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Original Investigation

Changes in the biological condition and isometric strength of male and female youth during social isolation

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Purpose: The aim of the study was to investigate how the biological condition and isometric strength differ between the groups of physically active young people, those who have previously experienced social isolation associated with the COVID-19 lockdown and those who have not. Such isolation involved a reduction in physical activity.
Methods: During the observational study, 876 women and men aged 18-23 years, who started studying in University of Health and Sport Sciences, were examined (572 – before pandemic, 304 – after lockdown). Biological condition was assessed based on selected features treated as indicators of health risk. Anthropometric measurements, body composition analysis using the bioelectrical impedance method and tests of upper and lower limb and back muscle strength were performed. Selected indices were calculated: Body Mass Index, Waist to Hip Ratio, Waist to Height Ratio, Body Adiposity Index, Subcutaneous Fat Distribution Index, Body Cell Mass Index.
Results: As a result of social isolation, gender-dependent changes in biological condition and strength was observed. People who experienced isolation were characterized by a higher percentage of fat (P= .001 for both sexes) and a lower percentage of muscle (P= .001 for men and P= .011 for women), with greater difference in fat content observed in women. Increased body circumferences were observed only in the females (for hip circumference P= .008, for arm circumference P= .009) and decreased strength only in the males (for right hand and back P= .001, for left hand P= .006 and for leg P= .011). Fat distribution pattern changed only among women – those who have experienced lockdown presented greater fatness around the waist (P= .029 for Waist to Hip Ratio).
Conclusion: It can be concluded that the experience of social isolation associated with physical activity restriction increased the health risk and decreased strength of young people in a gender-specific manner.

Keywords: body composition, strength, amateur sport, lockdown.

Introduction

The World Health Organization in March 2020 declared the global pandemic COVID-19.[1] The increasing number of infections that were dangerous to health and life has necessitated the introduction of strict restrictions on social contacts and participation in activities outside the home.[1] Such limitation of physical activity, causing a significant change in the lifestyle of many young people, carried the risk of deterioration of the biological condition.[2,3] Researchers point out that the health risk associated with the pandemic was the result of many overlapping factors.[2] The lockdown has negatively influenced motor behaviors, levels of regular exercise practice, eating and nutritional patterns, and the psychological status.[2,3] Each of these factors individually and the coexistence of several of them influenced the general condition of the population of different ages, increasing the risk of infection complications and reducing the effectiveness of vaccinations.[2]
The virus that caused the pandemic has been named SARS-CoV-2 by the International Committee on Taxonomy of Viruses.[4] In January 2020, the first infection with this coronavirus in Europe was confirmed in France, and at the beginning of March 2020 - the first infection in Poland.[1] At that time, the first restrictions related to the epidemic were introduced in Poland (cancellation of mass events, closure of schools, distance learning, suspension of the activities of cultural institutions). Finally, the state of the epidemic was officially announced.[5] Since then, wider lockdown has been introduced, and the duration of previously introduced restrictions has been extended.[6] The possibility of going outside was limited to essential situations, e.g., shopping, visiting a doctor, walking a dog. Parks, boulevards, beaches and even playgrounds were closed, effectively discouraging or deterring people from leaving their homes. Hairdressing and beauty salons, fitness clubs, rehabilitation facilities and swimming pools were closed. Out of fear of infection and the legal consequences of not complying with the restrictions, many people have completely limited their trips outside and their daily activities.[2,3,5]
The first period of isolation in Poland lasted from March 2020 (school closures, distance learning) until June 2020. During the summer holiday period, some restrictions were lifted and physical activity outside the home was possible.[6] However, from October 2020, the restrictions were reinstated (school closures again, distance learning) and the second isolation period lasted until the end of May 2021.[5,6] In total, the isolation period lasted approximately 12 months.
The government restrictions described above made it difficult

to maintain the same level of physical activity as before the pandemic. The change in lifestyle, caused by the lockdown and the fear related to the risk of infection, constituted a separate health risk for young people.[5,6]

Despite the difficult pandemic situation, healthcare organizations monitored the biological condition of our population.[6] It was noted that the percentage of men and women with excessive body weight increased during the pandemic, particularly in the oldest age groups. At the same time, in the years 2019-2021, the percentage of Poles not engaging in recreational physical activity increased.[6] Research was also conducted on students' groups,[5,7,8] indicating unfavorable changes in body composition related to lowered level of physical activity.

