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STUDY ON THE CORRELATION BETWEEN PHYSICAL DEVELOPMENT INDICES AND HEALTH STATUS PARAMETERS IN MIDDLE SCHOOL STUDENTS WITHIN THE CONTEXT OF PHYSICAL EDUCATION AND SPORTS ACTIVITIES

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Abstract

Aim. In this study, we aimed to statistically evaluate the effect that an intervention (diet and physical exercise) may have on reducing obesity in children. To this end, we used several experimental parameters: height, weight, body circumferences (arm, hip, abdomen, chest), arm span, and body mass index (BMI). Data for all these parameters were collected both before and after the intervention, over a period of 12 months. Two groups of children were used: an experimental group, which received the intervention, and a control group, which did not receive the intervention but was measured at the same time intervals.

Methods. To test the statistical significance of the intervention, we used several types of tests, conducted with Microsoft Excel and the online statistical program VassarStats (vassarstats.net). We first applied a series of t-tests to determine whether significant differences existed between the control group and the experimental group.

Results. For these tests, we used the difference between the pre-intervention and post-intervention values. In this way, we examined whether there were significant differences between the two groups in how these parameters changed over time.

Conclusions. We found significant differences between the groups ($p < 0.05$ and |t Stat| > t Critical) for BMI, chest circumference (significant but borderline), and arm circumference—the latter being the most significant parameter among the circumferences tested.

Keywords: secondary school students, BMI, natural supplements, violin plots, physical activity.

Introduction

The present preliminary research aims to contribute to the optimization of the instructional-educational process specific to physical education lessons in lower secondary school, by integrating strategic sports games used internationally and evaluating their effectiveness in the Romanian school context. At the same time, the research seeks to develop students' general physical fitness and promote a healthy lifestyle among pupils from rural areas (Ergin, Lok & Lok, 2020).

The choice of this topic was motivated by the desire to deepen the theoretical and applied dimensions of the field of physical education and school sports, as well as to contribute, through scientific research, to the modernization and improvement of the content and teaching strategies used in physical education classes. A central objective is the formation and consolidation of an active and balanced lifestyle among students, which is essential for healthy growth and development (Deaconu, Voicu, Curpan & Văcărețu, 2022).

In the contemporary context, marked by a significant increase in sedentary behavior and a decline in physical activity levels among children and adolescents, the concern for optimizing students' physical development and motor capacity becomes a strategic priority for modern educational systems (Stoyel et al., 2020). Recent studies highlight the need to coherently integrate physical activity into students' daily lives as a fundamental component of physical, mental, and social health (Miroslava, & Miroslava, 2021).

In rural areas, challenges related to students' physical development are often intensified by factors such as limited access to sports infrastructure, lack of adequate equipment, or insufficiently organized physical education programs. Recent research shows that students from these areas display significant differences in motor parameters compared to those from urban environments, emphasizing the need for interventions adapted to the rural context (Imamova, 2022).

On the other hand, the international specialized literature indicates a growing interest in the use of natural supplements—such as plant-based products, vegetable protein extracts, or bioactive nutrients—as complementary means of supporting physical performance and bodily recovery among physically active children and adolescents. The rational use of these supplements, in correlation with age-appropriate physical exercise programs, can contribute to optimizing muscular development, endurance, coordination, and overall motor capacity (Jagim, & Kerksick, 2021).

Therefore, the present study aims to investigate ways of optimizing the physical and motor development of lower secondary school students from rural areas by combining regular physical exercise with the controlled use of natural supplements, drawing on internationally validated models published after 2020. The main goal is to identify effective, sustainable, and safe strategies that can be implemented in the rural educational environment, contributing to the

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development of an active and healthy lifestyle from the early years of lower secondary education (Marcu, Borz, & Oprea, 2020).

According to the specialized literature, a healthy lifestyle reflects a set of behaviors and attitudes that support general health and psychological well-being (Hodder et. al., 2022). It includes factors such as balanced nutrition, regular physical activity, proper rest, and maintaining emotional balance.

International studies confirm that promoting these behaviors from an early age has a lasting impact on health and school performance. Within this research, we will conduct a comparative analysis between traditional physical education programs and innovative programs focused on motor activity and mental components, used at the international level.

