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Original Article

The impact of sports and nutrition interventions on the bodyfat and BMI of primary school children (compared to the effects of a lockdown period while Covid19-pandemic)

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SUMMARY

Background & Aims: The increasing rates of overweight and obesity highlight the need for prevention. The EDDY prevention study aimed to assess whether a school-based program with sports and nutrition interventions could improve the lifestyle of elementary school children in Vienna, Austria.**Methods:** During the school year 2018/19, 146 children (8–11 years) were assigned to an intervention group (I1, n=73) or control group (C1). In 2019/20, 130 children were included as a second control group (C2) during the COVID-19 pandemic. Only the intervention group received weekly nutrition and physical activity lessons for 5 months. Weight, height, and body fat were examined at baseline and the end of the project. Body fat was determined by bioelectric impedance analysis using a multi-frequency segmental body composition analyzer. Changes in body fat percentage and BMI after the intervention were compared between groups using Wilcoxon or Student T-Test. Additionally, comparisons were performed with the control group exposed to the first COVID-19 lockdown, where no intervention occurred.**Results:** The baseline median BMI for the I1 was 20.3 (14.9–30.6) kg/m², while the C1 was 18.5 (14.0–26.3) kg/m². After the intervention, a significant modest reduction in body fat percentage ($P < 0.01$) was achieved [−1.35 (−4.20–0.90)%], compared to C1 [0.10 (−2.90–3.00)%] and C2 [1.88 (−2.55–7.51)%]. Significant differences in BMI

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changes were observed only between the I1 [0.44 (–1.29–1.84) kg/m²] and the C2 [1.31 (–0.49–3.27) kg/m²] ($P < 0.01$).

Conclusions: A 5-month health intervention promoting nutritional education and additional physical activity in schoolchildren from Vienna positively affected body fat percentage, highlighting the importance of adjusting the school system. The additional challenges of the COVID-19 lockdown were evident in fat mass and BMI, illustrating the dramatic consequences of a lack of daily structure and the important influence of the family environment. Differences in BMI and body fat development suggest the importance of assessing body composition to monitor children's nutritional status.

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1. Introduction

The impact and consequences of overweight and obesity have become an ever-growing problem for public health and have reached epidemic proportions. From 1975 to 2016, the prevalence of children and adolescents with overweight and obesity worldwide quadrupled [1]. According to the World Health Organization (WHO), one in three 11-year-old children in Europe has overweight or obesity. According to current COSI data (Childhood Obesity Surveillance Initiative), Austria ranks in the upper middle range. Moreover, during the COVID-19 pandemic, rates of obesity in school-aged children peaked [2]. Over 60% of children who are overweight before puberty are also affected in adulthood [3]. A recent literature review of NCD Risk Factor Collaboration has shown that from 1990 to 2022 worldwide, the age-standardized prevalence of obesity in adults rose in 188 countries for women and all countries except one for men [4].

Obesity leads to numerous sequelae and increases the risk of mortality. Metabolic changes such as hyperlipidemia and insulin resistance are accompanied by type 2 diabetes and hypertension. Type 2 diabetes is particularly significant, occurring 90 times more frequently in severe obesity than in lean individuals. The risk of hypertension is increased fivefold, and blood lipid levels rise proportionally to overweight, increasing the chance of heart disease, stroke, lung disease, gout, osteoarthritis, and various types of cancer [5]. Children and adolescents with overweight may also experience additional symptoms such as accelerated growth, altered sexual characteristics, and psychological disorders (depressive symptoms, eating disorders, etc.). All these developments place a significant burden on the healthcare system [5].

According to the WHO, overweight and obesity are conditions characterized by an abnormal or pathologically increased body fat percentage, leading to health-threatening consequences [1]. It is a pathological process with various complex causes dependent on multiple factors. These factors include genetic, individual, and psychosocioeconomic reasons and underlying organic diseases [5].

Pathophysiologically, overweight primarily arises due to excessive energy intake and a lack of physical activity, resulting in a positive energy balance over time and increasing body fat percentage [6]. For children and adolescents, the 90th percentile of BMI is considered the threshold for defining overweight, while the 97th percentile categorizes obesity [7].

Physical activity can reduce the risk of obesity and associated diseases [8]. Regarding the treatment of obesity, lifestyle changes yield the most remarkable success [5]. Due to the increasingly sedentary lifestyle of children, it is necessary to reevaluate and quantify recommendations for calorie intake and physical activity [9].