Research on the diversity and determinants of students' biological condition has been conducted at the Faculty of Physical Activity and Sport for several decades.[9,10] Due to the occurrence of the COVID-19 pandemic and the introduction of lockdown affecting the level of physical activity, the research project was extended, the results of which are presented in the manuscript below. Therefore, the aim of the paper was to assess body composition, fat distribution and isometric strength of young people after a period of pandemic-connected social isolation. The variables selected for the study are measures of human biological condition, health risk,[11,12] nutritional,[13] and also training status.[12,13] Isometric strength is treated as a fundamental metric in assessing muscle function and has been reported to indicate the health of an individual.[14,15]

The following research hypotheses were formulated:

1. The experience of social isolation by young people is associated with increased level of fat and decreased muscle mass percentage.

2.The experience of isolation is associated in young people with fat redistribution.

3. The level of isometric strength is lower in young people experienced an isolation period.

4. Differences in body components, subcutaneous fat layer and isometric strength have the same direction in both sexes.

Methods

Participants

The cross-sectional research whose results were used in the presented work was carried out in the years 2017-2022 as part of the internal grants. The research connected with the social isolation period was approved by the Research Bioethics Commission (resolution no. 2/2020) and conducted according to the requirements stipulated in the Declaration of Helsinki. The participants were fully informed about all the experimental procedures, and written informed consent was obtained from all of them.

All first-year students of the Faculty of Physical Education and Sport were invited to participate in the study. Participation was voluntary and after the measurements, the students received individual results with interpretation. 1% of those invited to participate in the study refused. Inclusion criteria were: status as a 1st year student of the aforementioned faculty, no health contraindications to the measurements, practicing sport at amateur level (training different disciplines at least four times a week for 60 minutes). Exclusion criteria included: practicing sports professionally, illness or injury preventing all measurements. Before the pandemic, 32 professional athletes and 3 people who could not pass the test due to limb injuries were excluded from the study (6.1%); after lockdown - 14 athletes and 3 people with injuries were excluded from the study (5.6%). All those who volunteered to participate in the study declared that they did not undertake any additional physical activity during the isolation periods (other than activities of daily living). The application of the aforementioned inclusion and exclusion criteria resulted in a more homogeneous group in terms of calendar age and sedentary behaviors during social isolation.

Ultimately, the measurements and tests were conducted on a group of 876 people aged 18-23: 550 men (age 20.2±1.0 years, body height 181.0±6.8 cm, body mass 77.5±10.2 kg) and 326 women (age 20.0± .9 years, body height 167.5±6.4 cm, body mass 61.0±8.4 kg). These students practice sport at amateur

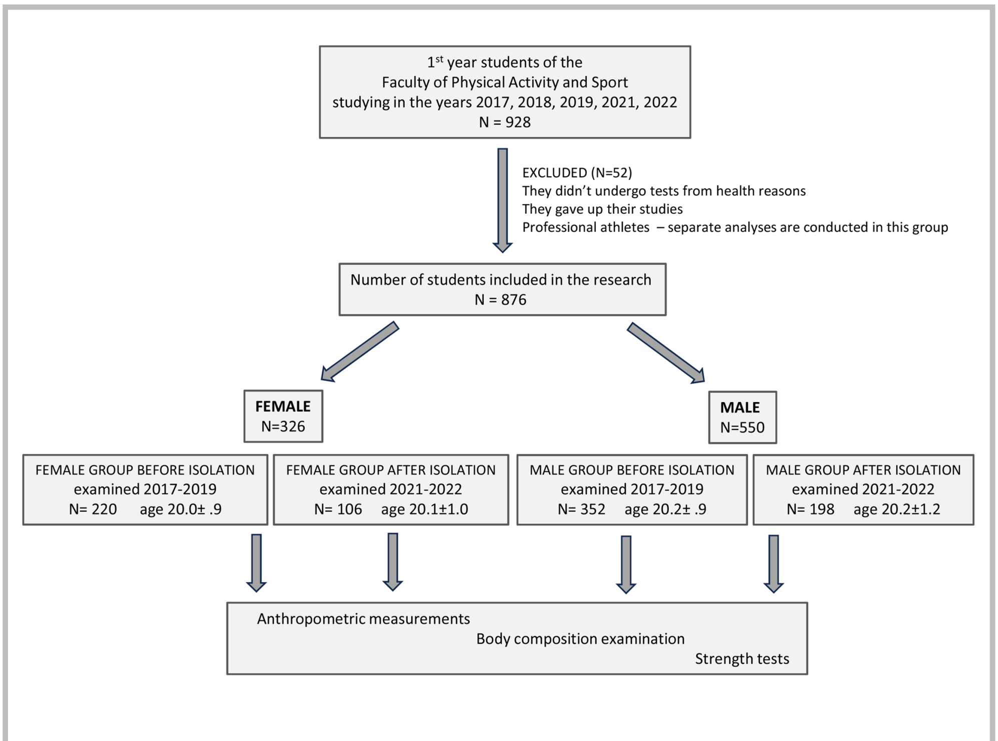

Figure 1. Flowchart of study design and data collection (N-number of participants)

