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**Science & Technology in childhood Obesity Policy**

Science and Technology in childhood Obesity Policy

# Science & Technology in childhood Obesity Policy

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# D7.4: Report on the cost effectiveness of the Healthy Lifestyle Intervention

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**Dissemination Level**

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| **PU** | Public | ☒ |

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| **RE** | Restricted to a group specified by the consortium (including the Commission Services) | |
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| Abbreviation | Definition |
|---|---|
| **BMI** | Body Mass Index |
| **NCDs** | Non-communicable diseases |
| **PA** | Physical activity |
| **PE** | Physical Education |

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# 1 Summary

**Introduction:** School-based physical activity interventions have repeatedly shown favourable effect on obesity prevention, although there have been several critiques of school environment being the ideal setting for such interventions and of physical activity interventions being as effective as combined physical activity, nutrition and family activation interventions.

**Methods:** The present study examines the cost effectiveness of a real-world, nationwide 8-year (2011-18), voluntary-based physical activity intervention in children aged 6-14 in Slovenia, called "Healthy Lifestyle". The intervention provided two (grades 1 to 6) to three (grades 7 to 9) additional lessons of physical education per week. Although the focus of the Healthy Lifestyle programme was the improvement of physical fitness and encouragement of active lifestyle, we examined its effectiveness on BMI units decreased and obesity cases reversed. We studied over 34,000 participants of the Healthy Lifestyle intervention and a similar number of non-participants with null duration of exposure to the intervention, coming from the same schools. We calculated BMI from measured weight and height, and employed Logistic Generalised Estimating Equations to estimate the effects of different durations of exposure to the programme on BMI (from one to 5 consecutive years of participation) in children with normal weight, preobesity and obesity at the start of the programme. Incremental cost-effectiveness ratio was used to assess the cost-effectiveness of different intervention scenarios on the BMI units reduced and obesity cases reversed.

**Results:** The analysis showed that the intervention group had significantly larger reduction of BMI than control group, that the size of reduction was growing with years of participation in the intervention, and that the reduction was largest in children initially with obesity and smallest in children initially with normal weight. The cost per BMI unit decreased ranged from € 123.97 in girls initially with obesity, after three years of participation, to € 773.82 in boys initially with preobesity, after only one year of participation. In general, cost effectiveness of the intervention on BMI units decrease and obesity cases reversed was higher in girls than in boys. The number of obesity cases reversed in the group initially with obesity was the highest after four years of participation in girls and after 5 years of participation in boys. The cost effectiveness of obesity case reversed ranged from € 680.33 per obesity case reversed in boys and € 2,219.47 per reversed obesity case in girls, both in the fifth year of participation.

**Conclusion:** We found that a large-scale, population-based intervention, focusing on improvement of physical fitness through additional physical activity, delivered in real-world conditions achieved higher cost effectiveness in BMI units decrease than similar interventions, focusing specifically on obesity reduction and using multidimensional and multidisciplinary approaches. At the same time the cost effectiveness of obesity cases reversed was similar to the multidimensional and multidisciplinary interventions targeting obesity. We also confirmed that 1- and 2-year exposure to intervention had the lowest cost effectiveness on obesity cases reversed but that the exposure from 3 years onwards compared to 2-tear exposure increased the cost effectiveness on obesity cases reversed. This proposes that the best cost effectiveness in obesity cases reversed is achieved in interventions that last more than two years.

## 2 Background

Childhood obesity poses a global public health challenge.[1, 2] Obese children are more likely to become obese adults with increased risks of diabetes, hypertension, lower quality of life, development of noncommunicable diseases and premature death.[3-7] According to World Health Organization, 41 million children under the age of 5 are struggling with obesity and 340 million children in the 5- to 19-year-old age group are affected by it.[8] The key driver of the obesity epidemic is the expanding obesogenic environment, which includes unhealthy changes in food systems and reduction of physical activity.[8] The increased nutritional and sedentary pressure have been on the rise in the last decades worldwide and a similarly unfavourable situation—accompanied also by profound socio-political changes—has been occurring also in Slovenia. Although childhood obesity is persisting as a serious public health challenge in Slovenia, the recent evidence shows that some of the challenges have been properly addressed and have resulted in modest decline of obesity among Slovenian children and youth especially in the last decade.[9]

Due to the growing environmental obesogeneity it is unlikely for the decline of childhood obesity to occur naturally and should be induced by interventions, targeting the obesogenic agents. The existing evidence indicates that the intervention programs focused on children's physical activity and diet-changing interventions are the most effective tools for introduction of sustainable lifestyles.[10-12] Since childhood obesity is a complex problem with many social and environmental factors it seems that also solutions must be multidimensional,[12] but there is no consensus on how much emphasis should be put on each influencing dimension. In addition, several authors have been proposing that school-based interventions have not been effective for improving body mass index to curb childhood obesity[13] while other have been arguing that interventions, focusing only on physical activity are less effective than the ones focusing also on diet and family activation.[14, 15] The duration of such interventions is another question that has not yet been resolved. It seems that long-term interventions focusing on dietary behaviour, physical activity, and psychological support are the most effective in reducing childhood obesity,[16] but there is a lack of evidence on the effects of interventions, not focused on obesity per se, that have a potential for reducing childhood obesity because they are focusing on its cofounders.

Healthy Lifestyle was one of such interventions, introduced in 2011, which focused on improving children's lifestyles through better availability of organised physical activity and improved physical fitness, without explicitly addressing obesity.

The present study is an attempt to examine the cost-effectiveness of a large-scale, long-lasting physical activity intervention Healthy Lifestyle on OB prevalence in children aged 6-14. Our focus is on the effects of the intervention on BMI as the most frequent clinical indicator of obesity, and on the reversal of obesity, utilising the cost-effectiveness analysis (CEA) with incremental cost-effectiveness ratio (ICER). Since there is a research gap in the effects and cost effectiveness of specific intervention on BMI changes in children who initially have normal weight, overweight or obesity, our analysis will try to establish which of the three subgroups experienced the most pronounced changes in BMI and what were the differences in cost effectiveness. We will also try to establish whether the affects and cost effectiveness of the intervention on the initial obesity cases reversed was changing with longer participation in the intervention.

# 3 Methods

## 3.1 Intervention

Healthy Lifestyle was a nation-wide intervention, introduced in Slovenia in the period 2011-2018. It provided two (grades 1 to 6) to three (grades 7 to 9) additional physical education (PE) lessons per week—thus providing one PE lesson per day—to children aged 6 to 14. In grades 1 to 5, PE specialist teachers were delivering additional PE lessons instead of classroom teachers thus improving quality along quantity of PE.

