Results Obtained from the Anthropometric Evaluation Carried Out on High School Students during Physical Education Classes

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Abstract

In this study, we aimed to statistically evaluate the effect of an intervention combining diet and physical exercise on reducing body weight in middle school students. In this sense, we used several experimental parameters: Height, weight, perimeters (arm, hip, abdomen, chest), wingspan and body mass index. In this study, data were collected on these parameters before and after the use of natural supplements, with an interval of 12 months. 2 groups of children were used: an experimental group and a control group, in which natural supplements were not administered, but data were collected using the same time intervals. The students were administered one Spirulina 500 mg capsule and one Safflower Oil capsule once daily for 3 months, followed by a one-month break. This regimen was then repeated for 3 more months, with another one-month break. The results of the paired t-tests for the fold measurements show a significant difference between the before and after treatment values for the abdominal fold parameter (T = 2.34, p = 0.026). The treatment effect is therefore most visible in the abdominal fold changes, where we observe significant differences in the direction of a decrease in this parameter.

Keywords: *middle school students, body mass index (BMI), anthropometrics*

JEL classification: I12; I23

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1. Introduction

Anthropometric measurements

To demonstrate the hypothesis derived from our scientific approach, a series of anthropometric measurements was conducted. We resorted to a complete morphological examination, which, due to its complexity, also proved to be:

- ✓ Clinical, because it had the subject in front of it

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- ✓ Aesthetic, because it appreciated the harmony of development
- ✓ Anthropometric, because it measures the various components
- ✓ Biometric, because it interprets the measured values.

The basic examination that allows for the assessment of physical development through objectification is the anthropometric examination. It provided us with data through the direct measurement of body dimensions [10]. These measurements allowed the formulation of very valuable conclusions, which could be quantified.

The records were made on the following indicators:

- Body weight
- Height
- Waist circumference
- Thoracic circumference (at rest, during deep inspiration/expiration)
- Upper limb circumference (forearm)
- Adipo-centimetry (abdominal, neck, back, arms, thighs).

Determining body composition in middle school students:

To determine body composition, we will take into account body height or waist (T), body weight (G), and the thickness of five skinfolds (PI.C). When we talk about body composition, we are actually talking about the "active mass" (MA) represented by the skeletal muscles and the bone skeleton, the "adipose tissue mass" which, together with the internal organs, represents the passive mass of the body, the active Body mass index (BMI) indicates whether you are at a healthy weight for your height. BMI is used as a screening tool for overweight and obesity. In adults, a person with a BMI between 25 and 29.9 is considered overweight, and obese if the BMI is >/= 30. In children and adolescents, BMI is calculated in the same way, but interpreted differently. BMI for children is most often compared to the average body mass index of other children of the same age and gender. Obesity is associated with conditions that are the leading causes of death worldwide, such as type 2 diabetes, coronary artery disease, stroke, and some types of cancer [9]. Maintaining a healthy weight means supporting overall health, both now and in the future. This involves considering factors such as Body Mass Index (BMI) and, ultimately, body density."

Body mass index (BMI) is a widely used screening tool to evaluate body fat, based on body weight relative to height. It serves as an indicator for assessing obesity levels and identifying the extent of weight modification required to achieve a healthy BMI range [8]. Given the direct correlation between body weight and health, maintaining a BMI within the recommended parameters is essential for promoting overall well-being and reducing the risk of disease [7].

Higher body weight increases the risk of health problems, such as:

- ➢ cardiovascular diseases;
- ➢ heart failure;
- ➢ high blood pressure;
- ➢ myocardial infarction;
- ➢ stroke;

- joint diseases;
- some types of diabetes;
- some types of cancer.

Statistics show that people whose body mass index is in the range of 18.50 - 25 have a better health status. Exceeding this range, both plus and minus, represents a risk for health status. Body mass index values over 25 coincide with a proportional increase in health problems - the higher the weight, the greater the risk of health problems. But being underweight also represents a risk of health problems [6].

The further the body mass index "moves" from the range of 18.50 - 25, the greater the risk of health problems [11].

For adults aged >/= 20 years, BMI falls into one of the following categories:

- BMI < 18.5: underweight
- BMI 18.5-24.9: healthy weight
- BMI 25-29.9: overweight
- BMI >/= 30: obesity

Obesity is commonly divided into the following categories:

• Grade 1: BMI 30-34.9

• Grade 2: BMI 35-39.9

• Grade 3: BMI >/= 40. Grade 3 obesity is sometimes referred to as “morbid” obesity[14].

The classification of body mass index into these ranges is based on the effect that excess body fat has on the occurrence of certain diseases and on death in general:

• Body mass index takes into account the presence of an average amount of body fat, including abdominal fat (fat found inside the abdominal cavity, around the organs). Intra-abdominal fat is what increases the risk of type 2 diabetes and cardiovascular disease, compared to subcutaneous fat, in the deeper layers of the skin [3].

For children and adolescents, body mass index (BMI) is calculated using the same formula as for adults, but it is interpreted differently. BMI is interpreted based on age and gender, because children are still growing and developing, and boys develop differently from girls. For adults, BMI interpretation is independent of gender or age.