level (sport activities including different disciplines at least four times a week, during classes at the university and outside the university). In order to perform comparative analyses, two groups of people were defined: 1) people examined in 2017-2019 were included in the "before pandemic" group with mean age of 20.15+/-.89 years; 2) people tested in 2021-2022 - in the "post-lockdown group" with mean age of 20.17+/-1.15 years (Figure 1). The compared groups did not differ significantly in terms of age. In 2020, there was a temporary ban on conducting tests in direct contact (introduced by order of the university authorities), as well as government bans hindering the organization of tests and preventing anthropometric measurements. The differences in the size of the pre- and post-lockdown study groups were only due to the fact that the first study group included 3 consecutive years and the second group included two years. This selection of study groups was partly dictated by the period of research funding (grant implementation).

Measurements
The measurements were carried out in the Central Research Laboratory at the University of Health and Sport Sciences (Quality Management System Certificate: PN-EN ISO 9001:2015 - Certificate Reg. No.: PW-15105-22X). Anthropometric measurements, body composition analysis using the bioelectrical impedance method and strength tests were carried out each year in the same season (October/November). All anthropometric and body composition measurements were done during the morning at a room temperature.

Anthropometric measurements
Length, width and circumference measurements were performed with certified anthropometric equipment: Martin anthropometer and analog ruler (GPM Instruments GmbH, Zürich, Switzerland). The body mass was measured with the use of an electronic scale (TP-200/1 WTL II B, Fawag S.A., Lublin, Poland). Skinfolds thickness was measured at the subscapular, abdominal,

Table1.Statistical characteristic of anthropometric variables and body mass components in male and female groups examined before pandemic and after lockdown.

Variables	Males				Females			
	Mean+SD		*P*	η^2	Mean+SD		*P*	η^2
	Before pandemic	After lockdown			Before pandemic	After lockdown		
Body mass [kg]	77.78±10.51	76.99±9.73	.386	.001	59.99±8.04	63.25±8.79	.001	.003
Body height [cm]	181.22±6.80	180.52±6.82	.242	.002	167.24±6.24	167.93±6.66	.361	.002
Waist circumference [cm]	80.53±6.40	80.55±6.25	.974	.000	70.03±6.28	71.00±6.81	.205	.005
Hip circumference [cm]	98.98±5.69	98.78±5.98	.694	.000	95.73±6.25	97.77±6.84	.008	.022
Thigh circumference [cm]	58.06±4.63	57.63±4.63	.298	.002	56.40±4.76	57.26±5.24	.144	.007
Calf circumference [cm]	38.10±2.56	37.89±2.49	.367	.001	35.60±2.60	36.11±2.58	.098	.008
Arm circumference relaxed [cm]	30.18±3.08	30.22±3.05	.868	.000	25.90±2.55	26.89±2.58	.001	.032
Arm circumference tensed [cm]	33.94±3.19	33.96±3.37	.929	.000	27.91±2.79	28.76±2.61	.009	.021
Subscapular skinfold [mm]	10.25±3.34	9.82±3.40	.148	.004	11.14±3.58	11.21±3.56	.883	.000
Triceps skinfold [mm]	5.83±2.67	5.00±2.58	.001	.022	9.89±3.87	8.54±3.85	.003	.026
Biceps skinfold [mm]	4.04±1.91	4.88±2.51	.001	.033	6.65±3.08	7.24±3.30	.129	.007
Forearm skinfold [mm]	3.76±1.20	3.51±1.13	.294	.002	4.61±1.65	4.85±1.86	.255	.004
Suprailiac skinfold [mm]	10.72±5.55	9.38±5.00	.005	.014	13.08±5.42	10.75±4.74	.001	.043
Abdominal skinfold [mm]	11.01±5.32	11.3±5.20	.495	.000	13.39±4.94	12.72±4.87	.251	.004
Calf skinfold [mm]	6.05±2.50	5.68±2.31	.655	.001	8.05±3.41	7.56±3.06	.211	.005
Fat mass [%]	17.99±4.76	19.78±5.07	.001	.031	25.25±5.32	27.73±6.11	.001	.043
Muscle mass [%]	57.99±5.07	55.89±6.23	.001	.033	49.70±5.48	47.86±6.34	.011	.023
Body cell mass [%]	58.87±3.17	57.69±4.80	.002	.022	55.22±2.89	53.64±5.4	.002	.035

suprailiac, triceps, biceps and calf locations with the use of Tanner/Whitehouse skinfold caliper (Holtain LTD, Crosswell, Crymych, Pembs, UK). Professional anthropologists performed measurements according to International Standards for Anthropometric Assessment.[16] Technical error of measurement was <1% for breadths, lengths and girths and <3% for skinfolds.