The main objective is to identify effective ways to optimize the physical education lesson for lower secondary school students by increasing its attractiveness, student engagement, and performance levels (Reale, Roberts, Lee, Bonsignore, & Anderson, 2020).

Numerous educational studies have shown that promoting the playful dimension within motor activities generates complex cognitive, affective, and social benefits. Dynamic games stimulate the pleasure of participating in physical activities, contributing to the development of motor skills, the improvement of cooperation abilities, and the strengthening of interpersonal relationships among students (Delipovici, 2020).

This topic presents significant scientific and practical interest, with the potential to generate practical solutions for improving the national system of physical education and sports at the lower secondary level. From the perspective of modern, student-centered didactics, the integration of interactive and strategic learning methods is necessary in order to capitalize on the motor, intellectual, and socio-emotional dimensions of students.

By applying strategic games and exercises based on international models, we aim to develop reflective and critical thinking skills, increase the level of personal responsibility, promote a balanced lifestyle, and strengthen socialization within the school environment (Tarbeeva et. al., 2021). Additionally, diversifying the school curriculum by introducing these methods can contribute to increasing the lesson's density and attractiveness, as well as to modernizing educational content.

Modernizing the physical education lesson requires a revision of traditional didactics by implementing interactive, research-based methods adapted to the psychophysical characteristics of lower secondary students. Modern student-centered didactics grounds the instructional process on scientific principles of active learning, with the ultimate goal of fostering the holistic development of the student's personality (Tihulcă, & Popescu, 2020).

The starting point of this research is improving the quality of the educational process in physical education by optimizing motor content and teaching methods. The enjoyment of participating in physical activities represents a key psychological factor in forming positive attitudes toward physical effort, significantly influencing students' motivation and involvement.

The selection of this topic was directly influenced by the teaching experience accumulated through activities conducted with lower secondary students, as well as by the desire to understand and improve the balance between physical activity and mental activity. At the same time, both the specialized literature and school practice have highlighted the need to develop programs for preventing and combating overweight and obesity, starting as early as primary school (ages 6–11), through educational activities, awareness, and the involvement of families and teachers (Deaconu et. al., 2022).

In this context, the proposed research aims to design and implement an integrated program intended to optimize the physical development and motor capacity of students from rural areas, by combining physical exercise with the use of natural supplements, in accordance with the principles of health education and sustainable development (Deforche et. al., 2003).

Objectives

The purpose of the preliminary research is to analyze the usefulness and effectiveness of structured physical programs and activities, as well as to evaluate their impact on students' physical development and individual training. The approach aims to identify strategies adapted to the rural environment that can contribute to improving physical fitness and strengthening health.

At the same time, the research seeks to investigate the complementary potential of physical well-being programs in combination with the use of natural plant-based supplements, with the aim of optimizing physical development parameters and supporting overall health. This integrated approach may offer relevant perspectives for designing educational and nutritional interventions tailored to the needs of lower-secondary students.

Methods

The study was organized and conducted between February 2023 and March 2024, following a phased structure and an experimental design specific to research in the fields of physical education and biomedical sciences. The investigations focused on analyzing functional, morphological, and biological indicators in middle school students (Hayriye, Cihan, & Bircan, 2023).

The study was carried out in three rural middle schools, using two distinct samples:

•Experimental group: 40 middle school students who participated in intervention programs and received natural supplements.

• Control group: 40 students from the same rural environment who did not receive the experimental intervention and were used for the statistical comparisons needed to validate the results.

Throughout the study, statistical data were collected and analyzed regarding:

- ❖ anthropometric evaluation;
- ❖ determination of vital lung capacity through spirometry;
- ❖ measurement of skinfold thickness;
- ❖ assessment of exercise capacity using the Aeroscan test on an ergometric bicycle.

The research was carried out using a standardized procedure in the selected schools, all located in rural areas, ensuring comparable conditions for both groups included in the study.