Since 2000, the Centers for Disease Control and Prevention (CDC) in the United States has introduced BMI calculators or charts for use in clinical practice [12].

These can be used for children starting at age 2, when a child’s height can be accurately measured. They use the child’s BMI, age, and gender to produce a child’s BMI percentile. A child’s BMI percentile shows how their BMI compares to the BMI of other boys and girls of the same age. These percentiles are calculated from the CDC growth charts, which were based on the body mass index of children in the United States who participated in national surveys collected from 1963-65 to 1988-94. For children aged 2-19 years, BMI for age is used to screen for overweight, healthy weight, or underweight. Depending on the BMI percentile, a child is considered:

- Underweight: BMI < 5th percentile
- Normal weight: BMI percentile between 5th and 85th
- Overweight: BMI percentile between 85th and 95th
- Obese: BMI >/= 95th percentile [15].

You should visit your paediatrician for routine checkups to check your child's body mass index at least once a year. A single BMI-for-age measurement is not enough to assess long-term weight, as your child's height and weight will change as they grow. It is important to track your weight over time to ensure that you are reaching and staying within a healthy weight range [18].

However, there are some situations where BMI can underestimate or overestimate these risks when BMI is in the range of 25-35.

The percentage of obese boys has doubled in the last 10 years. During this period of economic growth for Romania, an unhealthy nutritional transition has also occurred, with an increase in the consumption of foods with low nutrient content and high energy density (concentrated sweets, juices, fast food, chips), which leads to weight gain in children and adults, with lifelong health impacts [1].

Overweight is defined when the body mass index >1 standard deviation using the WHO nomograms for children and adolescents aged 5-19; Obese is defined when the body mass index >2 standard deviations using the WHO nomograms for children and adolescents aged 5-19; Underweight is defined when the body mass index <- 1 standard deviation using the WHO nomograms for children and adolescents between 5-19 years. Moderate and severe underweight is defined when the body mass index < -2 standard deviations using the WHO nomograms for children and adolescents between 5-19 years [2].

Scope

In this study, we wanted to statistically interpret the effect that the use of an intervention (diet and physical exercise) can have on the reduction of body weight in middle school students [5]. In this sense, we used several experimental parameters: Height, weight, perimeters (arm, hip, abdomen, chest), wingspan and body mass index. In this study, data were taken regarding these parameters before and after the use of natural supplements, with an interval of 12 months [7]. 2 groups of children were used, one experimental group and one control group, where natural products were not administered, but the data were measured using the same time intervals.

2. Methodology

Participants

The research was conducted in three secondary schools located in a rural environment, using samples from the secondary education classes in these schools.

The study test group consisted of 40 healthy volunteers, 16 girls and 24 boys, aged 11 and 12 years. Of the 40 students included in the control group, 24 are from Baia Elementary School and 16 are from Jurilovca Elementary School, in Tulcea County, 19 girls and 21 boys.

The study duration was 12 months. During this period, students in the experimental group were administered one 500 mg Spirulina capsule and one Safflower Oil capsule daily for three months, followed by a one-month break.

The study included two groups of students:

1. Experimental group – received natural products.
2. Control group – did not receive any natural products, but their data were measured at the same time intervals as the experimental group.

This study design allowed for a comparative analysis of physical and metabolic performance changes between the two groups.

Instruments

Adipocentimeter. The purpose of measuring folds is to estimate body fat distribution and overall body composition, which provides insight into an individual's nutritional and health status [13].

The purpose of measuring body perimeters in middle school students is to assess growth patterns, body proportions, and physical development, which can provide valuable information about their nutritional status, health, and overall physical fitness [17].

Statistical Analysis. The statistical analysis was performed using Python 3.12 with the SciPy package included to calculate descriptive statistics, t-test statistics [4], and plot graphs, along with the Shapiro-Wilk test and the Lavene test [16].

Procedure

- Written informed consent was obtained from all participating students.
- Participants had the option to withdraw from the study at any time.
- Measures were taken to ensure data confidentiality and comply with ethical research standards.

3. Results

Results obtained from the anthropometric evaluation before and after the administration of natural products in parallel with the sports tests

The middle school students were administered one capsule of Spirulina 500 mg and one of Safflower Oil once daily for 3 months, followed by a one-month break. This regimen was then repeated for 3 more months, with another one-month break. We first used a series of T-tests to determine if there were significant differences between the experimental group and the control group. For these tests, we used the difference between the initial and post-intervention values (Δ Armspan, Δ Arm perimeter, Δ Thorax perimeter, Δ Abd p, Δ Hip p, Δ BMI). We thus checked whether there was a significant difference between the way the tested parameters varied between the test group and the control group. We obtained significant differences between the groups ($p < 0.05$ and the absolute value of t Stat > t Critical) for the parameters BMI (body mass index), chest circumference (significant but borderline results) and arm circumference, the most significant parameter for these perimeter measurements [13].