Body composition analysis

Body composition was examined by bioelectrical impedance analysis (BIA) using the BIA-101 Anniversary Sport Edition analyzer (Akern, Pontassieve, Italy; tetrapolar version, electrode position: hand-foot, Bodygram® HBO software). The measurements were taken in accordance with manufacturer's recommendations: the subjects were fasting during the measurements, they were lying on their backs in a horizontal position, their limbs were resting at 40-degree angle from the body and the time between the measurement and their last physical effort was 12 hours or more. Body fat percentage (FM%), muscle mass percentage (MM%), as well as body cell mass (BCM%) were estimated.

Anthropometric indexes

Based on anthropometric measurements and tissue components, indicators describing the biological condition, health risk, nutritional and training status of the students were calculated:

1) *Body Mass Index BMI* = weight [in kg] / body height^2 [in m^2]; The BMI expresses the overall massiveness/size of the body, and at the "population level" it positively correlates with body fatness.[13]

2) *Waist to Hip Ratio WHR* = circumference of the waist / circumference of the hips; It is considered as an estimate of abdominal fat or visceral fat mass. Increased WHR values indicating central obesity correlate with a worse prognosis regarding health and long-term survival.[17]

3) *Waist to Height Ratio WHtR* = circumference of the waist / body height; The WHtR informs us about the accumulation of fat at the waist level. The higher the values, the more fat is accumulated at the waist level, which increases health risks.[18]

4) *Body Adiposity Index* BAI = (circumference of the hips [in cm] / height^1.5 [in m]) – 18; BAI expresses the percentage of fat in body weight, calculated indirectly from anthropometric measurements.[19]

5) *Subcutaneous Fat Distribution Index* SFDI = (∑ of limb skinfolds: triceps+forearm+medial calf) / (∑ of trunk skinfolds: subscapular+suprailiac+abdominal); The SFDI provides information on the distribution of subcutaneous fat in the limbs and trunk locations. In adults, the mean values of the index do not exceed 100, indicating that subcutaneous fat content predominates on the trunk.[10,20] The smaller the values, the greater the difference between the trunk and limb fat layer.

6) *Body Cell Mass Index* BCMI = body cell mass [in kg]/ body height^2 [in m^2]; Body cell mass measurement has been suggested as a tool for evaluating nutritional and training status. It was proved that nutritional status, physical activity level and training, and disease states alter its values, which in turn serves as a biomarker of these processes.[11,21,22] Body cell mass is the total mass of all the cellular elements in the body which constitute all the metabolically active tissue (the oxygen-requiring, carbon-dioxide producing, glucose-burning cellular mass comprising all non-adipose cells as well as the aqueous compartment of adipocytes).[23] Higher BCMI values were recorded in elite athletes, which is related to the greater muscle content in these groups.[24,25]

Strength tests

Strength capabilities are also treated as indicators of the health of the population.[14,15,26] Hand grip strength was measured using the hand grip dynamometer (TKK5001, Takei Scientific Instruments Co, Ltd, Tokyo, Japan). The aim of this test was to measure the maximum isometric strength of the muscles in the hand and forearm. During the test, the upper limb was straight and pointing downwards.[27] Back and leg strength was measured using the back and leg dynamometer (TKK5402, Takei Scientific Instruments Co, Ltd, Tokyo, Japan). For the back strength test, the tested person was asked to stand straight on the dynamometer base so that the bar was level with the kneecap, and for the leg strength test, the person started the test with the knees bent (at an angle of 30 degrees) and then straightened the knees with pulling the bar.[28] Each volunteer performed three trials for these tests with 30 seconds of rest in between. The highest score was recorded in kilograms.