The additional lessons were organised immediately after school. Schools were allowed to include children of two consecutive grades in one class (e.g. children from grade 1 and grade 2) but they had to adhere to legislative demands regarding the maximum number of children per class, which meant between 16 and 30 children per class. Classes that specifically included children with difficulties in somatic and motor development were organised as separate classes in which the maximum number of children was limited to ten in order to provide more individualised approach but the same contents were delivered in all classes.

The focus of Healthy Lifestyle program was the improvement of physical fitness through increase of school-based physical activity. The level of physical fitness is the direct outcome of physical activity and is defined as the ability to perform strenuous physical activity with vigor and without excessive fatigue, and to demonstrate physical activity traits and capacities that are consistent with minimal risk of developing hypokinetic diseases.[17] The existing evidence shows that higher values of BMI are associated with declines in physical fitness and that children with obesity are achieving the lowest levels of physical fitness.[18]

The program required from teachers to provide at least twelve different sports per triennia but they had to prioritise the three most established sports in the local environment. It also promoted urban sports, that were not specifically covered in the physical education curricula at the time, and the teachers had to provide also basic information on healthy dietary and lifestyle habits.

The intervention was available to all children in individual participating school and was organised in the form of elective course. The involvement in Healthy Lifestyle was therefore voluntary and accessible to all but it especially encouraged the inclusion of children who had not been exercising in the local sports clubs or who had been experiencing difficulties in somatic and motor development.

The intervention was financed by the European Social Fund with the aim to increase the first employment opportunities of recently graduated PE teachers. Schools were granted funds for half-time employment of additional PE teacher but had to provide sport facilities and equipment. All primary schools in Slovenia have two standardly well equipped gyms and outdoor sports facilities. The funding of the intervention was administered by the Ministry of Education, Science and Sport of the Republic of Slovenia.

## 3.2 Study design and sample

Out of 451 primary schools in Slovenia, 216 were involved in the Healthy Lifestyle intervention for at least one school year. The national coordinator of the intervention programme was the Slovenian Sports Agency Planica which has been publishing annual public calls for inclusion of new schools in the programme.Between 18,000 and 35,000 children have been included in the intervention in a single year.

This meant that interested schools were joining the programme every year of the intervention, which started with the first round of 78 schools in school year 2010/11, and continued with additional 32 in 2011/12, 19 in 2012/13, 17 in 2013/14, 16 in 2014/15, 33 in 2015/16, 8 in 2016/17 and 13 in 2017/18. The participating schools did not differ from non-participating schools in proportions of regional distribution, size, or urbanisation level, but the participating schools did show higher levels of baseline obesity, which could have contributed to their decision to participate in the intervention. Between 18,000 and 35,000 children have been included in the intervention in a single year.

| Scenario | N (boys, girls) | Age yrs (SD) | PBH (SD) | PBMI (SD) | PTSF (SD) | School OB (SD) |
|---|---|---|---|---|---|---|
| **Baseline control** | 34,473 (17,114, 17,359) | 10.37 (2.26)* | 52.43 (28.79) | 52.41 (29.72)* | 54.66 (28.85)* | 7.12 (2.80)** |
| **Baseline treatment** | 29,152 (15,634, 13,518) | 9.06 (2.25)* | 52.32 (28.74) | 52.94 (29.30)* | 55.17 (28.63)* | 7.65 (3.11)** |
| **1 yr control** | 34,473 (17,114, 17,359) | 11.37 (2.26)** | 53.30 (28.78)* | 52.32 (29.78)* | 55.19 (28.66) | 7.12 (2.80)** |
| **1 yr treatment** | 29,152 (15,634, 13,518) | 10.06 (2.25)** | 53.93 (28.64)* | 53.05 (29.46)* | 55.47 (28.39) | 7.65 (3.11)** |
| **2 yrs control** | 21,809 (10,603, 11,206) | 11.98 (1.96)** | 53.81 (28.69)** | 52.24 (29.73)** | 54.45 (28.91)** | 7.04 (2.75)** |
| **2 yrs treatment** | 15,293 (8,523, 6,770) | 10.55 (1.96)** | 54.90 (28.41)** | 53.72 (29.43)** | 55.74 (28.81)** | 7.99 (3.28)** |
| **3 yrs control** | 14,426 (6,867, 7,559) | 12.42 (1.70)** | 53.72 (28.86)** | 51.68 (29.77)** | 54.61 (28.95)* | 7.03 (2.76)** |
| **3 yrs treatment** | 8,599 (4,987, 3,612) | 11.19 (1.70)** | 55.56 (28.38)** | 53.46 (29.44)** | 55.64 (28.61)* | 8.22 (3.35)** |
| **4 yrs control** | 7,766 (3,655, 4,111) | 12.82 (1.44)** | 53.38 (28.79)** | 50.66 (29.78)* | 54.31 (28.87) | 7.01 (2.78)** |
| **4 yrs treatment** | 4,421 (2,685, 1,736) | 11.86 (1.46)** | 55.86 (28.26)** | 52.49 (29.74)* | 54.94 (28.94) | 8.42 (3.47)** |
| **5 yrs control** | 4,502 (2101, 2401) | 13.19 (1.20)** | 53.07 (28.73)** | 50.16 (29.85)** | 53.88 (28.66)* | 7.03 (2.75)** |
| **5 yrs treatment** | 2,337 (1,461, 876) | 12.60 (1.20)** | 56.06 (28.10)** | 53.23 (29.50)** | 55.78 (29.34)* | 8.49 (3.56)** |

Schools were entering the intervention in different years while, at the same time, children were entering, exiting and re-entering the intervention in different grades. The complexity of various scenarios of individual participation presented a challenge in terms of analysis. We, therefore chose an approach that gives the most straightforward insight into possible effects of the intervention on BMI change and prevalence of obesity. Since it is impossible to assess the effects of an intervention without the baseline status of BMI and obesity, the analysis includes only children who had been enrolled in an individual school a year before the school joined the intervention. Since we are employing a quasi-experimental design which limits the possibilities for controlling multiple environmental factors that could effect the outcomes, we sampled the control group of non-participating children from the participating schools. The children in the control group never participated in the intervention while the children in the treatment group participated from 1 to 5 years. The number of children in the control group was declining each year because after grade 9 (around age 14) children in Slovenia conclude their primary education and enrol in secondary schools (Table 1). Due to small number of children who participated more than 5 years, we limited the analysis to 5-year participation.

