturbances in police officers' nutritional status suggest the need to train staff responsible for planning and implementing mass catering to optimize the nutrition and nutritional prophylaxis of metabolic diseases. Moreover, the obtained results justify the need for performing educational activities in health promotion and developing a guide on the principles of rational nutrition and prevention of diet-related diseases, taking into account the specific nature of the service in the Police.

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Data Availability Statement: The data presented in this study are available upon request from the corresponding author. The data are not publicly available due to privacy/ethical restrictions.

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Assessment of Risk Factors for Development of Overweight and Obesity among Soldiers of Polish Armed Forces Participating in the National Health Programme 2016–2020

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Abstract: The aim of this study was to assess the prevalence of overweight and obesity among Polish Armed Forces soldiers and to analyze risk factors impacting body mass. In total, 1096 male, Caucasian soldiers (36.31 ± 8.03 years) participated in this study. Anthropometric data were obtained, and questionnaires evaluated sociodemographic, environmental, behavioral and biological factors known to be associated with obesity. Only 33% of the total number of participants had normal body weight, and 17.3% were considered obese (according to WHO criteria). The results showed that being 40 years or older, sleeping six hours or less per day, more frequent reaching for food in stressful situations, having a mother with excessive body weight, not exercising or exercising at most two days per week, and spending two hours a day or more in front of the TV increase the risk of obesity. Taken together, the results show that factors such as family history of obesity, dietary habits, physical activity, length of sleep and ability to cope with stress could be used to identify soldiers at higher risk of developing obesity in order to provide them with personalized prevention programs.

Keywords: BMI; body mass index; obesity; overweight; risk factors; soldiers

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1. Introduction

Epidemiological data indicate that overweight and obesity are two of the main public health problems. They affect all age groups and countries all over the world regardless of their developmental stage [1–4]. According to a report by the World Health Organization (WHO), the prevalence of overweight and obesity has increased dramatically in the general population over the past decades. Now, 39% of adults worldwide are overweight and 13% are obese ([5] (https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight, accessed on 27 August 2021)).

It is now widely accepted that occupational factors may play an important role in the occurrence of excessive body weight [6,7]. Military personnel, as an occupational group, are more exposed to stress, harmful environmental factors and limitations in food selection or availability, especially during military exercises or military missions [8,9].

Studies have shown an alarmingly high prevalence of excessive body weight among soldiers all over the world. Soldiers fulfilling the criteria of obesity constitute 8% in the US Army [10], 12% in the British Army [11], 13% in the Iranian Army [12,13] and 6% in the Polish Air Force [14]. A higher percentage of soldiers with excessive body weight was found in the Saudi Arabian Army, where obesity was diagnosed in 44% of soldiers [15].

Alarmingly high percentages of overweight and obese Polish soldiers, 58% and 27%, respectively, in those over 50 years of age were reported by Gielerak et al. in the implementation of the MIL-SCORE (Equalization of Accessibility to Cardiology Prophylaxis and Care for Professional Soldiers) program, which aimed to assess the prevalence of cardiovascular risk factors in a population of 6440 Polish soldiers [16]. According to the authors of the program, the professional staff of the Polish Army, due to the specific conditions of performing their tasks, seems to be particularly exposed to risk factors for adverse cardiovascular events. The results of the MIL-SCORE program showed the occurrence of hypertension in 45% of soldiers and lipid disorders in more than half of the participants. Coronary heart disease was diagnosed in 3% of Polish soldiers over 50 years of age and <1% of younger soldiers. Diabetes affected 7% of the oldest soldiers and 3% of soldiers aged 40–50 years. In the age subgroup > 50 years, high and very high results of cardiovascular risk assessment were observed in almost one-third of soldiers [16]. The results of the MIL-SCORE program indicate that Polish soldiers have multiple cardiovascular risk factors, including obesity, which reflect trends observed in the general population. This confirms the trends observed in earlier studies [17].

The above studies on obesity among military personnel most often evaluated sociodemographic factors such as age, sex, marital status, military rank and employment. Only one of these studies evaluated the effects of fitness and physical activity on body weight [13]. Risk factors contributing to the obesity epidemic are of interest to many researchers worldwide. In particular, the Organisation for Economic Cooperation and Development (OECD) identifies economic, social and physical factors that have changed dynamically over the past 20–30 years and have influenced diets and levels of physical activity at work, at home and leisure time [18]. Other researchers have placed emphasis on lifestyle factors [19], including particular attention to the impact of stress on weight gain [20,21].

In the present work, as compared to previous studies on military personnel, we propose considering the simultaneous influence of a much larger number of environmental and behavioral factors on the prevalence of obesity among Polish soldiers. These factors include time spent in front of the television [22,23], time spent in front of the computer [24], time spent sleeping [25], dietary factors (e.g., snacking, consumption of fast food and sweets) [26], family history of obesity [22], leisure time activities [27] and the effects of mood and stress on eating behavior [28].

To our knowledge, despite the constantly deteriorating nutritional status among soldiers of the Polish Armed Forces, no one has undertaken an investigation of the risk factors for overweight and obesity in this professional group so far. In addition to assessing the most important risk factors for the development of overweight and obesity among soldiers of the Polish Armed Forces, the aim of our work was to propose a model of the probability of obesity based on risk factors. Achieving these objectives will help design more effective obesity prevention programs for these soldiers.

2. Materials and Methods

2.1. Participants

Full anthropometric and questionnaire data were obtained in a group of 1096 Caucasian men (36.31 ± 8.03 years, mean body mass 84.94 ± 14.84 kg, mean body height 177.56 ± 7.35 cm and mean body mass index (BMI) 26.85 ± 3.95), soldiers of the Polish Armed Forces (370 soldiers of the Navy, 283 soldiers of the Land Forces, 184 soldiers of the Air Force, 86 soldiers of the Garrison Warsaw and 41 soldiers of the Territorial Defence Forces) from military units from all over Poland that have declared their willingness to participate in the National Health Programme 2016–2020. The invitation to participate in the National Health Programme was earlier sent to all commanders of the military units. If they agreed, invitations had been sent via e-mail to their subordinates. All soldiers who expressed their willingness to participate in the Program were enrolled. The research was conducted between April 2018 and October 2020. An additional 133 participants had incomplete datasets and were not included in the analyses. All participants accounted for about 1% of the Polish Armed Forces.

All procedures were approved by the Institutional Review Board of the Military Institute of Aviation Medicine, Warsaw, Poland (decision No. 01/2018 of 9 March 2018), and have been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. All participants provided informed consent.

2.2. Study Design

Body height was measured with an anthropometer (Holtain, UK, https://holtain.co.uk/anth.php, accessed on 20 January 2022) to the nearest 1 mm, in a standing upright position, without shoes. Body weight was determined in underwear alone, after emptying the bladder. Participants were categorized on the basis of BMI based on World Health Organisation (WHO) criteria (5). Three groups were created: BMI in the range 18.5–24.9 (normal), BMI in the range 25.0–29.9 (overweight) and BMI $\geq$ 30.0 (obese). Participants with a BMI < 18.5 were not included.

2.3. Instruments for Data Collection

A research questionnaire was used to identify obesity risk factors. The questionnaire asked about age; education; size of the community; being obese as a child/teenager; body weight at the age of 18; family history of obesity; number of meals consumed and their size; feeling satiated after eating; snacking during the day and at night; time of eating the last meal before bedtime; consumption of sweets, fast-food products, sugar, salt and water; eating in front of the TV/computer; paying attention to the caloric value of meals and food labels; number of days during the last week (7 days) when the respondent did moderate physical exercise; time spent in front of the TV; length of sleep; and ability to cope with stress. Respondents completed the survey in an online version. All procedures were performed in the morning hours.

2.4. Statistical Analysis

Descriptive statistics were calculated: mean, standard deviation and median. Compliance with the normal distribution of quantitative variables was checked using the Shapiro–Wilk test. The Kruskal–Wallis analysis of variance was used to check the differences between the three groups (depending on the BMI categories). A chi-square test was used to test for differences between participants' BMI categories and obesity risk factors. The multivariable logistic regression was applied to calculate odds ratios (ORs) and 95% confidence intervals (CIs). Statistical analyses were performed using PS IMAGO PRO 7 (IBM SPSS Statistics 27, Armonk, NY, USA). The level of statistical significance was set at $p < 0.05$.

2.5. Logistic Regression Model

Due to the fact that the effect of increased BMI may be related to expanded muscle mass (so-called muscular overweight), which is relatively common among soldiers [29–31], only groups with BMI corresponding to normal body weight and obesity were used to determine the odds ratio (OR) of BMI $\geq$ 30 for the risk factors in question. Overweight participants were not included in the analyses, as this group might have included participants with normal body fat and increased muscle mass. Logistic regression was used to calculate the probability of obesity in the study group of professional soldiers, depending on risk factors and their combinations. OR was calculated for factors that were found to be significant in initial verification using the chi-square test. The OR indicates how many times the risk of obesity (BMI $\geq$ 30) is higher in the group of participants with a given risk factor compared to the group of participants without the same risk factor. The model of the probability of obesity among study soldiers based on statistically significant risk factors is presented below.

$$P(Y=1) = \frac{e^{-1.977 + 0.994*STRESS + 0.968*MOTHER + 0.599*PHISICAL\ ACTIVITY + 1.315*AGE}}{1 + e^{-1.977 + 0.994*STRESS + 0.968*MOTHER + 0.599*PHISICAL\ ACTIVITY + 1.315*AGE}}$$

P—probability;
e—base of natural logarithm;
STRESS—eating when experiencing negative emotions (0 = No, 1 = Yes);
MOTHER—excessive maternal weight (0 = No, 1 = Yes);
PHYSICAL ACTIVITY—moderate exercise less than 3 days per week (0 = No, 1 = Yes);
AGE—age over 40 years (0 = No, 1 = Yes).

Based on the equation presented, the probability of obesity in the absence of risk factors as well as in the simultaneous presence of four risk factors was calculated.

3. Results

The mean age of the respondents participating in the study was 36.31 ± 8.03 years. The mean BMI of all participants was 26.85 ± 3.95. Only 33% of the total number of participants had normal body weight, 49.6% were overweight and 17.3% were considered obese (according to WHO criteria). The mean values per BMI group are presented in Table 1.

Table 1. Basic anthropometric parameters of the soldiers in relation to BMI.

Variable	All *n* = 1096		BMI 18.5–24.9 *n* = 362		BMI 25–29.9 *n* = 544		BMI ≥ 30 *n* = 190		
	X (SD)	**Me**	**X (SD)**	**Me**	**X (SD)**	**Me**	**X (SD)**	**Me**	***P***
Age (years)	36.31 (8.03)	36.00	33.78 (7.59)	33.00	36.71 (7.87)	36.00	39.93 (7.71)	40.00	**<0.001**
Body weight (kg)	84.94 (14.84)	84.70	71.81 (9.18)	73.00	86.74 (7.65)	86.00	104.82 (14.51)	102.00	**<0.001**
Height (cm)	177.56 (7.35)	178.00	175.80 (8.22)	176.50	178.59 (6.70)	179.00	177.96 (6.76)	178.00	**<0.001**
BMI	26.85 (3.95)	26.27	23.14 (1.49)	23.62	27.16 (1.39)	27.02	33.06 (3.90)	32.11	**<0.001**

n—sample size, X—mean value, SD—standard deviation, Me—median, *p*—*p* value for Kruskal–Wallis test result. Bold values denote statistical significance at the $p < 0.05$ level.

The soldiers at normal body weight were younger (33.78 ± 7.59 years) than soldiers with diagnosed obesity (39.93 ± 7.71 years). Most (50.7%) of the respondents lived in a city of more than 100 thousand inhabitants, 30.9% lived in a city of fewer than 100 thousand inhabitants and 18.4% lived in the countryside; 55.4% of the respondents were persons with higher education, and the rest of the soldiers had secondary education. Residence and education level of the participants had no significant effect on their body weight ($p < 0.05$).

The soldiers belonging to respective BMI groups showed no significant differences in the reported number of consumed meals per day, snacking between main meals, snacking at night, time of last meal consumption, salt intake, fast-food consumption, amount of consumed water, paying attention to the calorie content of meals, reading food labels or eating in front of TV. The results are presented in Table 2. Participants with BMI ≥ 30 reported being significantly more likely to be overfed after meals ($p = 0.016$) and to reach for food when experiencing negative emotions and bad mood as compared to participants with normal BMI (28.9% vs. 10.8%) ($p = 0.0001$). Soldiers with BMI ≥ 30 were significantly more likely to sweeten beverages as compared to soldiers with a normal body weight (47.4% vs. 57.7%) ($p = 0.002$).

Table 2. Eating behavior of soldiers according to BMI (n = 1096).

Question	Response	All (%)	BMI 18.5–24.9 (%)	BMI 25–29.9 (%)	BMI ≥ 30 (%)	*p*
Do you snack between main meals?	Always	7.6	8.6	6.8	8.0	0.585
	Sometimes	40.3	42.6	39.4	38.5	
	Never	52.1	48.7	53.8	53.5	
What kind of food do you eat most frequently between meals?	Sweets	18.5	18.1	19.1	17.3	0.042
	Fruit	31.4	36.2	30.8	24.0	
	Vegetables	8.1	9.2	7.4	8.4	
	Sandwiches	11.4	7.5	12.9	14.5	
	Everything	30.6	29.0	29.9	35.8	
How do you usually feel after meals?	Insatiable	7.0	6.7	6.5	9.0	0.016
	Stuffed	86.7	89.2	87.4	79.9	
	Overfed	6.3	4.2	6.1	11.1	
How many hours before bedtime do you eat your last meal?	Just before bedtime	3.6	3.3	3.3	4.7	0.209
	1 h before bedtime	20.7	17.7	21.5	24.2	
	2–3 h before bedtime	65.8	68.7	64.2	65.3	
	4 or more hours before bedtime	9.9	10.2	11.0	5.8	
Have you ever snacked at night?	No	80.6	83.1	80.5	76.2	0.193
	Yes, several times a week	3.3	1.7	4.0	4.2	
	Yes, several times a month	7.4	6.4	7.9	7.9	
	Yes, less than once a month	8.7	8.8	7.5	11.6	
How many hours do you sleep most often?	Less than 6 h	16.9	12.7	17.2	24.2	**0.003**
	About 6 h	47.6	46.4	48.5	47.4	
	7–8 h	34.6	40.6	33.0	27.4	
	More than 8 h	0.9	0.3	1.3	1.1	
When experiencing negative emotions, bad mood and well-being . . .	I reach for food more often	14.0	10.8	10.9	28.9	**< 0.001**
	I forget to eat	24.9	25.8	26.3	18.9	
	This has no effect on my eating behavior	61.2	63.4	62.8	52.1	
Do you sweeten your beverages/food?	No	52.4	51.1	56.8	42.3	**0.002**
	Yes	47.6	48.9	43.2	57.7	
Do you salt your food?	No	61.0	60.2	62.4	58.7	0.630
	Yes	39.0	39.8	37.6	41.3	
Do you eat sweets?	No	19.7	20.5	20.1	16.8	0.553
	Yes	80.3	79.5	79.9	83.2	
Do you eat fast food?	No	30.7	32.1	31.0	27.0	0.448
	Yes	69.3	67.9	69.0	73.0	
How much water do you consume daily?	Less than 1 l/day	17.6	21.1	14.9	18.7	0.171
	Approximately 1.5 l/day	52.8	52.1	54.1	50.8	
	More than 2 l/day	29.5	26.9	31.0	30.5	
Do you pay attention to the calorie content of your meals?	Always	18.7	22.2	18.2	13.3	0.106
	Never	31.0	31.0	31.3	30.3	
	Sometimes	50.3	46.8	50.6	56.4	
Do you read food labels when you shop?	Always	26.9	31.1	26.2	20.7	0.109
	Never	13.3	11.9	13.3	16.0	
	Sometimes	59.9	56.9	60.6	63.3	
Do you eat while watching TV, working on the computer?	Always	8.1	6.6	7.4	13.2	**0.022**
	Never	17.4	15.5	19.7	14.8	
	Sometimes	74.4	77.9	73.0	72.0	

p—*p* value for chi-square test result. Bold values denote statistical significance at the $p < 0.05$ level.

The analysis of the physical activity data showed that participants with BMI ≥ 30 performed moderate physical activity less frequently ($p < 0.001$) in the week preceding the study (Table 3), while they spent significantly more time in front of a computer and TV compared to normal weight and overweight participants ($p = 0.003$). Participants with obesity spent on average 4.31 ± 3.41 h/day in front of the computer and 1.79 ± 1.31 h/day in front of the TV.

Table 3. Characteristics of soldiers' physical activity as a function of their BMI category ($n = 1096$).

Question	All		BMI 18.5–24.9		BMI 25–29.9		BMI ≥ 30		*p*
	X (SD)	Me	X (SD)	Me	X (SD)	Me	X (SD)	Me	
Number of days in the last week (7 days) on which soldiers performed moderate physical activity	2.81 (1.98)	3.00	3.01 (1.98)	3.00	2.90 (1.98)	3.00	2.14 (1.81)	2.00	**<0.001**
Time spent in front of a computer/tablet per day (h)	3.71 (3.05)	3.00	3.62 (2.76)	3.00	3.57 (3.09)	2.50	4.31 (3.41)	3.00	0.045
Time spent in front of TV per day (h)	1.55 (1.28)	1.00	1.40 (1.22)	1.00	1.59 (1.30)	1.50	1.76 (1.31)	2.00	**0.003**

X—mean value, SD—standard deviation, Me—median, *p*—*p* value for Kruskal–Wallis test result. Bold values denote statistical significance at the $p < 0.05$ level.

In response to the question concerning body weight in childhood, most of the respondents declared that they had a normal body weight (76.3%), 11.4% declared that they were overweight, 2.3% declared that they were obese and 10.1% declared that they were underweight (Table 4). Soldiers with BMI in the obese range were significantly more likely to report excessive body weight in childhood ($p < 0.001$). In response to the question regarding body weight at age 18, 82.2% declared that they had a normal body weight, 8.7% declared that they were overweight, 1.3% declared that they were obese and 7.8% declared that they were underweight.

Table 4. The prevalence of obesity in the childhood of the surveyed soldiers and their parents depending on the current BMI category of the soldiers.

Question	Response	All (%)	BMI 18.5–24.9 (%)	BMI 25–29.9 (%)	BMI ≥ 30 (%)	*p*
Were you of normal weight as a child?	Yes	76.3	76.7	77.3	72.3	**<0.001**
	No, I was overweight	11.4	5.6	12.0	20.7	
	No, I was obese	2.3	1.1	2.2	4.8	
	No, I was underweight	10.1	16.7	8.5	2.1	
Were you of normal weight at the age of 18?	Yes	82.2	82.8	82.9	79.3	**<0.001**
	No, I was overweight	8.7	4.7	8.8	16.0	
	No, I was obese	1.3	0.0	1.8	2.1	
	No, I was underweight	7.8	12.5	6.4	2.7	
Was your mother of normal weight	Yes	62.7	72.0	61.8	47.3	**<0.001**
	No, she was overweight	30.7	24.1	31.8	40.3	
	No, she was obese	5.3	2.8	5.1	10.8	
	No, she was underweight	1.3	1.1	1.3	1.6	
Was your father of normal weight	Yes	66.7	69.6	68.5	56.2	**0.010**
	No, he was overweight	26.3	25.1	23.9	35.7	
	No, he was obese	4.6	2.5	5.2	7.0	
	No, he was underweight	2.3	2.8	2.4	1.1	

p—*p* value for chi-square test result. Bold values denote statistical significance at the $p < 0.05$ level.

Regarding the prevalence of obesity in parents, 62.7% of the soldiers at normal weight declared that their mothers were or had been of normal weight and 66.7% that their fathers were or had been of normal weight. Soldiers with obesity were significantly more likely to declare that their parents were overweight or obese ($p < 0.001$) as compared to soldiers at normal weight. Detailed results are presented in Table 4.

Interestingly, salting, eating sweets, eating fast food, snacking between meals, the time of the last meal before bedtime and snacking at night did not differ between soldiers belonging to the three groups (Table 2 above).

Risk Factors for BMI ≥ 30

The results of the analysis showed that six or less hours of sleep per day increased the risk of obesity by 74% (OR = 1.74; 95% CI: 1.19–2.54) in the study group with respect to those who slept seven or more hours (Table 5). More frequent reaching for food when experiencing negative emotions and bad mood and well-being increased the risk of BMI in the obese range by almost 4 times (OR = 3.64; 95% CI: 2.12–6.22) in relation to participants who declared they forgot to eat at that time or these situations did not influence their eating behavior.

Table 5. Risk factors for obesity in professional soldiers of the Polish Armed Forces (OR). Please note that the overweight group is not included in these analyses (further explanation in the text).

Risk Factor	Category	% Soldiers with BMI 18.5–24.9	% Soldiers with BMI ≥ 30	OR	95% CI
Sleep duration up to 6 h	No (7 h or more)	73.3	26.7	1	1.19–2.54
	Yes (up to 6 h)	61.1	38.9	1.74	
Eating when experiencing negative emotions, bad mood and well-being	No (I forget to eat or it does not affect my eating behavior)	70.5	29.5	1	2.12–6.22
	Yes (I reach for food more often)	41.5	58.5	3.64	
Excessive maternal weight	No	74.5	25.5	1	1.98–4.14
	Yes	50.5	49.5	2.86	
Excessive father's weight	No	70.4	29.6	1	1.23–2.57
	Yes	57.1	42.9	1.78	
Exercise less than 3 days per week	No (3 or more)	74.6	25.4	1	1.59–3.27
	Yes (up to 2 days)	56.3	43.7	2.28	
Time spent in front of the TV more than 2 h a day	No (up to 2 h)	70.9	29.1	1	1.07–2.23
	Yes (2 h or more)	61.3	38.7	1.54	
Age over 40 years	No (up to 39 years)	76.3	23.7	1	3.04–6.55
	Yes (40 and over)	41.9	58.1	4.46	

Soldiers whose mothers were overweight or obese were almost 3 times more likely to develop obesity (OR = 2.86; 95% CI: 1.98–4.14) than soldiers whose mothers' weight was normal. In contrast, those whose fathers were overweight or obese were almost twice more likely to develop obesity (OR = 1.78; 95% CI: 1.23–2.57).

Participants who did not exercise or exercised at most two days per week had more than 2 times the risk of obesity relative to those who reported exercising at a moderate level at least three days per week (OR = 2.28; 95% CI: 1.59–3.27). Participants who spent two or more hours a day in front of the TV had a 54% higher risk of obesity as compared to those who did not watch TV at all or watched no more than 2 h a day (OR = 1.54; 95% CI: 1.07–2.23).

Soldiers aged 40 years or older were more than 4 times more likely to develop obesity as compared to their younger counterparts (OR = 4.46; 95% CI: 3.04–6.55) (Table 5).

In the next analysis, the risk factors for obesity in the studied group of soldiers shown in Table 5 were entered into a logistic regression model. On the basis of multivariate analysis, the following factors remained statistically significant: reaching for food in situations of experiencing negative emotions and bad mood and well-being, excessive maternal body weight, practicing moderate-intensity physical activity less than 3 days a week and age over 40 years. Detailed results of the obtained logistic regression model are presented in Table 6. In the absence of risk factors, the probability of obesity in the studied group of soldiers was 12.2%, while in the case of the simultaneous occurrence of four risk factors, the risk of obesity was up to 86.9%.

Table 6. Logistic regression results for statistically significant obesity risk factors among surveyed soldiers.

Variable	B	Standard Error	*p*	OR	95% CI
Eating when experiencing negative emotions, bad mood and well-being	0.994	0.261	**<0.001**	2.70	1.62–4.51
Excessive maternal weight	0.968	0.205	**<0.001**	2.63	1.76–3.94
Moderate exercise less than 3 days per week	0.599	0.204	**0.003**	1.82	1.22–2.72
Age over 40 years	1.315	0.212	**<0.001**	3.72	2.46–5.65
Constant	−1.977	0.193	**<0.001**		

B—regression coefficient, *p*—*p* value. Bold values denote statistical significance at the $p < 0.05$ level.

4. Discussion

The emergence of obesity as a distinct disease could have far-reaching consequences for an organization where optimum health and physical fitness are required for personnel to perform their occupational roles effectively [32]. Our survey found a 17% prevalence of obesity in the Polish Armed Forces. This percentage is higher than that in the American, French, English or Iranian armies [10–13] but lower than that in the Saudi Army [15].

According to a report published in 2021 by the National Institute of Public Health–National Research Institute, in Poland, overweight occurs in 52.4% of men and 32% of women, and obesity occurs in 16.5% and 16.2%, respectively. The prevalence of overweight and obesity in the Polish military is comparable to that in the general male population in Poland ([33] (Accessed on 20 January 2022).

As in our study, age was also one of the most significant risk factors for obesity among soldiers in the Saudi Arabian [34], American [10,35], French [13] and UK armed forces [11,36]. The fact that obesity increases with the age of soldiers is worrying, as it suggests that obesity develops while serving in the Armed Forces, contrary to our expectations [37].

Smith et al. [35] note that age was associated with obesity among military personnel, most likely as a result of gaining small amounts of weight over many years. We agree with the thesis of Quertier et al. [13], that this relationship could result from changes in employment type, such as from active operational roles to more sedentary posts, which induce weight gain.

We observed in the study group that the probability of obesity among soldiers who had an obese mother is 26%, which is consistent with the literature [38]. However, in our case, not only obesity of mothers but also obesity of fathers was associated with a higher probability of BMI ≥ 30 in soldiers [39,40]. According to many authors [22,23], children of obese parents prefer a sedentary lifestyle, are more likely to consume high-calorie foods and spend more time in front of the television.

Reaching for food when experiencing negative emotions and a bad mood proved to be another highly significant risk factor for the development of obesity in the studied cohort of soldiers. Stress is significantly related to nutrition [28]. It can alter overall food intake in two ways, causing malnutrition or overeating, which can be influenced by the severity of the stressor [21]. People seek to minimize the feelings of tension that accompany stressful situations by using the means available to them. Since food is often readily available and an immediately effective way of discharging emotions, it is often used to alleviate the effects of stress. Evidence from longitudinal studies suggests that chronic life stress may be causally linked to weight gain [21], consistent with our results. Studies by other authors also confirm that chronic occupational stress and a lack of social support at work are risk factors for obesity [20,41,42]. Therefore, it seems important to create programs to reduce stress among professional soldiers.

A modifiable lifestyle factor strongly associated with obesity among soldiers was also time spent sleeping and watching TV per day. Too much time watching television is also a lifestyle component associated with obesity, due to lack of exercise and/or frequent snacking promoted by TV watching [43]. Our results are consistent with previous studies showing an association between overall time spent in front of a screen and obesity, demonstrating that reducing time spent in front of a screen can reduce the prevalence of overweight and obesity [44]. Thus, the reduction of screen time should be considered for weight management programs.

There is consistent evidence that the amount of sedentary behavior (or low physical activity) is associated with higher levels of body fat [45]. In the military community, as in the general population, too little physical activity is also cited as one of the risk factors for obesity [13]. In this study, the probability of obesity in soldiers who spent less than three days per week on moderate exercise was 20%. In our study, 23.4% of soldiers who reported moderate physical activity up to two days during the last week had obesity. In the group of respondents who declared performing physical activity at least 3 days per week, 12% had obesity. In comparison, in Quartier's study [13], 16% of servicemen who reported less than 2 h of physical activity were obese, while the obesity prevalence was only 8% among those practicing 2 to 4 h per week and 6.6% for members undertaking at least 4 h a week.

Sleep is one of the main dependent factors, besides physical activity and diet, leading to the maintenance of good health and thus is important among soldiers. Too little sleep causes metabolic and endocrine changes, including decreased glucose tolerance, decreased insulin sensitivity, increased evening cortisol levels, increased ghrelin levels, decreased leptin levels and increased hunger and appetite [46]. Epidemiological studies have found a significant association between short sleep (typically < six hours per night) and increased risk of obesity [44]. A meta-analysis of 18 studies involving 604,509 adults found a pooled odds ratio (OR) for obesity of 1.55 (1.43–1.68) for less than five hours of sleep [25]. It was also estimated that for each additional hour of sleep, BMI decreased by 0.35. Our own research found that six or fewer hours of sleep per day increased the risk of obesity by 74% among soldiers.

Analysis of the study results showed that not all risk factors for obesity present in the general population were significant in this study group, such as eating sweets, eating fast food, snacking between meals or snacking at night.

Limitations

The selection of personnel was based on availability rather than on any particular characteristic associated with obesity. BMI alone may overdiagnose obesity because it does not take into account the real muscle mass, which is larger in soldiers than in the general population [29,31]. However, we used BMI to divide participants into groups to be consistent with the literature and to allow comparisons. It should be noted that soldiers in the obese range, but not in the overweight range, have an increased amount of body fat (e.g., [31]). Therefore, in the majority of our analyses, we compared soldiers at normal weight with soldiers with BMI exceeding 30 to minimize this bias. Nonetheless, our results are consistent with reports originating from other armies, as well as with general knowledge about obesity and its causes.

5. Conclusions

Overweight and obesity prevalence in the Polish Armed Forces is similar to that in other armies of developed countries and in the general population of Poland. Analyses of the results of the National Health Programme implemented in 2018–2020 clearly indicate that the level of existing efforts to prevent overweight and obesity among professional soldiers in Poland is insufficient. The results show that factors such as family history of obesity, dietary habits, physical activity, length of sleep and ability to cope with stress could be used to identify soldiers at higher risk of developing obesity in order to provide them with personalized prevention programs. Therefore, therapeutic interventions to reduce the prevalence of overweight and obesity among Polish soldiers should include self-monitoring of body weight especially after the age of 40, nutritional education, physical activity at least three days a week and psychological support for individuals who eat when experiencing negative emotions.

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Relationship between a Maximum Plank Assessment and Fitness, Health Behaviors, and Moods in Tactical Athletes: An Exploratory Study

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Abstract: A maximum plank hold (PH) has been implemented in the Army Combat Fitness Test (ACFT) with the Holistic Health and Fitness (H2F) program. The H2F program introduces a shift in wellbeing from a fitness centered approach to framework also comprising nutrition, sleep, mental, and spiritual components. The purpose was to analyze how a maximum PH correlated with fitness, lifestyle behaviors, and mood states in tactical athletes (TA) and assess differences between those who pass and fail. Forty-nine TA completed fitness testing, lifestyle behavior, and mood state surveys. Bivariate correlations were used to examine relationships with PH performance. PH time was significantly correlated with total body mass, fat mass, BMI, push-ups, and state physical energy (SPE). VO_{2max} was significantly different between the groups who passed and failed the PH. PH was not associated with lifestyle behaviors or trait mood states. PH performance could vary day-to-day as it was correlated with SPE. Individuals with poorer aerobic fitness and body composition may be at risk for failing the PH.