The following tables present descriptive statistics for the following measured parameters:

- body weight (kg), height (cm), arm span (cm), Body mass index (BMI, mass (kg)/ (height (m)^2)
- perimeters: arm perimeter (cm), thorax perimeter (cm), abdominal perimeter (cm) and hip perimeter (cm)
- folds: tricipital fold (mm), abdominal fold (mm) and subscapular fold (mm)

The parameters are presented as initial (before treatment) and final (after treatment) values. The differences between the final and initial values are presented for each parameter (for each parameter $\Delta\text{Parameter} = \text{Parameter}_{\text{final}} - \text{Parameter}_{\text{initial}}$)

For each parameter, except for the fold measurements, the control group is also presented in separate tables. This group was also tested before and after treatment, in order to control anthropometric changes in height, weight and other changes in body sizes.

Violin plots, split by test time (before or after treatment), test and control groups and then sex are presented for each parameter except for height, weight and arm span. These plots are a combination of both the distribution of the data (kernel density estimation) and a box plot. The box plot shows the first (Q1) and third (Q3) quartiles (the ends of the box, represented by a thick black line) and the median (white dot). The box whiskers (thin black lines) represent values outside of the interquartile range (IQR) that are not outliers. The whisker range is calculated as $Q3 + 1.5 * IQR$ and $Q1 - 1.5 * IQR$.

For each parameter, descriptive statistics also include the results of the Shapiro-Wilk test of normality of distributions. The null hypothesis of the Shapiro-Wilk test is that the tested data is normally distributed. Values above 0.94 of the test statistic (for our sample size of 40 subjects) and values below 0.05 of the p-value would lead us to reject this null hypothesis and would suggest that the data are not normally distributed. This test is used to validate the normality assumption of t-tests. However, since our sample size is relatively large (N=40), the t-tests are robust enough to non-normally distributed data [13].

Test group weight and height statistics

Table 1

	Initial weight	Final weight	Weight difference	Initial height	Final height	Height difference
N (number of samples)	40	40	40	40	40	40
df (degrees of freedom)	39	39	39	39	39	39
Median	67.45	70.15	3.75	150.5	161	10
Mean	66.93	69.99	3.06	150.93	161.5	10.58
Minimum	48.7	54.1	-6.6	134	144	3
Maximum	90.8	101	12.8	169	176	21
Standard deviation	10.44	11.6	4.34	7.93	7.78	3.73
Variance	108.95	134.63	18.88	62.84	60.51	13.94
Kurtosis	-0.2	0.28	-0.45	-0.32	-0.74	0.38
Skewness	0.36	0.63	-0.08	0.05	-0.31	0.64
Shapiro statistic	0.97	0.94	0.99	0.98	0.97	0.96
Shapiro p-value	0.39	0.03	0.96	0.79	0.38	0.2

Control group weight and height statistics

Table 2

	Initial weight	Final weight	Weight difference	Initial height	Final height	Height difference
N (number of samples)	40	40	40	40	40	40
df (degrees of freedom)	39	39	39	39	39	39
Median	68	75	7	162	170	8
Mean	67.27	74.33	7.06	159.4	168.75	9.35
Minimum	48.8	51.7	-1	145	155	3
Maximum	88.2	104	15.8	168	180	19
Standard deviation	9.28	9.87	3.58	6.54	6.81	4.02
Variance	86.07	97.35	12.82	42.76	46.38	16.17
Kurtosis	-0.07	0.92	0.3	-1.07	-0.8	-0.48
Skewness	0.03	0.29	-0.19	-0.54	-0.21	0.63
Shapiro statistic	0.98	0.97	0.97	0.9	0.96	0.94
Shapiro p-value	0.6	0.43	0.44	0	0.16	0.03

Test group arm span and BMI (Body mass index) statistics

Table 3

	Initial BMI	Final BMI	BMI difference	Initial arm span	Final arm span	Arm span difference
N (number of samples)	40	40	40	40	40	40
df (degrees of freedom)	39	39	39	39	39	39
Median	28.74	26.34	-2.58	152.5	162	8
Mean	29.22	26.7	-2.53	153.1	163.05	9.96
Minimum	24.35	21.13	-6.89	132.5	149	2
Maximum	35.91	36.21	2.68	166	177	28
Standard deviation	2.57	2.91	1.91	7.44	7.4	5.33
Variance	6.6	8.5	3.66	55.37	54.77	28.39
Kurtosis	0.14	1.52	0.55	0.03	-0.79	2.29
Skewness	0.66	0.78	0.37	-0.38	-0.17	1.32
Shapiro statistic	0.96	0.96	0.98	0.97	0.97	0.89
Shapiro p-value	0.15	0.13	0.74	0.47	0.34	0