Statistical analyses

Statistical analyses were performed using the Statistica™ 13.3

Table 2. Statistical characteristic of anthropometric indicators in groups of women and men examined before pandemic and after lockdown (WHR and WHtR values are commonly given without units)

Indexes	**Males**				**Females**			
	Mean+SD		***P***	**η²**	**Mean+SD**		***P***	**η²**
	Before pandemic	**After lockdown**			**Before pandemic**	**After lockdown**		
BMI [kg/m^2]	23.65±2.60	23.60±2.47	.464	.002	21.42±2.42	22.40±2.64	.001	.032
WHR	.81±.04	.82±.04	.556	.000	.73±.04	.73±.04	.246	.004
WHtR	.54±.04	.55±.03	.456	.001	.57±.07	.58±.04	.029	.015
BAI [%]	22.51±3.31	22.78±2.60	.331	.002	25.92±5.20	27.00±3.38	.050	.012
SFDI [%]	57.97±17.77	58.23±16.94	.865	.000	77.29±23.50	78.84±26.54	.592	.001
BCMI [kg/m^2]	11.43±1.37	11.23±1.27	.107	.006	8.78±.97	8.94±1.1	.221	.005

Table 3. Statistical characteristic of strength test results in male and female groups tested before pandemic and after lockdown.

Variables	Males				Females			
	Mean + SD		P	η²	Mean + SD		P	η²
	Before pandemic	After lockdown			Before pandemic	After lockdown		
Right-hand grip strength [kg]	48.03±8.28	45.01±7.47	.001	.032	29.73±4.70	29.55±5.86	.767	.000
Left-hand grip strength [kg]	44.34±7.82	42.36±7.62	.006	.015	27.51±4.91	27.47±5.46	.959	.000
Back strength [kg]	132.34±24.17	117.98±26.23	.001	.069	75.91±16.98	78.22±23.58	.361	.003
Leg strength [kg]	143.37±26.62	131.88±34.58	.011	.031	78.84±17.99	82.95±31.18	.461	.005

package (TIBCO Software Inc., Santa Clara, United States). Descriptive statistics were used to analyze the collected data quantitatively. The compliance of the distribution of the analyzed variables with the normal distribution was checked using the Shapiro-Wilk test. Differences in the level of development of the analyzed features between the groups tested before the pandemic and the groups tested after the lockdown periods were assessed using the One-Way ANOVA. The results in the text and tables are presented as mean and standard deviation. The significance level for all statistical tests and procedures was set at an α value of 0.05. An effect size was measured by eta-squared (η). The following interpretation was adopted: effect size considered large when $\eta^2 \geq .14$, medium when $\eta^2 \geq 0.06$ and low when $\eta^2 \geq 0.01$.[29]

Results

The group of male students who underwent testing before the COVID-19 pandemic did not differ significantly in terms of overall body size from the group tested after lockdown. Both male groups' height and body weight were similar (Table 1). They also had similar waist circumference, hip circumference and limb circumferences (Table 1).

In the case of female students, the group tested after lockdown was characterized by a significantly higher body weight of 3 kg compared to female students tested before the pandemic (59.99±8.04 *vs* 63.25±8.79 kg; *P*=.001; η^2 = .003), with the same body height in both groups. Women examined after lockdown also had a significantly larger hip circumference of 2 cm (95.73±6.25 *vs* 97.77±6.84 cm; *P*= .008; η^2 = .022) and arm circumference of 1 cm (25.90±2.55 *vs* 26.89±2.58 cm; *P*= .001; η^2= .032). An effect size for body mass, arm circumference and hip circumference was low. Waist circumference and lower limb circumference did not differ significantly between the compared female groups (Table 1).

When analyzing the thickness of the subcutaneous fat layer, significantly thinner triceps skinfold (5.83±2.67 *vs* 5.00±2.58 mm; *P*= .001; η^2= .022) and iliocristale skinfold (10.72±5.55 *vs* 9.38±5.00 mm; *P*= .005; η^2= .014) were noted in men tested after lockdown compared to men tested before the pandemic (Table 1). The thickness of the skinfolds on the forearm, lower leg, abdomen and back was similar in both male groups, while the thickness of the bicep's skinfold was greater in men examined after lockdown. An effect size for skinfolds was low.

In women examined after lockdown, the thickness of the triceps and suprailiac skinfolds was significantly smaller compared to women examined before the pandemic (Table 1; low effect size). The thickness of the remaining skinfolds did not differ in both female groups.

Significant differences were noted in the body composition. Both women and men tested after lockdown had a significantly higher percentage of fat mass compared to same-sex groups tested before the pandemic (Table 1). The difference for female students was almost 2.5% of fat (25.25±5.32 *vs* 27.73±6.11 %; *P*= .001; η^2= .043), and for male students, it was less than 2% (17.99±4.76 *vs* 19.78±5.07 %; *P*= .001; η^2= .031). The percentage of muscle mass was approximately 2% lower in both the groups of men and women tested after lockdown compared to those tested before the pandemic (women: 49.70±5.48 *vs* 47.86±6.34 %; *P*= .011; η^2= .023; men: 57.99±5.07 *vs* 55.89±6.23 %; *P*= .001; η^2= .033). Body cell mass was also significantly lower in women and men examined after lockdown (Table 1). An effect size for body components was low in both sexes.