The “EDDY” (Effect of sports and diet training to prevent obesity and secondary diseases and to influence young children's lifestyle) Kids Study was developed as the first scientifically based prevention study in Austria for reducing overweight and obesity by the Austrian Academic Institute and the University of Vienna (the Institute of Sports Sciences). Results of the prevention project have already demonstrated a positive influence on lifestyle and increased physical performance [10,11]. Moreover,

during the COVID-19 pandemic, and particularly during stringent mitigation measures such as home confinement, an increase in weight was observed, with boys and children with obesity more affected than girls and children with normal weight for age [12]. This retrospective study aimed to assess the effect of a short-term healthy intervention in BMI and body fat percentage in school-aged children from Vienna. Additionally, we compare it to the particular situation of the COVID-19 pandemic lockdown in 2020.

2. Material & methods

Study population

School children aged 8 to 11, during the school years 2018/19 and 2019/20, from an elementary school in the 12th neighborhood of Vienna, were included. In the school year 2018/19, 146 children were candidates to participate, and in the year 2019/20, 130 children. Children were divided into an intervention group and a control group, with the 3rd grade serving as the control group and the 4th grade as the intervention group (Figure 1). The assignment of children to their respective groups remained unchanged throughout the school year. During the school year 2018/19, $n = 66$ children were finally included in the intervention group (I1) and $n = 59$ children in the control group (C1). In 2019/20, $n = 47$ children were part of the control group (C2), and $n = 53$ children of the intervention group (I2). However, because of the COVID-19 pandemic lockdown, no interventions took place, and subsequently, the groups were summarized as one collective control group in 2019/20 (Figure 1).

Inclusion and exclusion criteria

All children between the ages of 8 and 11 years attending 3rd and 4th grade at the elementary school during the school year 2018/19 and 2019/20 were included. A declaration of consent from the participant's parent or legal guardian had to be signed to be included in the study for participation. Additionally, children had to have anthropometric and body composition measurements at baseline (December 2018 and 2019) and follow-up (June 2019 and 2020). Students who joined during the school year were excluded.

Nutrition education and physical activity intervention

Regarding the study intervention of 2018/19, at the beginning of the school year, an information session about the study objectives and methodology and a parent-teacher conference were conducted in November with a study presentation.

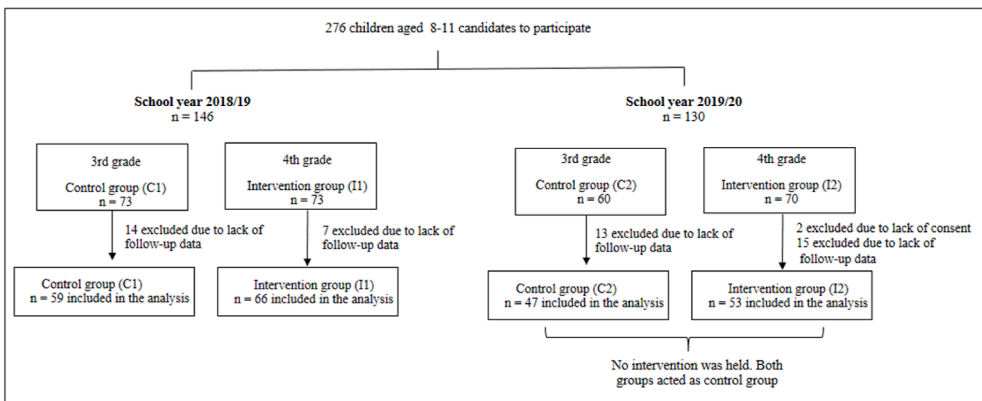


Figure 1. Flow chart of participants. EDDY Study (Effect of sports and diet training to prevent obesity and secondary diseases and to influence young children's lifestyle).

From mid-January, interventions began with nutrition classes once and physical education classes twice a week. The nutrition component focused on the practical preparation of healthy snacks and drinks. Each session began with a brief theoretical introduction, followed by practical application, making up the central part of the lesson. The physical education interventions were conducted by sports scientists and implemented during the two regular physical education classes per week. At least two study staff members were present at each session. Mondays focused on endurance, while Wednesdays focused on strength.

Due to the imposed restrictions to combat the COVID-19 pandemic, on-site interventions during the 2019/20 school year had to be suspended.