**Table 1.** Baseline characteristics of the intervention vs control group according to consecutive years of participation or non-participation in the intervention programme

Legend: N - number of children, Age yrs - baseline age in years, truncated to integer, PBH - baseline age- and sex-specific percentile value of height, PBMI - baseline age- and sex-specific percentile value of, PTSF - baseline age- and sex-specific percentile value of triceps skinfold, School OB - baseline obesity prevalence in individual school in %. * significant baseline difference between intervention and control group, $p < 0.005$, ** significant baseline difference between intervention and control group, $p < 0.001$.

At baseline, there were some significant differences between the intervention and control group (Table 1). The average baseline age of children in intervention group was lower in all five analysed participation scenarios and declined in groups with longer participation scenario of intervention. Treatment group were statistically significantly taller at baseline in all five scenarios but not in the year before intervention. Control group had lower percentile of triceps skinfold in the year before the intervention as well as in 2, 3 and 5-years participation scenario. It had also lower BMI percentile than treatment group in all scenarios. In all five participation scenarios, at the baseline the schools from intervention group had higher prevalence of obesity than the control group.

### 3.3 Anthropometric measurements

Anthropometric measurements of height, weight and triceps skinfold thickness were obtained through the SLOfit system—the Slovenian national surveillance system of children's somatic and motor development—in accordance with the standardised and uniform protocol.[19] The SLOfit measurements are organised in all Slovenian schools every April, assuring identical time interval between measurements in all schools with standard equipment.[20] The measurements in schools are performed by the PE teachers with the support of classroom teachers. PE teachers are thoroughly trained for this task in various courses during their study at the Faculty of Sport, University of Ljubljana which is the only institution in Slovenia, educating PE teachers in a five-year master programme.

Following the SLOfit system protocol children are barefoot and wearing only light clothes during the anthropometric measurements—typically shorts and t-shirt. Height is measured in the standing position with stadiometer to the nearest mm, and weight with medical scale to the nearest 0.1 kg. Triceps skinfold thickness is measured at the mid-point on the posterior surface of the left upper arm to the closest mm with Holtain calliper. The measurements of children whose parents provide positive consent are sent to the Laboratory for Diagnostics of Somatic and Motor Development at the Faculty of Sport, where the data is checked for logical errors, eventual errors are communicated back to teachers for correction. Schools receive feedback for every individual child and class after the age- and sex-specific national percentile ranks of 8 fitness indicators and 4 anthropometric indicators (height, weight, triceps skinfold, and BMI) are calculated. The participation rate of children in the studied period 2010-2018 has been above 94% in all years.

### 3.4 Statistical methods

Independent sample t-test was used to check the baseline difference in age, triceps skinfold, height, BMI and school baseline obesity between intervention and control group.

Logistic Generalised Estimating Equation (GEE) was used to analyse the effect of the intervention on BMI in the intervention and control group. GEE[21] is a multilevel regression method that adjusts standard errors to account for correlated data, such as the correlation of repeated measurements in a longitudinal study. A working correlation structure is specified before the analysis and defines the hypothesised relationship between repeated observations of individual subject. Regression parameters in GEE are first estimated through a generalised linear regression that initially ignores whether the data are longitudinal and—in the next step—the standard error estimates are adjusted according to the hypothesised correlation between different time points of the outcome. This adjustment then updates the standard errors in the analysis to account for repeated observations within the same subject.[22]

The change in BMI was analysed using a linear scale response. We specified a first-order autoregressive correlation structure (AR-1) for the main GEE models. This assumption is appropriate in the context of our balanced longitudinal data in which measurements closer in time are more correlated than measurements further apart in time. Balanced data occurs when subjects are assessed at the same intervals, which was the case in our study. In a first-order autoregressive structure, the correlation of the outcome between any two points in time is a mathematical power of their distance in time. For example, nutritional status a year apart would be correlated by $r_1$ (i.e., r raised to the power of one), nutritional status two years apart would be correlated by $r_2$ (i.e., r raised to the power of two), and so forth.

The outcome variable in the model was BMI. Time—as within-subject variable—was categorised into five categories, contrasting baseline versus 1st, 2nd, 3rd, 4th, and 5th year of children's participation or non-participation in the intervention.

Thirty different models were produced to assess the intervention effects on BMI by comparison of control and treatment group who were exposed to 1-, 2-, 3-, 4-, and 5-year consecutive participation or non-participation in the intervention and had different nutritional status at baseline.

The intervention was evaluated by the participation in individual year, interpreted as the odds of non-participation versus participation (0 vs. 1).

In order to overcome a common limitation of ignoring of micro-environmental settings[23] as well as individual biological factors that can have a strong positive or negative influence on BMI change, we included several covariates in the model. One of the most important micro-environmental factors is environmental obesogeneity.[24] Each school in the intervention had different prevalence of baseline obesity prevalence that could be considered as an indicator of environmental obesogeneity in the local environment. Since environmental obesogeneity is influenced also by affluence of the local environment we also included the Municipality Development Index (MDI)[25] in the model.

In any environment—even in markedly obesogenic ones—not all children suffer from the same level of obesity. Some children with obesity have less body fat than others, but the ones that have more, have lower odds of becoming non-obese than the ones who have less of it. To account for this intervention effect handicap we took into consideration also the baseline triceps skinfold percentile value of an individual. Furthermore, with longer intervention—as was the case with the Healthy Lifestyle intervention—individual growth cannot be ignored. The timing and tempo of growth spurt are characterised by big differences among peers, but also by sex-related differences with girls mostly it sooner than boys.[26] Growth spurt is preceded by increased energy accumulation in the form of body fat which can result in temporary rise of BMI that normalises afterwards. To account for these differences we considered also body height percentile to adjust for individuals whose speed of growth deviates from their peer group. Since children were entering the intervention at different ages, we also included age as a covariate.

Typically, the intervention disturbance is not considered in the analyses although the effectiveness of an intervention can be severely impaired by external factors such as discontinued funding, staff changes, policy changes or other unexpected events. Since Healthy Lifestyle intervention suffered from temporarily discontinued funding which in some cases resulted in six-month total or partial suspension of intervention, we also decided to control for this effect by including it in the model.

Each model was, therefore, adjusted for sex, baseline school obesity prevalence, economic affluence of local environment (Municipality Development Index), individual risk of obesity (baseline percentile of triceps skinfold thickness of an individual), individual maturation rate (body height percentile rank of an individual in certain year), age, and intervention disruption (designation whether an individual was exposed to disturbance of intervention in 2016).