Keywords: core endurance; aerobic fitness; energy; military; body composition

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1. Introduction

Tactical athletes (TA) are composed of law enforcement, firefighter, and military personnel. Physical aspects of TA's duties require muscular strength, muscular endurance, power, agility, speed, anaerobic, and aerobic fitness [1,2]. Deficiencies in any area of fitness may compromise safety, mission success, and increase risk of musculoskeletal injury. Despite a robust list of physical requirements needed to complete varying occupational tasks, fitness tests for TA have historically emphasized local muscular endurance and aerobic fitness [3,4]. Research has concluded that these fitness tests provided an incomplete assessment of TA's occupational readiness and need to assess more areas of fitness related to job tasks that require high levels of force and power production [5]. Thus, attempts have been made to establish new fitness testing protocols to better assess all realms of fitness associated with occupational tasks [6].

The Army Combat Fitness Test (ACFT) was developed by the United States (U.S.) Army to replace the Army Physical Fitness Test (APFT) that had been in use for four decades [3]. To assess core function, the ACFT now replaces the APFT's sit-up assessment with the plank hold (PH). The ACFT assesses soldiers against an age and gender-scaled standard [6]. Notably, the PH is now the only event graded against a gender-neutral standard. Due to scrutiny over the ACFT, a congressionally mandated independent review by the RAND Corporation was conducted to better determine the efficacy of this new occupational fitness assessment. This review found incomplete evidence to support the use of the ACFT in the Army's soldiers and no conclusive evidence to support the leg tuck or PH event predicting performance on combat tasks or injury risk [7].

Traditionally, TA fitness assessments have utilized maximum sit-ups as a measure of local core muscular endurance [3]. As a result, the majority of previous literature has correlated only the sit-up event with performance on fitness tests and military occupational tasks [8]. Meta-analyses have shown only weak to moderate significant correlations between sit-up performance and performance on occupationally specific tasks [8]. The PH event requires isometric contraction of the total core and has been correlated with performance on tasks that are integral to TA such as marksmanship, balance, one-repetition maximum box lift, and ruck march performance [9–11]. Greater core strength, endurance, and stability may also reduce the risk of injuries [12]. While aspects of TA occupational duties may differ, TA present similar injuries. Military [13], law enforcement [14], and firefighters [15] all frequently report low back pain. Historically, sit-ups have been used to assess core endurance but evidence suggests that sit-ups can increase compressive forces in the lumbar spine, a contraindication for individuals with low back pain [16]. The PH is easy to implement in tactical athlete populations and has more validity than sit-ups in assessing core endurance and predicting injury risk [17]. Likewise, PH training has been shown to reduce low back pain [18].

In recent decades, a holistic approach to wellness has been adopted by the military, fire, and police departments. Concomitantly with the ACFT, the U.S. Army is implementing the Holistic Health and Fitness (H2F) program. The H2F program represents a paradigm shift from physical fitness being viewed as the primary determinant of solder readiness to holistic framework comprising nutrition, sleep, mental, and spiritual, along with physical, components. Law enforcement agencies [19] and firefighter departments [20] have also begun adopting more holistic views of tactical athlete health. Moving forward, in addition to promoting physical fitness, there is an emphasis on healthy lifestyle behaviors and mental health [21,22]. The "Big 3" modifiable healthy lifestyle behaviors of sleep, physical activity, and diet have been positively correlated with mental health and well-being in adults [23]. Unfortunately, the shiftwork and unpredictable hours of TA's occupations often lead to sleep deprivation, long hours of sitting, and poor diets [24,25]. Poor lifestyle behaviors can, in turn, have a negative effect on TA's mental and emotional health and ultimately, performance and longevity.

Worsened mental health (i.e., depression) can present as feelings of lower energy and higher fatigue. State and trait mental and physical energy and fatigue may influence physical performance and have been shown to be correlated with balance which could influence injury risk [26]. Negative mood states have been associated with decreased performance on a ruck march in the summer at U.S. Army Ranger School [27]. Interestingly, certain personality types may be less likely to adopt unhealthy lifestyle behaviors. For example, the personality trait known as grit (i.e., the inclination to pursue long-term goals with sustained interest and effort over time) appears to have a positive influence on living a healthy lifestyle in terms of the "Big 3" modifiable behaviors [28]. Moreover, grit has been reported to be associated with better physical performance in U.S. Military Academy cadets and increased retention in a U.S. Army Special Operations Forces selection course [29,30]. Thus, state and trait energy and fatigue, grit, and mood states may be factors influencing operational readiness in TA.

The primary aim of this study was to examine whether the maximum PH performance is associated with common fitness assessments, modifiable lifestyle behaviors (i.e., sleep, diet, and physical activity), as well as moods and personality in TAs. We hypothesized that PH performance would be positively associated with body composition, aerobic endurance, and upper body muscular endurance as well as healthy lifestyle behaviors and grit. Given the recent adoption of the maximal PH assessment on the ACFT and gender-neutral scoring, there is some uncertainty of the implications of the pre-determined cut-off time to determine passing, or failing, of the PH. Thus, a secondary aim was to assess differences in fitness, lifestyle, and health between those who pass and fail the PH event based on ACFT standards. We hypothesized that those who passed the PH event would be fitter and report living a healthier lifestyle. Our analyses utilized an approach similar to current holistic frameworks of performance optimization employed by a majority of TA organizations.

2. Materials and Methods

2.1. Experimental Approach to the Problem

A cross-sectional observational design was used in which participants were required to complete a standardized testing battery. Testing was completed during a single 90-min session and each participant was tested individually. Participants were asked to avoid strenuous exercise up to 48 h before testing and avoid food or fluid intake other than water for 2 h before testing. Upon reporting to the laboratory, participants completed an informed consent followed by a series of electronic questionnaires regarding moods, personality, and lifestyle behaviors. Once the questionnaires were completed, anthropometric measures (i.e., height, mass, and body composition) were obtained. Participants then performed a series of movement assessments (i.e., wall sit and reach, Y-balance test, overhead squat, and Apley scratch test). Next, a dynamic warm-up was performed before completing the following fitness assessments in this order: countermovement jump, 1-repetition maximum bench press, pull-up, push-up, PH, and maximal oxygen consumption test. All participants were provided familiarization and standard instructions for the assessments. All test sessions were conducted by researchers at George Mason University. For all testing sessions, at least one of the researchers present was a National Strength and Conditioning Association Certified Strength and Conditioning Specialist.

2.2. Subjects

The sample of the study consisted of 49 (males = 41, females = 8) tactical athletes (law enforcement officers, $n = 29$; firefighters, $n = 20$) 38 $\pm$ 7.8 years of age with 12 $\pm$ 8.3 years of service. Participation in the study was purely voluntary and there were no formal requirements to participate as part of their employment. Participants were recruited via email and flyers. To be eligible for the intervention, participants were required to: (1) be either recruits or currently employed emergency responders in Northern Virginia; (2) not have surgery or injury in the last 3 months; (3) ability to run, perform pull-ups, and push-ups without pain; (4) no history of cardiovascular, pulmonary, renal, or metabolic disease; and (5) engage on average 30 min of physical activity daily. All participants were informed of the benefits and risks of the study and signed the informed consent. The study was approved by George Mason University's Institutional Review Board (IRB #: 12179B). Data was collected using appropriate safeguards to protect participant's identifying information. All procedures were conducted in accordance with best practices related to ethical issues in exercise science research [31].

2.3. Procedures

The order of testing was the same for all participants. Upon arrival to the testing facility, participants completed the informed consent and questionnaires. The anthropometric measurements were then taken. The movement and fitness assessments were performed afterwards. To minimize the effect of fatigue, each participant was given exactly 5 min of rest between fitness assessments. Participants performed a dynamic warm-up using a standard and supervised procedure to minimize risk of skeletal muscle injury during fitness assessments. Rest periods were derived from pilot testing of the protocol.

2.4. Questionnaires

Participants completed a series of electronic questionnaires to assess lifestyle behaviors, personality, and mood states. The order in which the questionnaires were completed was as follows.

2.4.1. Energy and Fatigue

The mental and physical energy and fatigue scale was used to measure the complexity of mental energy, mental fatigue, physical energy, and physical fatigue. The validity and reliability of this instrument has been supported by the work of Boolani et al. [32] and O'Connor [33]. State responses were assessed on a 100-point scale from "never" to "always".

Trait responses were assessed on 10-point scale from "never" to "always". Participants completed mood state questionnaires prior to and following 90-min of strenuous exercise. The Cronbach's alpha for trait and state mood were as follows: trait physical energy = 0.92, trait physical fatigue = 0.87, trait mental energy = 0.82, trait mental fatigue = 0.91, state physical energy = 0.78, state physical fatigue = 0.91, state mental energy = 0.73, and state mental fatigue = 0.94.

2.4.2. Grit

The 8-item short grit scale (Grit-S) was used to measure grit, defined as perseverance and passion towards long-term goals [34]. An aggregated score was divided by 8 to determine total grit scores ranging from 1 (not at all gritty) to 5 (extremely gritty). The Cronbach's alpha for the current study was 0.76.

2.4.3. Diet

Dietary behaviors were assessed via the Rapid Eating Assessment for Participants Short Version (REAP-S), a 16-item questionnaire including 13 items addressing first part frequency of food choices (i.e., In an average week, how often do you: Eat less than 2 servings of fruit a day?) and 3 items addressing the will to change dietary behaviors [35]. Higher summation of the first 13-items were indicative of healthier diets. Participants reporting <5 scores of 1 were categorized as having good diets and participants with ≥5 scores of 1 were categorized as having poor diets. The REAP-S questionnaire has good test-retest reliability and is a valid instrument when compared with the Healthy Eating Index (r = 0.472, $p < 0.001$) for measuring dietary behavior [35]. The Cronbach's alpha for the current study was 0.71.

2.4.4. Sleep

The Pittsburgh Sleep Quality Index (PSQI) was self-reported to assess sleep quality. The PSQI is a 19-item questionnaire that scores seven components: subjective sleep, sleep latency, sleep duration, sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction. A total sum is then reported as an overall PSQI global score. Participants were categorized as 'good' and 'bad' sleepers. Good sleep was quantified as a PSQI global score that is less than or equal to 5, while bad sleep is a PSQI global score of more than 5. Using frequency of distribution, we defined the top and bottom third of PSQI scores as extreme values of good and bad sleepers (PSQI ≤ 3 and PSQI ≥ 7). The PSQI survey has demonstrated acceptable test-retest reliability (r = 0.87), high sensitivity (98.7%), and specificity (84.4%) [36]. The Cronbach's alpha for the PSQI for the current study was 0.73.

2.4.5. Physical Activity

Participants were asked to self-report physical activity (PA) through the International Physical Activity Questionnaire-Short Form (IPAQ-SF), a 7-item scale including the frequency (exercise sessions per week), duration (minutes per session), intensity (light, moderate, vigorous), and time spent seated (hours and minutes) over the previous seven-day period. The IPAQ-SF has a moderate to high degree of reliability with Interclass Correlation Coefficients (ICC) between 0.71 and 0.89 [37,38].

2.5. Anthropometric Measures

Height and weight were recorded to the nearest 0.01 cm and 0.01 kg, respectively, using a stadiometer (Detecto, Webb City, MO, USA) and digital scale (BOD POD; Cosmed USA, Concord, CA, USA). Percent body fat, fat mass, and fat-free mass were measured using air displacement plethysmography (BOD POD model 2000A; BOD POD, Cosmed USA, Concord, CA, USA) following standardized procedures by the manufacturer. Air displacement plethysmography has been shown to be a reliable and valid method of assessing body composition [39].

2.6. Movement Assessments

2.6.1. Wall Sit and Reach

The WSR test was administered to determine flexibility using the methods described in the study by Liemohn et al. [40]. Trials were measured in cm. The WSR has been previously reported to be a valid (r = 0.77) and reliable (ICC = 0.95) test to assess lumbosacral flexibility [41].

2.6.2. Y-Balance Test

The YBT device (Functional Movement Systems, Chatham, VA, USA) was used to collect dynamic postural stability data following the methods described by Wright et al. in the anterior direction [42]. Performances were measured in cm. The YBT has been reported to be valid and reliable [43].

2.6.3. Overhead Squat and Shoulder Mobility

To assess hip mobility, participants completed 3 repetitions of an overhead squat. The overhead squat was performed and assessed in accordance with the Functional Movement Screen™ protocol [44]. Shoulder mobility was assessed using the Apley Scratch Test. Participants were instructed to make a fist with each hand. Then, they reached one arm overhead, with their fist behind their neck, and reached the other arm to the small of their back, reaching upwards as far as they can [44]. Distance between participants' fists was measured in cm. All steps were repeated for the measure on the other side. The functional movement screen deep squat and Apley Scratch assessments have been reported to have strong inter-rater and intra-rater reliability [45].

2.7. Fitness Testing

2.7.1. Countermovement Jump

The countermovement VJ was used to measure lower body power. Participants performed the VJ assessment directly following a dynamic warm-up. Instructions were to use a countermovement technique and jump as high as possible on each attempt. Participants were given 2 warm-up jumps at 50% and 75% effort, respectively. Three attempts were completed, and the highest jump height was recorded. The VJ was performed on a timing mat (Just Jump, Perform Better, Cranston, RI, USA). The use of flight time to measure jump height has been reported to be valid for assessing countermovement jump performance [46].

2.7.2. Upper Extremity Muscular Fitness Testing

Common upper extremity muscular fitness tests were performed to profile the upper body pushing and pulling ability of participants. A 1RMBP was used to assess upper body strength. The 1RMBP has been reported to have good to excellent test-retest reliability [47]. Posterior upper body muscular endurance was measured with pull-ups to failure. Anterior upper body muscular pushing endurance was measured with push-ups to failure. These assessments were conducted following a previously published protocol [48].

2.7.3. Prone Forearm Plank

Core muscular endurance was assessed with a prone forearm PH for maximum time. Participants were required to perform the PH with forearms on the ground, elbows at 90 degrees, and contacting the ground directly below the shoulders. The head, shoulders, hips, knees, and ankles were required to be in a straight line during the test. The posture was the same as required by the ACFT PH assessment. A demonstration of the correct posture was provided prior to the start of the test. Instructions were to "keep a straight line between your shoulders, hips, knees and ankles" and "hold the position as long as possible". The researcher began the timer when the participant initiated the PH. The timer was stopped when the participant exhibited volitional fatigue or noticeable degradation in form of the PH. At no point in the test were participants informed of the duration of the

PH. Once subjects were in the correct position, the test began exactly 5 min following the push-up assessment. During the testing, subjects were provided 1 warning if they began to deviate from the correct posture. Time was recorded to the nearest second on a stopwatch. The isometric prone PH has been reported to be a valid and reliable assessment of core muscle function [49].

2.7.4. Maximal Oxygen Consumption

Participants completed the Wellness-Fitness Initiative (WFI) Treadmill ramp protocol which has been validated in tactical athlete populations [50]. Peak VO_2 was assessed; tests were terminated due to an RER $\geq$ 1.15, plateau, or reduction in exercising heart rate with an increase in workload, or volitional fatigue. Breath-by-breath indirect calorimetry was measured by a calibrated metabolic cart (TrueOne 2400, Parvo Medics, Salt Lake City, UT, USA). Heart rate was continuously recorded with a wearable chest strap monitor (H10, Polar-Electro, Kempele, Finland). Physiological variables were continuously monitored and recorded during all stages of the test. Exertion was self-reported at each stage of the test via the 15-point (6–20) Borg rating of perceived exertion (RPE) scale. Prior to that start of the VO_{2max}, participants were shown a visual of the 15-point RPE scale and were verbally instructed that 6 was considered extremely easy (i.e., laying down watching television) and 20 was maximal effort (i.e., pushing a boulder up a mountain). In the last 30-s of each stage, the researcher held up the RPE visual and participants were verbally instructed to point to the number that corresponded with their physical efforts.

2.8. Statistical Analysis

The data collected, analyzed, and presented in this study are from a larger on-going project. Recently, survey questionnaires to assess personality and mood were added to the testing protocol. This led to a total sample size of 49 for anthropometric, movement, and fitness measures, but only 18 participants completing the additional measures of lifestyle, personality, and mood states. The data reported are not the primary focus of the on-going project and as a result, apriori sample size calculations were not conducted. However, apriori sample size calculations in G*Power (version 3.1.9.7, Heinrich-Heine-Universitat Dusseldorf, Dusseldorf, Germany) were computed for correlations (tails = 2, alpha = 0.05, power = 0.8) and for large effects, a sample size of 26 would be adequate. Data were compiled, cleaned, and scored into Microsoft Excel (Microsoft Inc., Redmond, WA, USA). Normality was assessed with Shapiro–Wilk test and visualized with Q-Q plots. Normality testing revealed that a PH was normally distributed, but a majority of data were not normally distributed.

Spearman Rho rank tests were run to determine correlations between PH and measures of body composition, fitness, personality, and mood states. Duration of PH was transformed into a dichotomous variable of "Pass" or "Fail" based on the cut-off times set by the U.S. Army [51]. The composition of the groups were as follows: (1) Anthropometric, movement and fitness measures: Pass group: n = 41, males: 35, females: 6, fire: 17, police: 34; Fail group: n = 8, males: 6, females:2, fire: 3, police: 5; and (2) Lifestyle, personality and mood state measures: Pass group: n = 16, males: 15, females: 1, fire: 1, police: 15; Fail group: n = 2, males: 2, females: 0, fire: 0, police: (2) Group differences between those who passed cut off times and those who did not were determined with the use of Mann–Whitney U tests. Effect sizes of Mann–Whitney U tests were determined with the Glass rank biserial coefficient (rg) and interpreted as small (rg = 0.11 to <0.28), medium (rg = 0.28 to <0.43), and large (rg $\geq$ 0.43) [52]. Sex differences in fitness variables were assessed, following the primary analyses, with Mann–Whitney U tests. All analyses were completed using the R Environment and packages psych, car, Rcdmr, mlogit, ggplot2, devtools, and WMWssp (R Foundation for Statistical Computing, Vienna, Austria), alpha was set at <0.05.

3. Results

All demographic, fitness, lifestyle behaviors, personality traits, and mood state variables are provided in Table 1. The majority (84%) of the sample met the ACFT standards for the PH. Although not statistically significant, the group that did not meet the ACFT PH standards self-reported greater durations of total PA (Pass: 762.82 ± 797.19, Fail: 835 ± 855.60), but the group who met the standards engaged in greater VPA (Pass: 261.25 ± 141.76, Fail: 135.00 ± 148.49, rg = 0.500). A large effect for VO_{2max} (p = 0.002, rg = 0.695) and plank hold duration ($p < 0.001$, rg = 0.948) were found to have significant group differences between those who passed and failed the PH determined by the ACFT standards (Table 1). PH duration had weak, negative correlations with fat mass (ρ = −0.38, p = 0.007) and BMI (ρ = −0.35, p = 0.013) (Table 2). For fitness parameters, PH duration was found to have a weak positive correlation with maximal push-ups (ρ = 0.29, p = 0.045) (Table 3). Additionally, PH duration had moderate, positive correlation with state physical (ρ = 0.61, p = 0.047) energy (Table 4). There were no significant correlations between PH duration and variables for grit, lifestyle behaviors, and personality traits. PH time was the only fitness variable for which males did not outperform females (p = 0.83, rg = 0.048).

Table 1. Demographic, fitness, lifestyle, and personality characteristics of the tactical athletes.

Variables	Total: Mean (SD)	Pass: Mean (SD)	Pass: (Min, Max)	Fail: Mean (SD)	Fail: (Min, Max)	Effect Size (rg)	p-Value
Demographics and Anthropometrics (Total: n = 49, Pass: n = 41, Fail: n = 8)							
Age	38.39 (7.78)	38.88 (7.46)	(23.00, 25.00)	35.00 (9.07)	(23.00, 50.00)	0.250	0.272
Years of Service	11.98 (8.31)	11.81 (8.07)	(0.00, 30.00)	11.44 (9.66)	(1.50, 26.00)	0.061	0.796
Height (cm)	176.35 (8.02)	175.53 (8.06)	(158.00, 194.50)	179.59 (7.56)	(168.00, 190.00)	0.259	0.256
Mass (kg)	84.42 (15.13)	82.10 (12.25)	(47.78, 102.60)	95.60 (23.65)	(61.70, 139.9)	0.409	0.072
Body Fat (%)	23.12 (7.03)	22.45 (6.69)	(7.50, 35.20)	26.69 (8.52)	(15.20, 40.8)	0.256	0.261
Fat Free Mass (kg)	65.95 (11.26)	64.47 (10.90)	(39.19, 92.50)	72.93 (11.75)	(51.88, 87.94)	0.384	0.091
Fat Mass (kg)	19.99 (8.24)	18.71 (6.10)	(5.10, 32.30)	26.53 (14.13)	(11.30, 57.00)	0.402	0.076
BMI	27.01 (3.83)	26.54 (2.96)	(18.50, 32.79)	29.48 (6.61)	(20.73, 43.66)	0.335	0.140
Movement (Total: n = 49, Pass: n = 41, Fail: n = 8)							
WSR (cm)	30.96 (9.57)	30.18 (9.25)	(14.5, 50.50)	35.19 (11.25)	(22.00, 58.00)	0.256	0.261
YBTA (cm)	3.52 (2.88)	3.61 (3.04)	(0.00, 13.00)	2.75 (1.91)	(1.00, 6.00)	0.155	0.495
Overhead Squat	1.67 (0.63)	1.73 (0.60)	(0.00, 3.00)	1.38 (0.74)	(0.00, 2.00)	0.256	0.187
SMR (cm)	25.67 (12.01)	25.04 (10.33)	(0.00, 53.00)	28.38 (19.54)	(0.00, 68.00)	0.009	0.978
SML (cm)	28.04 (12.53	27.70 (11.11)	(0.00, 55.00)	29.12 (19.61)	(0.00, 66.00)	0.012	0.967
Fitness (Total: n = 49, Pass: n = 41, Fail: n = 8)							
Vertical Jump (in)	21.38 (4.15)	21.47 (4.03)	(13.80, 29.60)	21.16 (5.19)	(15.00, 28.70)	0.064	0.786
1RM BP (kg)	98.11 (26.95)	98.84 (25.85)	(20.41, 145.45)	92.27 (34.24)	(38.50, 127.01)	0.092	0.686
Pull up (reps)	8.57 (6.02)	9.07 (5.92)	(0.00, 21.00)	5.88 (6.58)	(0.00, 15.00)	0.290	0.202
Push up (reps)	38.06 (19.17)	39.50 (18.66)	(5.00, 105.00)	29.38 (21.49)	(6.00, 60.00)	0.271	0.233
Plank Hold (s)	109.21 (42.99)	115.19 (35.28)	(72.00, 249.00)	61.80 (13.09)	(36.00, 78.00)	0.948	<0.001 ***
VO_{2max} ($mL \cdot kg^{-1} \cdot min^{-1}$)	44.71 (5.11)	45.78 (4.75)	(35.90, 58.50)	39.48 (3.92)	(34.2, 44.09)	0.695	0.002 **

Table 1. *Cont.*

Variables	Total: Mean (SD)	Pass: Mean (SD)	Pass: (Min, Max)	Fail: Mean (SD)	Fail: (Min, Max)	Effect Size (rg)	*p*-Value
Lifestyle Behaviors (Total: *n* = 18, Pass: *n* = 16, Fail: *n* = 2)							
Grit	3.87 (0.46)	3.84 (0.48)	(3.00, 5.00)	4.06 (0.27)	(3.87, 4.25)	0.344	0.478
REAPS	29.39 (3.15)	29.25 (3.28)	(25.00, 35.00)	30.50 (2.12)	(29.00, 32.00)	0.250	0.620
PSQI	4.83 (1.86)	4.94 (1.95)	(3.00, 11.00)	4.00 (0.00)	(4.00, 4.00)	0.312	0.498
VPA (min/wk)	247.22 (143.86)	261.25 (141.76)	(40.00, 540.00)	135.00 (148.49)	(30.00, 240.00)	0.500	0.289
MPA (min/wk)	202.78 (219.73)	194.38 (230.13)	(0.00, 720.00)	270.00 (127.28)	(180.00, 360.00)	0.406	0.397
LPA (min/wk)	320.83 (425.39)	307.19 (425.30)	(0.00, 1680.00)	430.00 (579.83)	(20.00, 840.00)	0.031	1.000
Sitting (min/wk)	1908.33 (2455.85)	2041.88 (2581.50)	(240.00, 10,500.00)	840.00 (0.00)	(840.00, 840.00)	0.063	0.944
Moods and Personality (Total: *n* = 18, Pass: *n* = 16, Fail: *n* = 2)							
Trait PE	7.44 (2.71)	7.56 (2.80)	(1.00, 12.00)	6.50 (2.12)	(5.00, 8.00)	0.344	0.476
Trait PF	3.61 (2.06)	3.31 (1.85)	(0.00, 6.00)	6.00 (2.83)	(4.00, 8.00)	0.656	0.154
Trait ME	7.67 (2.25)	7.75 (2.35)	(3.00, 12.00)	7.00 (1.41)	(6.00, 8.00)	0.219	0.667
Trait MF	2.94 (1.98)	2.88 (2.09)	(0.00, 6.00)	3.50 (0.71)	(3.00, 4.00)	0.281	0.554
State PE	201.28 (62.43)	205.00 (64.73)	(90.00, 300.00)	171.50 (37.48)	(145.00, 198.00)	0.375	0.439
State PF	78.39 (63.86)	76.75 (61.77)	(3.00, 220.00)	91.50 (108.19)	(15.00, 168.00)	0.063	0.944
State ME	207.06 (61.80)	208.25 (65.63)	(99.00, 300.00)	197.50 (10.61)	(190.00, 205.00)	0.000	1.000
State MF	69.00 (66.54)	67.88 (66.24)	(0.00, 253.00)	78.00 (96.17)	(10.00, 146.00)	0.063	0.944

Note: ** $p \leq 0.01$; *** $p \leq 0.001$; Abbreviations: 1RM—1 Repetition Maximum, BP—Bench Press BMI—Body Mass Index, WSR = Wall Sit and Reach, YBTA = Y-balance Test Asymmetry, SMR = Shoulder Mobility Right, SML—Shoulder Mobility Left, VO_{2max}—Maximal Oxygen Consumption, REAPS—Rapid Eating Assessment for Participants, PSQI—Pittsburg Sleep Quality Index, VPA—vigorous physical activity, MPA—moderate physical activity, LPA—light physical activity, PE—Physical Energy, PF—Physical Fatigue, ME—Mental Energy, MF—Mental fatigue.

Table 2. Correlation Matrix—Demographics, Body Composition, and Mobility.

	Plank	Age	YOS	Height	Mass	BF	FFM	FM	BMI	WSR	YBTA	Squat	SMA
SMA	0.061	−0.023	−0.147	−0.101	−0.034	0.081	−0.139	0.073	0.015	−0.254	0.128	0.287 *	-
Squat	0.277	−0.064	0.049	0.059	−0.047	−0.178	−0.061	−0.190	−0.168	−0.029	0.000	-	
YBTA	0.190	0.128	0.019	−0.046	0.014	−0.030	0.056	−0.017	0.047	−0.001	-		
WSR	−0.073	−0.430 **	−0.225	−0.021	−0.091	−0.031	−0.037	−0.040	−0.121	-			
BMI	−0.351 *	0.180	0.152	0.193	0.776 **	0.478 **	0.369 **	0.747 **	-				
FM	−0.379 **	0.146	0.073	0.132	0.569 **	0.882 **	−0.019	-					
FFM	−0.246	0.051	0.153	0.650 **	0.645 **	−0.374 **	-						
BF	−0.267	0.107	0.020	−0.198	0.191	-							
Mass	−0.270	0.150	0.213	0.729 **	-								
Height	−0.072	0.055	0.121	-									
YOS	0.102	0.748 **	-										
Age	0.207	-											
Plank	-												

Statistical significance: * $p \leq 0.05$, ** $p \leq 0.01$. Abbreviations: YOS—Years of Service, BF—Body Fat %, FFM—Fat Free Mass, FM—Fat Mass, BMI—Body Mass Index, WSR—Wall Sit and Reach, YBTA—Y-Balance Test Asymmetries, SMA—Shoulder Mobility Asymmetry.

Table 3. Correlation Matrix—Performance.

	Plank	CMJ	Bench	Pull-Up	Push-Up	VO_{2max}
VO_{2max}	0.277	0.223	0.043	0.300 *	0.142	-
Push	0.287 *	0.417	0.537 *	0.724 **	-	
Pull	0.139	0.613 **	0.499	-		
Bench	0.073	0.410	-			
CMJ	−0.026	-				
Plank	-					

Statistical significance: * $p \leq 0.05$, ** $p \leq 0.01$. Abbreviations: CMJ—Countermovement Jump, VO_{2max}—Maximum Oxygen Consumption.

Table 4. Correlation Matrix—Mood States.

	SPE	SPF	SME	SMF	Grit	REAPS	PSQI	Plank
Plank	0.609 *	0.046	0.573	−0.109	−0.166	0.027	−0.369	-
PSQI	−0.431	0.497	−0.666 *	−0.532	0.107	0.111	-	
REAPS	−0.009	−0.025	−0.581	0.380	0.192	-		
Grit	−0.285	−0.297	−0.386	0.115	-			
SMF	−0.591	0.601 *	−0.491	-				
SME	0.555	0.005	-					
SPF	−0.228	-						
SPE	-							

Statistical significance: * $p \leq 0.05$. Abbreviations: SPE—State Physical Energy, SPF = State Physical Fatigue, SME—State Mental Energy, SMF—State Mental Fatigue, REAPS—Rapid Eating Assessment for Participants Short Version, PSQI—Pittsburgh Sleep Quality Index.

4. Discussion

The main purpose of this exploratory study was to analyze how a maximum PH correlated with body composition, fitness, lifestyle behaviors, and mental and emotional health in TA. A secondary purpose was also to assess how those variables differ between those who pass and fail the event. The results of this exploratory study partially supported our hypothesis as it was found that PH time was negatively related to several measures of body composition (i.e., fat mass, BMI) and positively related to upper body muscular endurance (i.e., maximum push-ups). Additionally, we did find that those self-reporting greater state physical energy performed better on the PH. When we categorized participants into "Pass" and "Fail" groups based on the ACTF standards, VO_{2max} values were significantly different between the groups. Unexpectedly, there were no other significant differences in measures between the "Pass" and "Fail" groups. It is noteworthy that lifestyle variables and grit were not significantly associated with PH performance; however, our sample was small and rather homogenous in regard to many of these variables, which likely affected our findings.