Anthropometric and body composition information

Outcome variables were collected in the school setting at baseline (December) and after a five-month intervention (in June) from all children (intervention and control groups). Trained technicians measured body weight and height. Body composition and weight were analyzed using a TANITA scale (MC-780MA, TANITA Corporation, Tokyo, Japan). A stadiometer (SECA 213, Hamburg, Germany) was used for height measurement, with the child without shoes standing. Further, body mass index (BMI, $\text{weight-kg/square height-m}^2$) was calculated and classified according to age- and sex-specific percentiles standards to classify nutritional status [13]. Body fat percentage was expressed as a percentage (%) of total body weight (kg). Moreover, the percentage of body fat was categorized as “normal,” “moderate,” and “elevated” fatness [14] according to age and sex if values were < 90th percentile, 90–97th percentile, and $\geq$ 97th percentile, respectively. Due to COVID-19 mitigation measurements, measurements were performed during the school year 2019/20 while adhering to the COVID-19 regulations.

Ethical considerations

This study was performed in line with the principles of the Declaration of Helsinki. The study was approved by the Sigmund Freud University Research Ethics Committee (Vienna) – (PAFGRW90@EFQV885378–15 November 2016). Every parent or legal guardian signed a declaration of consent for participation. No compensation was provided, participation was voluntary, and the possibility of drop-out was available at any time. All data collected underwent an anonymization process.

Statistical analysis

Descriptive variables were presented as mean, standard deviation (SD), median, and 95% confidence interval (95% CI) and as absolute numbers and percentages according to study group and testing points (baseline and follow-up). Since some variables contain outliers that could distort the mean values, each variable's mean and median were given. Changes (difference Δ : follow-up – baseline) in BMI and body fat percentages between study groups were studied using the Wilcoxon test for the median, while the mean differences were calculated using the Student T-Test for independent samples. The difference in proportions according to sex and study group was assessed using the Chi-squared test. As a further exploratory analysis, the Pearson correlation was used to examine whether there was an association between the change (difference) in body fat percentage and the change (difference) in BMI in the intervention group 18/19 after the healthy intervention.

P-values < 0.05 were considered statistically significant.

3. Results

In the school year 2018/19, 125 children participated in the study (girls $n = 53$, 42.4 %). No differences in distribution by sex were observed according to study group ($P > 0.90$) and school year ($P = 0.81$). At baseline, the median BMI for the intervention group was 20.3 (95% CI: 14.9–30.6) kg/m^2 , which was higher for boys than girls (22.1 vs 18.4 kg/m^2 , $P = 0.02$). The overall body fat percentage

was 26.5 (15.5–40.7), with no differences regarding sex ($P = 0.07$). Table 1 shows body weight and body fat characteristics according to study group and school year. Differences in body fat classification were observed among sex ($P < 0.01$). Among boys, 35.2 % were classified with moderate body fat and 27.0 % with elevated body fat, while among girls, 15.5 % and 27.8 % were classified with moderate and elevated body fat, respectively.

The presentation of the baseline status of the BMI measurement parameter has already provided insights. Approximately 40 % of the children were classified with overweight before the start of the intervention, with about 20 % even classified as having obesity. In the intervention group, rates of obesity changed from 21 % at baseline, to 18 % at the end of the project (Figure 2). A general tendency for an increase in BMI was observed, being in the control/overall group in 2019/20 larger than in the other groups, indicating a pronounced effect of the lockdown situation.

Especially in the subcategory of children with obesity, an increase was observed: at the beginning of the study, 19 % of the children had obesity, while at the end, the number increased to 24 %, suggesting an adverse effect of the lockdown. Table 2 shows the BMI and body fat percentage changes from baseline to follow-up. No significant differences in BMI changes were observed between the intervention and control group in the school year 2018/19 after 5 months of the healthy intervention ($P = 0.96$). However, the median percentage of body fat in the intervention group lowered [−1.35 (−4.20–0.90) %], while in the control group, the latter changed by 0.10 % ($P < 0.01$). Moreover, significant differences were observed when the effect of the intervention in 2018/19 was compared to changes in BMI and body fat in the control group during 2019/20 ($P < 0.01$). While in the intervention group, BMI changed by 0.44 (−1.29–1.84) kg/m², in the control/overall group in 2019/20, it changed to 1.31 (−0.49–3.27) kg/m² (Table 2).

The steepest increase in BMI was observed for the control/overall group in 2019/20, which was exposed to the lockdown (Figure 3). The trend for the intervention and control groups in 2018/19 was relatively similar on average. This could be explained by increased weight during the intervention due to increased muscle mass because of the sports interventions. Furthermore, there is a noticeable difference between the various weight categories. For example, in the intervention group 2018/19, the number of children in the “overweight” category increased by 6 %, while it decreased by 3 % in the “obesity” category.