Since we tried to establish the possible differences in the effects of the intervention on BMI in children who had normal weight, preobesity or obesity at baseline, according to sex, we produced 30 different models with the same potentially moderating covariates. Not all covariates were significant in every model but they contributed to it.

Every model calculated the predicted value of BMI that considered the effects of the covariates, and the nutritional status of every child was calculated on the basis of the predicted BMI. The normal weight criteria was BMI < $85^{th}$ percentile of national age and sex specific BMI values, calculated on the data of over 7.5 million measurements in the period 1989-2020. The preobesity group criteria was set as $85^{th} \geq$ BMI < $95^{th}$ percentile and obesity group criteria was set at BMI ≥ $95^{th}$ percentile.

The number of obesity cases reversed were calculated as the difference between the number of obesity cases at baseline year and final year for all five participation/non participation scenarios separately for boys and girls. Chi-square test was used to assess the difference in number of cases with obesity between the baseline and final year in each scenario.

We performed the cost analysis as a retrospective analysis of the costs of intervention for all 5 participation scenarios. Costs were considered in total and broken down by year. The cost amount was provided by the Slovenian Sports Office Planica and included the total cost of the intervention programme, including the costs for salaries as well as costs for transportation, entrance fees, and all other eligible costs, related to the implementation of the programme.

We carried out CEA by determining the ICER in which the costs and effects values of the intervention were compared to a lack of intervention in which case the costs and effects were equal to 0. We used the ICER equation:[27]

$$ICER = (C_1-C_2)/(E_1-E_2)$$

whereas $C_1$ is the cost of a more effective intervention, $C_2$ is the cost of a less effective intervention, $E_1$ is the effect of a more effective intervention and $E_2$ is the effect of a less effective intervention. The outcome of the CEA was expressed as BMI units decreased and as the number of obesity cases reversed. ICER was computed for all cases in which the intervention was more effective in the treatment vs control group.

All statistical analyses were performed with IBM SPSS 26.0 and statistical significance was set at $\alpha$ = 0.05.

# 4 Results

## 4.1 Intervention costs

The Healthy Lifestyle intervention was carried out in 8 consecutive school years. The number of children varied from year to year as new schools were joining in (Table 2). Average annual cost per capita was EUR 69.73 and was varying from EUR 77.20 in the school year 2012/13 down to 59.32 in the school year 2015/16 when the financing was interrupted. The difference in annual per capita costs in different years occurred because the schools claimed the costs form the Slovenian Sports Office Planica based on the number of organised lessons. Since the number of children in individual classes varied, the per capita costs were higher if the classes included less children and lower if classes included more children. The average annual cost of the intervention was EUR 1,966,028. For the analysis the costs per capita were calculated separately for every child participating in the intervention in specific year.

**Table 2.** Annual costs of intervention per capita throughout the intervention

| School year | 2010/11 | 2011/12 | 2012/13 | 2013/14 | 2014/15 | 2015/16 | 2016/17 | 2017/18 |
|---|---|---|---|---|---|---|---|---|
| **Included children (N)** | 18,993 | 24,202 | 26,000 | 27,600 | 30,261 | 29,549 | 35,640 | 32,245 |
| **Annual costs (EUR)** | 1,156,322 | 1,754,087 | 2,007,291 | 2,026,940 | 2,070,681 | 1,752,964 | 2,618,384 | 2,341,557 |
| **Annual costs per child (EUR)** | 60.88 | 72.48 | 77.20 | 73.44 | 68.43 | 59.32 | 73.47 | 72.62 |

## 4.2 CEA of BMI change

The GEE analysis showed the increasing trend of BMI reduction with longer participation in intervention in all three nutritional groups in boys and in girls (Tables 3 and 4), which was observable also in the non-participating control group (Figure 1). The largest effect of the intervention on BMI was observed in the group of boys with initial obesity, in which BMI decreased for 3.4 kg/m$^2$. The significant difference in BMI reduction between intervention vs control group was observed in almost all scenarios, except in boys with preobesity, who participated/not participated for 5 years and in girls with obesity of the 5 year participating/not participating group.

**Table 3.** GEE analysis of effects on control vs treatment group on BMI change in boys

| Scenario | β | SE | 95% CI Lower | 95% CI Upper | Wald χ2 | Sig. | Exp. (β) |
|---|---|---|---|---|---|---|---|
| | | | **Normal weight** | | | | |
| **1 yr** | 0.219 | 0.0211 | 0.178 | 0.26 | 107.688 | 0.000 | 1.245 |
| **2 yrs** | 0.717 | 0.0321 | 0.654 | 0.779 | 499.277 | 0.000 | 2.047 |
| **3 yrs** | 0.851 | 0.0433 | 0.766 | 0.935 | 386.191 | 0.000 | 2.341 |
| **4 yrs** | 0.807 | 0.0595 | 0.691 | 0.924 | 184.226 | 0.000 | 2.242 |
| **5 yrs** | 0.574 | 0.0772 | 0.422 | 0.725 | 55.238 | 0.000 | 1.775 |
| | | | **Preobesity** | | | | |
| **1 yr** | 0.413 | 0.0688 | 0.278 | 0.548 | 36.092 | 0.000 | 1.512 |
| **2 yrs** | 0.413 | 0.0688 | 0.278 | 0.548 | 36.092 | 0.000 | 1.512 |
| **3 yrs** | 0.766 | 0.1139 | 0.542 | 0.989 | 45.195 | 0.000 | 2.150 |
| **4 yrs** | 0.591 | 0.1636 | 0.270 | 0.912 | 13.039 | 0.000 | 1.805 |
| **5 yrs** | 0.240 | 0.2288 | -0.209 | 0.688 | 1.099 | 0.295 | 1.271 |
| | | | **Obesity** | | | | |
| **1 yr** | 0.272 | 0.1031 | 0.070 | 0.474 | 6.965 | 0.008 | 1.313 |
| **2 yrs** | 0.715 | 0.1514 | 0.419 | 1.012 | 22.344 | 0.000 | 2.045 |
| **3 yrs** | 0.889 | 0.2182 | 0.461 | 1.316 | 16.584 | 0.000 | 2.432 |
| **4 yrs** | 0.630 | 0.2964 | 0.049 | 1.211 | 4.514 | 0.034 | 1.877 |
| **5 yrs** | 0.834 | 0.3707 | 0.107 | 1.56 | 5.056 | 0.025 | 2.302 |