Control group arm span and BMI (Body mass index) statistics

Table 4

	Initial BMI	Final BMI	BMI difference	Initial armspan	Final armspan	Arm span difference
N (number of samples)	40	40	40	40	40	40
df (degrees of freedom)	39	39	39	39	39	39
Median	26.03	25.84	-0.06	154.5	167	10
Mean	26.39	26.03	-0.36	155.9	166.4	10.51
Minimum	21.49	21.36	-4.29	140	155	4
Maximum	32.79	32.64	2.53	172	176	19
Standard deviation	2.52	2.39	1.49	7.02	5.8	4.17
Variance	6.36	5.71	2.21	49.24	33.68	17.4
Kurtosis	0.07	0.47	0	-0.31	-0.92	-0.52
Skewness	0.38	0.16	-0.58	0.44	-0.03	0.58
Shapiro statistic	0.98	0.97	0.96	0.93	0.97	0.93
Shapiro p-value	0.61	0.3	0.17	0.02	0.25	0.01

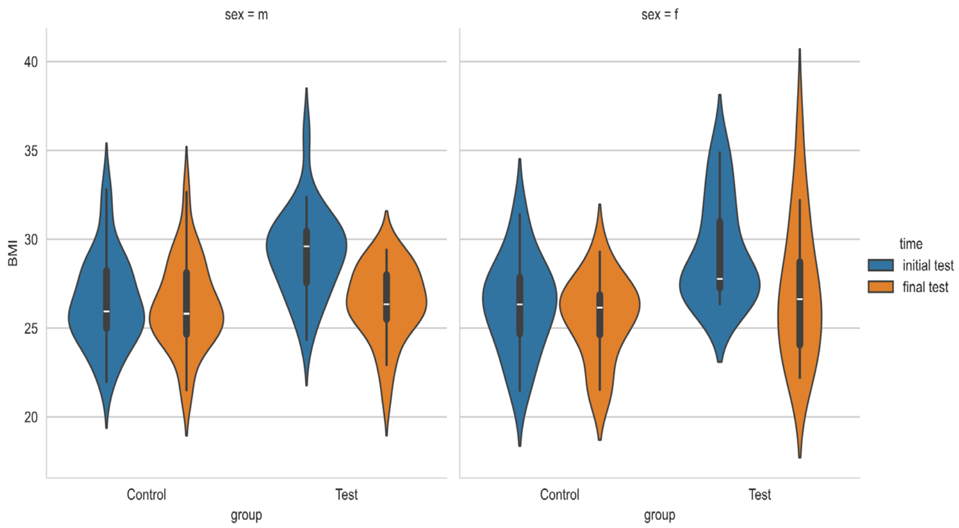

Figure 1. Violin plots of control and test groups for BMI (body mass index)

The test group data shows a visible decrease in the body mass index, compared to the control group data, where the BMI is relatively constant.

The relatively constant values observed in the control group suggest that the decrease in the BMI values observed in the test group can be attributed to the treatment effect.

Test group arm and thorax perimeter statistics

Table 5

	Initial arm perimeter	Final arm perimeter	Arm perimeter difference	Initial thorax perimeter	Final thorax perimeter	Thorax perimeter difference
N (number of samples)	40	40	40	40	40	40
df (degrees of freedom)	39	39	39	39	39	39
Median	27	30	3	77.5	93.5	12
Mean	26.88	30.15	3.28	79.32	92.28	12.95
Minimum	19	22	1	59	70	3
Maximum	33	35	7	96	110	37
Standard deviation	2.78	2.9	1.24	9.53	9.82	6.89
Variance	7.7	8.44	1.54	90.84	96.36	47.43
Kurtosis	0.51	-0.1	0.71	-0.6	-0.14	2.22
Skewness	-0.14	-0.37	0.77	-0.17	-0.45	1.25

	Initial arm perimeter	Final arm perimeter	Arm perimeter difference	Initial thorax perimeter	Final thorax perimeter	Thorax perimeter difference
Shapiro statistic	0.97	0.96	0.91	0.97	0.97	0.91
Shapiro p-value	0.39	0.19	0	0.39	0.29	0

Control group arm and thorax perimeter statistics

Table 6

	Initial arm perimeter	Final arm perimeter	Arm perimeter difference	Initial thorax perimeter	Final thorax perimeter	Thorax perimeter difference
N (number of samples)	40	40	40	40	40	40
df (degrees of freedom)	39	39	39	39	39	39
Median	26	28.5	2	77	95.5	15
Mean	26.68	29	2.33	81.18	96.52	15.35
Minimum	20	23	1	57	70	5
Maximum	33	36	4	99	118	26
Standard deviation	2.89	3.16	0.97	10.29	10.25	4.46
Variance	8.38	10	0.94	105.79	104.97	19.93
Kurtosis	-0.03	-0.09	-1.06	-0.49	0.57	0.14
Skewness	0.28	0.61	-0.01	-0.25	-0.15	0.06
Shapiro statistic	0.95	0.94	0.87	0.95	0.96	0.99
Shapiro p-value	0.06	0.05	0	0.06	0.17	0.94