4.1. Plank and Body Composition

Despite routine fitness testing, being overweight and obese is prevalent in the U.S. military, law enforcement, and firefighter populations [53,54]. Individuals classified as overweight or obese may display decreased athletic performance. Obese firefighters displayed 27% lower back and core endurance scores than their non-obese counterparts in a study by Mayer et al. [54]. In the current study, 82% of the sample were categorized as overweight and 10% were considered obese per BMI standards. Additionally, negative correlations were observed by Mayer et al. between BMI and body fat percent with core and back endurance [54]. Similarly, in the current study fat free mass and BMI were negatively correlated with PH outcomes. Two of the "Big 3" modifiable lifestyle behaviors, physical activity and diet, can directly contribute to BMI and fat free mass. Thus, individuals at risk for performing poorly or failing the PH due to poor body composition may benefit from a holistic approach rather than strict PH training.

4.2. Plank and Fitness Assessments

VO_{2max} was the only fitness assessment that was significantly different between PH pass/fail groups. These findings were not unexpected as core endurance training has been found to increase running economy, VO_{2max}, and running performance in both fit and unfit populations [55,56]. Greater core endurance may lead to better running economy and efficiency which would contribute to better performance on aerobic fitness assessments. For example, in U.S. Army soldiers, PH performance has been found to be moderately correlated with time to complete a 3200 m march with a 25 kg load [11].

Push-ups were the only fitness assessment significantly correlated with PH performance. This was expected because push-ups require an individual to maintain their body in a straight line, such as a plank. Because proper push-up form requires core endurance, testing both in the same session may lead to increased fatigue on the latter event. However, due to the weak correlation, the two assessments may not be redundant and may not warrant the exclusion of one of the two from the ACFT using criteria similar to that of Cesario et al. [57]. Practitioners should provide adequate rest periods between the two assessments for their TA to reduce the risk of carry over fatigue.

4.3. Plank & Mobility/Balance

Greater core strength and endurance has been found to be correlated with a decreased risk of musculoskeletal injury in athletes and general population [12,58]. Likewise, YBT and FMS outcomes are indicators of injury risk in tactical athletes [59]. Thus, core endurance, YBT, and FMS outcomes are of importance to tactical strength and conditioning professionals. Previous literature found moderately-strong correlations between PH outcomes and single-leg balance in soldiers [10]. Similarly, a significant, weak correlation was found between PH and FMS scores in firefighters and between trunk flexor and extensor endurance and FMS scores in military personnel [60,61]. However, the current study found no significant relationship between a maximum PH and YBT outcomes in TA. It is possible no relationship was found in the current study because only the anterior portion of the YBT was tested. Additionally, we found no significant relationship between PH and outcomes of the FMS overhead squat and the Apley Scratch shoulder mobility test. Okada et al. also found no significant correlations between core stability and FMS scores [62]. Therefore, core endurance may contribute to injury risk in a different way than the components of the YBT and FMS, and thus, all three assessments may complement one another when ascertaining injury risk.

4.4. Plank & Health Behaviors

Despite assessing numerous lifestyle and health behaviors and moods, PH performance was only significantly correlated with state physical energy in this population of TA. In regard to lifestyle behaviors, this finding can be interpreted as living a healthy lifestyle does not by itself equate to greater levels of fitness and vice versa (i.e., being fitter does not mean one necessarily displays healthy lifestyle behaviors). Furthermore, it has been reported that state and trait physical and mental energy were indicators of postural control and gait [26]. The PH is an event that requires isometric control of a specific posture, thus, the physical energy of a TA on that specific testing day may be one of the greatest contributors to performance. Grit has been previously correlated with physical performance in cadets and active duty military [29,30]. It is plausible that because the TA in the current study scored similarly on levels of grit, the lack of variability resulted in non-significant findings. Previous research has used larger populations where even small differences in grit may be reflected in performance and positively influence engagement in healthy lifestyle behaviors [28,63].

4.5. Limitations & Future Research

The sample population was comprised of professional law enforcement officers (n = 29) and firefighters (n = 20). Anecdotally, numerous participants mentioned a history of prior military service; however, it was not formerly documented as part of the research procedures. In comparison, the Active Duty U.S. Army mean age is 27.0 years for enlisted soldiers and 34.7 years for officers with a male:female ratio of 83:17 [64]. However, the current sample population has body composition and fitness outcomes similar to that of an Active Duty 101st Airborne Division cohort [65]. Regardless of population, this is one of the first studies to analyze the PH's correlation with body composition, fitness assessments, and health and lifestyle behaviors. Most research with TA correlated the PH with occupation specific tasks such marksmanship, balance, one-repetition maximum box lift, and ruck march performance [9–11,62]. Outside of that, a majority of research utilizing TA examines the sit-up event [66]. Therefore, comparisons and contrasts between results must also consider utilizing research on athletes and the general population.

A main limitation of the study was the modest sample size. Post-hoc power analysis indicated that for the anthropometric, movement, and fitness data, the correlations were adequately powered; however, the lifestyle, mood, and personality variables had low power (<0.80) due to the smaller sample size (n = 18). Another limitation was that the PH was included in battery of assessments that could have induced fatigue prior to the plank. However, the ACFT and other occupational physical fitness assessments also include several assessments, thus making the current results more generalizable to test batteries rather than stand-alone assessment. Once more ACFT data is available, future research should assess the PH event in soldiers and how it may correlate with other ACFT events, body composition, and health and lifestyle behaviors. Moreover, data used in this study is part of an ongoing project; a recent addition of subjective measure to the methodology lead to a small data pool in terms of self-reported measures. Small variance in the subjective measure independent variables is not ideal for analyses and likely affected our findings. Due to the nature of fitness assessments, it is plausible that participants did not give their best effort during testing. All participants were given the same instructions and similar levels of encouragement during testing to maximize the likelihood of best effort. However, because participation was voluntary and performance was not consequential to their jobs, unlike the ACFT, participants may not have given full effort. Lastly, due to time constraints, only two of the seven FMS assessments were given. Thus, a composite FMS score could not be given. Future research should administer the entire FMS and YBT tests and ascertain how they may relate to performance on the entire ACFT.

5. Conclusions

The US Army has recently adopted the maximum PH event as part of their annual fitness testing (i.e., ACFT) despite limited literature supporting its use to predict occupational performance or injury. Considering the variables associated with PH performance (i.e., body mass index, fat mass, push-ups, state physical energy), as well as the only variable within this study that was significantly different between PH pass and fail groups was $VO_{2max,}$ there are several preliminary conclusions that can be provided from this exploratory study. First, while the PH event is considered a test of core endurance, not aerobic fitness, it seems the two fitness measures may be intertwined and those with poor aerobic fitness are more at risk for failing the event. Additionally, individuals with greater BMI and fat mass may display worse performance on the PH. The lack of difference in PH performance between males and females in the study provides support for the PH as a 'gender neutral' assessment. Thus, to improve PH performance, it would be suggested that strength and conditioning practitioners implement training to enhance VO_{2max} and body composition. In regard to PH assessment it is appears that a TA's physical energy on a testing day may influence their PH performance. Factors such as the time of day testing occurs, testing after a shift, or testing groups of TA together could all influence physical energy [67,68]. These should be documented to aid in interpreting individual results over multiple tests on the same individual.

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Use of the Dietary Inflammatory Index to Assess the Diet of Young Physically Active Men

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Abstract: Background: Chronic inflammation can lead to the development of obesity, diabetes and other chronic diseases. One of the factors causing inflammation is diet. The aim of this study was to assess the inflammatory potential of the diet, expressed by the DII index, in young physically active men. Methods: A total of 94 physically active students aged 19–23 participated in the study. The subjects' diets were assessed on the basis of 4-day dietary records, which were then analyzed using the computer program "Diet 5.0". The DII was calculated for each participant based on the individual consumption of the selected dietary components. The concentration of CRP protein was also determined. Results: Participants was divided into groups according to values of DII. Diets with different DIIs provided similar amounts of calories, but differed significantly in the content of many nutrients. Participants whose diets showed the most anti-inflammatory effects consumed significantly more protein, magnesium, iron, zinc, antioxidant vitamins, and B vitamins compared to others. The highest concentration of CRP protein was observed in men whose diet was described as the most pro-inflammatory (Q4 group). A significant relationship was found between DII and body fat (%) in men in the most anti-inflammatory (Q1 group) and neutral diet (Q2–Q3 group). Conclusions: The Dietary Inflammatory Index is a promising method of describing the effect of dietary intake on the risk of inflammation in young, healthy individuals engaging in regular physical activity.

Keywords: inflammation; nutrition; DII; physical activity; young men

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1. Introduction

Inflammation is a defensive reaction of the immune system to a pathological factor that damages cell structures. It is the natural response of any healthy organism to neutralize pathogens and maintain homeostasis. The normal inflammatory response occurs when the threat is present and resolves when the threat is over [1,2]. However, the action of certain biological, psychological, social, and environmental factors can prevent acute inflammation from subsiding and contribute to the persistent presence of chronic inflammation in the body. Chronic inflammation is characterized by the activation of the immune system components that often differ from those involved in an acute immune response [3]. Shifting the inflammatory response from short-term to long-term leads to severe changes in the functioning of all tissues and organs, which can increase the risk of various diseases in both young and old people. Long-term inflammation in the body is now linked to the development of chronic non-communicable diseases such as obesity, diabetes, and cancer [4,5].

Factors contributing to the development of long-term inflammation include chronic infections, lifestyle-related obesity, intestinal dysbiosis, sleep disturbances, psychological stress, social isolation and environmental and industrial pollution [2]. According to existing data low physical activity and poor diet also contribute to the occurrence of chronic inflammation [6]. The link between physical inactivity and an increased risk of diseases associated with long-term inflammation has been well documented [7,8]. It is assumed that lack of physical activity promotes inflammation as it causes the body to store more fat, especially visceral fat [9]. It is also believed that in physically inactive people, the intensification of inflammation is a result of the reduced secretion of anti-inflammatory substances by the skeletal muscles. These substances are cytokines (e.g., IL-6, Il-8) and other small proteins (e.g., brain-derived neurotrophic factor BDNF, irisin) called myokines [10]. It should be emphasized that myokines are produced by skeletal muscles and have systemic anti-inflammatory effects primarily during muscles' contraction [11]. Decreased production of myokines in physically inactive people is associated with increased pathophysiological changes typical of chronic inflammation, including insulin resistance, dyslipidemia and high blood pressure [12]. On the other hand, exercise-induced damage to muscle fibers is known to cause transient inflammation which, if overtrained, can turn into chronic inflammation [13]. Thus, the relationship between exercise and inflammation is more complex and depends on many factors.

The same goes for diet. For example, following a Mediterranean Diet based mainly on fruits, vegetables, fish and other products containing many unsaturated fatty acids is associated with the reduction of inflammation [14]. In turn, the Western Diet, very popular in developed countries, characterized by a high consumption of saturated fatty acids and simple carbohydrates, contributes to a significant increase in the level of inflammatory markers in the blood (e.g., C-reactive protein, CRP). It has been shown that these nutrients negatively affect the intestinal microflora, and by increasing the permeability of the intestinal barrier, they cause inflammation [15].

A growing number of studies confirming diet influence on the occurrence of inflammation have contributed to the creation of an indicator called the Dietary Inflammatory Index (DII) [16,17]. DII was established in 2013 on the basis of numerous publications from 1950 to 2007, which described the influence of 45 food components, then included in the DII, on inflammation development [18]. Each component of DII was given an individual positive or negative point value. Positive values were assigned to ingredients and/or products that exhibit pro-inflammatory properties (e.g., saturated fatty acids), while negative values were assigned to ingredients and/or products with anti-inflammatory properties (e.g., vitamins, minerals) [19]. This relatively new dietary index was validated against inflammatory cytokines [20,21]. The studies conducted so far have also confirmed its relationship with the occurrence of components of the metabolic syndrome, such as high waist circumference, high TG concentration or hypertension [22]. Thus, the development of the Diet Inflammatory Index allowed for a better assessment of the quality of consumed food, mainly in the context of its impact on health.

Previous studies which analyzed DII mainly concerned middle-aged and elderly people, often in the early or advanced stages of the disease (e.g., cancer, diabetes) and characterized by moderate physical activity. For example, a large 2017 United States study looked at ethnically diverse people aged 45–75 participating in the cancer registry program [23]. This study confirmed an association between the pro-inflammatory potential of the diet, described by the DII index, and an increased risk of colorectal cancer. In another study by Visseres et al., the relationship of DII with the development of arterial hypertension was investigated in women aged 51–53 years [24]. Therefore, data on the value of the Diet Inflammatory Index of healthy young people are insufficient. Meanwhile, the few existing studies show that the diet of young people, especially men, often promotes chronic inflammation, thus increasing the risk of diseases related to it [25,26].

Taking into account the above information, as well as the importance of proper nutrition for maintaining high physical performance, it seems advisable to undertake research on the inflammatory potential of the diet, expressed by the DII index, in young, physically active men.

2. Materials and Methods

2.1. Subjects

Students of the Józef Piłsudski University of Physical Education in Warsaw, whose physical activity results only from participation in sports activities provided in the study program, took part in the study. The duration of physical activity ranged from four to seven hours/week. Additional inclusion criteria for the study were: being healthy, not taking medications, not smoking, and consenting to participate in the study. Participants were recruited on the basis of advertisements in student dormitories and by word-of mouth. Originally, it was planned to recruit 100 physical education students. This many students agreed to participate in the research. However, complete data were obtained in 94 young men aged 19–23 years.

The study protocol has been approved by the Józef Piłsudski University of Physical Education Ethics Committee. Participants were informed about the purpose and procedures of the research and provided their written consent.

2.2. Anthropometric and Biochemical Measurements

Assessment of the basic anthropometric parameters, i.e., body weight and height, was performed using standard methods and equipment. Height was measured to the nearest 0.5 cm and body weight was measured to the nearest 0.1 kg. Based on both parameters, body mass index (BMI) was calculated. Waist (cm) was measured using a standard, retractable, non-metallic tape at the midpoint between the lower rib and the top of the iliac crest. Waist-to-height ratio (WHtR) was calculated. Body fat content (%) was assessed by the bioimpedance method (BIA) in the tetrapolar version using the BC-418 device (Tanita Co., Tokyo, Japan). The following values of body fat percentage 14–17% were accepted as characteristic for lean men [27].

Anthropometric measurements were carried out in duplicate and then averaged. All measurements were taken by the same researcher, in the morning with the participants wearing sports outfits without shoes. Students were asked to arrive at the laboratory during 0800–1000 h after an overnight fast, and to refrain from exercise for 24 h prior to body composition analysis and blood collection. Blood for hs-CRP concentration was drawn from the antecubital vein by an authorized laboratory technician. hs-CRP concentration was measured by an immunoturbidimetric method with latex reinforcement using spectrophotometry. The blood was centrifuged (10 min; 3000 rpm), then the plasma was collected and hs-CRP was determined. The reference values for the study were <0.5 mg/dL, while the concentration of hs-CRP protein above 10 mg/dl indicates inflammation.

2.3. Diet Assessment

Dietary assessment was made on the basis of the nutrition records from 4 days (2 weekdays, 2 weekend days). Weekday notes were collected in the presence of a trained employee. Notes from weekend days were made by each participant, previously instructed on the correct recording method. Study participants were asked not to use any dietary restrictions while collecting nutritional data. To identify the size of consumed portions, the "Album of photos of products and dishes" developed at the Institute of Food and Nutrition was used [28]. The content of selected nutrients and energy was calculated using the "Diet 5.0" computer program, also developed at the Institute of Food and Nutrition in Warsaw.

2.4. Calculation of Dietary Inflammatory Index

The DII values were calculated according to the method proposed by Shivappa et al. [18]. To calculate the DII for each participant, the individual consumption of products and diet components were used. These values were normalized to the mean global consumption value (Z-score) and converted into the percentile score (PS). The PS parameters were then recalculated to a symmetric distribution to "0" (centered percentile value (CPV)) with values from "−1" (maximum anti-inflammatory) to "1" (maximum pro-inflammatory). The CVP values obtained for individual products/nutrients were then multiplied by the overall inflammatory effect score, which allowed the obtaining of the DII for individual dietary components. After summing up the DII values of all analyzed diet components, the total DII for each study participant were calculated [18]. Of the 45 original DII components, 35 were available for this evaluation. Components such as flavan-3-ol, flavones, flavonols, flavonones, and antho-cyanidins included in the original DII calculation were not analyzed in the current study because they were not available from the computer program "Diet 5.0".

2.5. Statistical Analysis

The normality of the distributions has been checked using the Shapiro-Wilk test. The significance of the differences between the groups depending on their distribution was assessed either using ANOVA for normally distributed data or the Kruskal-Wallis rank ANOVA for non-normalized data. Results are presented as means ± SD. Differences at $p < 0.05$ were considered significant. The relationships between the variables were assessed by analyzing the Spearman's simple correlation coefficients. The analysis was performed with the use of Statistica v.10. (StatSoft, Tulsa, OK, USA).

3. Results

The aim of the study was to determine whether young physically active men differ in body composition and the concentration of inflammatory markers, depending on the consumed diet described by the DII index. In addition, an analysis was performed to identify nutrients (DII components) that had the greatest impact on the pro-and anti-inflammatory nature of young men's diet. Therefore, the obtained data was divided into quartiles (Q1; Q2; Q3; Q4) based on the values of the calculated DII. The following groups were distinguished: the group with the most anti-inflammatory diet (Q1) with DII values −3.39; −1.05, the group with the most pro-inflammatory diet (Q4) with DII values 1.34; 4.23 and the group with the neutral diet (Q2–Q3) with DII values −1.03; 1.30.

The data presented in Table 1 show that the men included in the particular quartile groups did not differ in body height and body mass, as well as in the content and distribution of body fat. The body fat content of all study participants indicated that they were lean.

Table 1. Anthropometric characteristics of participants (mean ± SD).

	$Q1_{n=24}$ (25%) Most Anti-Inflammatory Diet	**$Q2–Q3_{n=49}$ (50%)**	**$Q4_{n=22}$ (25%) Most Pro-Inflammatory Diet**
DII (min; max)	(−3.39; −1.05)	(−1.03; 1.30)	(1.34; 4.23)
Age [years]	21.4 ± 2.12	21.2 ± 1.72	22.0 ± 2.24
Height [cm]	179.5 ± 5.92	180.9 ± 5.54	180.5 ± 4.55
Body mass [kg]	77.3 ± 7.42	77.8 ± 6.92	77.6 ± 8.59
BMI	24.0 ± 2.30	23.7 ± 1.67	23.8 ± 2.23
Body fat %	12.0 ± 3.08	10.7 ± 2.90	12.7 ± 3.46
WHtR %	43.9 ± 3.90	43.8 ± 2.17	44.4 ± 2.92

DII (Dietary Inflammatory Index), BMI (Body Mass Index), Waist-to-Height Ratio (WHtR).

Table 2 displays the amount of energy, macro and micronutrients consumed by study participants. Only the DII components found in the students' diet were included in this table. It was observed that diets with different DIIs provided similar amounts of calories, but differed significantly in the content of many nutrients. Participants whose diets showed the most anti-inflammatory effects consumed significantly more protein ($p < 0.05$), magnesium ($p < 0.001$), iron ($p < 0.001$), zinc ($p < 0.001$), antioxidant vitamins A, E, C ($p < 0.001$), B vitamins ($p < 0.001$), thiamine ($p < 0.05$), riboflavin ($p < 0.001$), niacin ($p < 0.001$) and B6 ($p < 0.001$) and cholesterol ($p < 0.05$) compared to others. Moreover, it was noticed that the diets from the Q1 group were characterized by a significantly higher amount of saturated fatty acids than diets from the Q4 group ($p < 0.0$—$p < 0.001$). In turn, those whose diets had the most pro-inflammatory effects (Q4 group) consumed the least monoand polyunsaturated fatty acids and fiber of all participants ($p < 0.05$) (Table 2). In addition, analyzing the consumption of omega-3 and omega-6 polyunsaturated fatty acids, it was found that men following the most anti-inflammatory diet consumed significantly more omega-3 fatty acids compared to those with the most pro-inflammatory diets (2.38 ± 0.78 g vs. 1.54 ± 0.67 g, $p < 0.001$).

Table 2. Daily energy, macronutrient, and micronutrient intake in participants (mean ± SD).

	$Q1_{n=24}$ (25%) Most Anti-Inflammatory Diet	$Q2–Q3_{n=49}$ (50%)	$Q4_{n=22}$ (25%) Most Pro-Inflammatory Diet
DII (min; max)	(−3.39; −1.05)	(−1.03; 1.30)	(1.34; 4.23)
Energy [kcal]	2726.9 ± 372.14	2697.2 ± 393.93	2768.7 ± 588.94
Protein [g]	146.1 ± 25.56 A*	135.6 ± 43.63	120.6 ± 32.32 B***
Fat [g]	100.2 ± 27.40	100.8 ± 18.66	110.1 ± 30.89
Carbohydrates [g]	334.4 ± 58.00	319.6 ± 62.06	327.8 ± 80.54
Magnesium [mg]	477.1 ± 88.59 A***	354.4 ± 92.31 C**	271.4 ± 61.13 B***
Iron [mg]	17.7 ± 3.53 A***	13.4 ± 4.68 C*	10.8 ± 3.03 B***
Zinc [mg]	16.8 ± 3.86 A***	13.2 ± 6.69 C**	9.6 ± 2.58 B***
Vitamin A [µg]	2403.1 ± 1812.39 A***	1101.5 ± 400.59	962.2 ± 502.44 B***
Beta-carotene [µg]	8840.0 ± 5722.61 A***	3304.7 ± 1809.25	2253.7 ± 1368.87 B***
Vitamin E [mg]	16.4 ± 4.82 A*	13.1 ± 4.26 C*	10.5 ± 3.38 B***
Thiamine [mg]	2.1 ± 1.59 A*	1.5 ± 0.43	1.4 ± 0.35 B**
Riboflavin [mg]	3.3 ± 2.38 A***	2.1 ± 0.83	1.6 ± 0.46 B***
Niacin [mg]	35.4 ± 16.97 A***	21.6 ± 13.83 C**	12.9 ± 6.08 B***
Vitamin B6 [mg]	3.7 ± 2.47 A***	2.2 ± 0.83 C***	1.5 ± 0.41 B***
Vitamin C [mg]	247.4 ± 163.58 A***	104.5 ± 97.76	76.9 ± 30.83 B***
Saturated fatty acids [g]	38.2 ± 13.76	35.9 ± 11.20	28.8 ± 12.41 B*
Monounsaturated fatty acids [g]	40.1 ± 10.55	39.6 ± 12.03 C*	30.8 ± 11.03 B*
Polyunsaturated fatty acids [g]	12.6 ± 4.13	15.3 ± 5.45 C*	12.0 ± 4.00 B*
Cholesterol [mg]	630.2 ± 268.32 A*	457.5 ± 263.80	370.1 ± 103.79 B**
Dietary fiber [g]	31.1 ± 5.31 A***	23.8 ± 4.70 C*	20.4 ± 2.57 B***

A—significant differences between Q1 vs. Q2–Q3; B—significant differences between Q1 vs. Q4; C—significant differences between Q2–Q3 vs. Q4; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

In all groups, the anti-inflammatory DII values were determined mostly by fiber, vitamin B6 and vitamin E (Figure 1). In the Q1 group, the anti-inflammatory nature of the diet was also influenced by vitamin C, vitamin A, beta-carotene, zinc and magnesium. The same minerals had a significant impact on the health-promoting DII values in men from the Q2–Q3 group. Conversely, total calorie intake and the amount of consumed fat, including cholesterol, increased the pro-inflammatory properties of the diets of all the surveyed men. The consumption of saturated fatty acids showed such an effect only in the diet of subjects from the Q1 and Q2–Q3 groups. It was also observed that the pro-inflammatory DII in men from Q4 group was significantly influenced by vitamin C and beta-carotene (Figure 2).

The highest concentration of hs-CRP protein was observed in men from the Q4 group, whose diet was described as the most pro-inflammatory. However, this difference reached statistical significance only compared to the Q2–Q3 group ($p < 0.05$) (Figure 2).

There was no statistically significant correlation between the hs-CRP protein concentration and the DII score in the group following the most anti-inflammatory diet (Q1) as well as in the group following the most pro-inflammatory diet (Q4) (Table 3). However, a statistically significant relationship was found only between this dietary index and body fat (%) in groups Q1 and Q2–Q3 ($p < 0.05$) (Figure 3).

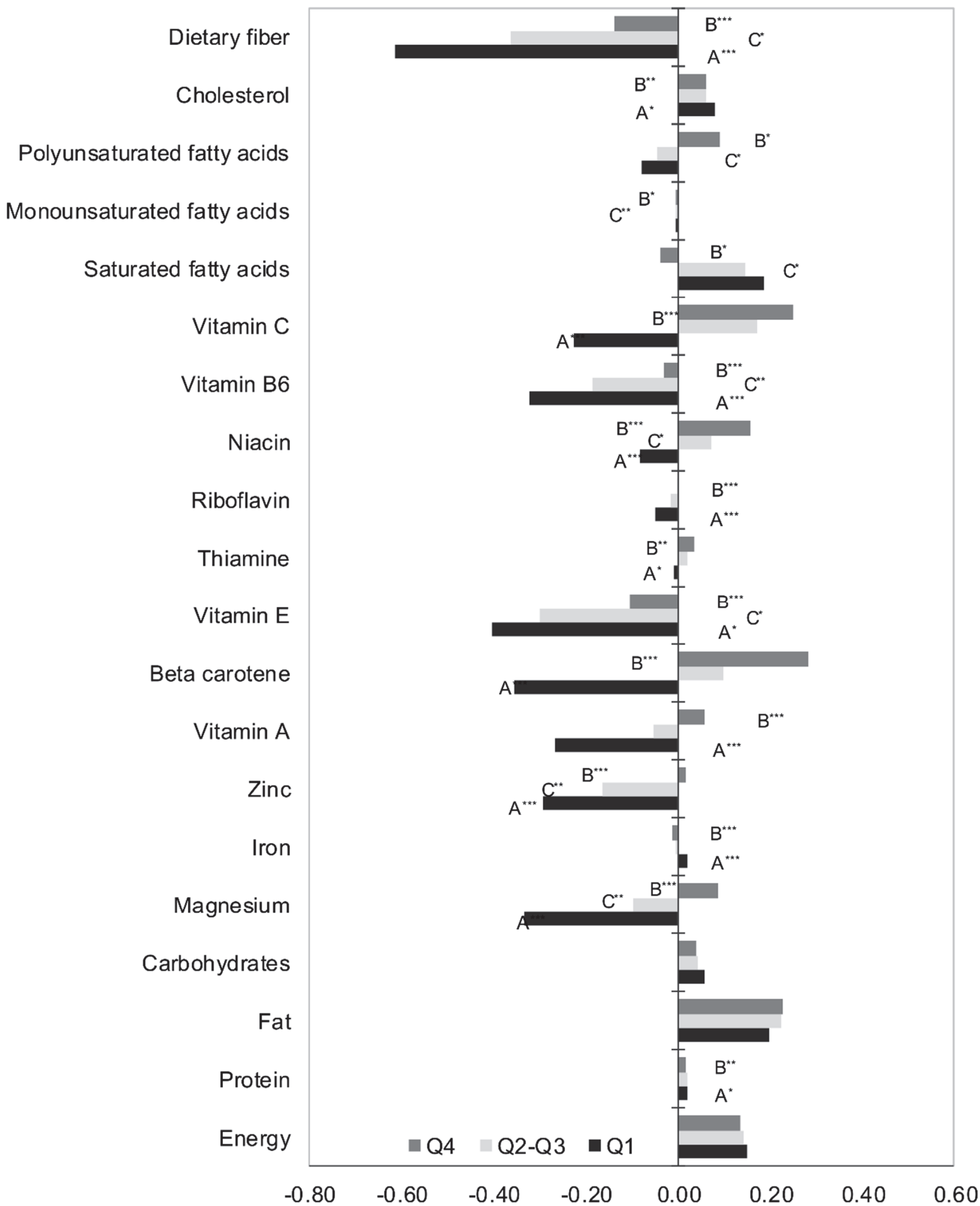

Figure 1. The overall inflammatory effect of energy, macro and micronutrients (mean value). A—significant differences between Q1 vs. Q2–Q3; B—significant differences between Q1 vs. Q4; C—significant differences between Q2–Q3 vs. Q4; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

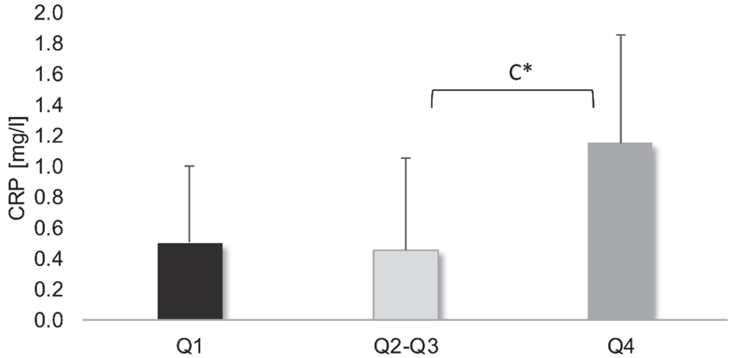

Figure 2. Protein C reactive (hs-CRP) concentration in men with different DII (median ± quartile).; [C]—significant differences between Q2–Q3–Q4; *—p < 0.05.

Table 3. Spearman's simple correlation coefficients for hs-CRP, DII, FAT and WHtR.

	Q1$_{n = 24}$ (25%) Most Anti-Inflammatory Diet	**Q2–Q3$_{n = 49}$ (50%)**	**Q4$_{n = 22}$ (25%) Most Pro-Inflammatory Diet**
	hs-CRP [mg/l]		
DII	0.209 p = 0.326	−0.049 p = 739	0.048 p = 0.829
FAT %	−0.159 p = 0.456	−0.071 p = 0.629	−0236 p = 0.278
WHtR %	−0.044 p = 0.839	−0.135 p = 0.355	−0.166 p = 0.449

* p < 0.05.