**Table 4.** GEE analysis of effects on control vs treatment group on BMI change in girls

| Scenario | β | SE | 95% CI Lower | 95% CI Upper | Wald χ2 | Sig. | Exp. (β) |
|---|---|---|---|---|---|---|---|
| | | | **Normal weight** | | | | |
| **1 yr** | 0.235 | 0.0219 | 0.192 | 0.278 | 114.487 | 0.000 | 1.265 |
| **2 yrs** | 0.831 | 0.0341 | 0.764 | 0.898 | 595.722 | 0.000 | 2.296 |
| **3 yrs** | 0.937 | 0.0467 | 0.845 | 1.029 | 402.059 | 0.000 | 2.552 |
| **4 yrs** | 0.807 | 0.0665 | 0.677 | 0.938 | 147.313 | 0.000 | 2.242 |
| **5 yrs** | 0.554 | 0.0875 | 0.383 | 0.725 | 40.130 | 0.000 | 1.740 |
| | | | **Preobesity** | | | | |
| **1 yr** | 0.157 | 0.0437 | 0.071 | 0.242 | 12.876 | 0.000 | 1.170 |
| **2 yrs** | 0.789 | 0.0742 | 0.644 | 0.935 | 113.004 | 0.000 | 2.201 |
| **3 yrs** | 1.097 | 0.1264 | 0.849 | 1.345 | 75.330 | 0.000 | 2.995 |
| **4 yrs** | 1.151 | 0.1867 | 0.785 | 1.517 | 37.966 | 0.000 | 3.160 |
| **5 yrs** | 0.887 | 0.2293 | 0.437 | 1.336 | 14.959 | 0.000 | 2.427 |
| | | | **Obesity** | | | | |
| **1 yr** | 0.544 | 0.1212 | 0.306 | 0.781 | 20.115 | 0.000 | 1.722 |
| **2 yrs** | 1.333 | 0.1858 | 0.969 | 1.698 | 51.519 | 0.000 | 3.794 |
| **3 yrs** | 1.417 | 0.2338 | 0.959 | 1.875 | 36.744 | 0.000 | 4.126 |
| **4 yrs** | 0.953 | 0.325 | 0.316 | 1.590 | 8.594 | 0.000 | 2.593 |
| **5 yrs** | 0.397 | 0.4192 | -0.424 | 1.219 | 0.898 | 0.340 | 1.488 |

We then calculated the average per capita cost of participation for children with initial normal weight, preobesity and obesity, according to the duration of their participation in the intervention (Table 5), which served as the basis for ICER.

ICER analysis showed that the highest cost effectiveness was achieved in the group of girls with initial obesity in their second year of participation. In general, the intervention was more cost effective in girls which was most expressed the group of girls with initial preobesity.

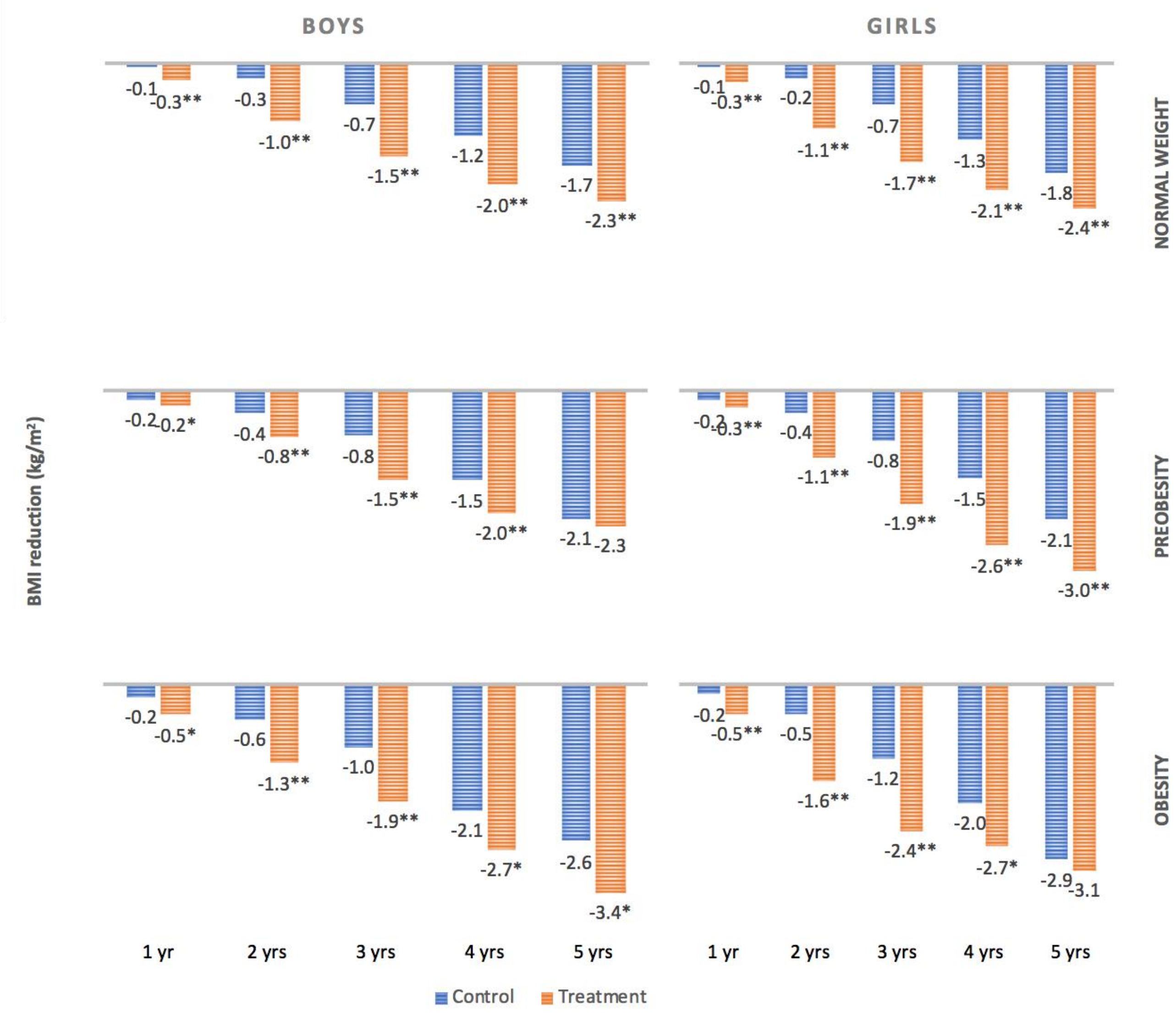


**Figure 1.** BMI changes in children with initial normal weight, preobesity and obesity according to duration of their participation/non participation in the intervention