Table 1. The schools in which the research was carried out

No	Schools Used in the Research	Rural
1.	Baia Secondary School	Rural
2.	Jurilovca Secondary School	Rural
3.	Cerna Secondary School	Rural

Research Subjects

In this study, the sample consisted of a total of 80 middle school students from three rural schools, both girls and boys, aged between 13 and 14. To ensure the internal validity of the study and the comparability of results, participants were organized into two distinct groups, in accordance with the adopted experimental design:

1. Experimental Group

The experimental group consisted of 40 students from two rural middle schools:

- ✓ Baia Middle School
- ✓ Jurilovca Middle School

This group benefited from the implementation of the intervention program established within the research, which included the specific project activities and the use of natural supplements (Spirulina and Safflower Oil), in accordance with the detailed study protocol (Jalolov & Imamova, 2023). All assessments — anthropometric, functional, physiological, and biological — were carried out before and after the intervention, using standardized tools and procedures, so that the actual effects of the applied program could be accurately determined.

2. Control Group

The control group consisted of 40 students from:

- ✓ Cerna Middle School

Participants in this group were not subjected to the intervention program or the use of natural supplements. They were evaluated at the same stages and under similar conditions as those in the experimental group, allowing valid comparisons and enabling the identification of any differences determined exclusively by the intervention and not by natural or contextual variations.

Justification for the Sample Structure

The distribution of students into two groups from different schools aimed to:

- ➢ avoid experimental contamination (mutual influence between groups);
- ➢ ensure uniform contextual conditions, as all schools were located in rural areas;
- ➢ facilitate data collection in distinct stages, without interference between the procedures applied to each group;
- ➢ increase external validity by including several schools from the same demographic area.

Table 2. The research subjects of the experimental group

No.	Initials	Year of birth	No.	Initials	Year of birth	Rural background
1.	A.B.J	2010	**21.**	J.B.C	2009	R
2.	A.F.A	2010	**22.**	G.C	2010	R
3.	A.I.A.M	2010	**23.**	H.M.N	2011	R
4.	B.A.I	2011	**24.**	M.E	2011	R
5.	B.F.A	2011	**25.**	M.E	2011	R
6.	B.F.V	2009	**26**	M.P.F	2010	R
7.	B.I.C	2010	**27.**	N.M.G	2010	R
8.	B.L.G	2010	**28.**	P.A	2010	R
9.	B.R.G	2010	**29.**	P.O.E	2011	R
10.	B.T	2011	**30.**	P.V.	2011	R

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11.	C.A.F	2010	**31.**	P.V.M	2011	R
12.	C.M	2011	**32.**	R.A.V	2010	R
13.	C.N.M	2011	**33.**	S.L.N	2009	R
14.	C.V.N	2011	**34.**	T.A.G	2011	R
15.	C.S.E	2010	**35.**	T.P.R	2011	R
16.	D.B.I	2011	**36.**	V.A.G	2011	R
17.	D.M	2010	**37.**	V.D	2010	R
18.	D.M.A	2010	**38.**	V.D.A	2009	R
19.	D.M.G	2010	**39.**	Z.A.M	2010	R
20.	D.S.V	2011	**40.**	U.A.V	2011	R

In our study, a sample of subjects from another school was also included, which was used as the control group.

Table 3. The research subjects of the control group

No	Initials	Year of birth	No	Initials	Year of birth	Rural background
1.	C.D.	2011	**21.**	P.I.	2010	R
2.	D.R	2011	**22.**	C.S.	2010	R
3.	E.V	2011	**23.**	B.V.	2010	R
4.	F.V.	2011	**24.**	D.R.	2010	R
5.	F.F.	2011	**25.**	D.M.	2010	R
6.	I.S.	2011	**26**	D.L.	2010	R
7.	L.G.	2011	**27.**	C.I.	2010	R
8.	N.R.	2011	**28.**	G.C.	2010	R
9.	T.S.	2011	**29.**	D.A.	2010	R
10.	Z.R.	2011	**30.**	M.G.	2010	R
11.	A.M.	2011	**31.**	O.S.	2010	R
12.	B.R.	2011	**32.**	D.E.	2010	R
13.	D.M.	2011	**33.**	M.C.	2010	R
14.	D.B.	2011	**34.**	I.A.	2010	R
15.	J.L.	2011	**35.**	E.F.	2010	R
16.	J.B.	2011	**36.**	R.M.	2010	R
17.	L.E.	2011	**37.**	L.A.	2010	R
18.	M.E.	2011	**38.**	I.N.	2010	R
19.	N.O.	2011	**39.**	P.C.	2010	R
20.	S.D.	2010	**40.**	U.C.	2010	R

In our study, alongside the participating students, three physical education teachers, a biochemical engineer, a phytotherapy physician, and a laboratory physician were involved, contributing through their specific expertise to the implementation and monitoring of the experimental stages.