It was noticeable that the mean baseline BMI, especially in the year 2018/19, differed by nearly 2 points between the intervention and control groups, which may introduce certain limitations in interpreting the trend.

The assessment of the body fat parameter at the beginning of the study also revealed dramatic conditions of the nutritional status in this young population from a medical point of view (Figure 4). Overall, approximately 27 % of the participating children had moderate body fat levels at the start of the study, with around 16 % were classified in the category of elevated body fat.

Table 1
Body mass index and body fat characteristics by school year and study group at baseline

Mean ± SD Median (95% CI)	2018/2019		2019/2020
	Intervention group N = 66	Control group N = 59	Control group ^a N = 100
Age (years)	9.8 ± 0.7 10 (9–11)	8.7 ± 0.7 9 (8–10)	9.2 ± 0.8 9 (8–10)
Body weight (kg)	43.8 ± 13.6 41.8 (26.4–71.8)	36.8 ± 9.9 35.5 (23.0–53.7)	40.3 ± 11.4 38.0 (26.0–61.5)
BMI (kg/m ²)	21.0 ± 4.9 20.3 (14.9–30.6)	19.1 ± 3.8 18.5 (14.0–26.3)	20.2 ± 4.2 19.3 (14.7–28.2)
Body fat (%)	27.7 ± 8.2 26.5 (15.5–40.7)	25.5 ± 6.7 24.2 (16.1–39.5)	27.7 ± 7.4 27.2 (16.6–40.9)

SD: standard deviation; CI: confidence interval; BMI: body mass index; body fat assessed by electrical bioimpedance; %: percentage.

^a As an intervention could not be held due to the COVID-19 pandemic, the assigned intervention and control groups were considered one collective control group.

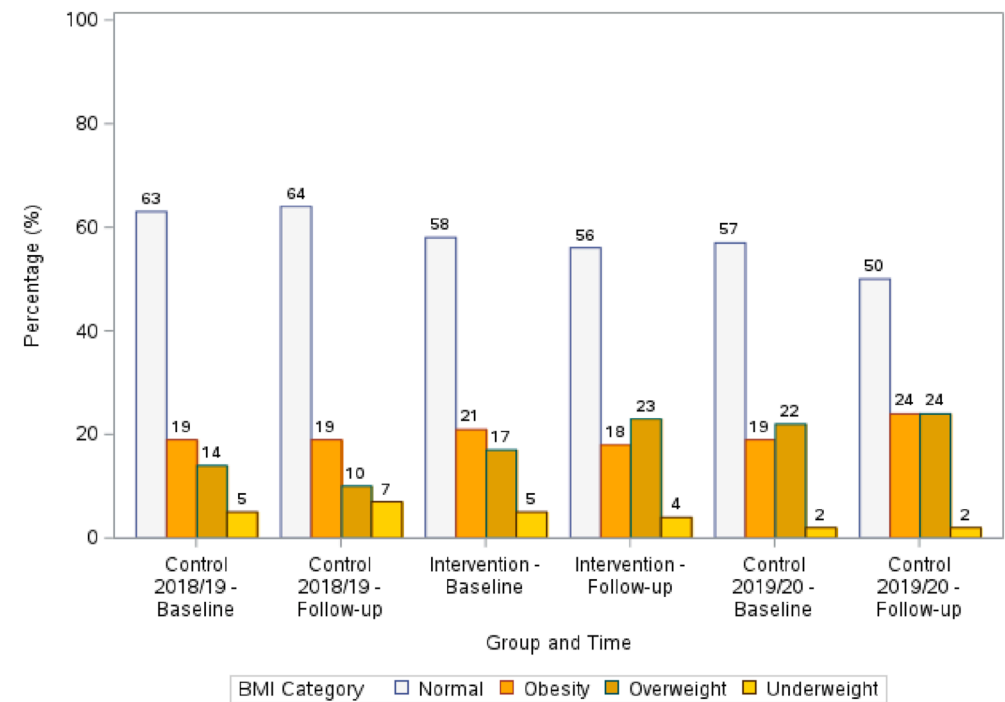


Figure 2. Categorical classification of BMI according to group, at baseline and follow-up.