**Table 5.** Average per capita annual costs according to duration of their participation in the intervention

| Nutritional status | Sex | 1 yr | 2 yrs | 3 yrs | 4 yrs | 5 yrs |
|---|---|---|---|---|---|---|
| **Normal weight** | Boys | €67.40 | €137.85 | €210.43 | €282.36 | €350.89 |
| | Girls | €67.45 | €137.90 | €210.37 | €282.34 | |
| **Preobesity** | Boys | €67.43 | €138.11 | €210.62 | €282.29 | €351.01 |
| | Girls | €67.14 | €137.51 | €210.30 | €282.49 | €350.78 |
| **Obesity** | Boys | €67.51 | €137.77 | €210.56 | €282.59 | €351.34 |
| | Girls | €67.30 | €137.74 | €210.45 | €282.44 | €350.59 |

**Figure 2.** ICER results in BMI reduction in treatment vs control group

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### 4.3 CEA of obesity cases reversed

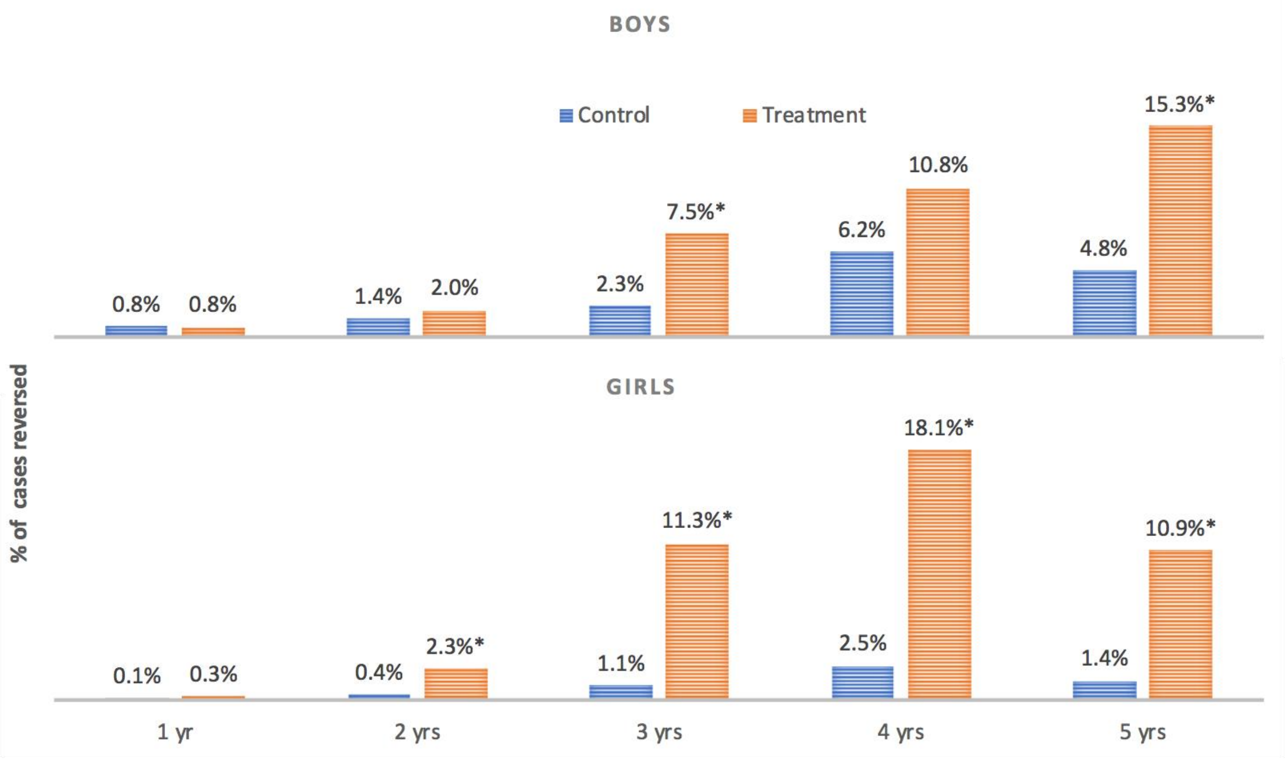
To assess the cost effect of the intervention in obesity cases reversed we analysed the transition of children who had obesity at baseline to preobesity or normal weight (*N* = 4,063) for each of the 5 scenarios. We first compared the reversed cases of obesity between treatment and control group and calculated the adjusted number of reversed cases in treatment group by adjusting the difference in the sizes of both groups (Table 6).

**Table 6.** Number of reversed cases of children with obesity in five scenarios of participation/non participation

| Scenario | Sex | Control | | Treatment | | |
|---|---|---|---|---|---|---|
| | | N of obesity | N of obesity cases reversed | N of obesity cases | N of obesity cases reversed | Adjusted N of obesity cases reversed |
| 1 yr | Boys | 1,111 | 9 | 1,004 | 7 | 7.7 |
| | Girls | 1,119 | 1 | 829 | 2 | 2.7 |
| 2 yrs | Boys | 666 | 9 | 573 | 10 | 11.4 |
| | Girls | 692 | 3 | 420 | 8 | 13.2* |
| 3 yrs | Boys | 428 | 10 | 338 | 20 | 25.3* |
| | Girls | 466 | 5 | 203 | 10 | 23.0* |
| 4 yrs | Boys | 195 | 12 | 154 | 16 | 18.4 |
| | Girls | 240 | 6 | 103 | 8 | 18.6* |
| 5 yrs | Boys | 104 | 5 | 94 | 13 | 14.4* |
| | Girls | 138 | 2 | 54 | 4 | 10.2* |

Legend: * $p < 0.05$

In the aversion of cases of obesity the intervention was more effective in girls because it revealed statistically significant difference the control and treatment group in the two- ($\chi^2$ (1, 1112) = 5.776, $p$ = 0.016), three- ($\chi^2$ (1, 669) = 9.570, $p$ = 0.002), four- ($\chi^2$ (1, 343) = 5.107, $p$ = 0.024), and five-year ($\chi2$ (1, 192) = 4.551, $p$ = 0.033) participation/non participation