Respecting ethical norms regarding research in the socio-human field was a priority. In this regard, the following ethical requirements were fulfilled:

- obtaining informed consent from the parents of the participating students;
- obtaining collaboration agreements from the schools involved;
- obtaining institutional approval and support for the entire duration of the research.

Results

The study was conducted over a 12-month period, between February 2023 and March 2024, and included two distinct groups: the experimental group and the control group. Both groups were selected from rural middle schools, based on the same eligibility criteria, in order to ensure the comparability of results.

1. Study Design and Organizational Phase

During this phase, the objectives, general methodology, and experimental design were established. The assessment instruments, operational procedures, and intervention schedule were defined. Additionally, all required ethical approvals were obtained (parental consent, institutional approval, and consent from the teaching staff), and an interdisciplinary team responsible for implementing the research was formed (physical education teachers, a biochemical engineer, a phytotherapy physician, and a laboratory physician).

2. Baseline Evaluation

Before the intervention began, all students in the experimental group underwent an initial set of assessments, which included:

- ✓ anthropometric evaluation (height, weight, body mass index);
- ✓ determination of vital lung capacity through spirometry;
- ✓ measurement of skinfold thickness for the estimation of body composition;
- ✓ assessment of exercise capacity using the Aeroscan test performed on a cycle ergometer (evaluation of oxygen consumption, RER, power output, and lipid and carbohydrate metabolism).

These data served as baseline reference values for monitoring progress throughout the intervention.

The control group did not undergo these initial assessments involving specialized equipment and did not complete hematological analyses. They were kept outside the biometric evaluation procedures to avoid influencing the specific effects of the natural supplements administered to the experimental group.

3. Intervention Phase

- ✓ The actual intervention lasted 12 months and was applied exclusively to the experimental group.

Throughout this period:

- ✓ students received a daily capsule of Spirulina (500 mg) and a capsule of Safflower Oil, according to the protocol;
- ✓ the general evolution of their health status was monitored;

relevant physiological and behavioral changes were recorded in accordance with the study objectives.

The control group did not receive natural supplements and did not participate in any form of nutritional or physiological intervention. Its purpose was to provide a neutral comparison baseline, uninfluenced by supplementation.

4. Continuous Monitoring and Data Collection (throughout the intervention)

During the intervention, data reflecting the dynamics of physiological and functional parameters in the experimental group were collected and analyzed at regular intervals. Monitoring included:

- ✓ periodic anthropometric measurements;
- ✓ tracking changes in body composition;
- ✓ functional assessments and systematic observations regarding exercise tolerance.

These data were centralized and prepared for the final statistical analysis.

5. Final Evaluation

After the 12-month intervention period, the experimental group underwent the same battery of assessments previously conducted at baseline:

- ✓ anthropometric evaluation;
- ✓ spirometry;
- ✓ measurement of skinfold thickness;

The purpose of this final evaluation was to determine the changes produced as a result of continuous natural supplementation.

The control group, in accordance with the experimental design, did not undergo these final tests and was not subjected to biological analyses, functioning exclusively as a non-intervention reference sample.

6. Statistical Processing and Data Interpretation

All data obtained from the experimental group during the initial and final phases were centralized and statistically analyzed using specific techniques: distribution verification, comparisons of means, parametric and non-parametric tests, evaluation of the significance of differences, and determination of the strength of relationships between variables.

The results were interpreted in relation to the research hypotheses, forming the basis for preliminary conclusions regarding the effects of natural supplements on the metabolic, functional, and anthropometric parameters of the students in the experimental group (Tomczak, & Tomczak, 2014).

Study Content / Intervention Plan

The nutritional intervention was carried out between February 2023 and March 2024.