Table 2
Changes in BMI and body fat from baseline to follow-up

Mean ± SD Median (95% CI)	2018/2019 Changes (difference Δ)			2019/2020 Changes (difference Δ)	
	Intervention group N = 66	Control group N = 59	<i>P</i> ^a	Control group ^c N = 100	<i>P</i> ^b
BMI (kg/m ²)	0.48 ± 0.89 0.44 (−1.29–1.84)	0.49 ± 1.26 0.14 (−0.62–3.19)	0.96 0.26	1.45 ± 1.53 1.31 (−0.49–3.27)	< 0.01 < 0.01
Body fat (kg)	0.08 ± 1.35 −0.05 (−2.00–2.20)	0.68 ± 1.38 0.40 (−0.60–3.30)	0.02 < 0.01	2.47 ± 2.92 1.90 (−0.50–7.20)	< 0.01 < 0.01
Body fat (%)	−1.49 ± 1.84 −1.35 (−4.20–0.90)	−0.08 ± 2.20 0.10 (−2.90–3.00)	< 0.01 < 0.01	2.29 ± 3.86 1.88 (−2.55–7.51)	< 0.01 < 0.01

^a P-value for the difference between groups in school year 2018/19.
^b P-value for the difference between intervention group (2018/19) and control group (2019/20).
^c As an intervention could not be held due to the COVID-19 pandemic, the assigned intervention and control groups were considered one collective control group.

A median decrease in body fat percentage could be observed in the intervention group [−1.35 (−4.20–0.90) %] after five months (Figure 5). The number of children with normal body fat levels in the intervention group increased by 15 %, and those in the category of moderate and elevated body fat were correspondingly reduced (Figure 4). Conversely, the situation was observed in the control group 2019/20, where a median increase in body fat percentage [1.88 (−2.55–7.51) %] was noted in children restricted by the lockdown. The body fat content of the control group in 2018/19 remained nearly the same on average, with a tendency to decrease slightly (Table 2). Overall, a significant difference was

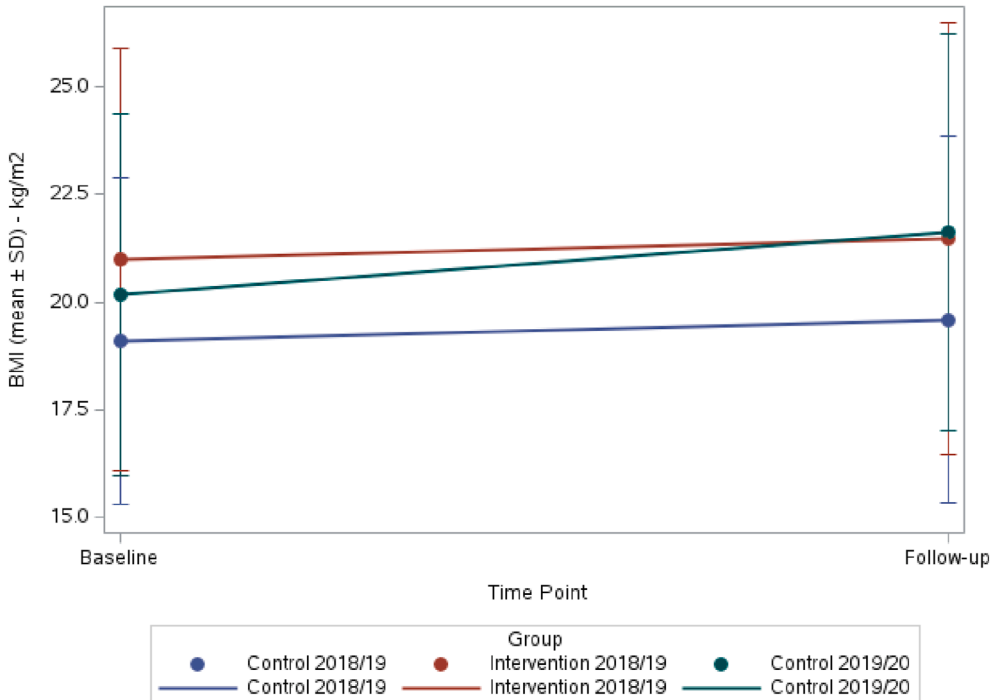


Figure 3. Course of BMI from baseline to follow-up.

observed between changes in the percentage of body fat achieved in the intervention group when compared to the control group 2018/19 and the control group 2019/20 ($P < 0.01$) (Table 2).

The results of the correlation analysis between BMI and body fat percentage changes in the intervention group showed a statistically significant correlation between those two parameters ($\alpha = < 0.01$). Analogous to the correlation coefficient result ($r = 0.46$, indicating a moderate correlation), a wide variance can be observed in the data (Figure 6).

On average, a clear linear correlation was noticeable; however, the average width of scattering is in the same order of magnitude as the difference between the minimum and maximum values. Further, it can be seen that the BMI still increases with a constant body fat content (parameter $d = \text{positive}$).