The values of anthropometric and body composition indices (BMI, WHR, WHtR, BAI, BCMI) did not differ significantly between the male groups (Table 2). Both male groups were also characterized by a similar pattern of subcutaneous fat distribution described as ratio of the limbs skinfolds to the trunk skinfolds thickness (SFDI) (Table 2). Other trends were observed in women. Female students examined after lockdown were characterized by significantly higher values of the BMI (21.42±2.42 *vs* 22.40±2.64 kg/h²; *P*= .001; η^2= .032) and WHtR (.57± .07 *vs* .58 ± .04; *P*= .029; η^2= .015) and BAI (25.92±5.20 *vs* 27.00±3.38 %; *P*= .050; η^2= .012) compared to women examined before the pandemic (Table 2; low effect size), which indicates lower adiposity of the latter. There were no differences between the analyzed female groups in the WHR, SFDI or BCMI (Table 2).

The grip strength of both hands (right: 48.03±8.28 *vs* 45.01±7.47 kg; *P*= .001; η^2= .032; left: 44.34±7.82 *vs* 42.36±7.62 ; *P*= .006; η^2= .015) and the strength of the back (132.34±24.17 *vs* 117.98±26.23 kg; *P*= .001; η^2= .069) and lower limbs muscles of men (143.37±26.62 *vs* 131.88±34.58 kg; *P*= .011; η^2= .031) turned out to be significantly lower in the group tested after lockdown, compared to men tested in previous years, before pandemic (Table 3). An effect size for back strength was medium in this case. In women, no differences in strength levels were observed between the study groups. In male and female groups examined after lockdown, an increase in intra-group diversity of the limbs and back strength was observed.

Discussion

During the COVID-19 pandemic, and especially during periods of isolation (lockdown), there was an increased health risk in various age groups due to, among other things, limited physical activity.[2,3] In universities and high schools teaching was carried out online and physical activity was reduced.[5,7]

No sports activities required using the school's infrastructure and conducting in direct contact was allowed. Government restrictions made it difficult to maintain the same level of physical activity as before the pandemic, which carried the risk of deterioration of biological condition.[3]

Therefore, the aim of the study was to find out whether situation of social isolation was associated with a decline in the biological condition and isometric strength in the group of physically active young people. In the presented work, the biological condition was assessed based on selected anthropometric indicators of body structure, nutritional status and training status, as well as the body composition.

As a result, it was found that the anthropometric indicators did not significantly differ between the male groups examined before and after the pandemic-related isolation. Both groups of male students had similar BMI and BCMI values, which may indicate that the overall body size and the mass of metabolically active cells did not change during the isolation period (BCMI is discussed in detail below). The average BMI, which was approximately 23.6 kg/m^2 in both groups, indicates that the sports university students have a correct weight-growth relationship. However, the body composition analysis provided additional information indicating a higher percentage of fat with lower percentage of body cell mass and muscle mass in the students group tested after lockdown. This result confirms that BCM could be considered as useful biomarker for interpreting training status and reflects well a decrease in muscle mass. However,

when physical activity is limited, the BCMI is considered to be insufficient to interpret the training status. In such an unusual situation, BCMI do not reflect a muscle mass characteristic, as reported in athletes' groups.[24,25]

Returning to anthropometric indexes, WHR and WHtR values were similar in the men groups examined in the 2017-2019 and 2021-2022. This means that fat deposit at waist level does not show any significant change during social isolation. This is also confirmed by the lack of differences in the thickness of the abdomen skinfold, as well as in the circumference of the waist and hips, and the smaller thickness of the skinfold over the iliac crest in male students examined after lockdown. This is particularly important for the health risks associated with the android type of fat accumulation.[17,30-33] Although the distribution of fat in the visceral deposit was determined based on anthropometric measurements, it can be concluded that a single factor - the accumulation of fat at waist level - did not pose an additional health risk for the examined male students.