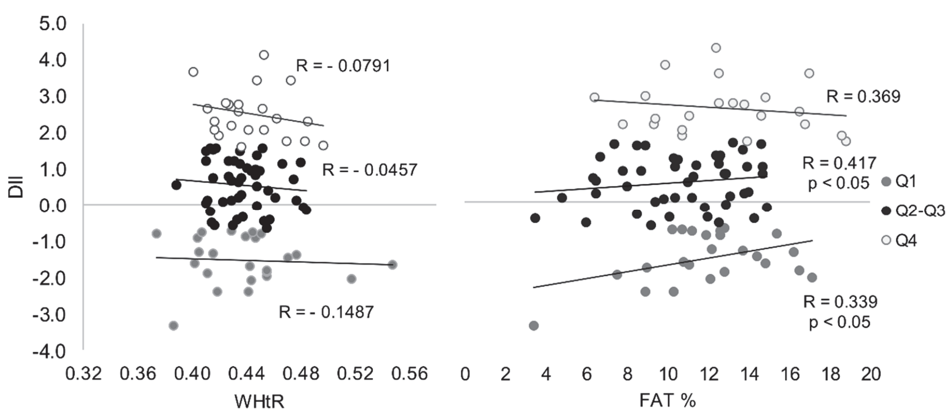

Figure 3. Correlation between DII and WHtR (**left**) and FAT (**right**) content in men with different DII.

4. Discussion

Nutrition has a significant impact on the health and psychophysical development of every human being, from the prenatal period to later old age. An appropriate diet is conducive to proper course of the growth process, maintaining a normal body weight in adult life and protecting against the effects of aging (e.g., sarcopenia, osteoporosis) [29–31]. It is well known that proper nutrition is also important in the prevention of numerous diseases: metabolic (e.g., obesity, diabetes), respiratory system (e.g., asthma), circulatory system (e.g., atherosclerosis, heart disease), as well as cancer and mental diseases (e.g., depression) [18,32–35]. Conversely, bad nutritional habits contribute to increased inflammation in the body, which leads to the development of these diseases [36,37].

There is no doubt that physically active people should be characterized by a properly balanced and healthy diet [38]. The aim of this study was to calculate the Diet Inflammatory Index for young men with moderate and regular physical activity and to use it to evaluate the impact of diet on their health. The DII values observed in this study ranged from −3.39 to 4.23. This range of DII score was comparable to those reported by Akbaraly et al. (−3.35 to 4.23), who studied the relationship between DII and recurrent depressive symptoms in a large British population of adult men and women aged 35–55 years [39]. In comparison, the diets of obese men and women aged 43.4 ± 10.9 years studied by Abdurahman et al. [40] were characterized by a DII ranging from −4.42 to 3.34, whereas in Iranian adults participating in the Salari-Moghaddam et al. project, which assessed the relationship between DII and psychological disorders, it was found that DII values ranged from −4.49 to 5.39 [41]. It seems that the differences in the DII values observed by various authors can be largely explained by the number of components included in the DII calculations. This was the case of our study, in which, due to the limitations of the program used to analyze nutritional interviews, 35 out of 45 components proposed by Shivappa et al. [18] were used to calculate the DII. However, due to the fact that the "Diet 5.0" program is the recommended tool to assess the diet of the Polish population [42], it was decided to use it in the research. Moreover, it should be emphasized that in this study the pro-inflammatory nature of the diet was assessed only in men, while the authors of the above-mentioned studies analyzed the values of DII in both sexes.

It is worth quoting here the results of the analysis by Steck et al., who showed that the DII value for fast food diets is 4.0, and for these Mediterranean diet is −4.0 [19]. Comparing this to the DII values obtained in the participants of our own research, it can be concluded that among them were people (group Q4; DII: 1.34; 4.23) with a diet that was unfavorable to their physical fitness. There is much evidence in the literature that consumption of a pro-inflammatory diet may have a negative impact on physical performance due to the occurrence of insulin resistance, faster development of muscle fatigue, as well as prolongation of post-exercise regeneration [43].

This study showed that young men whose diets had different inflammatory potentials did not differ in body shape and composition. The values of BMI and body fat content in all studied groups were within the normal range for young, regularly physically active men [44]. This can be explained by a similar intake of calories in the diet by the surveyed men from the quartile groups distinguished on the basis of the DII value. The similar diet energy consumption was probably related to the fact that all participants of this study were students of the same university, following the same program, requiring a similar amount of physical effort. It should be assumed that the energy expenditure related to the physical education program of studies makes the majority of students lean. However, it is disturbing to find that some students' diets with pro-inflammatory DII values may reduce the health benefits of an active lifestyle.

The differences in the DII values of the students' diets resulted from their different composition. The anti-inflammatory nature of the students' diet was primarily determined by the higher consumption of protein, antioxidant vitamins, B vitamins, zinc, iron and magnesium. Other authors drew similar conclusions, stating that a properly composed anti-inflammatory diet should rely on a high intake of vitamins, minerals and substances of plant origin (e.g., a macrobiotic diet) [19]. Our own research also showed that insufficient fiber intake makes the diet more pro-inflammatory. The observation that insufficient consumption of monounsaturated and polyunsaturated fatty acids applies to diets with a higher DII also confirms the reports of other researchers [45]. Therefore, this study shows that the diets of young active men are characterized by deficiencies of these nutrients, which according to the literature negatively affects their health and physical performance [46]. However, the analysis of the physically active young men's diets also gave quite surprising results. An example is the finding that vitamin C and beta-carotene increased the pro-inflammatory nature of the diet in most participants. This observation is difficult to explain, thus further investigations are needed.

As expected, the highest levels of hs-CRP were found in men whose diets had the highest DII values (Q4 group). Although previous studies mostly confirmed the existence of a relationship between DII and inflammatory markers [18,47], this study did not show a significant relationship between hs-CRP and DII score in any of the groups. Perhaps this was due to the fact that our participants were healthy people, with generally low hs-CRP values, within the normal range, whereas a statistically significant relationship was observed between the DII and the body fat content, which is considered to be an indicator of the nutritional status.

The present study had some limitations to consider. First, the study participants were young, physically active men, thus the obtained results may not be generalized. Second, herbs and spices were excluded in dietary recall cause to lack of intake information. Third, there was a small sample size compared to other DII studies (men $n = 94$).

Besides these limitations, this study has several advantages. First, despite the similarities in anthropometric measurements between groups, differences in DII values were noticed. This may indicate that DII may be the first and easy tool to detect health problems despite the lack of visual symptoms (e.g., obesity). Second, our results confirmed that consuming diet with a high DII increases the risk of disease also in young physically active people.

5. Conclusions

To our current knowledge, this is the first study in which the DII for young Polish people was calculated. The Dietary Inflammatory Index is very promising as it can detect any inflammation depending on the diet one has. Due to its low cost, this method allows for a quick assessment of the quality of the diet and its impact on health. However, additional studies on the relationship with dietary inflammation are needed.

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Institutional Review Board Statement: This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Ethics Committee of Jozef Piłsudski University of Physical Education in Warsaw.

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Article

The Structure of the Relationship between Physical Activity and Psychosocial Functioning of Women and Men during the COVID-19 Epidemic in Poland

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Abstract: Since the coronavirus disease (COVID-19) pandemic is a serious crisis in many countries around the world, it is important to conduct empirical research aimed at identifying risks and factors protecting the functioning of people affected by it. For this reason, the goals of the present research were to determine the level of physical activity and the severity of symptoms characteristic of mental disorders, cognitive disorders and the quality of social functioning, as well as the structure of the relationship between physical activity and psychosocial functioning of 226 women and 226 men during the COVID-19 epidemic in Eastern Poland. The research was conducted using the *IPAQ-SF Questionnaire*, *GHQ-28 Questionnaires*, *TUS Test-6/9 version*, the original *SFS Scale* and a self-developed sociodemographic survey. The collected data indicate that women as compared to men show lower levels of weekly physical activity, walking, moderate activity, vigorous activity and quality of functioning in family relationships, but higher severity of mental health disorders, somatic symptoms, functional disorders, depressive symptoms, cognitive disorders, perceptual work disorders, attention deficits and higher quality of functioning in work relationships. On the other hand, the structural model indicates that physical activity, interacting with mental health disorders and cognitive disorders, is positively associated with the social functioning of the respondents, and gender is the moderator of the occurring dependencies. This suggests that physical activity adapted to the condition of health may be an important component of gender-individualized psychopreventive interventions.

Keywords: COVID-19 epidemic; gender; physical activity; psychosocial functioning

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1. Introduction

The leading health and social problem in many countries around the world is the coronavirus (COVID-19) pandemic. Up to 6 August 2022, a total of 588,081,229 cases of disease were recorded in various regions of the world, including 6,434,821 deaths and 559,178,151 recoveries. In Poland, the reach of the epidemic is 6,093,571 people, of which 116,660 patients have died and 5,335,862 have already been cured [1].

Empirical evidence from different countries affected by the pandemic suggests that symptoms of anxiety and depression (16.0–28.0%) and sleep disorders (38.9%), which are associated with impaired cognitive dynamics and cognitive deficits, including attention and perceptiveness [2,3], are relatively frequent psychological reactions to the current crisis situation, with higher rates of symptoms of mental health disorders found in women than in men [4–6]. On the other hand, both the occurrence of the above-mentioned symptoms and the consequences of life limitations during the pandemic may disrupt the social life of many people, and thus lower the quality of their relationships with family members and friends and professional interactions [6,7].

When attempting to understand the nature of the aforementioned crisis, it is important to refer to the leading assumptions of the biopsychosocial model dominating in modern health sciences, which can explain intrapsychic reactions of people to the pandemic as a result of the interaction of a network of equivalent biological, psychological and social factors shaping health [8–10].

Taking into account the biological factors included in the considered model, it should be emphasized that empirical evidence from various countries affected by the pandemic indicates that gender moderates the resistance to stressors and has a significant influence on psychological variables important in coronavirus (SARS-CoV-2) transmission, specifically mental health and cognitive processes [8–12]. On the basis of a meta-analysis, it was proven that women exhibit a higher intensity of symptoms characteristic of depressive syndrome and anxiety disorders than men associated with the presence of attention and perceptiveness deficits, which may indicate that it is more difficult for them to cope with the current situation [13–17].

It was also observed that the mental condition and the state of cognitive processes during the current crisis may be of significant importance for social functioning, including family, interpersonal and professional interactions [18]. It is postulated that the quality of these relationships is directly related to the received social support, acting as a factor protecting against the negative consequences of experienced stress [19].

It has been observed that during the transmission of SARS-CoV-2, women report a greater sense of loneliness than men [15,17]. Moreover, regardless of gender, in many countries, including Poland, Spain, Australia, the United States, Sweden and China, due to social isolation, quarantine, working from home and other pandemic restrictions, the number of social interactions decreased [15,17,20–22]. This at the same time reduces the likelihood of receiving support, and thus increases the risk of developing unwanted psychological symptoms, including depression, anxiety disorders and accompanying problems in cognitive functioning [23].

Bearing in mind that, according to the adopted approach, a human is a living system, constituting an indivisible whole, composed of biological, psychological and social dimensions, which, under the influence of incoming information, or, in other words, the requirements of the environment, remain in a dynamic balance, it is extremely important to pay attention to factors supporting its remedial efficiency, and their consequences on the general health condition [9,10].

One of the key forms of preventive action recommended by the World Health Organization (WHO) is regular physical activity, defined as any type of body movement initiated by working muscles that causes energy expenditure. It includes walking, moderate and vigorous activity, which, at the same time, strongly distinguishes it from other forms of leisure activities, including time spent on passive leisure such as sitting and lying down [24,25].

The available literature shows that physical activity understood this way reduces the risk of developing undesirable mental symptoms as well as disorders in cognitive functioning, because by increasing the metabolism of kynurenine and the expression of kynurenine aminotransferase in skeletal muscles, it minimizes the consequences of environmental stress, and thus prevents the appearance or reduces the severity of symptoms characteristic to neuropsychiatric disorders [26].

It has been proven that systematic physical exertion delays neurodegenerative processes and regulates monoamine metabolism, as well as neuroimmune functioning [27]. The physiological changes taking place under the influence of training support the proper functioning of the hypothalamic–pituitary–adrenal axis (HPA), the excessive activation of which, caused by increased and sustained release of cortisol, is associated with the risk of developing many disorders [28–30]. In addition, physical activity by stimulating the expression of the brain nerve growth factor (BDNF), as well as supporting the proper functioning of the Trk-B receptor and BDNF-Trk-B signaling, determines the neurophysiological processes taking place, which in turn has a beneficial effect on affective, cognitive and social functioning [31,32].

The vast majority of studies indicate that men have higher levels of physical activity than women, which may be due to different uses of the time available in the course of a day [33–36]. A nationwide study reported that, on average, men devote one hour and thirty-three minutes per day to sports, while women, on average, perform physical exercises for one hour and nineteen minutes per day. Moreover, men's workouts tend to be characterized by higher intensity than those performed by women. As a result, men's higher physical activity, to a greater extent than women's, may be a factor in protecting their mental fitness [35,36].

It is worth mentioning, however, that the results of studies conducted in different regions of Poland are not consistent. For example, in the population of residents of north-eastern Poland, it has been shown that, although moderate physical activity is undertaken more often by men (53.9%) than by women (34.7%), and that men, compared to the opposite sex, are almost twice as likely to ride a bicycle (31.5% vs. 13.1%), but at the same time it has been observed that, regardless of gender, the physical activity of residents of this region is insufficient and differs significantly from levels recorded in other parts of the country, as well as in other European countries [33].

Results of a cross-sectional study conducted in a random sample of 6000 people between the ages of 40 and 64 in Japan are also of interest. They came to slightly different conclusions than the empirical works cited above. They observed that women, on average, spent 12.6% less time on sedentary lifestyles and 23.4% more time on low-intensity physical activity than men, but found no significant differences for moderate and vigorous physical activity [37].

This suggests that the conclusions of the empirical works published to date are inconclusive. The reported results vary depending on the region of Poland, as well as the part of world in which they're conducted [33–37], which at the same time suggests that they appear to be worth supplementing. The results of our own research will therefore allow us to determine whether, and possibly to what extent, the observations of other researchers reflect the situation of the people of Eastern Poland. Considering that there are no studies aimed at determining the level of physical activity, mental health, cognitive processes and quality of social functioning, as well as the importance of interactions between these variables in the population of women and men exposed to stress resulting from the COVID-19 epidemic in Eastern Poland, the data obtained can provide both valuable scientific observation and be used to develop psychoprophylaxis interventions.

Hence, the aim of this own research was to determine the level of physical activity, mental health, cognitive processes and quality of social functioning, as well as the structure of the relationship between physical activity and psychosocial functioning of women and men during the COVID-19 epidemic in Eastern Poland.

Two research questions were posed accordingly: (1) what is the level of physical activity, mental health disorders, cognitive disorders and social functioning, as well as (2) what is the significance of the interactions between physical activity, mental health and cognitive disorders for the social functioning of men and women during the COVID-19 pandemic in Poland?

In response, two hypotheses were formulated, assuming that during the COVID-19 epidemic in Poland, depending on gender, the following varies: (1) the level of physical activity, the intensity of symptoms characteristic of mental health disorders, cognitive disorders and the quality of social functioning as well as (2) the importance of the interaction between physical activity, mental health and cognitive disorders for social functioning.

2. Material and Methods

2.1. Design

While conceptualizing the author's own research, the biopsychosocial model of health was used [8–10]. Based on the above theoretical frameworks, in the quasi-experimental model, a cross-sectional research plan was designed.

In line with the adopted theoretical approach, in this research project, variables of biological (gender), psychological (physical activity, mental health disorders, cognitive disorders) and social (social functioning) factors were distinguished, which were assumed to interact with each other.

Whereas the prognostic factors of mental health and cognitive disorders, as well as the social functioning received, may vary depending on country and even region [12,38–40], the analysis focused on the consequences of the epidemic in the population of Eastern Poland, which means that the surveyed sample included only the inhabitants of these areas. Additionally, the concept takes into account the moderating role of gender, as it is an important biological determinant of susceptibility to physical activity, mental and cognitive disorders and social functioning [11,12,14,15,41].

It was assumed that the mentioned parameters are latent variables, which is characteristic of fully interactive approaches and at the same time allows for a detailed analysis of the mutual and multifaceted interaction of individual factors creating the structure of physical activity, as well as shaping the state of mental health, cognitive processes and social functioning [8–10,42].

Given that the biopsychosocial model of health [9], as well as numerous empirical premises, suggests a significant role of sociodemographic factors for the variables analyzed in the study, during the conceptualization of the research, many controlled variables, which may potentially influence the results, have been taken into account [13,43,44]. They include: gender [14,15], age [43], place of residence [38], level of education [45], marital status, number of children [15,46], professional activity [45] and health condition of the respondents [7,47,48].

In order to minimize the influence of gender on the obtained research results, the analyzed groups were of the same size. In the case of a health condition, a procedure based on establishing its constant level was applied. Age, marital status, place of residence and professional activity were checked by designating their subranges, and, as in the case of the other above-mentioned variables, the homogeneity of the studied groups was confirmed [42].

In the first stage of the analysis, the level of physical activity, mental health disorders, cognitive disorders and social functioning of women and men during the epidemic were assessed. In the next stage, the focus was on verified gender-related occurrence and significance of the interactions and relationships between the identified variables based on the modeling of structural equations in the confirmatory version.

The research was carried out in the population of adults of Eastern Poland in the period from June, 2020 to December, 2021. In total, 579 people declared their willingness to participate, and 452 women and men met the inclusion criteria (78.7%). Before and during the study, the participants showed no symptoms suggesting a risk of SARS-CoV-2 infection and were not quarantined.

The research was conducted in accordance with the guidelines of the Helsinki Declaration and received approval from the Bioethics Committee of the Medical University of Lublin (No. KE-0254/100/2020, 28 May 2020). The persons obtained all necessary information and explanations about the project. In addition, they were informed about the confidentiality of the data provided and about the possibility of receiving feedback based on individual results. In case of doubts, they had the opportunity to obtain additional explanations.

Due to the risk of SARS-CoV-2 infection and restrictions introduced in the country, each person was contacted online. The invitation to participate in the research along with contact details (telephone number, first and last names of persons to contact) was posted on the Internet on the website of NeuroCentrum [49]. It was available from 1 June 2020 to the end of November 2021. The invitation to participate in the study was extended to adult residents of Eastern Poland according to the adopted inclusion and exclusion criteria.

These inclusion criteria were: free and informed written consent to participate in the research, age (adults), origin (inhabitants of Eastern Poland), marital status (married or partnership), employment based on an employment contract or contract of mandate, no diagnosis of COVID-19 and a lack of SARS-CoV-2 symptoms, as well as good general psychophysical health. The exclusion criterion was: failure to meet at least one of the above-mentioned inclusion criteria.

Participants were recruited by phone. Those who declared their willingness to participate in the research, and at the same time met the inclusion criteria, provided the recruiter with a telephone number and an address. They were mailed an informed consent form necessary to participate in the study, along with written information about the research and a return envelope enabling the documents to be sent back. After receiving them, the individuals were contacted by phone so a convenient date to carry out the study could be set.

The questionnaire session was carried out during individual video conferences. After acquainting respondents with the rules of completing the questionnaire items, a sheet was presented to them with individual questions, and the range of possible answers were read, and answers were marked in the appropriate place on the test. On average, the research period lasted for 20 min.

2.2. Participants

The sample consisted of two groups of inhabitants of Eastern Poland (n = 452). The first was made up of women (n = 226), and the second was made up of men (n = 226). The participants were 18–80 years old. Detailed sociodemographic characteristics of the respondents by gender are presented in Table 1.

Table 1. Sociodemographic characteristics of the surveyed women and men.

Variables		Group				Group Comparison	
		Women		Men			
		M	*SD*	*M*	*SD*	*t*	*p*
Age		46.79	11.92	46.35	11.48	0.40	0.691
Number of children		2.39	1.02	2.22	1.12	1.71	0.09
		n	%	*n*	%	x^2	*p*
Place of residence	City	113	50.0	113	50.0	0.00	1.00
	Village	113	50.0	113	50.0		
Education	Primary	27	11.9	37	16.4	5.29	0.152
	Vocational	81	35.9	72	31.9		
	Secondary	78	34.5	64	28.3		
	Higher	40	17.7	53	23.4		
Marital status	Married	113	50.0	113	50.0	0.00	1.00
	Informal relationship	113	50.0	113	50.0		
Professional activity	Employment contract	113	50.0	113	50.0	0.00	1.00
	Contract of mandate	113	50.0	113	50.0		

Markings: *M*—mean, *SD*—standard deviation, *t*—value of Student's *t*-test for independent data, *p*—significance level.

The analyzed groups were homogeneous in terms of age, number of children, place of residence, education, marital status and professional activity.

2.3. Physical Activity Measurements

The Short Form *Physical Activity Questionnaire* (*IPAQ-SF*) was used to measure weekly physical activity. It contains seven questions about the time spent on activities that require vigorous and moderate physical effort, as well as time spent on walks and time spent in the form of passive rest (sitting, lying down). Weekly exercise level can be estimated in MET units (minute/week). It is the product of the activity coefficient for a specific activity, the number of active days and its duration in minutes. On this basis, the level of physical activity of the examined person is determined, which may be: (a) high—from 3 to 7 days of intense physical exertion or at least 1500 MET; (b) sufficient—3 to 7 days of vigorous physical activity for at least 20 min a day or 5 to 7 days of moderate exercise/walking for at least 30 min a day or 5 to 7 days of any physical activity that in total exceeds 600 MET; (c) insufficient—lack of physical activity or failure to meet the conditions of the two above-mentioned levels [25,50].

2.4. Mental Health Measurements

The *General Health Questionnaire* (*GHQ-28*) was used to measure mental health. The tool is used to assess mental health, which is divided into four dimensions: somatic symptoms, anxiety and insomnia, social dysfunction and symptoms of depression. The *GHQ-28* enables the identification of people whose mental condition has been subject to a temporary or long-term breakdown as a result of experienced difficulties or as a result of mental illness, and those who are at a significant risk of mental health disorders. The cut-off point is a score of 12 or more. The questionnaire has high internal consistency and validity rates. The values of Cronbach's *alpha* coefficients, calculated in the studied population of women, ranged from 0.76 to 0.82, and in the population of men ranged from 0.76 to 0.83 [51].

2.5. Cognitive Functioning Measurements

The *Attention and Perceptiveness Test* (*TUS*) version 6/9 was used to measure cognitive functioning in terms of attention and perceptiveness. The tool is used to assess cognitive disorders in three dimensions: perceptual work, perception deficits and attention deficits. The *TUS* enables the identification of people whose cognitive functioning condition has been subject to a temporary or long-term breakdown as a result of experienced difficulties or as a result of illness, and those who are at a significant risk of cognitive disorders. The questionnaire has high internal consistency and validity rates. The values of the absolute stability coefficients (3-week interval between tests), calculated in the studied population of women, ranged from 0.77 to 0.81, and in the population of men ranged from 0.78 to 0.83. The results were converted to sten scores [52].

2.6. Social Functioning Measurements

To measure social functioning during the COVID-19 epidemic, the *Social Functioning Scale* (*SFS*) was used. This scale was constructed for this study. The tool was developed on the basis of Falvo's [18] concept of social functioning. The *SFS* measures the quality of social functioning during the COVID-19 epidemic in three spheres, which include family and interpersonal and professional relationships. The test contains 21 questions that respondents refer to on a six-point Likert scale. The answers range from *definitely no* to *definitely yes*. The test validation and normalization procedure were carried out on a sample of 700 adults. The content validity coefficients of the *CVR* ranged from 0.96 to 1.00. The theoretical validity was verified by exploratory factor analysis with simple Oblimin rotation and Kaiser normalization and confirmatory factor analysis. Criterion validity was estimated on the basis of the analysis of the correlation matrix with dimensions theoretically related to social functioning: self-esteem, life satisfaction, social support and the results of other tests measuring social functioning. Cronbach's *alpha* coefficients in the group of studied women ranged from 0.81 to 0.88, and in the population of men, from 0.83 to 0.90. The results were converted to sten scores.

2.7. Measurements of Controlled Variables

For the measurement of controlled variables, a questionnaire created for the needs of the conducted research was used. It consisted of a series of questions about sociodemographic data (gender, age, place of residence, education status, marital status, number of children, professional activity) and the health condition of the respondents.

2.8. Statistical Analysis

Statistical calculations were performed on anonymized data using IBM SPSS 27 with AMOS software.

The description of the researched sample was based on the calculation of the percentage distribution of the qualitative data frequency, the mean values, standard deviation and minimum and maximum values of quantitative parameters.

The significance level of intergroup differences in terms of qualitative data was verified using the c^2 test. The reliability of the tests was estimated based on the Cronbach *alpha* measures.

The shape of the variable distributions was estimated on the basis of the Kolmogorov–Smirnov test. Levels of activity of the research subjects were compared using a c^2 test, while the effect size was determined based on Cramer's *V* value. The verification of intergender differences was carried out using Student's *t*-test for independent data, the statistically significant results of which were supplemented by estimating the size of the effects using Cohen's *d* coefficient.

The characteristics of the physical activity of the respondents, their mental health, cognitive functioning and social functioning were determined on the basis of the mean value, standard deviation and minimum and maximum values.

The estimation of measurement models and the interactive structural model was performed using SEM structural equation modeling in the confirmatory version, in which the *Maximum Likelihood* method was used. The use of an advanced method of statistical analysis made it possible to verify the occurrence and significance of mutual and multifaceted interaction of individual factors forming the structure of physical activity for women and men, shaping the state of mental health and cognitive disorders, as well as social functioning. In the presented models (measurement and structural), the values placed next to the arrows indicate the estimates of standardized coefficients for a given path, while the values above the observable variables represent the constants in the equation. The coefficients for random factors (variables e) are initially arbitrarily set at the level of 1 as non-standardized, and after standardization, their values are equal to 0 and are not presented.

In the work, the boundary point of committing a type I error is 0.05.

3. Results

3.1. Intergroup Comparisons

In the first step of the conducted analysis, levels of weekly physical activity of the subjects were compared. Results are shown in Table 2.

Table 2. Comparison of physical activity levels of women and men.

Variable		Group				Group Comparison		
		Women		Men				
		n	%	*n*	%	x^2	*p*	*V*
Physical activity *	High	34	15.0	174	76.9	156.53	0.001	0.59
	Sufficient	161	71.3	39	17.3			
	Insufficient	31	13.7	13	5.8			

Markings: *n*—count, %—percent, x^2—c^2 test value, *p*—significance level, *V*—effect size expressed by Crammer's *V* coefficient, *—levels of weekly physical activity were distinguished based on results expressed in MET units.

Nearly three-quarters of the women surveyed showed a sufficient level of weekly physical activity. A high level of activity characterized 15.0% of female respondents, and a low level of activity characterized more than one-tenth of female respondents.

In the group of men, more than three-quarters of the study participants were characterized by a high level of weekly physical activity. The activity of nearly one-fifth of the respondents was sufficient, while the lowest percentage of men showed insufficient weekly physical activity.

The analysis resulted in a strong statistically significant gender effect for weekly physical activity.

Women, compared to men, less often revealed a high level of physical activity, while more often, their weekly activity was classified as sufficient and insufficient.

In the second step of the analysis, the level of physical activity, mental health, cognitive processes and the quality of social functioning of the surveyed women and men were assessed. The results of the comparative analysis are presented in Table 3.

Table 3. Comparison of physical activity, mental health, cognitive processes and social functioning of women and men.

Variables		Group				Group Comparison		
		Women		Men				
		M	*SD*	*M*	*SD*	*t*	*p*	*d*
Physical activity *	Weekly activity	840.31	1013.04	1593.92	1244.42	5.97	0.001	0.56
	Walking	396.59	642.54	583.49	821.69	2.30	0.022	0.22
	Moderate activity	159.33	262.53	561.97	541.13	8.73	0.001	0.82
	Vigorous activity	285.39	381.90	448.45	591.34	2.98	0.003	0.28
	Sitting, lying down	228.88	101.39	209.01	87.94	1.85	0.66	-
Mental health disorders **	Overall Score	10.70	6.01	7.47	7.12	5.17	0.001	0.49
	Somatic symptoms	3.16	1.95	1.88	2.41	6.20	0.001	0.58
	Anxiety and insomnia	2.79	2.63	2.45	2.79	1.73	0.084	-
	Functional disorders	2.26	2.55	1.39	2.50	3.68	0.001	0.35
	Depressive symptoms	2.48	1.61	1.86	1.96	3.65	0.001	0.34
Cognitive disorders ***	Cognitive functioning	6.28	0.79	5.78	1.10	5.67	0.001	0.53
	Perceptual work	6.70	1.20	5.90	1.49	6.28	0.001	0.59
	Perception deficits	6.23	1.33	6.38	1.54	1.04	0.298	-
	Attention deficits	5.92	1.35	5.05	1.61	6.15	0.001	0.58
Social functioning ***	Overall Score	4.93	1.71	4.70	1.41	1.24	0.215	-
	Family relationships	4.77	1.85	5.70	1.73	4.98	0.001	0.47
	Interpersonal relationships	4.74	1.79	4.87	1.95	0.65	0.514	-
	Professional relationships	4.32	2.64	3.04	2.29	5.56	0.001	0.52

Markings: *M*—mean, *SD*—standard deviation, *t*—value of Student's *t*-test for independent data, *p*—significance level, *d*—measure of Cohen's *d* effect size, *—results expressed in MET units, **—raw results, ***—results expressed in sten.

The weekly physical activity of the surveyed women was classified as sufficient. However, in the male population it reached a high level. Regardless of gender, the respondents spent the most time on walks, then on intense physical activity, and the least on training with a moderate level of vigorous activity and passive rest (sitting, lying down).

The general mental health of the study participants was within the upper limit of the average results, which also suggests that in the analyzed population of women, in the event of the occurrence of adverse factors generating severe and chronic stress, there may be a risk of developing symptoms characteristic of mental health disorders. In women, somatic symptoms were most severely intensified, followed by anxiety and insomnia, symptoms of depression and symptoms typical of disorders in everyday functioning. In the group of men, the overall mental health condition was moderate. The respondents were dominated by a sense of anxiety and insomnia, while functional disorders, somatic symptoms and symptoms of depression were less severe.

The functioning of the cognitive processes of the studied populations was classified as moderate. In the female population, the most pronounced difficulties related to perceptual work, followed by perception deficits and attention deficits. The highest intensity of perception deficits was observed in men, while the problems with perceptual work and attention deficits were at a slightly lower level.

Social functioning of the analyzed groups was in the area of moderate results. Women did best in family relationships and among acquaintances and friends, and the worst in professional interactions. Men showed the highest level of coping skills in interpersonal relationships, then in family relationships, and the poorest quality of interactions in professional relationships.