The nutritional intervention represented the central component of the study and was applied exclusively to the experimental group, consisting of students from Baia Middle School and Jurilovca Middle School. The intervention lasted a total of 12 months, conducted between February 2023 and February 2024, with additional monitoring and final data interpretation carried out in March 2024.

1. Structure of the Nutritional Intervention

The students in the experimental group received daily natural supplementation according to the established protocol. The administration schedule was organized into repetitive cycles:

- ❖ 3 months of supplementation,
- ❖ followed by 1 month of break,

repeated throughout the entire 12-month research period.

The natural products used in the intervention were selected for their potential beneficial effects on metabolism, body composition, exercise capacity, immunity, and lipid profile.

2. Monitoring of the Intervention:

Throughout the nutritional intervention, the students in the experimental group were monitored through a complex set of periodic assessments conducted in parallel with the consumption of the natural supplements. These evaluations allowed the identification of physiological, functional, and structural changes associated with supplementation.

Anthropometric Assessments

At the beginning, during, and at the end of the intervention, the following measurements were conducted:

- body weight and height;
- calculation of body mass index (BMI);
- measurement of body circumferences;
- skinfold analysis.

These data made it possible to track changes in body composition and growth rates.

Functional Assessments

To determine general functional capacity, the students performed:

- the Aeroscan test on a cycle ergometer, used to evaluate energy metabolism and exercise tolerance;
- monitoring of cardiorespiratory responses during testing.

These assessments were conducted periodically to observe the body's adaptations to physical effort in the context of natural supplementation.

Physical Activity Conducted in Parallel

Both the experimental group and the control group (Cerna Secondary School) participated in the same motor activities carried out during physical education classes, in accordance with the school curriculum. This ensured a uniform context regarding the level of physical effort, so that the differences between the two groups could be validly attributed to the nutritional intervention.

Objective of the Intervention

The nutritional intervention aimed to evaluate how the use of natural supplements influences:

- body composition;
- vital capacity and respiratory function;
- energy metabolism during effort;
- lipid profile and other biological markers;
- correlations between physical development and overall health status.

By combining supplementation, functional assessments, and biological analyses, the research sought to develop an integrated perspective on the potential benefits of natural interventions on students' health (Department of Agriculture, & Department of Health and Human Services, 2020).

Intervention Plan

To support the overall development of students' motor abilities, we designed and applied a structured set of specific exercises, organized in accordance with the educational objectives of the Physical Education and Sport curriculum. The fundamental motor abilities—static and dynamic balance, segmental and general dynamic coordination, spatial-temporal orientation, speed, and accuracy of motor execution—are essential components of psychomotor development and directly influence performance in sports activities.

From the perspective of modern physical education methodology, optimizing these abilities requires a systematic, progressive approach adapted to participants' developmental level. In this regard, we developed a set of 18 specific exercises, grouped by motor categories, aimed at stimulating and strengthening the following components:

- sprint running;
- dexterity in handling objects and in movement;
- segmental and general strength;
- aerobic and mixed endurance;
- running long jump (development of explosive strength and coordination);
- throwing the oină ball (development of strength, accuracy, and upper-segment coordination).

The exercise set was designed to allow for progress monitoring, adaptation of motor workload, and integration into the standard structure of the physical education lesson, ensuring coherence between curricular objectives and the results obtained.

Recommended Structure of a Lesson Aimed at Developing Motor Abilities

Introductory Part (8–10 min):

- joint mobility exercises;
- light movements (walking, light jogging, lunges, skipping);
- core activation exercises: plank, trunk lifts, light squats.

Fundamental Part (25–30 min):

This section includes the exercises developed within the set of 18 items, distributed according to objectives:

- speed: short-distance runs (20–40 m), reaction to signal;
- coordination: exercises with hoops, markers, cones, direction changes;
- balance: line paths, gymnastics benches, single-leg balance with perturbations;
- strength: bodyweight exercises (pull-ups, push-ups, jumps), medicine ball games;

- long jump: progressive exercises, visual markers, run-up control;
- throwing: throwing the oină ball using various techniques (underhand, over-the-shoulder, with run-up).

Final Part (5–8 min):

- breathing exercises;
- static stretching;
- return to resting heart rate;
- brief feedback regarding execution.