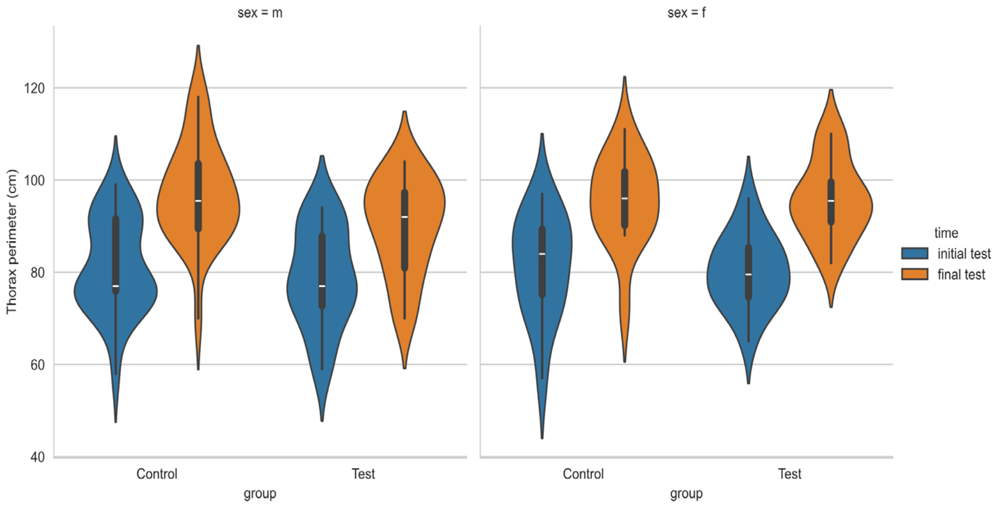

Figure 2. Violin plots for control and test groups for thorax perimeter

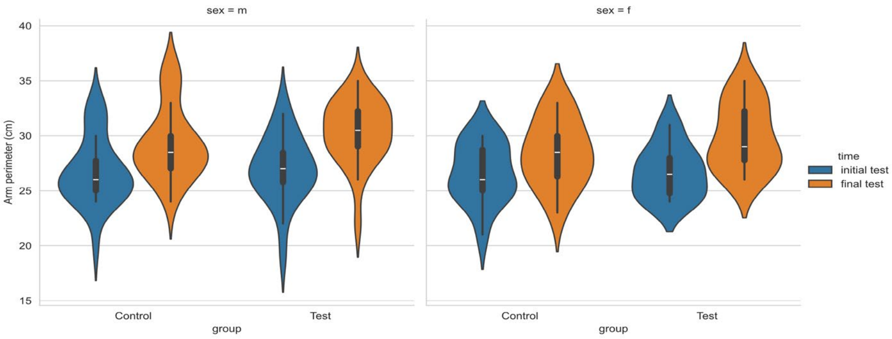

Figure 3. Violin plots for the control and test groups for arm perimeter

Both control and test groups show increased thorax and arm perimeter values. The increase is slightly steeper for the arm perimeter in the test group and slightly steeper for the thorax perimeter in the control group. These differences can be attributed to both fat and muscular tissue increases and will be further compared with the fold data.

Test group abdominal and hip perimeter statistics

Table 7

	Initial abdominal perimeter	Final abdominal perimeter	Abdominal perimeter difference	Initial hip perimeter	Final hip perimeter	Hip perimeter difference
N (number of samples)	40	40	40	40	40	40
df (degrees of freedom)	39	39	39	39	39	39
Median	81.5	85.5	2	94.5	96.5	3
Mean	81.9	84.88	2.98	93.28	97.18	3.9
Minimum	59	61	-20	65	69	-12
Maximum	110	112	22	114	125	30
Standard deviation	11.61	12.25	7.86	10.35	13.39	7.84
Variance	134.71	150.16	61.77	107.08	179.22	61.43
Kurtosis	-0.53	-0.49	1.83	0.48	-0.27	1.88
Skewness	0.04	0.23	0.22	-0.56	-0.12	1.13
Shapiro statistic	0.98	0.98	0.89	0.97	0.98	0.91
Shapiro p-value	0.86	0.65	0	0.41	0.84	0

Control group abdominal and hip perimeter statistics

Table 8

	Initial abdominal perimeter	Final abdominal perimeter	Abdominal perimeter difference	Initial hip perimeter	Final hip perimeter	Hip perimeter difference
N (number of samples)	40	40	40	40	40	40
df (degrees of freedom)	39	39	39	39	39	39
Median	85	90	4	95.5	98.5	2
Mean	83.74	88.5	4.76	97.25	99.18	1.92
Minimum	65	73	-1	84	82	-13
Maximum	95	105	14.5	115	122	15
Standard deviation	7.46	7.61	3.61	8.98	10.19	4.87
Variance	55.68	57.95	13	80.71	103.89	23.76
Kurtosis	-0.61	-0.62	0.35	-1.04	-0.74	2.21
Skewness	-0.34	-0.06	0.86	0.45	0.32	0.17

	Initial abdominal perimeter	Final abdominal perimeter	Abdominal perimeter difference	Initial hip perimeter	Final hip perimeter	Hip perimeter difference
Shapiro statistic	0.96	0.98	0.93	0.93	0.97	0.92
Shapiro p-value	0.13	0.61	0.01	0.01	0.35	0.01