As a result of the comparative analysis, a strong gender effect was noted for moderate activity; moderate gender effects for weekly activity, somatic symptoms, cognitive functioning, perceptual work, attention deficits and professional relationships; and weak gender effects for walking, vigorous activity, mental disorders, functional disorders, depressive symptoms and family relationships.

Compared to men, women showed a lower level of weekly physical activity, walking, moderate physical activity and vigorous physical activity, as well as a lower quality of family relationships. Moreover, more severe mental disorders, somatic symptoms, functional disorders, depressive symptoms, cognitive disorders, perceptual work disorders, attention deficits and a higher quality of relationships in the area of professional life were more often noted in the female population than in men. On the other hand, sitting and lying down, anxiety and insomnia, perception deficits, social relationship and interpersonal relationships were at a comparable level in the analyzed groups.

3.2. Estimation of Measurement Models

Prior to estimation of the complete interactive structural model presenting the relationships between physical activity, mental health, cognitive disorders and social functioning, its four measurement parts were estimated. Model specifications were carried out in the group of women and men.

In the first measurement model, physical activity is a latent variable, while its partial indicators are walking, moderate activity and vigorous activity. Figure 1 shows the results of verification of the constructed model of physical activity measurement in the group of women, and Figure 2 illustrates the measurement model of physical activity in the group of men.

As a result of the estimation, the following measures were obtained: CMIN/DF = 1.75; GFI = 0.99; AGFI = 0.99; NFI = 0.99; RFI = 0.95; IFI = 0.99; TLI = 0.99; CFI = 0.99; RMSEA = 0.001(0.001; 0.05); PCLOSE = 0.92; *N* HOELTER(1269; 1561), which confirm that the model reflects the nature of the relationships between the analyzed variablesvery well. The standardized values of factor loadings and the percentages of variances explained in each of the analyzed groups show that the constructed model of physical activity measurement is acceptable.

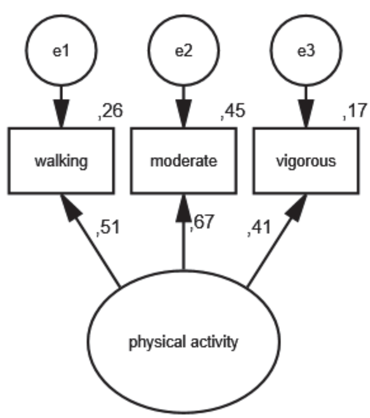

Figure 1. Standardized effects of the model of physical activity measurement in the group of women.

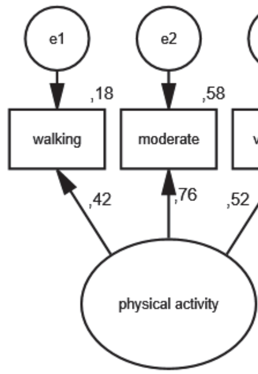

Figure 2. Standardized effects of the model of physical activity measurement in the group of men.

In the second measurement model, the presence of mental health disorders is an unobservable variable, and its partial indicators are somatic symptoms, anxiety and insomnia, functional disorders and the symptoms of depression. The results of the verification of the constructed model for measuring mental health disorders in the group of women are shown in Figures 3 and 4 illustrates the measurement model of mental health disorders in the group of men.

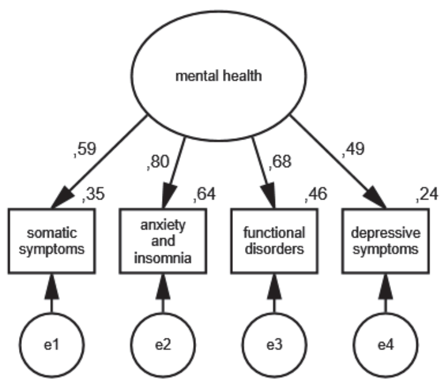

Figure 3. Standardized effects of the mental health disorder measurement model in the group of women.

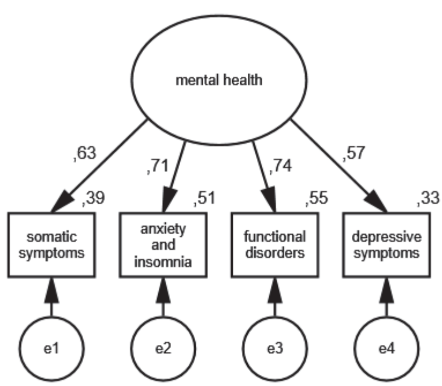

Figure 4. Standardized effects of the mental health disorder measurement model in the group of men.

The following measures were obtained during the verification of the model: CMIN/DF = 1.75; GFI = 0.99; AGFI = 0.99; NFI = 0.99; RFI = 0.95; IFI = 0.99; TLI = 0.99; CFI = 0.99; RMSEA = 0.001(0.001; 0.05); PCLOSE = 0.92; *N* HOELTER(1116; 1442), which confirm that it is correctly fitted to the data, and the standardized values of factor loadings and the percentages of variances explained in the group of women and men allow for recognizing the constructed model of mental health disorders measurement as acceptable.

In the third measurement model, the presence of cognitive disorders is an unobservable variable, and its partial indicators are perceptual work, perception deficits and attention deficits. The results of the verification of the constructed model for measuring cognitive disorders in the group of women are shown in Figures 5 and 6 illustrates the measurement model of cognitive disorders in the group of men.

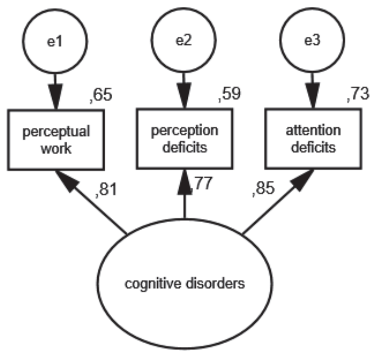

Figure 5. Standardized effects of the measurement model of cognitive disorders in the group of women.

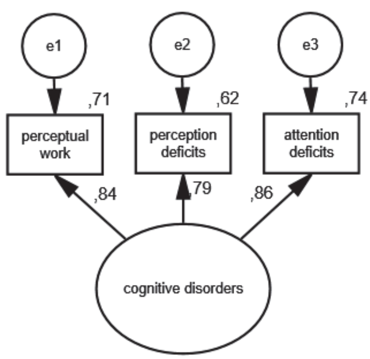

Figure 6. Standardized effects of the measurement model of cognitive disorders in the group of men.

As a result of the estimation, the following measures were obtained: CMIN/DF = 1.75; GFI = 0.99; AGFI = 0.99; NFI = 0.99; RFI = 0.95; IFI = 0.99; TLI = 0.99; CFI = 0.99; RMSEA = 0.001(0.001; 0.05); PCLOSE = 0.92; *N* HOELTER(1317; 1596), which confirm that the model reflects the nature of the relationships between the analyzed variablesvery well. The standardized values of factor loadings and the percentages of variances explained in each of the analyzed groups show that the constructed model of cognitive disorders measurement is acceptable.

In the fourth measurement model, social functioning is an unobservable variable, and its partial indicators are support received from family members, friends, colleagues and medical professionals. The results of the estimation of the social support functioning model in the group of women are presented in Figures 7 and 8 illustrates the measurement model of social functioning in the group of men.

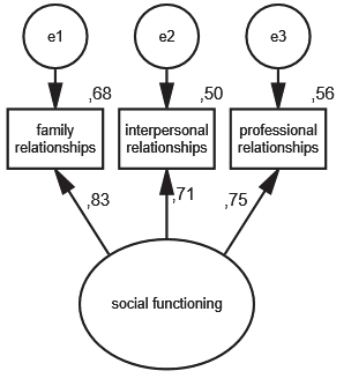

Figure 7. Standardized effects of the measurement model of social functioning in the group of women.

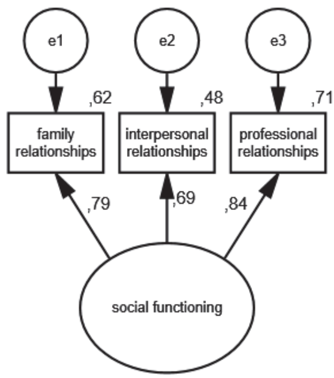

Figure 8. Standardized effects of the measurement model of social functioning in the group of men.

The following measures were obtained: CMIN/DF = 1.75; GFI = 0.99; AGFI = 0.99; NFI = 0.99; RFI = 0.95; IFI = 0.99; TLI = 0.99; CFI = 0.99; RMSEA = 0.001(0.001; 0.05); PCLOSE = 0.92; *N* HOELTER(1335; 1428), which confirm its compliance with the data. The standardized values of factor loadings and the percentages of variances explained in the groups analyzed indicate that the constructed model of social functioning measurement is acceptable.

3.3. Structural Model Estimation

The estimation and acceptance of the constructed measurement models allows for the estimation of the full interactive structural model, which was developed on the basis of the theoretical frameworks. As in the case of measurement models, its specification was carried out in the group of women and men. Figure 9 shows the construction and detailed standardized parameters of the interactive model of the relationship between physical activity, mental health, cognitive disorders and social functioning in the group of women, and Figure 10 depicts the results obtained in the group of men.

The accuracy of the interactive structural model was positively verified based on the following measures of goodness of fit: CMIN/DF = 1.38; GFI = 0.99; AGFI = 0.97; NFI = 0.98; RFI = 0.96; IFI = 0.99; TLI = 0.99; CFI = 0.99; RMSEA = 0.019 (0.008; 0.28); PCLOSE = 1.00; *N* HOELTER(1008; 1120).

In the group of women, the constructed model explained 51.0% of social functioning, which reflects the quality of tolerable family, interpersonal and professional relationships, and in the population of men, 41.0% of the variance of the analyzed variable was explained.

In the group of women, there was a strong, directly proportional correlation between mental health disorders and cognitive disorders ($p = 0.001$), as well as a weak negative relationship of physical activity with mental health disorders ($p = 0.001$) and with cognitive disorders ($p = 0.001$). There was also a moderate, inversely proportional relationship between mental health disorders ($p = 0.001$) and social functioning, as well as a weak relationship between cognitive impairment and social functioning ($p = 0.002$).

In the group of men, there was a strong, directly proportional correlation between mental health disorders and cognitive disorders ($p = 0.001$), as well as a moderate negative relationship of physical activity with mental health disorders ($p = 0.001$) and with cognitive disorders ($p = 0.001$). There was also a moderate, inversely proportional relationship between mental health disorders ($p = 0.001$), cognitive disorders ($p = 0.001$) and social functioning.

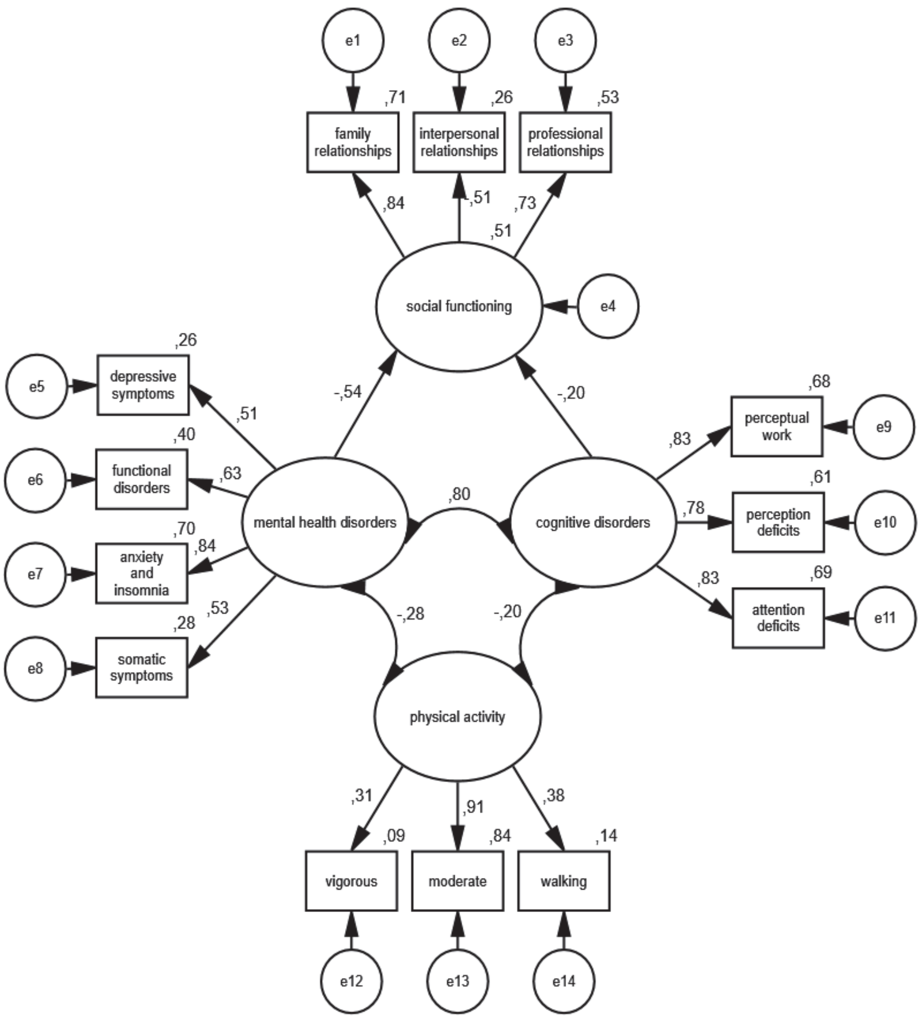

Figure 9. Standardized effects of the structural model of the relationship between physical activity and psychosocial functioning in a group of women.

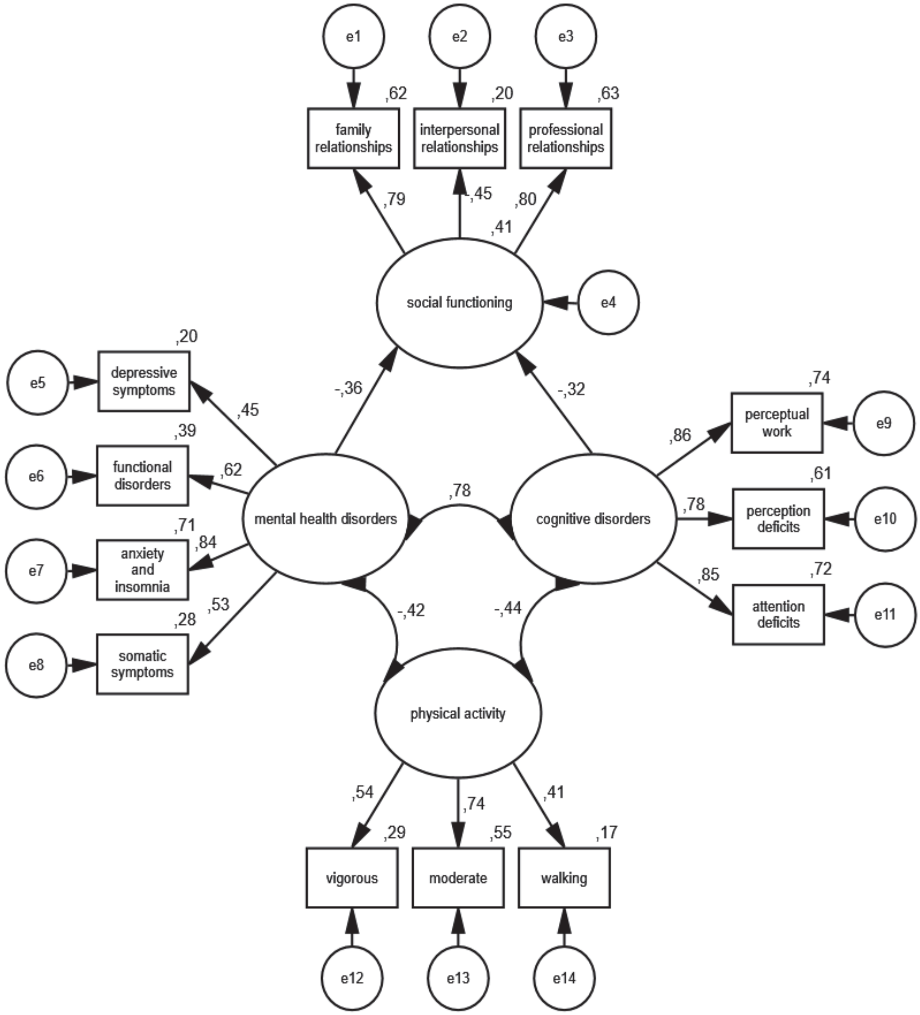

Figure 10. Standardized effects of the structural model of the relationship between physical activity and psychosocial functioning in a group of men.

The model shows that the consequences of the COVID-19 epidemic in Eastern Poland expressed in the form of mental health disorders and symptoms typical of cognitive disorders were moderated by physical activity from various sources. The more often the respondents engaged in physical activity by going for walks and training moderately and vigorously, the lower the risk was of developing mental disorders, manifested in the form of somatic symptoms, anxiety and insomnia, functional disorders and the symptoms of depression, as well as the occurrence of cognitive disorders, such as perceptual work disorders, perception deficits and attention deficits. Moreover, physical activity weakened the relationship between mental health disorders and disorders of cognitive processes and social functioning in family, interpersonal and professional relationships of the studied groups.

It should also be added that the comparisons of the values of parameters within and between groups showed that the relationship between mental health disorders and cognitive disorders was comparable in each group and stronger than the correlations between physical activity and mental health disorders and cognitive disorders. Moreover, in the case of women, the leading factor associated with the quality of social interactions was the state of mental health, which was less dependent on the level of physical activity than on the functioning of cognitive processes moderated by physical effort, while the quality of male social interactions depended on the relationship between the state of mental health and the cognitive functioning that is impaired by physical activity. In the population of women, compared to men, physical activity was less important for mental health and the functioning of cognitive processes, and the occurrence of symptoms typical of mental health disorders was more strongly associated with the quality of social interactions of women than men. It has also been shown that disorders of cognitive processes correlate more weakly with the social functioning of women than men.

4. Discussion

The outbreak of the COVID-19 pandemic caused severe and long-lasting stress in many people from different countries of the world, the relatively common consequences of which were mental health problems associated with deterioration of cognitive and social functioning [6,53,54]. Despite many published empirical studies devoted to the discussed issue, the role of physical activity in the prevention of psychosocial functioning of the inhabitants of Eastern Poland has not been analyzed so far [53,55,56].

Therefore, research was carried out to assess the level of physical activity, mental health, cognitive processes and social functioning, as well as the interactions and relationships between them, in the population of Eastern Poland, depending on gender.

With regard to the above goals, two hypotheses were formulated. The first of them assumed that during the COVID-19 pandemic, in the inhabitants of Eastern Poland, the level of physical activity and the severity of symptoms characteristic of mental health disorders, cognitive disorders and the quality of social functioning differed depending on gender.

The conducted analysis allowed us to positively verify the adopted assumption in terms of statistically significant gender differences regarding levels and severity of weekly activity, as well as the severity of vigorous activity, moderate activity, walking, mental disorders, somatic symptoms, functional disorders, depressive symptoms, cognitive disorders, perceptual work, attention deficits, family relationships and professional relationships. It has been shown that women were less likely than men to show a high level of physical activity, but more often their weekly activity ranked at sufficient and insufficient levels. It was also noted that surveyed men showed higher than average physical activity, walking, moderate physical activity and vigorous physical activity than women, and they functioned more efficiently in family relationships, but had more difficulty finding their way in professional interactions. Moreover, men showed a lower severity of mental disorders, somatic symptoms, functional disorders, depressive symptoms, cognitive disorders, perceptual work disorders and attention deficits as compared to women.

The men had a moderate state of mental health and cognitive processes, while women's scores in mental disorders and perceptual work disorders were approaching the edge of the elevated area. The average weekly physical activity of men was high, and that of women was at a sufficient level, with the activity of more than three-quarters of the men surveyed being high, at nearly one-fifth sufficient, and 5.8% insufficient. In contrast, the women's group reported markedly different results. Almost three-fourths of the female respondents showed a sufficient level of activity, while high and low activity levels were reported by 15.0% and 13.7% of the respondents, respectively.

Comparing the data obtained with the results of surveys conducted in other regions of Poland and the world, one can see significant discrepancies. The research already mentioned in the theoretical introduction proves that both men and women from the northeastern part of Poland manifest an insufficient and significantly understated level of physical activity in comparison to residents of other regions of this country and European countries. At the same time, men engaged in moderate physical activity and rode a bicycle more frequently than women [33].

Another empirical study also observed that women reported lower moderate physical activity than men, but were more likely to engage in light physical activity. It is worth noting, however, that because the study was conducted in a population of patients with a diagnosis of peripheral artery disease, vigorous activity was not analyzed in the study [57].

In contrast, a Canadian study, similar to our own, reported that women were less physically active than men during the COVID-19 pandemic, a result that was statistically significant [58]. Analogous observations have also come from the general population of Beirut [59]. In addition, women reported more barriers to engaging in systematic physical activity and reported significantly weaker mental fitness than the opposite sex [58,59]. A key observation appears to be that, among women, the most severe adverse mental health symptoms occurred in subjects whose physical activity was very low [58].

Thus, both the results of our own study and the conclusions of the work of other researchers suggest that, especially in the group of women, in the event of the occurrence or intensification of the impact of existing stressors, there may be a risk of developing undesirable symptoms in the state of mental health and cognitive processes [60]. This observation seems to be particularly important in the situation of a prolonged health crisis, because the effectiveness of coping, under the influence of chronic distress, may show a downward trend, and this directly implies an increased risk of undesirable symptoms in the field of mental health [61].

This effect was observed by Di Maio's team. On the basis of the conducted moderation analysis, he noted that the belief in the possessed remedial abilities was directly related to physical activity in a situation where the encountered challenges were relatively low. On the other hand, when these challenges were high, the relationship between physical effort and faith in one's abilities did not reach the level of statistical significance. The observed dependencies confirm the need to monitor not only direct but also long-term consequences in terms of the mental health of people affected by the COVID-19 pandemic [62].

The need to conduct this type of longitudinal research is also indicated by other researchers who, while forecasting the upcoming increase in the number of patients with depressive and anxiety disorders resulting from the current health crisis, as well as from the current problems of the mental health care system, point to the important role of physical activity in preventive interventions [7,63]. Systematic endurance training, by activating the HPA axis, stimulates the release of dopamine, which is responsible for self-regulation and mood [64,65]. The results of the meta-analysis, which included the data of 40,550 adults, show that the respondents who undertook systematic physical activity, compared to women and men with moderate and low activity, were less likely to develop mental disorders. The highest risk group was those who led a sedentary lifestyle [66], while the level of physical activity, physical fitness, mental health, cognitive processes and the quality of functioning in social interactions were higher in men than in women [67–70].

In this context, it should be noted, however, that the relationships between the aforementioned variables in the interactive and multidimensional approach have not been analyzed so far [71,72]. Taking into account the above premises, the second hypothesis assumed that during the COVID-19 pandemic in the inhabitants of Eastern Poland, depending on gender, the following are different: the importance of interactions between physical activity, mental health and cognitive disorders for social functioning.

The constructed structural model of the relationship between physical activity and selected aspects of psychosocial functioning allowed for a positive verification of the assumption. As a result of its estimation, in the group of women and men, the existence of interactions between physical activity, disorders of mental health and cognitive processes was confirmed, and their association with the social functioning of the analyzed groups was verified. Systematic physical activity, including intense and moderate endurance training and walking, was negatively associated with symptoms characteristic of mental health disorders, which include symptoms of depression, functional disorders, anxiety and insomnia and somatization, as well as cognitive disorders manifesting as weakened speed of perception and deficits in perceptiveness and attention to social functioning of the respondents.

In the case of women, the leading factor related to the quality of social interactions was the state of mental health, which was less dependent on the level of physical activity than on the functioning of cognitive processes, while the quality of men's social interactions was most dependent on the relationship between the state of mental health and the functioning of cognitive processes. Moreover, in the group of women, compared to men, physical activity was more weakly linked to the state of mental health and the functioning of cognitive processes, and the occurrence of symptoms typical of mental health disorders had correlated more strongly with the quality of women's social interactions than men's. In turn, cognitive disorders were more weakly linked to the social functioning of women than men.

Relating the observed regularities to the conclusions of the empirical works of other researchers, it can be seen that they are to some extent similar [67,73]. In a sample of 5856 adults aged 26–70 years, it was noted that in the male population, physical activity was more negatively associated with problems in the sphere of mental functioning than in the group of women [67].

Another empirical study positively verified and moderated the role of gender in relation to physical activity, health-related quality of life and perceived social support. It was shown that people with the lowest assessments of mental health status had a 1.8 times lower probability of obtaining social support than respondents who showed high and average assessments of mental condition, while the participants with the lowest results in terms of physical health were twice as likely to be deprived of the help of their relatives than women and men who perceived their somatic health as very good or average. Moreover, men with low physical activity compared to women more often reported poor mental and somatic health and a lower overall quality of life than women. It should be added, however, that the discussed model did not take into account the symptoms characteristic of cognitive disorders [73].

Summing up the discussion, it is worth emphasizing that the results of our own research seem promising in the context of preventing the psychosocial functioning of adult inhabitants of Eastern Poland who have been affected by the COVID-19 epidemic. Nevertheless, due to the existing limitations, the observed effects require further empirical verification.

The aforementioned limitations include the fact that, in order to minimize the risk of SARS-CoV-2 infection and taking into account the epidemic restrictions in the country, the study was conducted online, which might not have been fully comfortable for the participants. In addition, the study sample consisted of volunteers, who had access and the ability to use a computer, which, despite a relatively large number of observations and controlling for a number of side variables, could have affected the results. Consequently, the data may not fully reflect the psychosocial situation in the Eastern region of Poland. In addition, the study population was made up exclusively of people who were employed and those in marriages and partnerships. This suggests, therefore, that the research results obtained should be generalized, with some caution, only to the population of healthy, economically active residents of Eastern Poland with life partners.

It should also be added that there were no people infected with the SARS-CoV-2 coronavirus and COVID-19 patients among the participants, so in the subsequent studies, it would be worth verifying whether this factor differentiates mental health disorders, cognitive disorders and social functioning. Another area requiring exploration is the determination of the level of physical activity and these parameters and the relationships between them in the population of medical staff, especially those who specialize in COVID-19 treatment. Due to the specificity of their work, the indicators of physical activity, mental health and cognitive problems as well as social functioning may be higher in this group than in the general population. It is also important to mention that the region of Eastern

Poland is characterized by a relatively low transmission of the SARS-CoV-2 coronavirus; therefore, the psychosocial consequences of the epidemic may be lower in the inhabitants of this part of the country than in those affected by a higher epidemic risk.

Another aspect that should be mentioned in the context of discussing the limitations of the presented results is that due to the cross-sectional nature of the research and the lack of data from before the outbreak of the pandemic, the conducted analysis showed only the current intensity of individual parameters and the strength of the relationships between them; however, the dynamics of changes under the influence of SARS-CoV-2 transmission were not estimated. For this reason, it is not possible to precisely determine to what extent the current pandemic situation has influenced the change in the intensity of the analyzed variables and the strength of their relationships.

It is also worth mentioning that the measurement of physical activity was carried out using the short form of the questionnaire (*IPAQ-SF*), which may have made it slightly less reliable than the full version (*IPAQ*) [25,50]. However, the decision to choose the *IPAQ-SF* was based on the suggestions of the authors of the Polish adaptation of the test, who, based on the conclusions of a number of empirical studies, recommend the use of the abbreviated Polish version of the tool for research conducted both within one country and conducted internationally. They point out that the full version of the *IPAQ*—due to its detail—requires much greater involvement of the subjects, and this in turn directly implies impatience, a tendency to give random answers, skip questions or drop out of the survey [50]. Researchers from other regions of the world have also encountered similar problems with the full version of the test [25]. Given that in our study, in addition to the test used to measure physical activity, four other questionnaires were used, the aforementioned risks were reduced by using the *IPAQ-SF* [25–50].

Nevertheless, the presented study is the first and largest project focused on the analysis of the psychosocial functioning of the inhabitants of Eastern Poland during the COVID-19 epidemic, in which diagnostic tools with high psychometric properties and advanced statistical methods were used. This allowed for the visualization of the structure of mutual and multifaceted relationships between particular variables in the group of women and men.

Moreover, the discoveries are of great cognitive and practical importance. Determining the current level of psychosocial functioning of the inhabitants of Eastern Poland during the pandemic, in terms of the level of physical activity, mental health, cognitive processes and the quality of social functioning, as well as verifying the occurrence and significance of interactions and relationships depending on gender, not only enriches knowledge about the mechanisms shaping the responses of adults to the current health crisis, but it is above all the basic element that allows for taking effective preventive actions. Confirmation that various forms of physical activity are a factor protecting against negative effects on mental health, cognitive processes and social functioning may constitute the basis for developing gender-individualized, interdisciplinary psychopreventive interventions aimed at strengthening the intrapsychic and interpersonal spheres of women and men at risk of the negative consequences of SARS-CoV-2 transmission.

5. Conclusions

The conducted analyses allowed us to determine the current level of psychosocial functioning of the inhabitants of Eastern Poland, as well as the interactions and relationships between physical activity, disorders of mental health and cognitive processes and social functioning during the COVID-19 epidemic, which in turn allowed for the formulation of the following implicative conclusions:

- Taking into account that the population in question included people at risk of developing problems in psychosocial functioning, it would be important to support the analyzed population with an appropriate preventive program;
- Women, as compared to men, show a lower level of physical activity, including weekly activity, walking, moderate activity and vigorous activity, which may be a result of different uses of time in the course of a day, and for women, is associated with

higher recorded intensity of symptoms common to mental health disorders, especially somatic symptoms, functional disorders and depressive symptoms, as well as cognitive disorders—in particular those related to perceptual work and attention deficits, and also lower quality of functioning in family relationships, although higher coping skills in professional interactions are also seen; as a result, the developed program in the case of women should include interventions to support effective time management, and it is necessary that it be adjusted to the specifics of individual differences noted between women and men;

- Whereas physical activity, interacting with mental health disorders and cognitive disorders, weakens their coexistence and the relationship with social functioning, it is important to indicate that systematic exercise training adapted to the state of health and abilities of the organism may be an important element of psychoprophylaxis programs;
- Taking into account that in the male population, the negative associations of physical activity with symptoms typical of mental health and cognitive disorders are stronger than in the female population, while women's social functioning depends more on their mental health than on their cognitive deficits, and the quality of men's family relationships and interpersonal and professional relationships is similarly linked to mental health and cognitive disorders, the developed preventive interventions should be implemented early and tailored to the individual needs of the participants, which may translate into an amplification of their benefits.