Limb circumferences did not significantly differ between men groups. However, measurements of the limb's skinfolds revealed a change in the pattern of subcutaneous fat distribution, especially visible on the upper limb. In male students tested before the pandemic, the biceps skinfold was thinner than in those tested after lockdown. A different picture was provided by analyzing the triceps skinfold: it turned out to be thinner in the group tested after lockdown, which may be related to the different involvement of both muscles during everyday activities and may be perceived as a more health-risky pattern of fat distribution.[34,35]

Waist circumference and abdominal skinfold did not show increased accumulation of visceral fat. However, a slight change in the skinfolds with a clear increase in the total fat content, may indicate a change in the fat distribution pattern with an increase of internal fat deposit in the male group that had experienced limitations in physical activity. Previously published works have shown that physically active people have a characteristic fat distribution with a tendency to a strong reduction in visceral fat with relatively constant fat in the limbs, especially the lower ones (the so-called fit-fat distribution).[36] Based on the results obtained, it should be noted that when physical activity is limited, this pattern changes in the group of young men to become riskier for health.

Research conducted during the pandemic and also after isolation periods showed an increase in body weight in children, adolescents and adults.[5,7,37,38] Some studies have shown no change in body weight in boys and young men after a period of isolation, with both increased body fat and decreased muscularity.[39] In longitudinal studies, over several months, young men and women showed an increase in body weight and BMI, without a significant increase in fat content.[5] Also, according to these researchers, WHR values did not change significantly over several months of isolation, which indicated that fat accumulation at the waist level did not increase. This confirms the results described in the presented work with regard to male students. Changes within a year were described by Chwałczyńska and Andrzejewski.[7] According to these researchers, men's body weight and BMI increased slightly, but there were no significant changes in the percentage of fat. A slightly different picture of changes than that presented in this paper is probably due to a different research period. The cited authors studied small groups of students immediately before and during lockdown, while the presented work included larger cohorts of students and assessed differences in cross-sectional studies covering a longer period.

The other two anthropometric indicators analyzed in the study, SFDI expressing the ratio of subcutaneous fat in the limbs to the trunk and BAI expressing the percentage of fat content, turned out to be of little use in assessing the biological condition and health risk of young men in conditions of limited physical activity. Both male groups were characterized by a similar pattern of fat distribution in relation to the limbs and the trunk skinfolds and a similar BAI, although an increase in the values of the indicators could be expected, which would correspond to the observed higher content of total fat.[10,19]

An important difference observed during the research was a lower level of strength in the back muscles, leg muscles and hand grip in the male students tested after lockdown compared to the group before the pandemic. Combined with the lower muscle mass, this clearly indicates a deterioration in the biological condition of male students assessed on the basis of strength capabilities. Other authors, although they did not observe a significant decrease in the content of skeletal muscles of students during several months of isolation, showed that the COVID-19 pandemic negatively affected university students' well-being and led to a significant decrease in their physical activity and strength endurance level.[4] Other researchers have also demonstrated a deterioration in young people's physical fitness related to lockdown, expressed in worse results of some motor tests.[40]

A specific picture of the differences in biological condition between those experiencing lockdown and those who have not experienced social isolation is based on the comparison of female groups. Unlike men, women tested after lockdown had significantly higher body weight and fat mass than women tested before the pandemic. Similar changes were observed in longitudinal studies of Polish students,[7] in general population studies,[38] and even among college female athletes.[8]

Women examined after lockdown also had significantly larger hip circumference and arm circumference, which indicates a greater accumulation of internal fat in these areas. Measuring the thickness of skinfolds also revealed a change in how subcutaneous fat is distributed in women experiencing limited physical activity. In the group studied in 2021-2022, the triceps skinfold and suprailiac skinfold were thinner than in those studied before the pandemic. In this case, it can be assumed that in conditions of limited physical activity, the fat distribution pattern changes and subcutaneous fat tissue is no longer preferred which is an additional health risk factor for young women.[35]

Women examined after lockdown were also characterized by higher BMI, BAI and WHtR, which additionally confirms increased fat accumulation, more pronounced than in the case of men. It turned out that for women, the above-mentioned anthropometric indicators well reflect changes in body composition in the context of increased health risk in conditions of limited physical activities.

Among women, similarly to men, a lower percentage of muscle was recorded in the group examined in 2021-2022. However, the differences were less pronounced than in men and were not accompanied by a deterioration in strength capabilities. There were no differences in the level of grip strength of both hands or the muscles of the back and legs, as was observed in male students. Other researchers have shown a deterioration of certain elements of the physical fitness of young women related to lockdown, expressed in worse results of running tests.[40] Differences in the percentage of BCM content were also noted among the surveyed women, with no differences in the BCMI value. Lower BCM values in the female group in 2021-2022 indicate, as in the case of men, that BCM better reflect changes in the level of muscle mass than BCMI, differently as it was described previously in athletes population[24,25]

The previous research found that SFDI values increase in groups of women with lower physical activity,[10] which means that the distribution of subcutaneous fat on the trunk and limbs becomes more even. In female group with a higher activity level, the limbs are significantly less fatty than the trunk.[10] The current research does not confirm this relationship, as there were no differences in SFDI between women examined before the pandemic and after lockdown. Therefore, this indicator is of little use in assessing the biological condition and health risk of young women in conditions of limited physical activity. As described above, more information is provided by analyzing individual skinfolds and body composition.