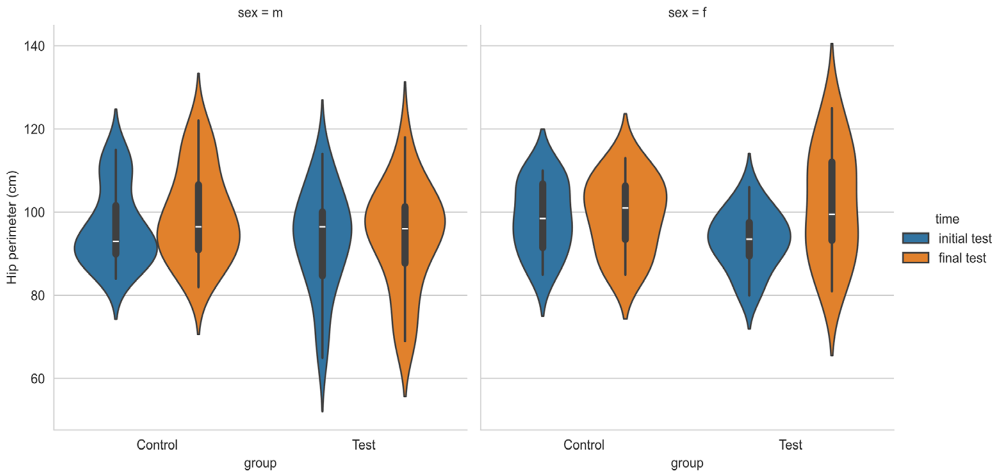

Figure 4. Violin plots for control and tests groups for hip perimeter

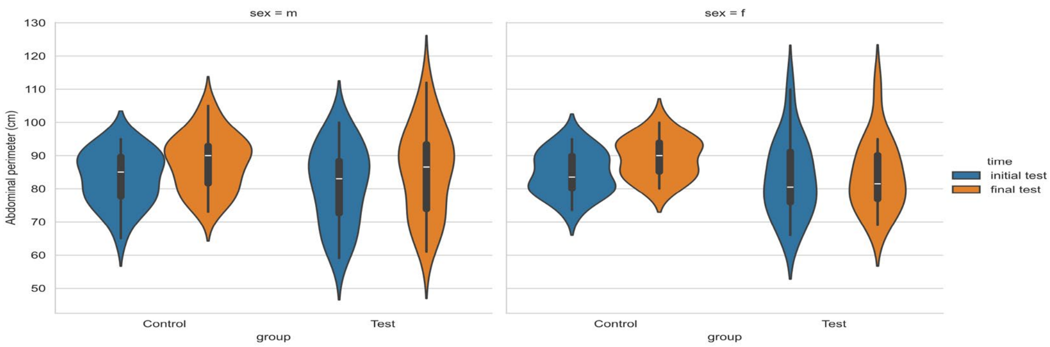

Figure 5. Violin plots for control and tests groups for abdominal perimeter

Both control and test groups show increased values for the abdominal and hip perimeters, except for a slight decrease in the hip perimeter of boys in the test group. It should be noted that the hip perimeter shows a higher increase for girls than for boys. The abdominal perimeter shows a steeper increase in the control group, compared to the test group. The hip perimeter difference between the final and initial measurements is overall higher for the test group.

Test group tricipital, abdominal and subscapular folds statistics

Table 9

	Initial tricipital fold	Final tricipital fold	Initial abdominal fold	Final abdominal fold	Initial subscapular fold	Final subscapular fold
N (number of samples)	40	40	40	40	40	40
df (degrees of freedom)	39	39	39	39	39	39
Median	21	21	38.5	30	21	20
Mean	23.5	21.69	34.17	24.85	22.55	18.24
Minimum	2	0.8	3	0.1	1	0.1
Maximum	48	42	50	48	60	48
Standard deviation	8.49	10.71	12.44	15.98	12	13.64
Variance	72.1	114.64	154.81	255.45	144.05	186.04
Kurtosis	1.33	-0.89	-0.11	-1.26	0.82	-1.1
Skewness	0.57	-0.02	-0.75	-0.33	0.51	0.1
Shapiro statistic	0.91	0.96	0.92	0.9	0.95	0.91
Shapiro p-value	0.01	0.16	0.01	0	0.06	0.01