4. Discussion

In summary, although modest, the significant reduction in body fat percentage through a sports and nutritional intervention demonstrated its positive impact on children's health, highlighting the importance of adjusting the school system. The observed impact of health-promoting measures could substantially reduce the burden on the healthcare system, as children with overweight and obesity present a higher probability of excessive weight during adulthood [15], leading to a higher risk of comorbidities that pose more significant health costs [16]. The intended results were achieved after just five months, reflecting how promoting healthy lifestyles can induce short-term changes in body composition. Even though the latter may have been related to lifestyle changes or advanced maturity in children, the positive modest reduction in body fat may have occurred without affecting BMI, as reported previously in the EDDY study [11,17] and elsewhere [18,19].

Expanding to larger study populations and extended study duration could yield further helpful insights and positive evidence for the effectiveness of increasing nutrition education and sports and physical activity, as evidence-based approaches that have been widely recommended to prevent

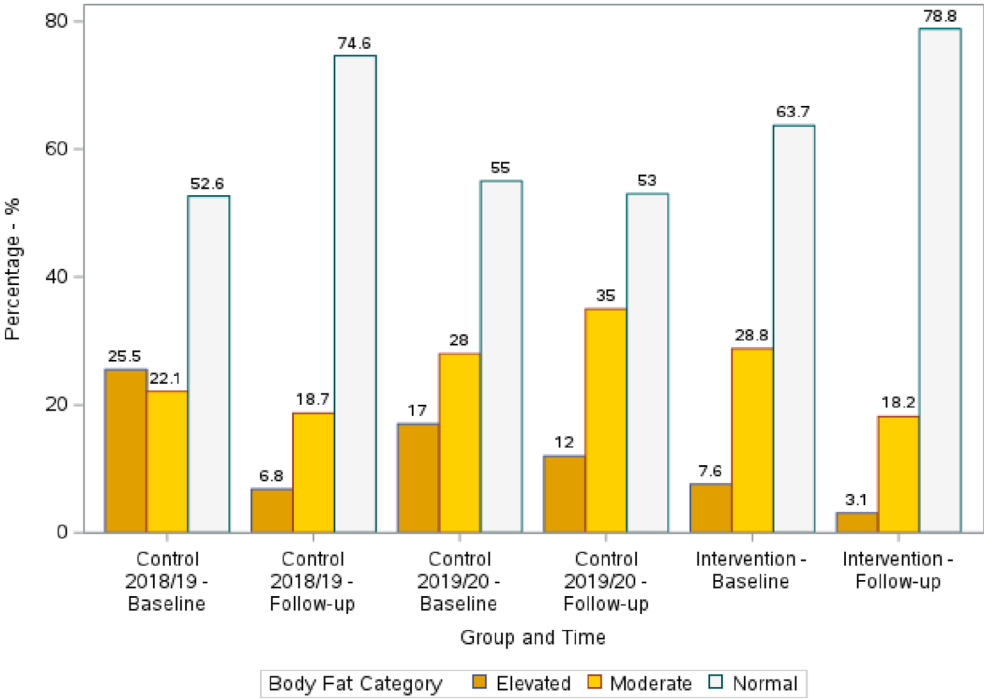


Figure 4. Categorical classification of body fat percentage according to group, at baseline and follow-up.