In conclusion, it appears to be important to develop a systematic and interdisciplinary psychoprophylactic physical training program individualized based on gender and health condition. Designing this type of intervention would provide an opportunity to improve the intrapsychic, cognitive and social functioning of Eastern Poland's population during the COVID-19 epidemic.

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Article

Effect of CrossFit Training on Physical Fitness of Kickboxers

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Abstract: Background: Kickboxing is a combat sport that is complex in technique, tactics, and movement structure, and requires an adequate level of motor skills as a foundation for activities during competitions. General physical fitness, defined as the effect of the externalization of motor skills, is the basis for athletic training regardless of the sport. The aim of this study was to determine the effect of modified training based on the principles of CrossFit on the development of general physical fitness in a group of kickboxers compared to a control group. Methods: The study was experimental in nature and was conducted in a group of 60 kickboxers, divided into experimental and control groups. Participants were selected by purposive sampling, and the criteria were training experience, sports skill level (minimum class 1 athletes), and consent to participate in the experiment. The intervention in the study group involved the introduction of CrossFit-based training into a conventional kickboxing training program. General and special physical fitness of the athletes were diagnosed. Results: Statistically significant differences were found in general fitness in terms of abdominal strength ($p < 0.001$), pull-ups ($p < 0.001$), dynamometric measurement of handgrip force ($p < 0.001$) (kg), clap push-ups ($p < 0.001$), standing long jump ($p < 0.001$), shuttle run ($p < 0.001$), sit-and-reach ($p < 0.001$), and tapping ($p < 0.001$). Furthermore, changes in special fitness were also demonstrated for the special kickboxing fitness test (SKFT) ($p < 0.02$), the total number of punches ($p < 0.001$), punching speed ($p < 0.001$), and hip turning speed ($p < 0.001$). There was also a correlation between characteristics of general fitness and special fitness ($p < 0.001$). Conclusions: The experimental training program based on the principles of CrossFit training had a positive effect on the general and special kickboxing physical fitness.

Keywords: kickboxing; CrossFit; training effectiveness; general fitness

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1. Introduction

General physical fitness, defined as the effect of the externalization of motor skills, is the basis for athletic training regardless of the sport [1–3]. By properly developing its level, it is possible to implement more precise and effective specialized training forms, which are a prerequisite for athletes' performance during tournaments [4–6]. Research also shows that inadequate levels of fitness may increase the likelihood of injury [7]. The development of the athlete's motor skills depends on sport [1]. Kickboxing is a combat sport that is complex in technique, tactics, and movement structure, and requires an adequate level of motor skills as a foundation for activities during competitions [8–10].

Research on the effectiveness of combat sports training indicates that it is highly dependent on general motor skills [11–14]. For kickboxers, the basis for high competitive performance is a high level of strength, dynamics, anaerobic capacity, and aerobic capacity, with the latter considered the necessary foundation for all activities. Therefore, physical preparation should be based on improving upper limb strength and speed (punches and combinations during offensive actions and blocks and dodges during defensive actions) and developing high levels of anaerobic power (dynamic kicks and punches) [15,16].

Training efficiency, which is the ability to endure loads based on sufficient physical capacity, is also an important element that increases the competitive performance of athletes [17–20]. The specifics of training at the elite level should be tailored to the individual athlete's needs. In search of opportunities to improve work efficiency during training, modern forms of training are implemented and verified, often differing from the classic training methods commonly used in kickboxing, which include repetition methods (at maximal or submaximal work intensity, full rests) and interval methods (low, medium, or high intensity, and incomplete rests) based on technical elements using special coaching devices such as focus mitts, kick shields, punching bags, etc. [5,21].

The growing popularity of CrossFit is of interest to researchers in the context of implementing this training modality, with its hallmark being competing during exercise [22,23]. This type of training, based on exercises derived from the arsenal of training means used in gymnastics, weightlifting, and strength and functional training, is focused on the continuous improvement of the athlete's performance in individual exercises through competition with a training partner or themself [24]. This model of strength and conditioning training can also be applied in the kickboxing environment.

The implementation of new forms of training and the detailed verification of their effects on the physical capabilities of athletes are widespread in combat sports [25–29]. Through the implementation of experimental training plans, it becomes possible to improve the quality of training, which can, in turn, affect the competitive performance of athletes [30]. The implementation of modern experimental forms of training in kickboxing is popular, and the novelty of our study is the introduction of the author's form of training based on CrossFit training with exercises commonly used in kickboxing. Contemporary analyses in the context of the implementation of CrossFit training in the structure of kickboxing include the effect of CrossFit exercises on the body posture of kickboxers [31], and a comparison of CrossFit training and other forms of resistance training to maintain an optimal level of fitness [32].

To determine the athlete's level of preparation for the competition, an analysis of a fight is performed [16,33,34] by determining the technical and tactical indices or by evaluating special physical fitness using tests corresponding to the structure of a kickboxing bout [35]. This type of analysis was conducted in the present study.

The aim of this study was to determine the effect of the author's training according to the principles of CrossFit on the development of general and special physical fitness in a group of kickboxers compared to a control group. The choice of general fitness tests was based on examinations performed in previous studies [16,33]. In this study, an attempt was made to find if the proposed experimental training program could be successfully implemented into the regular strength and conditioning programs in kickboxing.

2. Material and Methods

2.1. Study Group

The study was experimental in nature and was conducted in a group of 60 male kickboxers. Based on the sample size, as determined using G*Power software 3.1.9.4, it was shown that, with the estimated moderate effect size, at least twenty participants were needed in each group (effect size f = 0.65, power = 0.95, p = 0.05) [36]. In the present analysis, 30 participants in each group were recruited to ensure a more accurate analysis. Participants were selected by purposive sampling, i.e., subjective non-random sampling based on clear criteria for selecting a group for the study such as training experience, sports skill level (minimum class 1 athletes; in Poland, athletes are classified by sports skill classes: there are classes 1, 2, and 3, with each class determined based on winning during competitions), consent to participate in the experiment, and good health status. The inclusion criteria adopted were due to the high intensity of the proposed form of training that requires the participants to have bodies adapted to such a high level of exercise. The selected group was randomly divided into two (experimental and control) groups, each consisting of 30 athletes.

In the control group, training was conducted according to a standard general cycle. In the study group (experimental), training was modified (independent variable) by introducing an experimental program (CrossFit workout) into their standard training. The experiment required a high degree of accuracy and maximum commitment from the athletes. During the experiment, the athletes did not participate in sporting events or sparring at competitive intensity levels and did not report any injuries. Observation of the changes in the experiment and their quantitative evaluation were also performed. The dependent variable in this case was general and special physical fitness, viewed as differences in the fitness test results in both groups.

2.2. Morphological Characteristics of the Subjects

The mean training experience in all participants was 8.1 ± 4.24 years. They trained 1.5 to 2 h, 6 to 8 times per week. The mean age of study participants was 20.07 ± 1.46 years, body weight was 73.56 ± 8.13 kg, body height was 179.55 ± 0.45 cm, body fat was 14 ± 0.2%, and BMI was 23.63 ± 1.19 kg/m^2. Body composition and body weight were measured using a Tanita BC-601 body composition monitor (Tanita, Tokyo, Japan) [37] in the morning in fasting conditions, whereas body height was measured using a SECA 2017 body height meter (Seca, Hamburg, Deutschland). The examination was performed in the standing position, as recommended by the manufacturer. The subjects did not consume alcohol the day before the measurement and avoided large meals and extreme physical exercise.

2.3. Research Program and Methodology

According to the principles of the implementation of pedagogical experiments, the researcher's interference involved manipulation of the training process in the experimental group. The first examination took place before the experimental training in both groups, in the control and preparation mesocycle of the preparation period. Next, the group of participants performed a modified workout (by introducing an experimental program based on CrossFit workout into their standard training programs) three times a week during each training session. During this time, the control group performed standard kickboxing training without modification. After eight weeks, another examination was conducted (effect control).

Furthermore, each participant was instructed not to use specialized diets and supplementation during the experiment due to the strong relationship between diets and results obtained during tests. Diets were monitored using notebooks in which the participants recorded the foods they consumed using home measures based on a photo album of foods and products. The recording procedure was continued for 3 days: 2 working days and 1 day off [38]. The analysis of diet observations revealed neither specific diets nor the use of performance-enhancing supplements in the training groups. The experiment was approved (No./309/KBL/OIL/2019) by the Bioethics Committee of the Regional Medical Chamber in Kraków, Poland.

2.4. Principles of the Experimental Training

Using the principles of CrossFit training methodology [39] and typical kickboxing training exercises based on the most frequently performed techniques [40], a training program was developed to improve the physical fitness of kickboxers (Table 1).

Table 1. Methodology of the experimental training program.

Experimental Training Program: Methodology	
Number of exercises	8
Method and duration	AMRAP 10 min
External resistance	Body weight
Exercise intensity	Submaximal
Rests	No rest

AMRAP—As many rounds as possible, a method of training that involves performing as many sets of efforts as possible at a fixed number of repetitions in a given time.

The experimental training program is based on the AMRAP method (Table 2), which consists of performing as many sets of efforts as possible with a fixed number of repetitions in a given time (10 min in this case) [39]. To avoid boredom and training routine, a different training unit was planned for each workout of the week. Each workout was preceded by a warm-up and consisted of 8 exercises including boxing punches, kickboxing kicks, and exercises typical of the CrossFit methodology such as burpees (transition from standing upright to squat position, kicking the feet back to a front support position, returning to squat position, and jumping up), or box jumps. The training program was designed so that it was simple to perform and accessible to every participant. Therefore, additional equipment was kept to a minimum.

Table 2. The experimental training program used in the study.

Workout 1: Monday	Workout 2: Wednesday	Workout 3: Friday
- 40 × punching bag techniques: jab, punch - 40 × air squat - 30 × kick pad techniques: left. middle roundhouse kick 2×, right. middle roundhouse kick - 30 × box jumps (40 cm) - 20 × punching bag techniques: jab, punch, left middle roundhouse kick - 20 × sit-ups - 10 × burpees + punching bag combinations: jab, punch, high roundhouse kick - 10 × push-ups	- 60 × mountain climbers - 10 × punching bag techniques: jab, punch, left middle roundhouse kick - 30 × Russian twists - 30 × punching bag techniques: jab, punch, left. middle roundhouse kick - 30 × lunges - 15 × air squat + left middle front kick/right middle front kick - 15 × box jumps - 10 × burpees + punching bag combinations: left middle roundhouse kick 2×/right middle roundhouse kick 2×	- 50 × single under - 20 × (push-ups 2× + punching bag techniques: jab, punch) - 20 × spinal rock - 20 × (air squat 2× + left middle roundhouse kick/right middle roundhouse kick - 10 × hand release push-ups - 10 × burpees + kick pad combinations: jab, punch - 10 × tuck jumps - 5 × combinations of any 5 kicks on the bag

A detailed video illustration of the exercises is provided in the Supplementary Materials.

2.5. Physical Fitness Tests

Physical fitness was evaluated using selected items of the International Committee on the Standardization of Physical Fitness Test (ICSPFT) [2] and Eurofit Physical Fitness Test (EUROFIT) [41]. The entire test battery consisted of the following tests:

1. Cooper test (in m). A running endurance test consisting of 12 min of uninterrupted running. The running distance is measured [42].
2. Dynamic sit-ups (in reps). Evaluation of abdominal strength: the tested person lies on the mattress with feet 30 cm apart and knees bent at a right angle. Hands are intertwined, resting on the neck. The participant is assisted by a partner who holds the participant's feet so that they remain in contact with the ground. At the start signal, the participant sits up to touch the knees with elbows and then returns to the starting position. The exercise duration is 30 s [41].
3. Pull-ups (in reps). Evaluation of the strength of the shoulder girdle using the number of repetitions: the participant catches the bar with a pronated grip and hangs; at the signal, the participant bends their arms at the elbows and pulls the body up so high that the chin is above the bar and then, without a rest, returns to a simple hanging; the

exercise is repeated as many times as possible without a rest; the result is the number of complete pull-ups (chin over the bar) [2].

4. Measuring handgrip strength with a dynamometer (evaluation of static force). The participant stands with a small straddle with a dynamometer held tightly in the fingers. The arm is positioned along the body so that the hand does not touch the body, and the participant performs a short grip on the dynamometer with maximum force, with the other arm resting along the body. The better result of the two tests of maximal static strength (in kgf) of the dominant hand (HGSmax) using a handgrip dynamometer (MG 4800, Charder, Taichung, Taiwan) was recorded, with an accuracy of 1 kg. The better score of the right and left hand tests was recorded, and the interval between the tests was 5 min [41].
5. Flexibility test: sit-and-reach (in cm). The test is performed as a sit-and-reach movement, with the range of motion measured in cm, below the feet level. In a seated position, the participant reaches their arms forward as far as they can. The participant, in a straddle sitting position, reaches forward with the hands as far as possible by sliding the ruler on the surface of the box with a previously prepared scale. The better of the two results is recorded. If the participant reaches 10 cm beyond the toes, they achieve a score of 10. A box 40 cm long, 45 cm wide, and 35 cm high, a 65 cm long graduated box top protrudes 25 cm over the side wall that marks the width of the box and is used as a feet rest; the box top is fixed in such a way that the graduation mark drawn on it indicates 50 in the place where feet touch the surface of the box. A 30 cm-long ruler is placed loosely on the surface of the box perpendicularly to its longitudinal axis and used for moving with hands while performing a forward reach [41].
6. Shuttle run (in s). The participant runs on a signal to the second line 5 m away, crosses it with both feet, and comes back. They run 10 times for a distance of 5 m; the time of the shuttle run is measured and rounded to a decimal place of a second [41].
7. Tapping (assessment of the speed of upper limb movement). The participant stands with a small straddle, putting the non-dominant hand on a rectangular plate; the dominant hand should be placed crosswise on the opposite plate, and then the participant touches both plates alternately as quickly as possible. The participant performs a total of 50 movements, i.e., touches each plate 25 times. The better of the two results is recorded, determined by the time it takes to touch each plate 25 times, measured to the nearest 0.1 s. The equipment needed includes an adjustable height table (or vaulting box), two rubber discs 20 cm in diameter horizontally attached to the table with their centers 80 cm apart, a 10 × 20 cm rectangular plate placed in the middle between them, and a timer [41].
8. Clap push-ups (n)—in the front support position with feet on a gym bench (30 cm), the participant performs the maximum number of push-ups from the ground with a hand clap [43].
9. Standing long jump (in cm). The participant stands with the feet slightly apart in front of the starting line, bends the knees, and moves the arms backward at the same time, and then they perform an arm swing and jump as far as they can; the landing occurs on both feet while maintaining the upright position; the test is performed twice. The longest of the two jumps measured to the closest mark left by the participant's heel is recorded, with an accuracy of 1 cm [41].
10. To assess special fitness, the special kickboxing fitness test (SKFT) [35] and batteries of special fitness tests designed for combat sports in the standing position were used [44].
11. To evaluate special fitness levels and technical skills, all participants underwent the special kickboxing fitness test (SKFT) [45]. Description of the procedure for special kickboxing physical fitness test: Prior to performing the test, participants performed a warm-up that included 5 min of an easy run and 10 min of general warm-up and stretching (flexibility) exercises. The following tools were prepared to perform the test: adhesive tape to mark distances on the mat, a stopwatch to measure time, kick

shields and punch shields, a protocol for recording the results, and a sport tester (heart rate monitor). In the first station, the athlete performs, from a fighting stance, a combination of punches to the shield held by the partner: left and right straight punches to the head, without stopping, for 30 s. After completing this part of the test, the athlete runs 10 m in a straight line to the next station (No. 2), where, from the fighting position, they perform roundhouse kicks to the shield held by the partner for 30 s: left high kick (high roundhouse kick) and right high kick to the head. Next, the athlete runs back to the first station with shields and performs a left straight-right hook combination for another 30 s to the head. After completion of this part of the test, the athlete runs 10 m to the partner holding the shield in station 2 and performs middle roundhouse kicks for 30 s alternately with the right and left leg to the body trunk. The total special exercise time during the test is 2 min (4 $\times$ 30 s). Correctly performed kicks and punches were counted in each of the four parts. Heart rate (HR, bpm) was measured directly after completion of the test and after 1 min rest. The Garmin HRM chest strap was used in the tests. The proposed special fitness test allowed for the evaluation of the technical level of athletes in terms of the most effective and most frequently used hand techniques (punches) and leg techniques (kicks), speed (number of punches and kicks performed per time unit), special endurance (response of the circulatory system and number of punches and kicks), coordination (combination of kicks and punches), and flexibility (kicking range). The 10 m running distance used to move between stations corresponds to the diagonal of the largest ring found in ring combat sports. The technical skills used in the test ensure the selectivity of the test, making it inaccessible to those who do not perform special training and do not have the appropriate level of technical proficiency. Furthermore, after the test, based on the results obtained, the index of special fitness was calculated using a specialized formula:

$$\frac{\text{Final HR(bpm)} + \text{HR1min(bpm)}}{\text{Kick} + \text{Punches (N)}}$$

where:

Final HR—heart rate recorded immediately after completion of the test;
HR1 min—heart rate recorded 1 min after completion of the test;
Kicks—the number of kicks performed in the test;
Punches—the number of punches performed in the test.

The special fitness index reflects the level of a fighter's special fitness, which means the effective interaction of the body's exercise capacity, general fitness, and the athlete's technical skills. The interpretation of the score is inversely proportional: the higher the level of special fitness, the lower the value of the kickboxing test index.

12. Speed punches test. The punches are performed from a fighting stance. Each participant performs a combination composed of two punches: a left straight punch (Jab) to the head and a right straight punch (Punch) to the body trunk without changing the distance. The shields to which the participant performs 30 such combinations (60 punches in total) are held by a partner at the constant height. The time needed to perform 30 complete combinations is recorded in seconds to the nearest 0.1 s.
13. Hip-turning speed test: in the hip-turning speed (frequency) test, each athlete has a belt attached over the right hip (unless they fight in the opposite position) and, using the fighting stance, turns their hips to the left. This movement causes tension of the belt held by the coach standing behind the athlete (control). Next, the participant returns the hip. The participant is instructed to perform 30 hip turns (the number of belt tension instances is counted). The time taken to perform 30 turns was recorded.

The tests were conducted in a three-day mode at noon: trials 1–5 on the first day, trials 6–9 on the second day, and special fitness tests on the third. All tests were performed before and after the experiment, except for tapping, standing long jump, and flexibility tests, which were performed twice, and the better score was recorded. The intervals between the tests were designed so that the participants rested completely. A 20 min warm-up was conducted with the athletes prior to testing.

2.6. Statistical Analysis

Statistical analysis of logarithmic data was performed using STATISTICA v13.1 PL software (Statsoft, Kraków, Poland). Basic descriptive statistics were computed: arithmetic means, standard deviations, and 95% confidence intervals. The data were tested for normal distribution using the Shapiro–Wilk test, and Student's *t*-test for dependent variables was used to assess the significance of differences. Student's *t*-test for independent variables was used to determine the significance of differences between the control and experimental groups. The effect size was calculated using Cohen's d index. When d ranges from 0 to 0.2, the effect is small, i.e., negligible; it is medium from 0.2 to 0.5, large from 0.5 to 0.8, and extremely large when over 1.4. The relationships between the data were verified using Pearson linear correlation. Correlation values were interpreted as weak for the ranges of −0.5 to 0.0 or 0.0 to 0.5, and strong for −1.0 to −0.5 or 0.5 to 1.0 [46,47]. The level of statistically significant differences was set at $p < 0.05$.

3. Results

Statistically significant differences were found in the results of measurements before and after the experiment in the experimental group. Significant improvements in performance were noted in all tests except for the Cooper test. The analysis of the results (Table 3) indicated a statistically significant increase in abdominal muscle strength (5% difference), handgrip strength, an increase in the number of pull-ups (12% difference), an increase in the number of clap push-ups (9% increase), and an increase in the length of the long jump (1.8% difference), as well as a decrease in the time of the shuttle run (3% difference) and an increase in the results of the sit-and-reach test (8% difference) compared to the results of the initial test (pre-test compared to post-test). No statistically significant differences in the results of the Cooper test were observed ($p > 0.05$). In the control group, the only significantly improved result was the static strength test (handgrip test on a dynamometer). A comparison of the difference between the groups after the experiment revealed statistically significant differences in abdominal strength, clap push-ups, standing long jump, sit-and-reach, and tapping (Table 3).

The analysis of the changes in special fitness induced by the experiment showed a significant improvement in all the parameters measured in the experimental group. Furthermore, there were significant adverse changes in the control group in punch speed and hip-turning speed. The difference between the groups after completion of the experiment on the special kickboxing fitness test (SKFT) and the total number of punches in the test and the hip-turning speed were also found to be statistically significant (Table 4).

There were statistically significant relationships of endurance as measured by the Cooper test, total number of punches in the SKFT, speed of upper limb movements (tapping) with punching speed, and agility run with hip-turning speed. All the correlations were high and statistically significant at $p < 0.001$ (Table 5).

Table 3. General physical fitness of the participants before and after the experiment.

Parameters	Pre-Test		Post-Test		Mean Difference (95%CI) Pre-Post Test				Student's *t*-Test		Effect Size
	Mean	SD	Mean	SD	Mean	SD	−95%CI	+95%CI	*t*	*p*	Cohen's D
Abdominal strength (n) E	25.97	3.79	27.47	3.42	−1.5	2.1	−2.28	−0.71	**−3.91**	**<0.001**	−0.11
Abdominal strength (n) C	24.66	3.20	24.40	3.10	0.26	0.10	−0.12	0.66	1.39	0.17	0.08
Between group	t = 1.43 *p* = 0.15 d = 0.37		**t = 3.63 *p* = <0.001** d = 0.94								
Pull-ups (n) E	6.73	3.12	7.60	3.39	−0.87	1.25	−1.33	−0.40	**−3.79**	**<0.001**	−0.80
Pull-ups (n C	7.20	3.19	7.43	4.03	−0.23	−0.84	−0.99	0.52	−0.62	0.53	0.06
Between group	t = −0.57 *p* = 0.56 d = 0.15		t = 0.17 *p* = 0.86 d = 0.05								
Dynamometric measurement of handgrip force (kg) E	51.99	2.72	52.51	2.79	−0.52	0.40	−0.66	−0.37	**−7.14**	**<0.001**	−0.07
Dynamometric measurement of handgrip force (kg) C	52.11	3.01	52.69	3.13	−0.58	−0.12	−0.92	−0.22	**−3.29**	**0.02**	0.19
Between group	t = −0.16 *p* = 0.86 d = 0.04		t = −0.22 *p* = 0.82 d = 0.06								
Clap push-ups (n) E	11.03	4.87	12.23	5.53	−1.2	1.28	−1.67	−0.73	**−5.17**	**<0.001**	−0.04
Clap push-ups (n) C	11.66	5.03	11.43	4.73	0.23	0.3	−0.18	0.65	1.15	0.25	0.05
Between group	t = −0.49 *p* = 0.62 d = 0.13		**t = 0.60 *p* = 0.04** d = 0.16								
Standing long jump (cm) E	201.2	14.9	204.83	15.66	−3.63	2.77	−4.67	−2.60	**−7.17**	**<0.001**	−0.02
Standing long jump (cm) C	201.3	11.97	201.46	12.37	−0.16	−0.4	−1.09	0.76	−0.36	0.17	0.01
Between group	t = −0.02 *p* = 0.97 d = 0.01		**t = 0.92 *p* = 0.03** d = 0.24								
Shuttle run (s) E	19.37	2.58	18.71	2.23	0.63	0.74	0.36	0.91	**4.68**	**<0.001**	0.11
Shuttle run (s) C	18.61	2.08	18.64	2.07	−0.03	0.01	−0.07	0.00	−2.04	0.06	0.01
Between group	t = 1.19 *p* = 0.23 d = 0.33		t = 0.10 *p* = 0.92 d = 0.03								
The Cooper test (m) E	2375.83	240.75	2390.33	213.25	−14.5	237.87	−103.32	74.32	−0.33	0.74	0.00
The Cooper test (m) C	2400.60	213.37	2398.40	228.94	2.2	−15.57	−42.16	18.56	−0.79	0.43	0.01
Between group	t = −0.91 *p* = 0.36 d = 0.11		t = −0.89 *p* = 0.37 d = 0.04								
Sit-and-reach (cm) E	10.33	4.67	11.27	4.75	−0.93	1.34	−1.43	−0.43	**−3.82**	**<0.001**	−0.04
Sit-and-reach (cm) C	11.26	3.77	11.13	3.73	0.13	0.04	−0.19	0.45	0.84	0.40	0.03
Between group	t = −0.85 *p* = 0.39 d = 0.22		**t = 3.37** *p* = **<0.001** d = 0.03								
Tapping E	12.41	1.48	11.76	1.36	−0.65	0.52	−0.46	−0.84	**6.92**	**<0.001**	0.41
Tapping C	12.09	1.38	11.98	1.45	0.11	0.07	−0.62	1.01	0.49	0.62	0.08
Between group	t = 0.84 *p* = 0.40 d = 0.22		**t = 1.14 *p* = 0.05** d = 0.16								

E—experimental group, C—control group, SD—standard deviation, CI—confidence intervals, statistically significant values are bolded.

Table 4. Special physical fitness of the participants before and after the experiment.

Parameters	Pre-Test		Post-Test		Mean Difference (95%CI) Pre-Post Test				Student's *t*-Test		Effect Size
	Mean	SD	Mean	SD	Mean	SD	−95%CI	+95%CI	*t*	*p*	Cohen's D
SKFT- Index E	191.13	9.07	187.80	9.32	3.32	0	0.57	6.09	**2.47**	**0.02**	0.46
SKFT- Index C	189.70	9.87	188.51	10.48	1.92	−0.61	−2.94	6.74	0.80	0.42	0.12
Between group	t = 0.58 *p* = 0.56 d = 0.15		**t = 1.24 *p* = 0.05 d = 0.43**								
Total number of punches E	280.13	30.81	293.26	30.76	−13.3	0.05	−15.73	−10.53	**−10.32**	**<0.001**	0.43
Total number of punches C	286.15	29.63	278.26	33.17	7.86	−3.54	−2.23	17.96	1.59	0.12	0.25
Between group	t = -0.76 *p* = 0.44 d = 0.20		**t = 1.72 *p* = 0.04** d = 0.47								
Punching speed E	16.27	1.34	15.76	1.32	0.37	0.02	−0.38	0.63	**8.52**	**<0.001**	0.38
Punching speed C	16.15	1.39	16.22	−1.42	0.07	−0.07	−0.14	−0.00	**−2.12**	**0.04**	0.05
Between group	t = −0.33 *p* = 0.74 d = 0.09		t = −1.29 *p* = 0.20 d = 0.34								
Hip turning speed E	16.40	1.58	15.89	1.63	0.51	−0.05	0.32	0.71	**5.35**	**<0.001**	0.32
Hip turning speed C	16.64	1.42	16.82	1.35	−0.18	0.07	−0.30	−0.06	**−3.04**	**0.03**	0.13
Between group	t = −0.65 *p* = 0.50 d = 0.16		**t = −2.40 *p* = 0.02** d = 0.62								

E—experimental group, C—control group, SD—standard deviation, CI—confidence intervals, statistically significant values are bolded.

Table 5. Relationships between special physical fitness and general physical fitness of kickboxers after the experimental program.

Pearson Linear Correlation Coefficient	SKFT-Index	Total Number of Punches	Punching Speed	Hip Turning Speed
Abdominal strength	−0.67	−0.57	−0.09	0.11
	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Pull-ups	0.01	0.08	0.22	−0.06
	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Clap push-ups	0.01	0.10	0.08	−0.13
	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Standing long jump	−0.01	0.33	−0.27	0.16
	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Shuttle run	−0.30	0.05	0.24	**0.81**
	$p > 0.05$	$p > 0.05$	$p > 0.05$	**$p < 0.001$**
The Cooper test	0.13	**0.76**	−0.28	−0.24
	$p > 0.05$	**$p < 0.001$**	$p > 0.05$	$p > 0.05$
Sit-and-reach	0.03	−0.23	−0.29	−0.07
	$p > 0.05$	$p > 0.05$	$p > 0.05$	$p > 0.05$
Tapping	0.19	0.18	**0.84**	−0.08
	$p > 0.05$	$p > 0.05$	**$p < 0.001$**	$p > 0.05$

Statistically significant values are bolded.

4. Discussion

In this study, we attempted to determine the effect of CrossFit training on the general and special physical fitness of kickboxers. The results presented in this study allow for the verification of an experimental program based on CrossFit training. The idea of CrossFit training is to introduce a component of competing with a training partner or oneself, which increases the intensity and effectiveness of exercise [24]. The findings of the study show that the experiment had a positive effect on the fitness level in the experimental group, which was confirmed by statistically significant changes. Improvements were observed in abdominal muscle strength, shoulder girdle strength, and handgrip strength. The development of general body strength is a basic component of the preparation of a kickboxer to effectively use hand and foot techniques and to improve performance during the fight [4,48,49]. Furthermore, strength training is effective in protecting against injuries that are common in contact sports [50,51]. The results of our research show that it is advisable to use CrossFit training as a supplement to basic kickboxing training in the preparation period. The experimental training also improved dynamic upper and lower limb strength as measured by standing long jump and clap push-ups. Muscle strength of both upper and lower limbs is essential for the athlete to win in full-contact formulas in kickboxing such as K1, low kick, and full contact [52,53]. Taking into account the significant changes, it can be concluded that the training used in the experiment led to the increase in dynamic strength in the experimental group despite the lack of exercises with additional external resistance. A high level of dynamic power allows for the effective use of technical actions that affect the level of technical and tactical indices and thus fighting performance [16,33]. Another effect of the implemented training program was a progression in speed, as confirmed by statistically significant changes recorded in the test of speed of hand movements (plate tapping test) in the experimental group. Accordingly, the authors' program induced improvements in upper limb speed in plate tapping and special fitness tests (punching speed). The relationship between these two components was confirmed by the high correlation between each other. It is worth noting that these abilities play a key role in full-contact formula (K1, low kick, full contact), light forms (kick light, light contact), and intermittent forms (point fighting) [54], as well as in any fight using upper limbs (boxing, karate, etc.). According to Kimm and Theil, hand speed is especially important in boxing, both to protect against attack and throw punches [55]. A kickboxer who delivers punches at a fast pace can effectively attack the opponent, anticipate their intentions, and effectively defend against the opponent's attack. A high frequency of upper limb movements and punches is highly desirable, especially in limited-contact formulas where a point advantage determines victory [9]. The observed progression can be explained by the use of plyometrics in the experimental training involving the upper limbs, such as burpees, combined with dynamic, explosive boxing actions on a bag. The purpose of these actions was to develop the muscles' ability to generate a large force in a short time (high force rate) or improve dynamics [56]. In addition to these characteristics, agility, balance, and coordination also play an important role in the training process [15]. An improvement in the results after the experimental training was also observed in the agility test (shuttle run). This ability determines the speed of movement, which is a precondition for effective movement in the fighting area and defense. Furthermore, the ability to move quickly and the footwork speed are the basis for meeting the technical and tactical objectives of the fight [57].