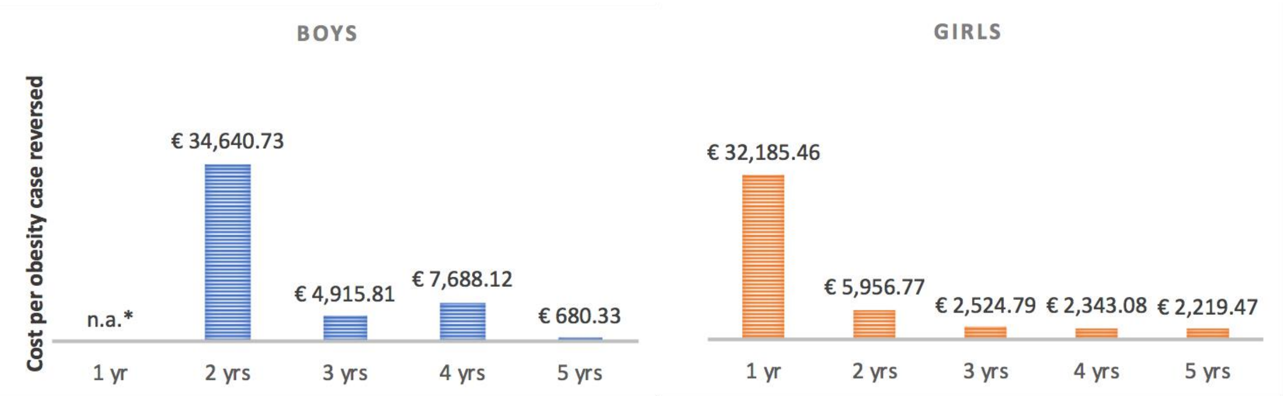
scenario, but no significant difference was observed after one-year of participation/non-participation (Figure 3).

Legend: * $p < 0.05$

**Figure 3.** Percentage of children with obesity reversed in five scenarios of participation/non participation

In boys, statistically significant difference was observed only in the three- ($\chi^2$ (1, 766) = 6.435, $p = 0.011$) and five-year ($\chi^2$ (1, 198) = 4.863, $p = 0.027$) participation/non-participation scenario, although the percentage of reversed cases of obesity in treatment group indicated to be higher in all scenarios.

ICER on obesity cases reversed in boys could not be calculated in the 1-year participation/non participation scenario since after the first year of the intervention, control group experienced more cases of obesity reversed than the treatment group (Figure 4). In the ICER analysis we used the adjusted number of reversed cases of children with obesity of treatment group vs the number of reversed cases in control group. The costs of the individual scenario per number of children was also calculated according to the adjusted number of reversed cases. The cost effectiveness in regard of reversed cases of obesity was the lowest in the 1-year participation scenario. In boys and girls the highest cost effectiveness was achieved in the 5-year participation scenario with € 680.33 per obesity case reversed in boys and € 2,219.47 per reversed obesity case in girls. The difference in cost effectiveness according to different scenarios was substantial.




Legend: * ICER in 1-year scenario for boys could not be calculated since the number of obesity cases reversed in control group exceeded the number of obesity cases reversed in the treatment group.

**Figure 4.** ICER results in the obesity cases reversed

In boys, 5-year participation was 50-times more cost effective than 2-year participation, 7-times more cost effective than 3-year participation and 11-times more cost effective than 4-year participation. In girls, the 5-year participation was almost 3-times more cost effective than 2-year participation, similarly effective as 3-year participation and more than 4-times more cost effective than 4-year participation.

### 4.4 Long-term gains simulation model

A microsimulation study by Su et al.,[28] showed that over a 10-year period of obesity, the annual medical costs of individuals with obesity vs normal weight peers amounts to around

€ 3,090.00 per year. When we compared the costs of the intervention for children with obesity in all five scenarios of participation (Table 7) with assumption their obesity in adulthood would last 10 years if not reversed, the simulation showed that the cases of reversed obesity in boys from the 5-year participation group would be cost-saving in less than 2 months and that all participation scenarios over 2 years would be cost-saving in less than a year. The simulation also showed that 1-year scenario in girls and boys, and 2-year scenario in boys would take more than 2-years to eventually reach the cost-saving threshold. Even the least effective 1-year scenario in girls would, nevertheless, become cost-saving in less than seven years.

**Table 7.** Long term gains of the intervention among children with initial obesity

| Scenario | Sex | Obesity cases reversed | Cost of the intervention for reversed cases | Annual savings | Months to cost-saving |
|---|---|---|---|---|---|
| **1 yr** | **Boys** | 7.7 | €67,136.38 | €23,793.00 | 33.9 |
| | **Girls** | 2.7 | €54,703.64 | €8,341.88 | 78.7 |
| **2 yrs** | **Boys** | 11.4 | €83,957.71 | €35,299.14 | 28.5 |
| | **Girls** | 13.2 | €60,645.56 | €40,729.14 | 17.9 |
| **3 yrs** | **Boys** | 25.3 | €75,336.96 | €78,255.62 | 11.6 |
| | **Girls** | 23.0 | €45,334.33 | €70,933.00 | 7.7 |
| **4 yrs** | **Boys** | 18.4 | €48,842.16 | €56,710.59 | 10.3 |
| | **Girls** | 18.6 | €29,618.39 | €57,600.00 | 6.2 |
| **5 yrs** | **Boys** | 14.4 | €6,383.48 | €44,443.40 | 1.7 |
| | **Girls** | 10.2 | €18,248.95 | €31,586.67 | 6.9 |

## 5 Discussion

Children included in the Healthy Lifestyle intervention were achieving significantly higher reductions in BMI than their peers from the control group, although both groups were experiencing the declining trends of BMI in the period of the intervention. This is also in concordance with a recent population-based study on reversing general trends of childhood obesity in Slovenia in the period of the Healthy Lifestyle intervention,[9] which shows that there were also other drivers that contributed to the reversal of the obesity trends.