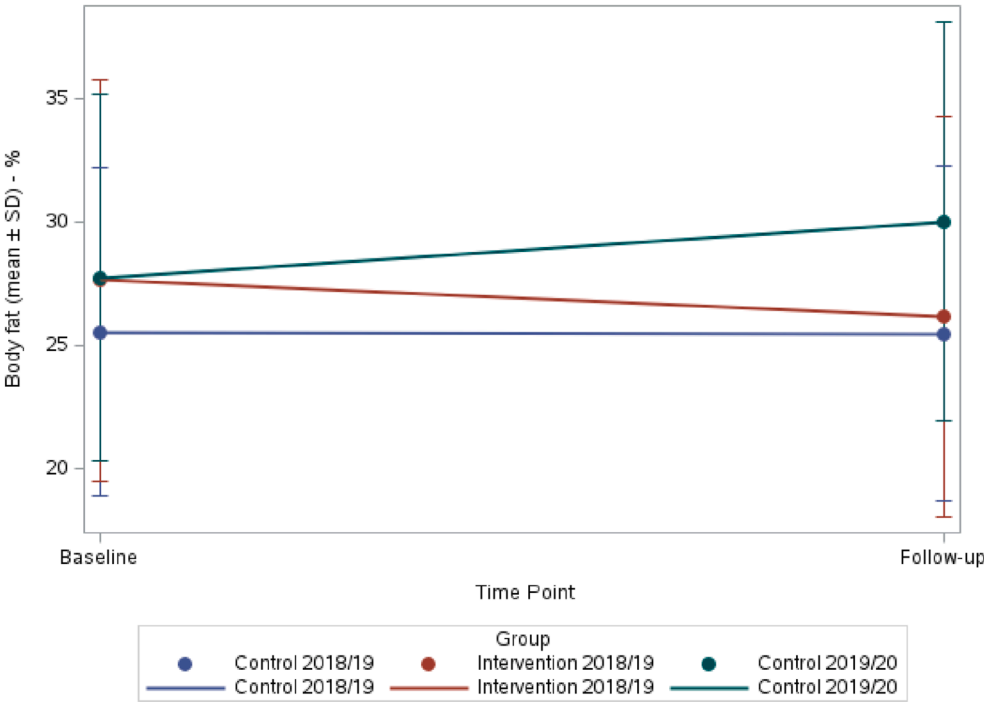


Figure 5. Course of percentage of body fat percentage from baseline to follow-up.

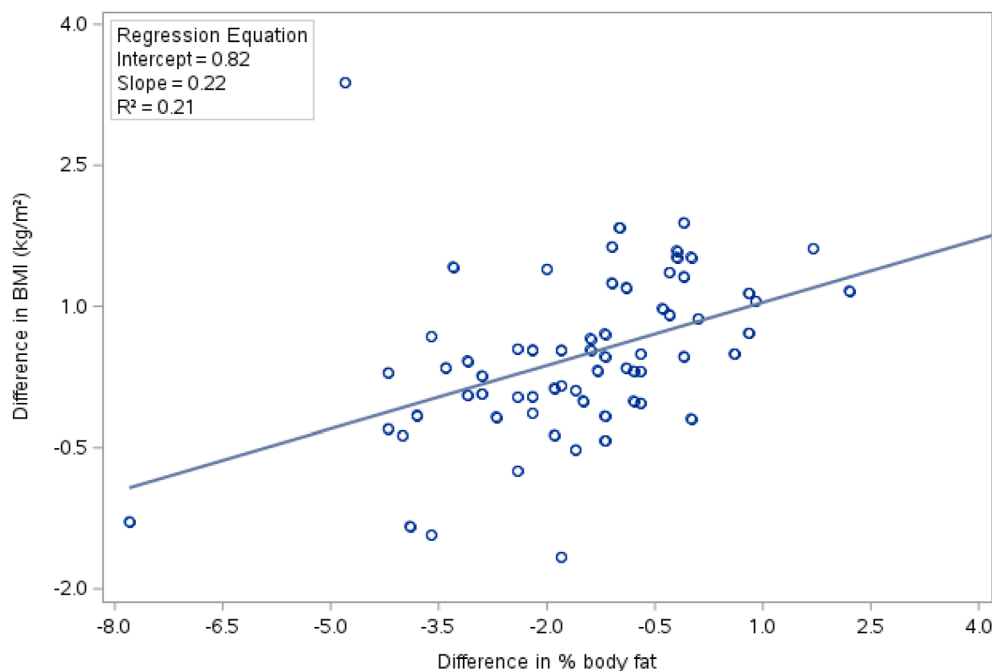


Figure 6. Scatter plot of the difference in BMI and body fat percentage among participants in the intervention group 2018/19.

excessive weight gain in school-aged children [20,21]. Moreover, to achieve the recommended by the WHO [22] of at least 60 minutes per day of moderate-to vigorous-intensity physical activity across the week to confer the benefit of reduced adiposity, among other health benefits, enhancing physical education to ideally daily classes would be the most obvious and crucial approach to contribute to this [21]. On the other hand, just the fact of engaging and enjoying the physical activity lessons in school, even if they are available a couple of days a week, creates an environment that allows children to acquire skills and knowledge for movement throughout life. Even though information about children's extracurricular physical activity was not available for this analysis, a recent study among adolescents has found that the odds of being sufficiently active increased in those who participated in 1–2 days/week of physical activity lessons [23]. In this sense, the limited access to space and opportunities for physical activity during the COVID-19 confinement contributed to limited energy expenditure, partially explaining the higher increase in body fat and BMI [22] in the control group in 2019/2020. Previous reports from the EDDY study monitoring nutritional status during the strictest lockdown period showed a higher BMI increase than when confinement measures were less strict [12].