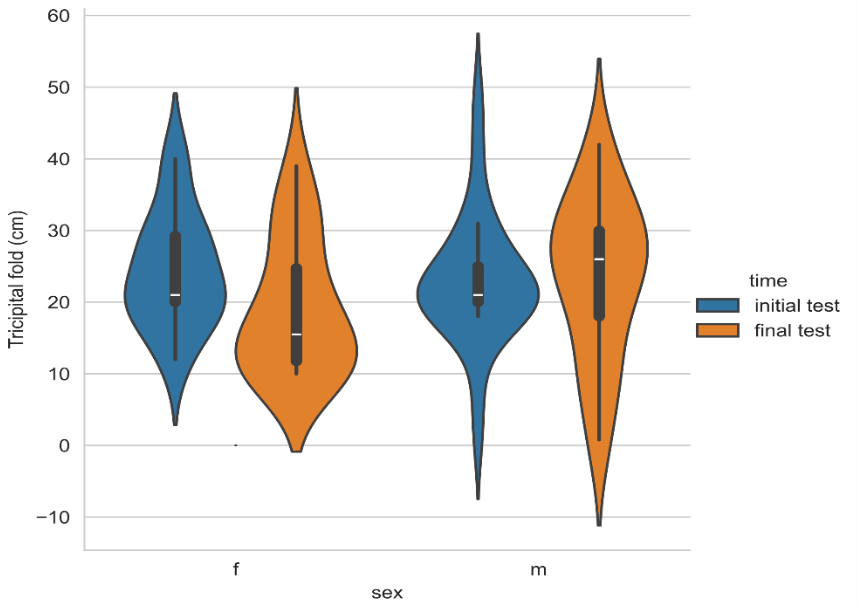

Figure 6. Violin plots for the test group, for the tricipital fold

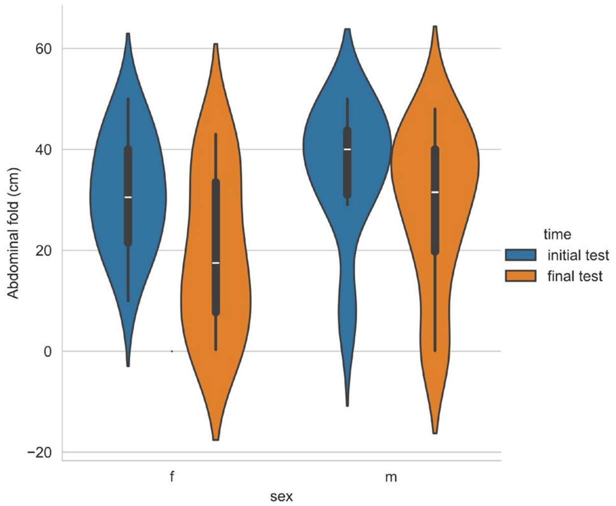

Figure 7. Violin plots for the test group, for the abdominal fold

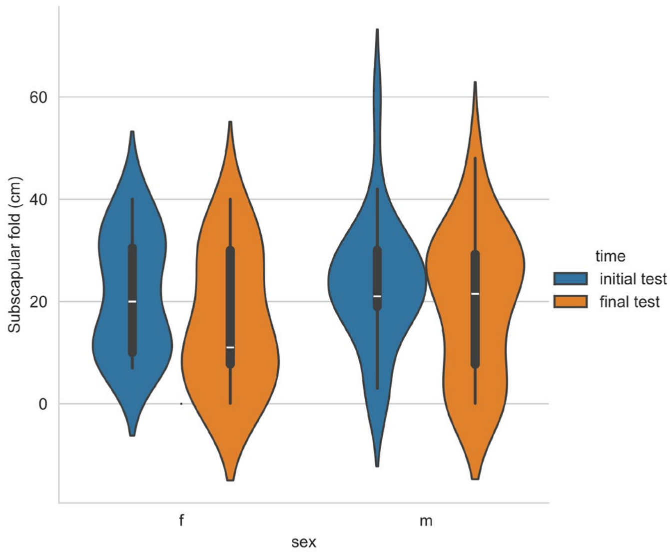

Figure 8. Violin plots for the test group, for the subscapular fold

When comparing the initial and final data for fold measurements (only test group data are present), we can observe a general decreasing trend for all values. Exceptions to this trend can be observed when the data is split by sex, revealing that boys have increased arm and subscapular folds after treatment.

The results of the tests demonstrate a positive effect of the treatment when looking at the BMI, where we see an important average decrease, mainly in the test group. At first glance, this result cannot be so clearly explained by changes in the perimeter measurements, where, across the two testing periods, we observed increases for both the control and test groups. However, when taking into account the controls, we can see lower average increases in the test group for the thorax and abdominal perimeters compared to the controls. Not the same thing can be said about the arm and hip perimeters, where the average increase was more significant in the test group. Nevertheless, it should be noted that these perimeter changes cannot be explained solely by adipose tissue changes, but also by muscular mass gain and other physiological changes.

Contrary to the perimeter measurements, the fold measurements showed a general, even if not uniform, decrease trend, which would suggest that these measurements can more accurately explain the BMI changes. Unfortunately, the control group was not included in the measurements for these parameters, and we also had to eliminate some outlier values from the test data due to extremely low values (<5 mm). For the tricipital, abdominal and subscapular measurements, we eliminated 3, 8 and 11 values, respectively.

In the following, to more accurately quantify the differences between the different groups and test periods, we assess the effect of the treatment using t-tests. Since we expect both increases and decreases in the final measurements, we chose to perform two-tailed t-tests at the significance level of 0.05.