Over the course of the study, significant differences were observed in body characteristics associated with fatness and also in strength between groups that experienced social isolation and those that did not. The eta-squared values indicate a low or medium effect size; however, it should not be forgotten, that the benchmarks are arbitrary and should not be interpreted rigidly.[29] Small effect sizes can have large consequences for health.

Practical Application

Our research has shown that the organisms of young women and men involved in amateur sport have responded to the social isolation associated with the COVID-19 pandemic in a gender-specific manner. This knowledge is extremely valuable for maintaining proper biological condition in both men and women and confirms the need for gender-specific training programmes and health checks. Women who experienced social isolation showed increased body fat mass and a different fat distribution, but no differences in strength levels. In contrast, in men who experienced social isolation, fat content did not differ significantly, but a different, more health-risky fat distribution was noted. At the same time, significantly lower limb and trunk strength was found in these men. The results therefore indicate the need for differentiated training methods to reduce fatness in women and improve the level of muscle mass and strength development in men. This means that training for women should mainly include aerobic efforts of longer duration. For men, on the other hand, anaerobic training that focuses on strength and muscle mass gains is advisable. Future research should look at which specific training methods are most effective in improving biological condition and reducing health risk in each gender.

Our research has also identified which commonly used measures of health risk are useful and which are not useful for monitoring biological condition in socially isolated and activity-limited settings. The variables that proved to be most useful for assessing biological condition and health risk under social isolation were, in men - biceps skinfold, fat and muscle mass and isometric strength test; while in women – body mass, hip circumference, arm circumference, fat and muscle mass and indexes such as BMI, WHtR and BAI. These variables showed significant differences between the pre-pandemic and post-isolation study groups and indicate a deterioration in the biological condition of young people. Also, the decrease in BCM with a simultaneous decrease in muscle mass values observed in both women and men indicates that this biomarker well reflects changes in physical activity and training status. This knowledge will allow for the appropriate selection of diagnostic tools to monitor the health status of men and women and the development of differentiated training programmes adapted to both sexes.

The limitations of the study include the cross-sectional nature of the research, which allows for comparison of the biological condition of youths' cohorts but does not provide indirect information about cause and effect. Also, the lack of assessment of energy expenditure should be considered a limitation of the study. More accurate information on physical activity (including energy expenditure) should be included in future research. Other limitations are imposed by the specificity of research methods, such as measurement of the skinfolds thickness and body composition analysis using the BIA analyzer without the possibility of examining visceral adiposity. This approach made it possible to draw indirect conclusions about changes in fat distribution connected with social isolation.

Conclusions

Considering the cross-sectional study results, it can be concluded that the experience of social isolation associated with physical activity restriction were connected with decreased biological condition and increased health risk in a gender-specific manner. These observations were made in young people who were physically active and engaged in amateur sport.

The results support the hypothesis that the experience of social isolation by young people is associated with increased amount of total body fat and decreased muscle mass in body weight, as well as with fat redistribution. A slight difference in skinfold thickness and subcutaneous fat distribution was observed. Isometric strength levels are lower in men after a period of isolation. In women group, our hypothesis relating to strength was not confirmed. Differences in body components have the same direction in both sexes, but their values vary. Fat redistribution, i.e. an increased accumulation of visceral fat in relation to subcutaneous fat (as evidenced by higher WHtR and BAI values) appeared mainly in women, whereas reduced muscle mass and isometric strength was more visible in men.

Future research should investigate which specific training methods are most effective in improving biological condition and reducing health risk in each gender. During the planning of public health strategies, the gender differences we have identified should be considered and gender-specific programmes should be created.

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Ethical Committee approval

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Informed Consent Statement

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

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Author-s contribution

Conceptualization, A.S. and J.P.; methodology, A.S.; formal analysis, A.S.; investigation, A.S., J.P. and A.B.; data curation, A.S.; writing—original draft preparation, A.S.; writing—review and editing, J.P. and A.B.; visualization, A.S.; supervision, A.B.; funding acquisition, A.S. All authors have read and agreed to the published version of the manuscript.

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