In the following tables are presented descriptive statistics for the following measured parameters:

- body weight (kg), height (cm), arm span (cm), Body mass index (BMI, mass (kg)/ (height (m) (Reale, Burke, Cox, & Slater, 2020).
- 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 the consumption of natural supplements) and final (after the consumption of natural supplements) values. The differences between the final and initial values are presented for each parameter (for each parameter ΔParameter = Parameter final – Parameter 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 the consumption of natural supplements, in order to control for physiological changes in height, weight and other changes in body sizes (Plonsky, & Oswald, 2014).

Violin plots, split by test time (before or after the consumption of natural supplements), 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 (González-Estrada, & Cosmes, 2019).

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 (O'Neill, & Mathews, 2002).

Overall, these tables and figures establish the descriptive foundation necessary for further inferential analyses, enabling an accurate interpretation of the intervention's impact and facilitating the selection of appropriate statistical testing procedures. The results obtained are presented in the following tables.

Table 4. Test group weight and height statistics

	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

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Table 5. Control group weight and height statistics

	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

Table 6. Test group arm spa and BMI (Body mass index) statistics

	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

Table 7. Control group arm span and BMI (Body mass index) statistics

	Initial BMI	**Final BMI**	**BMI difference**	**Initial armspan**	**Final armspan**	**Armspan 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

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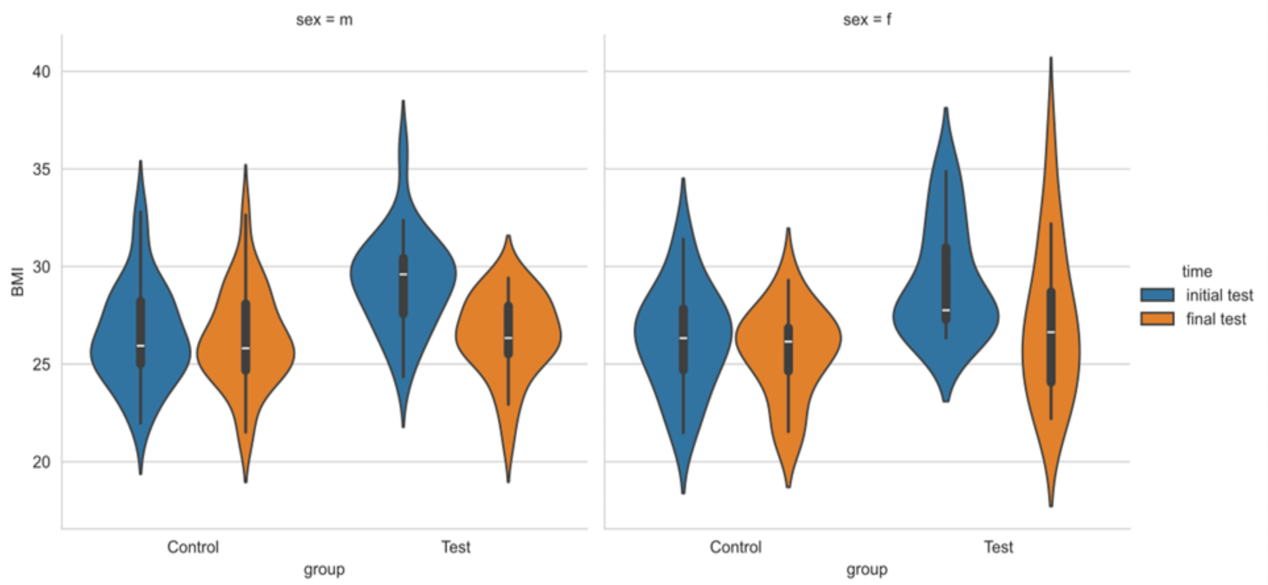

Figure 1. Violin plots of control and test groups for BMI (body mass index)

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

The relative 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 effect of natural supplement intake.