In the present study, a high correlation was observed in the experimental group between the hip-turning speed in the special fitness test and shuttle run results. Interpretation of the relationships leads to the conclusion that the kick speed, associated with hip turning, is determined by agility, with its components being coordination and speed [2,15]. There was a significant increase in flexibility in the experimental group after the experimental training program. Flexibility is one of the elements needed to master technical skills [15]. The sit-and-reach test showed the progression of flexibility in athletes in the study group. The improvements may be due to the training used, which included high kicks that required a large range of motion. The Cooper Test, which measures the athlete's aerobic endurance level, showed small and statistically insignificant improvements in both groups. This may be explained by high baseline levels of running endurance in the kickboxers tested, whereas the specific kickboxing training and experimental training did not allow for significant development of this ability. It is worth noting that the higher level of the Cooper test results translates directly into higher special fitness, as evidenced by the high positive correlation with the total number of punches in the test. Furthermore, the experimental group showed a statistically significant reduction in the physical fitness index in the SKFT test, which indicates an improvement in the athletes' special endurance. Favorable changes were found in all special fitness parameters, i.e., the total number of punches, punching speed, and hip-turning speed. This leads us to assume that the applied training based on the components of CrossFit has a positive impact on the athlete's performance, which is measured by the results of special fitness tests [45,58].

Limitation in the Study

A major limitation of our study was the lack of detailed verification of the study groups. We were unable to conduct the experiment in a closed facility where both groups would have the same conditions for functioning and training. Furthermore, we did not perform a direct test to evaluate VO_2max based only on running endurance.

5. Conclusions

The experimental training program based on the principles of CrossFit training had a positive effect on the physical fitness of the kickboxers in terms of strength, flexibility, agility, and speed indices in the experimental group. The experimental training program based on the principles of CrossFit training had a positive effect on special physical fitness. There were significant correlations in the parameters of special and general fitness, i.e., Cooper test vs. total of punches and kicks, shuttle run vs. hip-turning speed, and tapping vs. punching speed after the experimental training program.

Practical Implication

The presented experimental training program can be implemented to improve the quality of kickboxing training in terms of improving general and special physical fitness in the preparation period.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/ijerph19084526/s1, Video S1:1 workout, Video S2: 2 workout, Video S3: 3 workout.

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Article

Health Enhancing Physical Activity Policies in Poland: Findings from the HEPA PAT Survey

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Abstract: Insufficient physical activity (PA) is one of major risk factors for serious diseases and premature mortality worldwide. Public policies to enhance PA across society are recognized as an effective tool against the problem. This paper presents the results of a comprehensive assessment of national-level PA policy approach in Poland. A standardized survey of Word Health Organization named the Health-Enhancing Physical Activity Policy Audit Tool (HEPA PAT) was used for data collection. Content analysis and strengths, weaknesses, opportunities, and threats analysis (SWOT) were used to characterize various PA policy aspects, to appraise the current situation, and accommodate organizational and environmental factors that it is influenced by. The results show that the national PA policy approach has been constantly developing in Poland, but there is room for improvement in a number of areas. The most important weaknesses are the lack of clear leadership, no mechanisms in place to coordinate efforts undertaken at different levels, and lack of collaboration across different levels of government and across different sectors of economy. Providing an umbrella covering all PA promotion policies and activities is, therefore, a key issue to be addressed. The country should seize the opportunity coming from an increasing awareness of a healthy lifestyle among Polish society.

Keywords: physical activity; Poland; HEPA PAT; public health; public policy

1. Introduction

Non-communicable diseases are responsible for almost three quarters of global deaths [1], and a lack of physical activity (PA) is one of their major risk factors [2,3]. Lee et al. [4] estimated that 6% of the burden of coronary heart diseases, 7% of type 2 diabetes, 10% of breast cancers, and 10% of colon cancers are caused by an inactive lifestyle. He also estimated that with a 25% increase in global PA level, more than 1.3 million deaths could be averted each year. Therefore, regular PA is an effective prevention strategy against numerous chronic diseases and may reduce their risk by 20–30% [5]. Despite the empirical evidence on the health benefits of PA [4,6], over a quarter of the world's adult population and more than three quarters of the world's adolescents do not adhere to current PA guidelines [7]. In addition, no improvement has been noticed in global PA levels since 2001 [7]. For this reason, promotion of PA is a topic of great importance for both the World Health Organization (WHO) and the European Union (EU) [8,9].

Since 1995, the WHO has been providing evidence-based recommendations for PA [10]. The newest were published in 2020 [11]. The document provides details on the amount, type, and frequency of PA that is needed for health and well-being for specific population groups, such as small children, school-aged children, adults, the elderly, or pregnant women. According to Oja and Titze [10], PA recommendations targeting individuals are insufficient to achieve desired PA levels across the population, however, they may provide foundations for actions to improve the situation and metrics for their monitoring. Thus, policies to promote PA may be used as a response to the global physical inactivity problem. Compared to individual-level interventions, policies are targeted at a broader audience, community, or population, and therefore, have a wider spectrum of influence [12]. Sallis et al. [13] define PA-related policies as 'legislative, regulatory, or policy-making actions that have the potential to affect physical activity'. They may provide opportunities for increasing PA levels, provide funding for PA promotion, regulate the amount of obligatory sports at school, and coordinate activities undertaken at national or regional level [12,14]. Many studies provide evidence for the effectiveness of policies to promote PA [15–18]. Such policies have been successfully implemented in the areas of education, health, sport, urban design, or transportation. Taking the latter as an example, Brockman and Fox [19] assessed the impact of transport-related policies introduced in Bristol in 1997–2007 that included increasing parking fees, subsidies for bicycle purchases, introducing a car-sharing system, and public transport discounts, concluding that walking to work increased by 11%. Another policy introduced in Cambridge, which focused on increasing access to walking/cycling routes and places for PA, has significantly increased children's PA levels [20].

According to the WHO [21], the central role in promoting healthy lifestyles and creating an environment that encourage behavior changes belongs to the governments. The role is not limited to the health sector but also to other sectors such as transport, education, sports, or the environment. National governments have a steering and coordinating role in implementing strategies and meeting recommendations developed by WHO [21,22] or EU [8] at the national level. They have resources to provide effective legislations, develop programs, and ensure an appropriate infrastructure, funding, monitoring, or research opportunities. National policy is an important platform for governments to develop, coordinate and deliver large scale actions across multiple sectors, involve stakeholders, assign roles and responsibilities, define common objectives and gain visibility at the political level [23]. However, not all countries use the potential their governments have in PA promotion.

To assess the national PA policy potential and approaches, the WHO proposed a policy audit tool (Health-Enhancing Physical Activity Policy Audit Tool—HEPA PAT) and a wide variety of countries have used it so far [24–27]. The HEPA PAT is a standardized questionnaire designed to collect comprehensive, systematic, and comparable data on the approaches to PA promotion at the national policy level [23,28]. The completed HEPA PAT questionnaire provides a comprehensive overview on the current status of a country's approach to enhancing PA, allows to identify strengths and weaknesses of the current national policy approach, indicates synergies and discrepancies between national level policy documents, and identifies whether there is enough communication and collaboration between sectors [23]. Finally, it allows for country comparisons [23,24], communication of good practices, and success stories to be used by other countries.

This paper presents the results of a comprehensive assessment of national-level PA policy approach in Poland based on the data systematically collected with the use of HEPA PAT questionnaire. The paper aims to answer the following questions: What are the strengths and weaknesses of the Polish PA policy approach? What policy areas need to be improved? The findings from this study will contribute to advanced knowledge in this particular area and to help policymakers and practitioners design and plan actions to increase PA levels among the whole of society. The rationale for this study is aligned with the work of the Policy Evaluation Network (PEN; https://www.jpi-pen.eu/). PEN aims to develop a consolidated approach to policy evaluation across Europe by developing and prioritizing an agreed set of indicators, measured using harmonized instruments that ideally can be used by existing monitoring and surveillance systems [29]. This study was also the first step in developing the prototype of 'Physical Activity Environment Policy Index', a tool that can be used to independently monitor and benchmark public sector PA policies and actions.

2. Materials and Methods

To identify and assess the current state of the national-level PA policy approach in Poland, the WHO's audit tool HEPA PAT version 2.0 was used [28]. The questionnaire consists of 29 questions in 10 subject areas (Table 1). The process of completing the HEPA PAT was supervised by the project coordinator (JŻ) and involved national stakeholders from several sectors such as sports, health, education, and transport.

Table 1. The overview of the HEPA PAT structure.

Section	Goals	Data Collection		
		Focal Point	Desk Review	Expert Survey
Background information and country context	To give a brief overview of the country's organization, government structure, distribution of responsibilities across sectors and ministries, and entities involved in PA promotion at the national level.		X	
Leadership and partnerships	To identify what entities provide leadership for PA promotion, whether there are mechanisms or agencies that ensure and coordinate cross-sectoral collaboration.	X		
Policy documents	To give an overview of how the PA promotion agenda was shaped in past policy documents; to indicate the current policy documents important for further shaping the PA promotion agenda across sectors; to assess the policy setting process; to show the link with other national policy documents and with documents at the global or EU level.	X	X	
Policy scope, content and implementation	To identify population groups targeted by PA promotion activities; to describe communication processes; to give examples or case studies of large-scale PA promotion activities across sectors.	X		X
Recommendations, goals and targets	To give an overview of national recommendation on physical activity and sedentary behavior and how different population groups are targeted; to identify national goals or targets set in national policy documents.		X	
Surveillance	To collect information on how PA and sedentary behavior are monitored, what data are being collected, and what is the frequency of data collection; to show whether and how the data are used in national PA promotion policies.	X	X	
Evaluation	To identify whether the past national policy documents were evaluated and how; what were the results and whether and how they were used in new policies.	X	X	
Funding and commitments	To give an overview of funding for PA-related policies and interventions; to identify what is the political commitment to the national PA promotion agenda.			X
Capacity-building through a national network	To identify whether there is any professional network or system to link and support professionals involved in PA promotion.			X
Experience of policy implementation, progress and remaining challenges	To indicate the main achievements and challenges related to country level PA promotion; to give experience-based recommendations for other countries.			X

The process of data collection started in March 2019 and was completed in July 2019. It consisted of the following stages: (i) identification of stakeholders; (ii) collecting the data from the 2018 survey for the EU Monitoring Framework after obtaining consent from the national PA Focal Point and the WHO; (iii) desk research conducted by the authors, including the identification and the review of existing policy documents, programs, activities carried out at the national level and related to PA promotion; (iv) in-depth expert interviews to obtain additional information and input for the HEPA PAT; (v) completing the HEPA PAT questionnaire by the authors. The in-depth interviews with experts involved the representatives of the Polish Ministry of Health, the Ministry of Sport and Tourism, the Ministry of Infrastructure, and the Ministry of Education (currently the Ministry of Education and Science). The participants were selected based on their expertise in the PA policy setting and policy implementation.

Similarly, data were collected in Ireland, The Netherlands, and Germany [23,24,27]. While the results of this four-country comparison have been published elsewhere, this article presents the results for Poland in a higher level of detail.

In order to characterize the various policy aspects related to the development, implementation, monitoring, and evaluation of PA policies, a content analysis of the completed HEPA PAT questionnaire was performed. This is a research technique widely used for making inferences from analyzing documents that were generated or obtained in the course of research [30]. The HEPA PAT categories served as basic themes for the analysis. The research questions were raised to understand the information of how it is presented: How is the process (e.g., implementation, evaluation) organized? What are the outcomes? What lacks in the process? The conclusions were drawn from the HEPA PAT content to the context, which is the history and current state of PA policy approach in Poland, using the experience and knowledge by researchers directly involved in the data collection process.

To summarize the results, a SWOT (strengths, weaknesses, opportunities, threats) analysis was used. This is a powerful tool widely used in strategic planning and management, which is helpful to appraise the state of the art and accommodate organizational and environmental factors that influence the current situation [31]. SWOT analyses have been adopted in some qualitative studies to evaluate policy approaches in recent years, including energy planning strategies [32,33], the compressed natural gas industry, [34] or urban transport system [35]. It has also been applied to evaluate PA promotion in a household group survey [36]. In this paper, SWOT is used to structure the factors influencing and shaping PA promotion policy at the national level in Poland. For this purpose, the particular components of SWOT representing internal (strengths and weaknesses) and external (opportunities and threats) factors, respectively, were summarized in a 2 × 2 matrix. The matrix components were further divided into rows comprising factors in accordance with the adopted themes and matching them horizontally (i.e., strengths with corresponding weaknesses; opportunities with corresponding threats).

3. Results

3.1. Leadership and Partnership

Poland is a unitary state with a strong central government. In line with the EU recommendations on promoting health-enhancing PA (HEPA) across sectors [8], Poland has appointed a National PA Focal Point at the Ministry of Sport and Tourism, Department of Sport. The Ministry is responsible for the development and implementation of national sport and tourism strategies. It undertakes many activities to promote PA, but these are limited mainly to the area of sport. The Ministry does not provide any leadership and any umbrella for PA promotion activities implemented in other areas (i.e., health, transportation, and social policy).

Apart from the Ministry of Sport and Tourism, other government ministries have their own role in PA promotion. Table 2 presents information about ministries, their responsibilities, and how they are related to PA promotion. The Ministry of Health, responsible for health policy, develops and implements the national health strategy, which covers

PA-related tasks. The Ministry of Family and Social Policy, responsible for the welfare of Polish families and the whole society, supports the development of care services and cares for the PA of seniors. The Ministry of Education and Science, responsible for teaching and education, supports the development of educational programs, including physical education (PE) classes at schools. Although the Ministry of Infrastructure, the Ministry of Investment and Development, and the Ministry of the Environment do not have special roles in PA promotion, they indirectly support PA by different programs devoted to active transport, active mobility, and development of green transport.

Table 2. The role of Polish ministries in PA promotion.

Name of the Ministry	Main Competences	Competences Related to PA Promotion
Ministry of Sport and Tourism	Development of the general and professional sport	Commissions PA monitoring; implements actions to enhance PA among society and specific population groups; develops and implements the national sport strategy.
Ministry of Health	Health policy development and implementation	Implements actions to prevent faulty posture in children and adolescents; establishes rules on medical eligibility for PE classes; develops and implements the national health program, including actions to enhance PA level among society.
Ministry of Family and Social Policy	Responsible for the welfare of Polish society	Supports the development of care services; implements actions to increase awareness and enhance PA among seniors.
Ministry of Education and Science	Teaching and education	Supports the development of health education and PE educational programs in schools; supports actions towards preventive healthcare for school children.
Ministry of Infrastructure	Transport infrastructure development and ensuring its rational use	Indirectly involved in PA promotion by implementing programs devoted to green and active transport, including active transport in strategies to promote low-carbon and compact cities, including active transport in strategies to reduce emissions from transportation.
Ministry of Investment and Development	Construction, housing urban planning, and development	
Ministry of Environment	Environment protection	

There are currently no special mechanisms or agencies to ensure the co-operation between particular ministries in the implementation of the PA policies at the national level. There is also no agency at the national level to promote and coordinate PA activities with the subnational level, either horizontally or vertically.

3.2. Policy Documents

The most important policy documents that influenced the shaping of the PA policy agenda in Poland were the National Health Programme 2007–2015 [37], the Sport Development Strategy until 2015 [38], and the Directions of Tourism Development until 2015 [39]. These programs covered the sectors of sport, health, education, and tourism. All were continued and covered the period until 2020 [39–41]. In addition to the mentioned programs, there are policy documents in other sectors that have implications for PA behavior; these are the Transport Development Strategy until 2020 [42] which appeared in transport sector, and the National Urban Policy 2023 [43], which is rooted in the urban planning sector. Key policy documents related to PA promotion are listed in Table 3.

While there are a number of current key policy documents expressing the intention to increase the national level of PA (e.g., [39–41,44]), there are no clear references across these documents and links to other documents. The only existing links refer to policies at the European level. An example is the Sport Development Programme 2020 [41], which takes the European Commission's White Paper on Sport [45] as a basic document setting strategic guidelines for the role of sport in Europe and Poland.

Table 3. Key PA policy documents in Poland.

Name	Sector	Main Goal(s)
The National Health Programmes 2007–2015 and 2016–2020	Health	To improve population health and life quality; to reduce inequities in health.
The National Sport Development Strategy 2015 and Sport Development Programme 2020	Sport, Education	To achieve the optimal level of pro-health behavior among different groups of Polish society by promoting sport and enhancing physical activity.
The Directions of Tourism Development until 2015 and until 2020	Tourism	To strengthen the development of competitive, innovative, and sustainable tourism that favors the country's socio-economic development and increases competitiveness of Polish regions.
The Transport Development Strategy until 2020	Transport, Infrastructure	To increase the accessibility, safety, and efficiency of transport through the development of a coherent, sustainable, and user-friendly transportation system.
The National Urban Policy 2023	Urban planning, Infrastructure	To strengthen the sustainable development of cities and urban areas; to improve life quality of residents.

3.3. Policy Scope and Implementation

Nearly all population groups, including preschool children, adolescents, individuals with disabilities, clinical populations, families, and migrant populations, are covered in the documents identified.

Although there is no nationwide mass media communication strategy to promote PA in Poland, some agencies are funding initiatives that utilize mass media, i.e., social media channels. However, no coordination of these initiatives is ensured.

On the other hand, there are many successful programs and interventions in Poland promoting PA in sectors such as health, sport, education, transport, and environment. The most successful and widespread programs in recent years were the National Talent Base, the Local Sports Animator, the Orlik 2012, and the Stop Abstention from PE Classes (Table 4).

Table 4. Selected PA-related programs and interventions implemented in Poland.

Name	Description
The National Talent Base	A publicly available program that monitors and tests the level of physical fitness of youth. (https://narodowabazatalentow.pl/)
The Local Sports Animator	A systematic project promoting PA and sports among children and youth by enabling them to participate in extracurricular and out-of-school sports activities (https://orlysportu.pl/).
Orlik 2012	A program which provided for the construction of modern sport facilities in every municipality in Poland.
Stop Abstention from PE Classes	A program aimed at promoting PA among school-aged children and adolescents and encouraging them to attend PE classes.

3.4. PA Recommendations, Goals and Targets

Poland has official guidelines for recommended levels of PA in different age groups, including children of all ages, adults, and seniors [46]. In case of adults, the recommendations are also targeted to pregnant women and adults with chronic diseases, but not to people with disabilities. The document is based on the WHO recommendations and considers the results of the study on PA among Poles conducted in the years 2015–2017. The recommendations set minimum and optimal time of weekly PA recommended in particular groups and propose the type and intensity of activity that should be undertaken, i.e., for seniors, it is recommended to undertake 150 min of moderate PA per week, including exercises to improve balance, coordination, and to strengthen all body muscles.

Sedentary behavior is not addressed by any national recommendations. This is an important weakness of the Polish PA promotion system, while many countries provide recommendations in this regard (i.e., Estonia, Greece, and France) [47].

Improving the PA levels in Poland was the main goal of the Sport Development Programme 2020 [41]. According to the program, the percentage of residents that undertake the recommended amount of PA was to be increased by 3.5% and the percentage of residents that never do exercise or play sport was to be lined up with the EU average. Mid-term evaluation indicates that even though the situation has improved, Poland is still far away from achieving these goals [48].

3.5. Surveillance

Poland has been conducting regular PA monitoring among different age groups for the past ten years. In 2016, the country joined the WHO's European Childhood Obesity Surveillance Initiative (COSI) [49]. Within the initiative and financed by the National Health Programme [40], a standardized survey and body measurements were conducted among 8-year-olds in 2016 and 2018. The results of the study provide information on the level of PA and sedentary behavior of school pupils. According to the latest results, a large proportion (61%) of children do 1–2 h of PA daily, however there is also a significant proportion (10–20% depending on the type of day) who are not active at all. The time spent on watching TV or using electronic media is approximately 1.5 h on an average school day and 2.5 h during non-school days.

Since 2010, Poland has been carrying out the regular monitoring of PA among children aged 11–15 using the HBSC methodology [50]. The studies were conducted in 2010, 2014, and 2018. The latest study [51] showed that the recommended PA level in Poland is achieved only by 17.2% of teenagers. Most of the teenagers (approx. 60% during working days and 80% during weekend) spend more than two hours a day sitting in front of TV, computer, tablet, or smartphone, and this percentage is increasing.

Pilot studies are also carried out in other age groups, e.g., among older youth (17–19) and in pre-school children. The health and PA level among Polish residents have also been a subject of a study based on the European Health Interview Survey (EHIS) [52] in 2009, 2014, and 2019. Since 2014, the Ministry of Sport and Tourism has been committing research on the PA levels of Polish residents on an annual basis, using the International Physical Activity Questionnaire (IPAQ) [53]. The aim of the study is to indicate the percentage of Polish residents meeting the WHO's recommendations regarding the time spent on PA (according to the latest results these are met by only 21.8% of residents aged 15–69 [54]).

A regular monitoring of PA is also provided by the Main Statistical Office (2008, 2012, and 2016), using a questionnaire survey in households. The respondents are asked about their perceived physical fitness and the level and regularity of PA.

Despite the amount of data collected and updated in the above-mentioned studies, most policy documents do not take the results into account. The exception is the National Sport Development Programme 2020 [41], whose goals were based on the diagnosis using surveillance data, as well as the data used for program monitoring. The existing data are also not commonly used for PA promotion activities. However, some good practices can be found. In 2009–2012, the National Supreme Audit Office has investigated the organization of PE classes and the levels of participation. The results were alarming—physical fitness among children decreased, they often had bad posture, and they experienced the fastest weight increase in Europe. The PE classes were also neglected by schools and teachers; according to the results, 65% of the classes were not even conducted. In response, the Ministry of Sport and Tourism has initiated the promotional campaign Stop Abstention from PE classes (Table 4), which aimed to fight against the scourge of PE exemptions and increasing parents' awareness about the importance of PA for children's health and fitness.

3.6. Evaluation

Among the policies in place, only the National Sport Development Programme [41] was developed based on previous program evaluation results and includes a detailed evaluation plan. The evaluation is done at the strategic (achievement of program goals) and operational level (implementation of the program action plan). An evaluation report is published on an annual basis.

One-time evaluation was also done for the National Health Programme [55]. However, this evaluation was only based on the qualitative assessment of the organization of particular initiatives and their strengths and weaknesses, but did not assess whether the goals of the program were achieved.

3.7. Funding and Commitments

According to the Ministry of Finance, in 2015, public expenditure on sport and PA amounted to 1.1 billion euro, of which over 90% was spent by local governments. This means that local governments play a key role in financing sport and recreation from public sources. Local government units allocate much more funds to physical activity promotion than the state budget. The public expenditures on sport and PA represent 0.4% of the national GDP [56]. The budget spent per capita was 43 euro in 2015 and increased to 60 euro in 2019; however, it is still 50% lower than the EU average [57,58].

At the national level, the delivery of PA-related policy is funded from several sectors (public funds). The largest funding comes from the sport and recreation sector and the transport sector; much less is dedicated from the sectors of health, education, tourism and social affairs. A large amount (70 million euro) was dedicated for financing initiatives within the National Sport Development Programme [38].

3.8. Capacity Building through a National Network

National networks that support professionals in PA promotion primarily include publicly funded associations and informal networks. An example is the National Talent Base (https://www.narodowabazatalentow.pl), which collects and shares data and knowledge about the level of physical condition of children and adolescents as well as helps to discover young talents in sport. Another example is the Polish Active Mobility Association (PUMA) that supports local governments in promoting and improving conditions for active transport.

3.9. Summary

Table 5 summarizes the results of the Polish HEPA PAT obtained from both the expert interviews and the Polish HEPA Focal Point with the help of the SWOT analysis. It indicates the strengths and weaknesses of the PA policy approach and highlights external opportunities and threats that may influence its future development.

Table 5. SWOT analysis of PA promotion in Poland.

Strengths	Weaknesses
There is a WHO focal point designated in the Ministry of Sport and Tourism.	There is no leader agency (nor leadership) responsible for PA promotion.
There are ministries directly (sport) and indirectly (i.e., health, transportation, and social policy) involved in PA promotion.	There is no cross-sectoral coordination on the national level. There is no link between policies, programs, and interventions implemented by different bodies (e.g., ministries) and no coordination of their activities. There is no vertical coordination between national and local level PA promotion activities. There is no umbrella strategy at the national level (the implemented programs and interventions are not a part of any wider PA promotion strategy).

Table 5. *Cont.*

Strengths	Weaknesses
There is a PA promotion policy in place (the National Sport Development Programme). There are several policies that indirectly link to PA promotion (in the area of i.e., health or transportation). There are many successful programs and interventions to promote PA in sectors like health, sports, education, transport, and environment.	A clear PA promotion policy is limited to the area of sport. There is no central policy document that would serve as an umbrella for PA-related policies in the areas of sport, health, transportation, etc.
There is a regular monitoring of PA levels across different society groups, especially children and adolescents.	The existing monitoring tools and methods do not account for different external and internal conditions (e.g., age of participants and weather conditions).
There is a publicly available tool (the National Talent Base) to measure physical fitness among youth using systematic measurements.	There is no evaluation of implemented programs and interventions; new programs and interventions are usually not based on previous evaluation results.
National recommendations on increasing PA include a wide range of age and social groups; including pregnant women and elderly people.	No recommendations are targeted at people with disabilities. There are no national recommendations on reducing sedentary behavior among different population groups.
The existing policy documents strongly refer to the relevant European policies.	There are no clear cross-sectoral links between policy documents.
	There is no national communication strategy regarding PA promotion.
Opportunities	**Threats**
There is an increasing awareness of a healthy lifestyle among Polish society; it is trendy to be active and fit.	There is a social tolerance for inactivity. Sedentary behavior is progressing in society; there is an alarming and increasing trend in time spent in front of electronic devices, especially among children, adolescents, and young adults.
Availability of open sport infrastructure constantly increase (e.g., new outdoor gyms are financed by governmental program).	Financing of new PA infrastructure and opportunities strongly depends on the country's economic situation which is not constant.
There are many bottom-up initiatives by local governments and NGOs that supports PA promotion (promotional campaigns, competitions, mass events, marathons, etc.).	Implementation of many PA promotion interventions is affected by and depends on COVID-19 conditions.
There are structures in Polish parliament responsible for PA promotion related tasks.	The activity of parliament's structures designated to promote PA is very low and isolated.

4. Discussion

HEPA PAT turned out to be a powerful tool for identifying the strengths and weaknesses of PA policy approach in Poland. The summary of results of its application presented in Table 5 allows conclusions to be drawn on what are the successes, what are the failures, where is a room for improvement, and what needs to be done from scratch regarding the efforts to increase the national PA level.

It is clear that the most important weakness of the Polish PA policy approach is the lack of clear leadership and the lack of mechanisms to coordinate efforts at different levels and to ensure effective collaboration (both vertically across different levels of government and horizontally across different sectors). In the meantime, governments are encouraged by the WHO to set up a national coordinating mechanism that addresses PA within the context of a comprehensive plan for noncommunicable-disease prevention and health promotion. Local authorities should be closely involved. WHO recommendations underlie that multisectoral and multidisciplinary expert advisory boards should be established. They should include technical experts and representatives of government agencies, and have an independent chair to ensure that scientific evidence is interpreted without any conflict of interest [21]. None of these currently exist in Poland.

There are government structures that are actively promoting PA in the areas they are responsible for (i.e., sports, health, urban policy, transport, etc.), but their potential as policy makers is untapped. Their actions are undertaken independently and without linkage to policies in other sectors, even when they have the same goal of making the Polish society healthier and more active.

Not only governmental structures, but also many processes, are already in place and dealing with PA promotion. Providing an umbrella covering all PA policies and activities is, therefore, an extremely important issue to be addressed in Poland. This is exactly what the WHO [21] recommended to its member states, emphasizing that it is governments that create the conditions for change in promotion of healthy lifestyles.

There are also strengths of the Polish PA policy approach. One of these is a regular PA monitoring. Data are collected in different population groups (i.e., adults, school-aged children, and adolescents) and mostly on a regular basis, with the use of different methodologies. However, the existing monitoring tools and methods do not account for different external and internal conditions that may be influential (e.g., age group and weather conditions). The surveillance data come mainly from self-reported surveys (e.g., IPAQ). According to Winckers et al. [59], who compared IPAQ results with accelerometer data, using subjective PA measures leads to a general overestimation of PA; low data validity is especially observed in a lower-educated adult group. This may raise a question of validity of the surveillance data, which is not complemented with objective measurements.

Despite the amount of data being collected, these are rarely used in policy formulation or evaluation. The only policy document that is based upon the data and uses these data for evaluation is the National Sport Development Program [41], developed by the Ministry of Sport and Tourism. Lack of a clear evaluation plan makes it impossible to monitor whether other programs or interventions have met their objectives and how they should be changed in the future to be more effective. With single exemptions, the data are also not used for PA promotion or communicated to the society.

Based on WHO guidelines [11], Poland sets the recommended daily PA for most population groups. However, the recommendations are communicated to the society to a low extent. It is not evaluated to what extent people are aware of their existence. An important problem identified during the HEPA PAT data collection process was the lack of Polish recommendations on reducing sedentary behavior, which affects a large share of population [57].

While the surveillance data enable regular monitoring and evaluation, not all major policy documents have an evaluation plan included. The need for improvement in policy evaluation both in Poland and in other countries was also highlighted by Gelius et al. [24].

The results of this study show the potential of the efforts taken so far in improving PA level across society. Numerous actions are undertaken at different levels; different policy documents are in place, different sectors are engaged, and a large amount of data are collected. What is missing is effective coordination making the linkage between different activities and bodies engaged, and between actions undertaken at different levels (i.e., national, regional, and local). Poland may benefit from this comprehensive assessment in numerous ways. The country may use the results to prioritize actions regarding PA promotion that has to be undertaken and formulate recommendations for further activities. The methodology may be used by the country in order to monitor particular areas of PA policy approach. Other countries may also benefit from this comprehensive assessment. They may use the adopted methodology in order to identify strengths and weaknesses of their PA promotion policy approach; they may use the results to identify and compare the weak and strong points of the PA policy. Finally, they may use some practices that were assessed as successful in Poland.