For the parameters where we have control data (BMI and perimeters), we used independent t-tests to compare the test and control group data, as well as to examine individual differences between the final and initial values for both the control and test groups (Δ Parameter = Parameter $_{final}$ – Parameter $_{initial}$). A significant difference between ΔTest and ΔControl would show a significant effect of the treatment (positive or negative).

For the parameters where we have control data (BMI and perimeters), we used paired (dependent) t-tests to compare the control measurements before and after treatment. These measurements were controlled by subtracting the control mean from each subject, for both before and after treatment measurements. A significant difference between the before and after measurements would indicate a significant effect of the treatment.

For the parameters where we lack control data (fold measurements), we performed paired (dependent) t-tests between the before and after measurements. A significant difference between before and after measurements would indicate a significant effect of the treatment.

For each t-test, Levene tests for homogeneity of variance are also included for reference, but not strictly necessary since we have equal sample sizes that would guarantee that the t-tests are robust enough even when the variance is significantly different between the groups. The Levene test assumes that the variance of the two compared groups is equal. Values below 0.05 of the Levene p-value lead us to reject this null hypothesis and conclude that the two groups compared have unequal variances.

Δ Control vs Δ Test groups independent t-test results for BMI, arm perimeter, thorax perimeter, abdominal perimeter and hip perimeter

Table 10

	BMI	Arm perimeter	Thorax perimeter	Abdominal perimeter	Hip perimeter
Degrees of freedom (df)	39	39	39	39	39
Significance level (α)	0.05	0.05	0.05	0.05	0.05
T statistic	-5.66	3.81	-1.85	-1.31	1.35
T critical (two-tailed)	2.02	2.02	2.02	2.02	2.02
p-value (two-tailed)	$2.41*10^{-7}$	$2.71*10^{-4}$	0.068	0.19	0.18
Levene statistic	1.7	0.36	2.82	4.38	4.94
Levene p-value	0.2	0.55	0.1	0.04	0.03
Cohen d effect size	-1.27	0.85	0.41	0.29	0.3

The results for the independent t-tests show significant differences between the control and test groups for the BMI (T=-5.66, p<0.05) and arm perimeter (T=3.81, p<0.05) measurements and a nearly significant difference for the thorax perimeter. This test shows that the change across the two testing periods differs significantly between the test and control groups, suggesting that the treatment had an effect on these two parameters. However, the treatment has an opposite effect on these two parameters, as the BMI is decreased, the arm perimeter increases after the treatment period. We can see large effect sizes for both the BMI and the arm perimeter (d= -1.27 and d = 0.85, respectively).

Controlled initial vs final paired t-test results for BMI, arm perimeter, thorax perimeter, abdominal perimeter and hip perimeter.

Table 11

	BMI	Arm perimeter	Thorax perimeter	Abdominal perimeter	Hip perimeter
Degrees of freedom (df)	39	39	39	39	39
Significance level (α)	0.05	0.05	0.05	0.05	0.05
T statistic	7.17	-4.85	2.2	1.44	-1.6
T critical (two-tailed)	2.02	2.02	2.02	2.02	2.02
p-value (two-tailed)	$1.26*10^{-8}$	$2.04*10^{-5}$	0.03	0.16	0.12
Significance level (α)	0.05	0.05	0.05	0.05	0.05
Levene statistic	0.04	0.54	0.001	0.06	2.05
Levene p-value	0.84	0.47	0.97	0.8	0.16
Cohen deffect size	0.79	-0.33	0.25	0.15	-0.17

The results of the paired t-tests for the BMI and perimeter measurements show significant differences between the final and initial measurements for BMI ($T=7.17$, $p<0.05$), arm perimeter ($T=-4.85$, $p<0.05$) and thorax perimeter ($T=2.2$, $p=0.03$), when controlled by subtracting the average control group values. The test suggests that the treatment had a significant effect on these parameters, even if not in the same direction. The controlled values of the BMI and thorax perimeter decreased, while the arm perimeter increased, suggesting that these parameters are the best indicators of the effect of the treatment. Between these parameters, the BMI is the only one where we see a large effect size ($d = 0.79$), while for the arm and thorax perimeters we see a small effect size ($d=-0.33$ and $d=0.25$, respectively).

Paired t-test results for before and after treatment measurements for tricipital fold, abdominal fold and subscapular fold

Table 12

	Tricipital fold	Abdominal fold	Subscapular fold
Degrees of freedom (df)	39	39	39
Significance level (α)	0.05	0.05	0.05
T statistic	0.53	2.34	0.09
T critical (two-tailed)	2.02	2.02	2.02
p-value (two-tailed)	0.6	0.026	0.93
Significance level (α)	0.5	0.5	0.5
Levene statistic	3.82	0.54	0.001
Levene p-value	0.054	0.47	0.97
Cohen d effect size	0.13	0.48	0.02

4. Conclusions

The results of the paired t-tests for the fold measurements show a significant difference between the before and after treatment values for the abdominal fold parameter ($T = 2.34$, $p = 0.026$). The treatment effect is therefore most visible in the abdominal fold changes, where we notice significant differences, in the direction of a decrease of this parameter.

Data Availability Statement: Data are available upon request from the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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