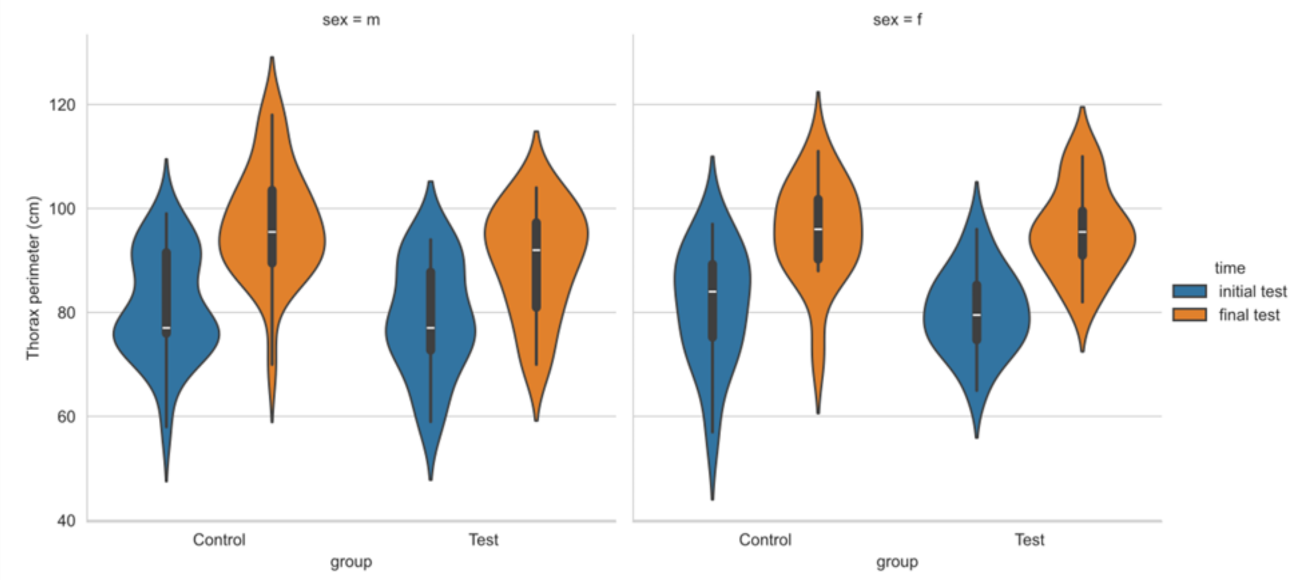

Figure 2. Violin plots for control and test groups for thorax perimeter

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.

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Table 8 .Test group abdominal and hip perimeter statistics

	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

Table 9. Control group abdominal and hip perimeter statistics

	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
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

Both control and test groups show increased values for the abdominal and hip perimeters, except for a slight decrease of 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.