The present study suffers from some limitations. The research was conducted at the national level only, and no regional or local level PA-related activities were included. Thus, the subnational level requires investigation and will be a subject of further research.

As data collection took place in 2019, the influence of the COVID-19 pandemic on policies promoting physical activity in Poland could not be assessed in this study.

5. Conclusions

The study provides a comprehensive overview and assessment of the efforts undertaken to promote PA at the national level in Poland. The results confirm that the national PA policy approach has been constantly developing in Poland and currently includes multiple sectors and covers major population groups, although there is still room for improvement in most fields. While the need for improvement is recognized in most countries [24,60], lack of clear leadership and coordination of policies in Poland is almost an impassable barrier in increasing effectiveness of PA promotion in Poland. The findings from this study may help policymakers and practitioners design and plan actions to increase PA levels among the whole of society.

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Article

The Influence of *FTO, FABP2, LEP, LEPR,* and *MC4R* Genes on Obesity Parameters in Physically Active Caucasian Men

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Abstract: Obesity is a complex multifactorial abnormality that has a well-confirmed genetic basis. However, the problem still lies in identifying the polymorphisms linked to body mass and composition. Therefore, this study aimed to analyze associations between *FTO* (rs9939609), *FABP2* (rs1799883), and *LEP* (rs2167270), *LEPR* (rs1137101), and *MC4R* (rs17782313) polymorphisms and obesity-related parameters. Unrelated Caucasian males (n = 165) were recruited. All participants had similar physical activity levels. The participants were divided into two groups depending on their body mass index (BMI) and fat mass index (FMI). All samples were genotyped using real-time polymerase chain reaction (real-time PCR). When tested individually, only one statistically significant result was found. The *FTO* A/T polymorphism was significantly associated with FMI (p = 0.01). The chance of having increased FMI was >2-fold higher for the *FTO* A allele carriers (p < 0.01). Gene–gene interaction analyses showed the additional influence of all investigated genes on BMI and FMI. In summary, it was demonstrated that harboring the *FTO* A allele might be a risk factor for elevated fat mass. Additionally, this study confirmed that all five polymorphisms are involved in the development of common obesity in the studied population and the genetic risk of obesity is linked to the accumulation of numerous variants.

Keywords: genes; SNPs; obesity-related traits; obesity risk; physical activity; Caucasian men

1. Introduction

Obesity is defined as excessive body weight gain due to an increased accumulation of body fat that presents a leading cause of the largest public health problems [1], since nearly 40% of adults are overweight and 10–15% are obese worldwide [2]. Obesity phenotypes are associated with a higher risk of many medical problems such as cardiovascular events, metabolic disorders, type 2 diabetes, neuropsychiatric disorders, and some types of cancer, the majority of which can lead to elevated mortality risk [3–6]. An analysis of the latest work in the literature has shown that modifiable factors positively affect our well-being and health. The best effect can be achieved by combining positive actions in the field of diet, supplementation, moderate but systematic physical activity, and adding the right amount of sleep per day [7,8].

Obesity is a complex multifactorial disease that has a well-confirmed strong genetic basis but needs behavioral, developmental, and/or environmental influences to develop [1,9,10]. Several studies have demonstrated the role of lifestyle, including caloric intake and physical activity level, in the regulation of body weight [11,12]. However, the problem still lies in identifying the genes and polymorphic sites related to obesity and describing the biological mechanisms by which they exert their effects [9].

Although studies of the common obesity genetics were determined by genome-wide association studies (GWASs), this stage was set by research on monogenic obesity, which emphasized that the leptin–melanocortin signaling pathway is the major regulator of food intake. Several genes involved in the development of monogenic obesity are in or near loci subsequently linked by GWASs with obesity-related traits. To date, over 600 genes and chromosomal regions have been associated with the regulation of body weight and composition [9,13]. The genetic risk of common obesity is linked to the accumulation of numerous loci, each contributing a small part of the total obesity risk [9]. Therefore, the analysis of haplotypes and interactions between candidate genes are more informative than methods based on individual signal-nucleotide polymorphism (SNP) and might give additional information important for understanding complex interactions between various gene variants [14,15]. Consequently, in our study, we decided to analyze five of the most promising polymorphic sites localized within obesity-related genes: fat mass and obesity-associated (*FTO*), fatty acid-binding protein 2 (*FABP2*), leptin (*LEP*), leptin receptor (*LEPR*), and melanocortin-4 receptor (*MC4R*), which are characterized in Table 1 [9,16–22]. The genes were selected based on a literature review and our own previous studies. Recently, studies have confirmed that these SNPs are linked to obesity-related traits such as BMI, hip circumference, total body weight, body fat percentage, and cardiometabolic traits, among others. The noted associations are replicable across different ethnic populations as well as various age groups [9,13,16–22]. Guilherme et al. (2019) suggested that SNPs, which can affect body composition parameters, might influence physical performance [23].

Table 1. Characteristics of the studied genes and polymorphic sites.

Gene	Chromosome Location	Gene Product	Variant	Functions of the Protein
FTO	16q12.2	2-oxoglutarate (2-OG) Fe (II) dependent demethylase	rs9939609; T > A	influencing the activity of pathways controlling daily food intake, nutrient preference, appetite, and satiety as well as control overeating
FABP2	4q26	fatty acid binding protein 2	rs1799883; G > A; Ala54Thr	participating in the absorption, intracellular transport, and metabolism of dietary fatty acids and their acyl-CoA esters in the small intestine
LEP	7q32.1	leptin	rs2167270; G > A;	regulating appetite by its inhibitory effects on food intake and increases in energy expenditure by stimulating the metabolism and physical activity
LEPR	1p31.3	leptin receptor	rs1137101; A > G; Gln223Arg	mediating leptin signaling
MC4R	18q21.32	melanocortin-4 receptor	rs17782313; T > C	the major regulator of food intake and energy expenditure

The above-mentioned findings highlight the selected genes' association with body mass and body composition parameters. However, the results are inconsistent and the interactions between these candidate genes are still unknown. Thus, this study aimed to examine the associations between *FTO* (rs9939609), *FABP2* (rs1799883), *LEP* (rs2167270), *LEPR* (rs1137101), and *MC4R* (rs17782313) polymorphisms and obesity-related traits. Therefore, we studied individually and in gene–gene interaction models the alleles and genotypes distribution in a group of physically active Caucasian men measured for selected body mass and body composition traits.

2. Materials and Methods

2.1. Participants

One hundred and sixty-five unrelated military professionals were selected for this study. All participants were aged 19–54 years, ancestrally fitted (all volunteers were Polish and Eastern Europe residents for 3 generations), and they represented similar physical activity levels. The experimental protocols used in this study were conducted in accordance with the World Medical Association's Declaration of Helsinki and were positively verified by the Ethics Committee of the Military Institute of Hygiene and Epidemiology (no. 1/XXI /2016). The participants received an information sheet regarding the research details, aim of the study and procedures applied, as well as potential risks and benefits associated with their participation. All volunteers gave written, informed consent for the genotyping, and they were informed that the study will be anonymous and the results would be private.

2.2. Body Composition Measurements

Height was measured using a portable stadiometer (without shoes) (TANITA HR-001, Tanita Corporation, Tokyo, Japan). Body composition (including fat %) and body weight were measured using bioelectrical impedance analysis (BIA) using the TANITA MC-780 machine (Tanita Corporation, Japan) with an accuracy of 0.1 kg according to the procedure specified in the instruction manual (lightly dressed, without shoes). All measurements were performed according to the procedure specified in the instruction manual and without any metal objects. The following parameters were noted: BMI (kg/m^2), height (cm), weight (kg), fat mass index (FMI; kg/m^2) [24], visceral tissue index (VTI; level), and fat percentage (%).

The participants (n = 165) were divided into two groups depending on their BMI (body weight/height^2; kg/m^2). The control group (CON$_{BMI}$; n = 77) comprised people with BMI between 20.0 and 25.0, while the overweight group (OVER$_{BMI}$; n = 88) had a BMI of ≥25.0. They were also divided into two groups depending on their FMI (fat mass/height^2; kg/m^2). FMI values between 3 and 6 were classified as normal fat mass; FMI lower than 3 —fat deficit; FMI higher than 6—excess fat. Participants whose FMI values were 6 and lower were classified into the CON$_{FMI}$ group (n = 124), while those whose FMI values were higher than 6 were grouped into the OVER$_{FMI}$ group (n = 41). Statistically significant differences between participants in both groups were observed for parameters BMI (kg/m^2), age (years), weight (kg), FMI (kg/m^2), VTI (level) and Fat(%) (p-value < 0.01). No statistically significant difference was shown in the parameter height (cm) (p-value = 0.81, 0.34) (Table 2). Detailed characteristics of experimental groups are given in Table 2.

Table 2. Anthropometry and body composition of the participants.

Group	CON$_{BMI}$ (n = 77)	OVER$_{BMI}$ (n = 88)	p-Value	CON$_{FMI}$ (n = 124)	OVER$_{FMI}$ (n = 41)	p-Value
BMI (kg/m^2)	23.4 ± 1.3	28.7 ±3.5	<0.01	24.6 ± 1.9	31.0 ± 3.9	<0.01
Age (years)	29.6 ± 7.2	34.8 ± 7.7	<0.01	31.3 ± 7.3	35.5 ± 7.3	<0.01
Height (cm)	180.2 ± 7.4	180.4 ± 6.4	0.81	180.0 ± 6.8	181.2 ± 7.0	0.34
Weight (kg)	76.1 ± 7.6	93.4 ± 13.5	<0.01	79.9 ± 8.4	101.8 ± 14.9	<0.01
FMI (kg/m^2)	3.41 ± 1.0	6.5 ± 2.4	<0.01	4.0 ± 1.1	8.4 ± 2.2	<0.01
VTI (level)	3.2 ± 1.8	8.2 ± 3.6	<0.01	4.2 ± 2.2	10.9 ± 3.5	<0.01
Fat (%)	14.2 ± 3.7	22.1 ± 5.1	<0.01	15.8 ± 3.8	26.5 ± 3.7	<0.01

2.3. Genetic Analyses

The buccal cells of the participants were collected using swabs (Copan FLOQSwabs, Interpath, Murrieta, Australia). Genomic DNA was extracted from the donated buccal cells using a High Pure PCR Template Preparation Kit (Roche Diagnostics, Munich, Germany) according to the manufacturer's protocols. DNA samples of good quality and quantity were stored at -20 °C. The exclusion criteria were: failure in DNA extraction; DNA degradation; abnormal gene detection results; incomplete basic information. All samples were genotyped in duplicate, using TaqMan Pre-De-signed SNP Genotyping Assays, which are given in Table 3 (Applied Biosystems, Waltham, MA, USA) on a CFX Connect Real-Time PCR Detection System (Bio-Rad, Hercules, CA, USA) according to the manufacturer's recommendations. The assays contained primers and fluorescently labeled (FAM and VIC) minor groove binder (MGB) probes. The real-time PCR conditions were as follows: 5 min of initial denaturation (95 °C), then 40 cycles of denaturation (15 s, 95 °C) and annealing/extension (60 s, 60 °C).

Table 3. SNP genotyping assays used in the study.

Gene	Variant	Assay ID
FTO	rs9939609	C__30090620_10
FABP2	rs1799883	C____761961_10
LEP	rs2167270	C__15966471_20
LEPR	rs1137101	C___8722581_10
MC4R	rs17782313	C__32667060_10

2.4. Statistical Analyses

All statistical analyses were performed using the program R (version 2.0-1, The R Foundation for Statistical Computing; https://cran.r-project.org (accessed on 20 September 2021)). Anthropometric data are shown as mean values ± standard deviation and differences among experimental groups were analyzed with Student's t-test which was statistically significant when $p < 0.05$. To check the compliance of the variables with the normal distribution, the Shapiro–Wilk test was used and Levene's test was used for verification of the homogeneity of variance. Single-locus analysis was performed considering four genetic models (codominant, dominant, recessive and overdominant) and was calculated with the SNPassoc package for R. The models were constructed concerning the minor allele and were checked adjusted by age as a potential factor influencing the result. FDR-adjusted *p*-values were calculated with the fdrtool package for R. An odds ratio (OR) was used as a measure of association between an exposure and an outcome and to determine whether a particular genotype is a risk factor for being overweight. The Akaike information criterion (AIC) was used to evaluate how well a model fits the data. A genetic model-free Multifactor dimensionality reduction (MDR) was used to detect the influence of the common effect of gene × gene interactions on BMI and FMI, and it was calculated with MDR3.0.2 (http://sourceforge.net/projects/mdr/ (accessed on 20 September 2021)); chi-square test was used for checking the statistical significance of the model. Balance accuracy was used as the evaluation measure to rank potential models and cross-validation consistency was used to choose the best models. The association of single alleles with BMI was calculated with Pearson's chi-squared test with the STAT package for R. The level of statistical significance was set at the level of $p < 0.05$. Genotype frequencies were analyzed using Fisher's exact test with the STAT package for R.

3. Results

All genotype frequencies did not significantly different from the Hardy–Weinberg equilibrium expectations in the $OVER_{BMI}$ group (*p*-values range from 0.10 to 1.00), CON_{BMI} group (*p*-values range from 0.50 to 1.00), $OVER_{FMI}$ (*p*-values range from 0.56 to 1.00), CON_{FMI} (*p*-values range from 0.47 to 1.00), and the case–control group (*p*-values range from 0.33 to 1.00; Table 4).

Table 4. The probability that the genotype frequencies do not differ from Hardy–Weinberg expectations and minor allele frequencies (MAF).

SNP	MAF(%)	ALL	$OVER_{BMI}$	CON_{BMI}	$OVER_{FMI}$	CON_{FMI}
FTO (rs9939609)	allele A (38.48)	0.87	0.82	1.00	1.00	1.00
FABP2 (rs1799883)	allele T (23.94)	1.00	1.00	1.00	1.00	0.79
LEP (rs2167270)	allele A (46.36)	0.53	0.83	0.50	1.00	0.47
LEPR (rs1137101)	allele G (45.45)	0.88	0.83	1.00	1.00	0.86
MC4R (rs17782313)	allele C (20.00)	0.33	0.10	0.72	0.56	0.59

No significant association was found between *FTO* (rs9939609), *FABP2* (rs1799883), *LEP* (rs2167270), *LEPR* (rs1137101), *MC4R* (rs17782313) and the BMI value exceeding 25. All divisions were checked under four genetic models: codominant, dominant, recessive, and overdominant, *p*-values were between 0.11 and 0.98. The influence of single alleles on BMI division was also checked and no significant association was found (Table 5).

Table 5. Association analysis of the *FTO* (rs9939609) polymorphism with BMI.

Genetic Model	Genotype	$OVER_{BMI}$	%	CON_{BMI}	%	OR	95%CI		*p*-Value/*p*-Value */q-Value	AIC
Codominant	TT	32	36.4	31	40.3	1.00			0.74/0.84/0.62	233.4
	AT	41	46.6	36	46.8	1.10	0.57	2.15		
	AA	15	17.0	10	13.0	1.45	0.57	3.72		
Dominant	TT	32	36.4	31	40.3	1.00			0.61/0.56/0.58	231.7
	AT-AA	56	63.6	46	59.7	1.18	0.63	2.21		
Recessive	TT-AT	73	83.0	67	87.0	1.00			0.47/0.77/0.51	231.5
	AA	15	17.0	10	13.0	1.38	0.58	3.27		
Overdominant	TT-AA	47	53.4	41	53.2	1.00			0.98/0.72/0.69	232.0
	AT	41	46.6	36	46.8	0.99	0.54	1.83		
Alleles	T	105	59.66	98	63.64				0.53/-/0.54	
	A	71	40.34	56	36.36	1.82	0.84	1.89		

OR—odds ratio; 95% CI—confidence interval; AIC—Akaike information criterion; *p*-value *—adjusted by age *p*-value; q-value—FDR adjusted *p*-values.

The *FTO* gene polymorphism (rs9939609) was significantly associated with FMI exceeding 6 (Table 6). An association was found for the codominant (AA vs. TT), dominant (AT-AA vs. TT), and for the recessive genetic models (AA vs. TT-AT). The chance of being $OVER_{FMI}$ for the combination AA was over 4.7 times greater than for the combination TT in the codominant model (Fisher's exact test $p = 0.01$). The chance of being $OVER_{FMI}$ for the combination AT-AA was >2.7 times higher than for the combination TT in the dominant model (Fisher's exact test $p = 0.02$). The chance of being $OVER_{FMI}$ for the combination AA was >2.8 times higher than for the combination TT-AT in the codominant model (Fisher's exact test $p = 0.02$). Moreover, the chance of being $OVER_{FMI}$ was >2.0-fold higher for A allele with Pearson's chi-squared test *p*-value < 0.01. The model was supplemented with age as a potential factor influencing the result, because of statistical differences shown between groups for this variable (Table 6).

Table 6. Association analysis of the *FTO* (rs9939609) polymorphism with FMI.

Genetic Model	Genotype	$OVER_{FMI}$	%	CON_{FMI}	%	OR	95%CI		*p*-Value/*p*-Value */q-Value	AIC
Codominant	TT	9	22.0	54	43.5	1.00			0.01/0.01/0.02	182.2
	AT	21	51.2	56	45.2	2.25	0.95	5.35		
	AA	11	26.8	14	11.3	4.71	1.63	13.59		
Dominant	TT	9	22.0	54	43.5	1.00			0.01/0.01/0.02	182.6
	AT-AA	32	78.0	70	56.5	2.74	1.21	6.23		
Recessive	TT-AT	30	73.2	110	88.7	1.00			0.02/0.04/0.04	183.8
	AA	11	26.8	14	11.3	2.88	1.19	6.99		
Overdominant	TT-AA	20	48.8	68	54.8	1.00			0.50/0.32/0.53	188.6
	AT	21	51.2	56	45.2	1.28	0.63	2.59		
Alleles	T	39	47.6	164	66.1				<0.01/-/0.02	
	A	43	52.4	84	33.9	2.15	1.26	3.69		

OR—odds ratio; 95% CI—confidence interval; AIC—Akaike information criterion; *p*-value *—adjusted by age *p*-value; q-value—FDR adjusted *p*-values.

Gene–gene interactions' influence on BMI and FMI division was calculated with the MDR function. The best two-locus model in all divisions was that involving *FTO* (rs9939609) and *LEPR* (rs1137101), indicating a potential gene–gene interaction between these two genes. For BMI division, when genotypes AT × AA, TT × AA, TT × AG (*FTO* × *LEPR*, respectively) appear the model sorts the observations to join the CON_{BMI} group with a higher probability than joining the $OVER_{BMI}$ group ($p = 0.02$). For FMI division when the genotypes AT × GG, TT × AA, and TT × AG (*FTO* × *LEPR*, respectively) appear, the model sorts the observations to join the CON_{FMI} group with a higher probability than joining the $OVER_{FMI}$ group ($p < 0.01$; Table 7).

Table 7. Best gene–gene interaction models, as identified by MDR.

Number of Loci	Best Combination	Division	Cross-Validation Consistency	Testing Balance Accuracy	*p*-Value
2	*FTO* × *LEPR*	BMI	4/10	0.59	0.02
	FTO × *LEPR*	FMI	6/10	0.63	<0.01
3	*LEP* × *LEPR* × *MC4R*	BMI	5/10	0.64	<0.01
	FTO × *LEP* × *LEPR*	FMI	6/10	0.70	<0.01
4	*FABP2* × *LEP* × *LEPR* × *MC4R*	BMI	10/10	0.72	<0.01
	FTO × *FABP2* × *LEP* × *LEPR*	FMI	5/10	0.75	<0.01
5	*FTO* × *FABP2* × *LEP* × *LEPR* × *MC4R*	BMI	10/10	0.78	<0.01
	FTO × *FABP2* × *LEP* × *LEPR* × *MC4R*	FMI	10/10	0.81	<0.01

The best chosen three-locus model for BMI division involved the genes *LEP* (rs2167270), *LEPR* (rs1137101), and *MC4R* (rs17782313). The genotypes GG × AA × TT, GG × AG × TC, GG × AG × CC, GG × GG × TT, AA × AA × TT, AA × AA × TC, AA × AG × TT, AA × AG × CC, AG × AA × TT, AG × AG × TT, and AG × GG × CC (*LEP* × *LEPR* × *MC4R*, respectively) were selected by an algorithm to join the CON_{BMI} group ($p < 0.01$). For FMI division, the best three-locus model included the genes *FTO* (rs9939609), *LEPR* (rs1137101), and *MC4R* (rs17782313). The genotypes AT × GG × AA, AT × AG × GG, TT × GG × AG, TT × AG × AA, TT × AG × AG, and TT × AA × AG (*FTO* × *LEPR* × *MC4R*, respectively) were selected by an algorithm to join the control group with a higher probability ($p < 0.01$). When the genotypes TT × GG × GG, and TT × AA × AA (*FTO* × *LEPR* × *MC4R*, respectively) appeared, the model sorted the observations to join the CON_{FMI} group ($p < 0.01$). In all divisions in the four-locus and five-locus models when genotype was chosen to join the control group in *FTO* (rs9939609), only TT and AT genotypes appeared (Table 7).

4. Discussion

In the present study, we examined the allele and genotype distributions of the *FTO* (rs9939609), *FABP2* (rs1799883), *LEP* (rs2167270), *LEPR* (rs1137101), and *MC4R* (rs17782313) polymorphisms in a group of Caucasian men, who were divided into groups depending on their BMI and FMI. When tested individually, our statistical analyses showed that harboring the specific *FTO* genotype might be associated with FMI, which measures relative fat content. This association was found for the codominant (A/A vs. T/T), dominant (A/T-A/A vs. T/T), and also for the recessive genetic model (A/A vs. T/T-A/T). The chance of having an increased FMI was over two times higher for the *FTO* A allele carriers. This observation constitutes the first important finding of the present study, implying that harboring this specific allele is unfavorable for some individuals. The carriers of the A allele might have an increased accumulation of body fat and a higher risk of many obesity-related disorders.

In 2007, three independent groups demonstrated that a cluster of polymorphisms in the *FTO* first intron was strongly related to body mass and composition parameters and predisposes to overweight and obesity in children, teenagers, and adults [25–27]. Since then, many studies have proved that the *FTO* variants, especially the common A/T polymorphism (rs9939609), are significantly linked to obesity-related traits, e.g., BMI, FMI, body fat percentage, hip circumference, cardiometabolic traits, and many obesity-related medical problems. These associations are found across various ethnic populations and different age groups [18,25–29]. The A allele, identified as the risk allele, is linked to increased appetite and reduced satiety, a higher intake of dietary protein and fat, poor eating habits, and loss of control overeating, among others [18]. Consequently, it has been linked to the development of overweight and obesity, increasing the risk by 20–30%. About 16% of examined individuals are homozygous for the A alleles and these people weigh ~3 kg more than those without the risk allele [24]. In a previous study including 201 young women from Poland, the A allele was also associated with higher BMI [29]. Additionally, Zmijewski and Leońska-Duniec showed that the SNP within the *FTO* gene can influence athlete status in a study involving 196 elite swimmers and 379 control participants, who were all Caucasians. They found that harboring the T allele might be favorable for achieving success in sports such as swimming [30]. These results are in accordance with our study, which confirms that harboring the A allele is unfavorable for Polish men, who might have an increased accumulation of body fat. These results suggest that the *FTO* (rs9939609) polymorphism is a candidate marker for affecting body mass and body composition parameters in the Caucasian population.

A few potential biological mechanisms underlying the relationship between the *FTO* polymorphism and body mass and composition parameters have been revealed. The research has indicated that these associations are mediated through their functional interactions with distal surrounding genes. The first intron of the *FTO* gene contains a binding site for the transcriptional factor—cut-like homeobox 1 (CUX1). Through controlling retinitis pigmentosa GTPase regulator interacting protein 1 (RPGRIP1L) expression, it interacts with the leptin receptor [27,31]. The leptin signaling is mediated by this specific receptor, which in turn regulates food intake and energy expenditure [16]. Additionally, the *FTO* intron also includes an enhancer sequence, which interacts with the iroquois homeobox 3 (IRX3) promoter region, and thus the *FTO* SNPs regulate IRX3 expression in the human brain. The IRX3 relationship with obesity and the process of browning in adipose cells has been described [27,31,32]. Currently, some studies have indicated that the *FTO* gene is closely related to the regulation of levels of growth hormone and insulin-like growth factor I (IGF-1). IGF-1 is a crucial hormone in the development of metabolic syndrome, due to its influence on lipid and carbohydrate metabolism [33].

When the results obtained in our study were incorporated into the complex gene–gene interaction analysis, the novel finding was that all five studied polymorphisms are involved in the formation of obesity-related traits in the Caucasian population. These results imply that some individuals might benefit from carrying some combinations of genotypes. It was shown that for the two-locus model—*FTO* × *LEPR* interaction—both the BMI and FMI division genotypes, TT × AA and TT × AG, were associated with the absence of overweight. The same result showed the genotypes AT × AA with BMI division and AT × GG for FMI division. For three-locus model genotypes, GG × AA × TT, GG × AG × TC, GG × AG × CC, GG × GG × TT, AA × AA × TT, AA × AA × TC, AA × AG × TT, AA × AG × CC, AG × AA × TT, AG × AG × TT, and AG × GG × CC (*LEP* × *LEPR* × *MC4R*) showed a link to the lack of overweight in BMI division. The same association was shown for genotypes AT × GG × AA, AT × AG × GG, TT × GG × AG, TT × AG × AA, TT × AG × AG, and TT × AA × AG (*FTO* × *LEPR* × *MC4R*) in FMI division. For four-locus and five-locus models, only the genotypes TT and AT in *FTO* present when there was an association with the absence of overweight shown (both for BMI and FMI). In all models, when *FTO* was included, the genotypes TT and AT were linked with a lack of overweight, confirming that harboring the *FTO* T allele might be favorable for some individuals.

Although the analysis of individual SNPs showed only one association between harboring the specific *FTO* genotype and FMI, the gene–gene interaction analysis revealed numerous links between the genotypes of studied genes and obesity-related traits. This observation confirmed that the genetic risk of obesity is connected with the accumulation of numerous variants; thus, methods based on numerous SNPs are more informative than methods based on a single polymorphism. Cole et al. showed that the analysis of gene–gene interactions is a potential source of unexplained heritability, a significant focus of research into complex traits, including obesity, which involves a complex interaction between several genetic variants. Such polygenic traits frequently require etiologies in which complicated biological relations within different tissues, pathways, and networks underlie the trait development [15]. Studying gene–gene interactions has been especially important in the context of obesity [34], which is in accordance with our results.

Although numerous studies refer to the analysis of individual SNPs, which were selected for the present study, the literature on gene–gene interaction analyses is scarce. Therefore, the obtained results cannot be discussed with direct comparisons to other studies. In the study including 2386 individuals, De et al. analyzed interactions between twelve genetic variants robustly associated with obesity (*BDNF*, *ETV5*, *FAIM2*, *FTO*, *GNPDA2*, *KCTD15*, *MC4R*, *MTCH2*, *NEGR1*, *SEC16B*, *SH2B1*, and *TMEM18*). The authors underlined that the used methodology made it possible to reveal the background of interactions between genes known to influence BMI. They characterized the complicated interactions, emphasized new roles of the genes and highlight the involvement of regulatory frameworks in the development of obesity; e.g., rs17066891 in *MC4R* was identified as having the strongest main effect within this network, rs9940128 in *FTO* was identified as having the second strongest main effect in the network, and rs4358154 in *TMEM18* had the highest score for all measures which highlights the potentially significant role of this variant in the context of obesity [34]. In a study including 290 overweight/obese participants and 288 normal-weight controls, Rana et al. examined the effects of gene–gene and gene–environment interactions on the obesity risk in the Pakistani population. They analyzed the five obesity-associated genetic variants (*MC4R* rs17782313, *BDNF* rs6265, *FTO* rs1421085, *TMEM18* rs7561317, and *NEGR1* rs2815752). Surprisingly, the gene–gene interaction was not found to significantly influence any obesity-related anthropometric phenotype, such as BMI or body fat percentage [35].

The study group was very homogeneous, which is a strong point of our study. Participants had the same living conditions, physical activity levels, and meals, and yet the differences in the parameters related to body weight were statistically significant. This allows most of the environmental factors to be ruled out and might indicate a genetic background for the increased body weight. A potential limitation of our experiment is rather the small group size of the participants, which might not show the statistical power necessary to yield a meaningful analysis and the interpretation of the results. Previously, differences between sexes contribute to variation in the obesity-related traits such as levels of fasting glucose and insulin were described. Lagou et al. (2021) indicated that fasting insulin in women shows stronger genetic correlations than in men with waist-to-hip ratio and anorexia nervosa [36]. Unfortunately, this study only included adult men, and thus we did not have the chance to compare the results between different age groups and genders. The participants were also relatively young, healthy, and physically active, which could have influenced the results, because systematic exercise reduces body weight [37]. Additionally, it should be emphasized that this is an observational study and that no causal mechanisms can be inferred.

5. Conclusions

The results of the present study suggest that the *FTO* gene, when tested individually, and all selected genes (*FTO*, *FABP2*, *LEP*, *LEPR*, and *MC4R*), when tested in gene–gene interactions, can modify body weight and composition parameters (BMI and FMI). We showed that harboring the *FTO* A allele might be associated with an over two times increased FMI. This observation constitutes the first important finding of the study, implying that harboring this specific allele is unfavorable for some individuals. The carriers of the A allele might have an increased accumulation of body fat and a higher risk of many obesity-related disorders. The results suggested that the *FTO* (rs9939609) polymorphism is a candidate marker for affecting body mass and body composition parameters in the Caucasian population. From the gene–gene interaction analysis, we established the second novel finding. Namely, all five studied polymorphisms are involved in the formation of obesity-related traits in the Caucasian population. The results imply that some individuals might benefit from carrying some combinations of genotypes (e.g., for BMI: AT × AA, TT × AA, TT × AG; for FMI: AT × GG, TT × AA, and TT × AG-*FTO* × *LEPR*, respectively), as regards the BMI and FMI. Additionally, the gene–gene interaction analysis confirmed that harboring the *FTO* T allele might be favorable for some individuals. This observation confirmed that the genetic risk of obesity is connected with the accumulation of numerous variants; thus, methods based on numerous SNPs are more informative than methods based on a single polymorphism. Understanding the genetics of obesity can extend our knowledge of diet individualization and exercise programs. It is crucial for the prevention of obesity-related diseases, supplementation and medical care.

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