To our knowledge, our study is the first one analysing the effect of the same intervention on children with different initial nutritional status. Although the intervention was deliberately planned according to the ‘all-in’ principle in order to avoid stigmatising of children with preobesity and obesity and included children from the entire population the largest declines in BMI were observed among children with baseline obesity and preobesity, but also children with normal weight were experiencing significant decline of BMI which grew with the time of participation. The possibility to study the effects over several years of the intervention provide a valuable insight into the effects of longer participation in interventions and at the same time challenge the cost effectiveness of shorter interventions. This supports the WHO recommendation which emphasises interventions lasting a longer period of time to provide better and larger effects in comparison to shorter ones[29] but at the same time shows that even the recommended one-year minimum might not be enough to achieve sensible results. The decline of BMI in the Healthy Lifestyle intervention was larger than in many other reports of intervention effects. The lowest decline of BMI in our study was observed after 1 year of participation (0.2 units among the boys with preobesity to 0.5 BMI units in boys and girls with obesity), but from 2-year participation onwards, the BMI decline exceeded 0.8 units in the second year of participation in the intervention, and rose above 2 units from three years of participation onwards. In other studies, the decrease by 0.1 BMI unit was considered a threshold of improvement[12] although in our study even the control group largely exceeded this criteria. Moodie et al.[30] similarly reported a decline close to 0.1 BMI units in the study of an Australian intervention while Meng et al.[31] were reporting even increments of 0.65 BMI units in a large-scale Chinese intervention. In their meta analysis of school-based interventions Lavelle et al.[32] were reporting the 0.35 BMI units reduction in interventions specifically targeting overweight and obese children, while the interventions delivered to all children such as Healthy Lifestyle, were achieving even lower 0.16 BMI units reduction which is much lower than in our intervention.

The cost analysis showed that the annual costs per capita in the Healthy Lifestyle intervention was below € 70, which is among the lowest reported costs of interventions, targeting childhood obesity.[12, 33] The cost of a BMI unit reduced in Healthy Lifestyle intervention was also lower than in other interventions. An Australian intervention[34] which provided more active PE lessons with students developing their own physical activity plan, participating in a 10 week enhanced school sport program, having supervised recess and/or lunch physical activity opportunities, supportive school physical activity policy, and linking with the community and linking with parents reached around € 1,022.00 cost per BMI unit reduced.

An intervention in Poland,[12] including only children with obesity which included visits to a paediatrician, a physical activity specialist, a nutritionist, and a psychjologist, educational workshops for parents and children over 14, and additional visits to specialists, for example, to an endocrinologist reached € 19,640.00 per BMI unit reduced. A US intervention in which no additional hours of PE were introduced and was based only on following the requirement that 50% of PE time be spent in moderate to vigorous physical activity[35] reached € 291.00 per BMI unit reduced in two years. With exception of boys with initial preobesity and girls with initial obesity in which there were no significant differences in BMI reduction between the intervention and control group, the cost of BMI unit reduced was ranging from € 123.97 in girls with initial obesity after three years of participation to € 773.82 in boys with initial preobesity after only one year of participation in the intervention.

In regard of obesity cases reversed, the Healthy Lifestyle intervention proved to be comparable with similar interventions Bandurska et al.[12] reported € 5,495.00 cost of obesity case reversed which is very similar to the costs in the Healthy Lifestyle intervention in children with initial obesity who participated at least three years. Our analysis shows that 1-year participation is rather ineffective in reducing the number of obese children despite its potential to reduce BMI but it also showed that the longest period of inclusion was the most effective. The analysis of long-term gains of the intervention also confirm this and shows that the gains from 3-year and longer participation period convincingly outweigh the costs of the intervention in less than two years.

## 6 Strengths and limitations

Our study analyses a large-scale intervention delivered in real-life settings, which contributes to higher generalisability of our findings due to higher level of its ecological validity.[36] The study is also based on longitudinal monitoring of the effects during a five-year period, which allows us to infer causal relationship between the intervention and the obesity-related outcomes (BMI and prevalence of obesity), while also examining the sustainability of the effects over a longer intervention period. In our models, we accounted for several important confounders, including obesogeneity of the environment, maturation and age. Traditionally the intervention-effectiveness studies only considered the baseline differences in personal characteristics of intervention and control groups, or used only an indirect environmental indicators of obesity risks, such as socio-economic indicators, whereas our study used the baseline prevalence of obesity in individual school environment to control for environmental obesogeneity as well as the socio-economic conditions in the local settings in the form of Municipality Development Index. In contrast to existing studies, we also controlled for effects of individual's baseline subcutaneous fat which can mask the actual interventions' effects due to slower or less pronounced improvement of nutritional status. Through this approach we were also able to examine changes over time together with controlling factors which contribute to these transformations along with the intervention itself. The study controlled also for the maturation effects which can blur the actual decline in body mass due to increased accumulation of subcutaneous fat before the growth spurt and due to increased gaining of muscle mass in boys and fat mass in girls entering puberty.[37, 38] Our analysis studied all the described effects separately in groups of boys in girls with different initial nutritional status. Lastly, the ICER analysis provides a more accurate estimation of cost effectiveness than a simple cost-effect ratio because it shows the economic value of an intervention, compared with an alternative.

However, this study also has several limitations. First, we had no data available for estimation of body composition, but relied on BMI as an indicator of adiposity. Evaluation of cost effectiveness of a long-lasting intervention based only on BMI should therefore be taken with caution. It should also be noted that PA, alongside with fat mass reduction, typically increases lean mass, which leads to smaller changes in weight and an underestimation of the true effects on BMI change. Second, we were unable to collect information about dietary habits, physical activity outside the intervention and screen time, which represent important factors in changes of childhood BMI.[39, 40] There are also several other important determinants affecting BMI which were not recorded in this study, and are thus not included in analyses. Examples are genetic variation, epigenetics, endocrine disease, central nervous system pathology, sleep, infection and individual socio-economic and cultural factors.[41] Third, the non-random voluntary enrolment used in the intervention could have resulted in possible sampling bias. Thus, there is a possibility that some children and adolescents who had been more prone to behaviour change wanted to be a part of this intervention, omitting children with opposite characteristics. The analysis is constrained also by the time horizon of the intervention. Whilst the intervention appears to be cost effective and able to obtain health benefits for weight status at a relatively low cost, the sustainability of these behaviours remains unknown. Lastly, due to the unavailability of data we were unable to perform QALY (quality-adjusted life year) or DALY (disability-adjusted life-year) analyses which would provide better insight in to the cost effectiveness of the intervention than the ICER analysis.

## 7 Implications for future research

Using BMI as an outcome can result in the underestimation of the effects of the intervention due to muscle mass accumulation, and we urge future studies to include body composition measurement to assess actual changes in fat mass. Next, the sustainability of changes should be further examined in future studies by including follow-up assessments at different time points after the end of the intervention.

## 8 Ethical approval

The protocol, measurement procedures and data management of the SLOfit surveillance system were approved by the National Medical Ethics Committee of the Republic of Slovenia (No. 52/03/14) and is in accordance with the Helsinki Declaration. Healthy Lifestyle intervention did not require ethical approval since it was not an experiment and was independently evaluated by the SLOfit system.

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