Table 10. Test group tricipital, abdominal and subscapular folds statistics

	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

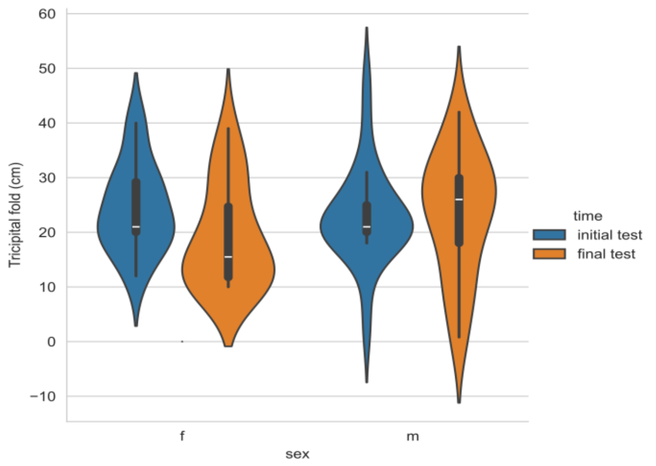

Figure 3. Violin plots for the test group, for the tricipital fold

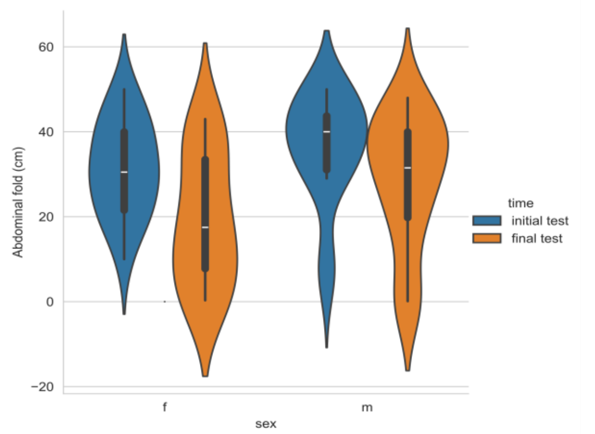

Figure 4. Violin plots for the test group, for the abdominal fold

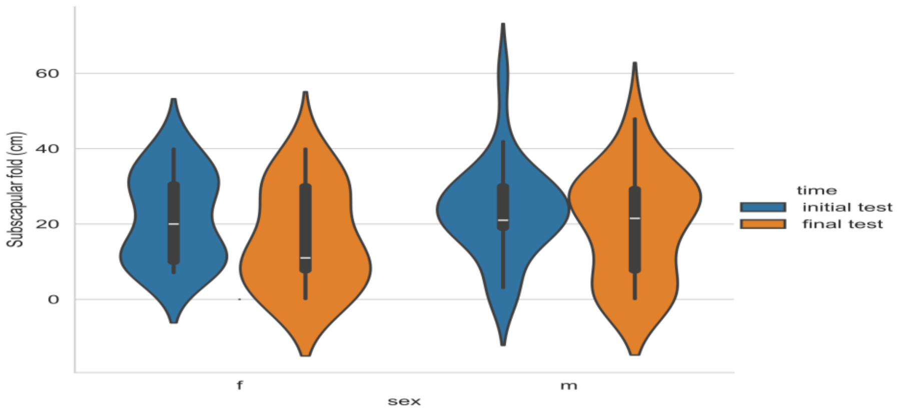

Figure 5. Violin plots for the test group, for the subscapular fold

Conclusions

The results of the tests demonstrate a positive effect of the consumption of the natural supplement on BMI, where we see a significant average decrease, mainly in the test group. At first glance, this result cannot be 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 the control values into account, we can see smaller average increases in the test group for the thorax and abdominal perimeters compared to the control group. The same cannot be said for the arm and hip perimeters, where the average increase was greater in the test group. Nevertheless, it should be noted that these perimeter changes cannot be explained solely by changes in adipose tissue, but also by muscle mass gain and other physiological changes.

In contrast to the perimeter measurements, the skinfold measurements showed an overall—though not uniform—decreasing trend, which suggests that these measurements may more accurately explain the BMI changes. Unfortunately, the control group was not included in the measurements for these parameters, and we also had to remove several outlier values from the test data due to extremely low measurements (<5 mm). For the triceps, abdominal, and subscapular folds, we removed 3, 8, and 11 values, respectively.

To more accurately quantify the differences between the groups and testing periods, we assessed the effect of the treatment using t-tests. Since we expected both increases and decreases in the final measurements, we performed two-tailed t-tests at a significance level of 0.05.

For the parameters where control data were available (BMI and perimeters), we used independent t-tests to compare the test and control groups. Specifically, we compared the pairwise individual differences between the final and initial values for both groups (ΔParameter = Parameter_final − Parameter_initial). A significant difference between ΔTest and ΔControl would indicate a significant effect of the consumption natural supplements (positive or negative).

For the same parameters (BMI and perimeters), we also used paired (dependent) t-tests to compare the adjusted before-and-after measurements. These measurements were adjusted by subtracting the control group mean from each subject's value, both before and after treatment. A significant difference between the before and after measurements would indicate a significant effect of the natural supplement. For the parameters without control data (skinfold measurements), we performed paired (dependent) t-tests between the before and after measurements. A significant difference between these measurements would again indicate a significant effect of the natural supplement.

For each t-test, Levene's tests for homogeneity of variance are also included for reference. While not strictly necessary—because equal sample sizes help ensure the robustness of the t-tests even when variances differ—Levene's test checks whether the variances of the two groups are equal. A Levene p-value below 0.05 leads us to reject this null hypothesis and conclude that the compared groups have unequal variances.

When comparing the initial and final data for the skinfold measurements (test group only), we observe a general decreasing trend across all values. Exceptions appear only when the data are split by sex, where we see that boys show increased arm and subscapular skinfolds after consuming the natural supplement.

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