From a perspective, enlarging the study population and thus rolling out daily physical activity lessons and similar combined interventions like the EDDY project to multiple schools or on a federal level proves challenging and requires a joined national policy. Although a National Action Plan on Physical Activity (NAP.b) and initiatives promoting free exercise programs and sports clubs have been presented in Austria [24], daily physical activity is still not yet part of the curricula. A significant limitation is the lack of teachers and qualified exercise instructors for these projects. Another obstacle is the varying weight classes and, thus, the different needs of the children. Therefore, the instruction of teachers on how to handle children affected by overweight/obesity should be focused on. Further, education about the theoretical basics of a healthy lifestyle should play a bigger part in children's daily study content, as only 5 % of the schools in Austria have reported having projects related to healthy lifestyle topics [25]. The nutritional education imparted by the EDDY project may have further reinforced the positive effect of physical activity in supporting a negative energy balance, as children

may have improved their ability to choose healthier food options as their nutritional knowledge increases, as previously shown by the study group [10].

Differences in BMI and body fat percentage response between the various weight categories were observed. The cause of this finding was not investigated in this study, but it provides interesting gaps for further research questions. The specific, notable changes in the development of the explained parameters during those interventions among children who were already classified with obesity indicate that they may not be reached effectively by the intervention and also need to be treated separately. Previous reports from the EDDY project stated that the children with excessive body weight for their age remained in those categories after the healthy intervention [17], inferring that a universal program advocating for healthy measures may not be effective. Likewise, data from the EDDY project, which investigated the implementation of a web-based intervention, showed that there were hardly any successes in responding positively to children already living with obesity, while the proportion of children with overweight could be reduced even through the digital format [26]. This also underlines the needed difference in the treatment strategies planned for children with obesity vs. those with overweight. For those affected by excessive weight, there should be readily accessible, individualized therapy options available, and a precise investigation of the causes should also take place [16]. Moreover, treatment should include a family approach, where the first step to approach the problem is for children, families, and teachers to recognize that excessive weight is a health problem even during childhood. Almost half of the parents from the EDDY study underestimated their child's weight [27].

Despite the significant correlation between body fat content and BMI, notable differences in parameter development during the intervention were observed. The fact that changes in body composition are not considered when using the BMI represents significant limitations. The observation that after the end of the intervention, the body fat percentage has decreased significantly while the BMI has increased should be proof enough to consider other methods in the future, though BMI is not inherently a “poor” indicator. In the event of an increase in BMI, which may initially be considered “bad,” this increase may be due to factors other than an increase in body fat, such as an increase in muscle mass. There was a statistically relevant correlation between the two parameters because the BMI, when considered in isolation, is directly proportional to weight, which typically increases with an increase in fat mass.

Nevertheless, as evident from the correlation results from our study, the BMI still increased with a constant body fat content (parameter $d = \text{positive}$). This indicates that there are other influences on BMI besides body fat percentage. Therefore, the use of BMI, especially for assessing children due to growth, should be replaced by more precise measurement parameters of body composition for future studies and clinical practice. Numerous other studies have already demonstrated this significant limitation in interpreting this parameter [28,29].

Some weaknesses in this study should be addressed. First, our results shall not be interpreted as representative of Austria's entire population of schoolchildren. For practical reasons, the intervention addressed children in 4th grade, whereas the control groups were in 3rd grade, which may have affected the results. On the other hand, the strengths of our study include the direct measurements of weight, height, as well as the assessment of body fat through bioimpedance analysis.

5. Conclusion

In conclusion, our study showed that a 5-month health intervention promoting nutritional education and additional physical activity in schoolchildren from Vienna positively affected body fat percentage. There is an urgent need to establish healthy lifestyle initiatives in the school curricula and to develop further available and accepted special programs for children and families living with obesity.

Data availability statement

The data presented in this study are available on request from the corresponding author due to ethical reasons.

Author contributions

All authors contributed to the study conception and design. Paula Moliterno, Magdalena Heindl: Methodology, Software. Paula Moliterno, Magdalena Heindl: Data curation, Writing- Original draft preparation. Magdalena Heindl, Hanna Rosenauer, Emma Malina-Altzinger, Tamara Konrad: Investigation. Kurt Widhalm: Supervision. Paula Moliterno: Writing- Reviewing and Editing.

All authors read and approved the final manuscript.

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Declaration of competing interest

The authors have no relevant financial or non-financial interests to declare.

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