# Compliance with clustered lifestyle intervention targets and their contribution to obesity in the IDEFICS study

Doctoral (PhD) Dissertation

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## Introduction

In the last decades a rapid growth of the prevalence of obesity was experienced worldwide, making it a public health crisis the importance of which can be best illustrated with the forecast that this phenomenon could reverse the increase in life expectancy having been observed in the past decades. Between 1980 and 2013 the global prevalence of overweight and obesity combined rose by 47.1% for children. In the last years, however, an unexpected yet welcomed plateauing of obesity epidemic was observed, though almost exclusively in developed countries. Explanation is not consensual: the saturation hypothesis, i.e. that the obesogenic environment has already affected all the susceptible individuals, is equally plausible as the beneficial results of cumulated intervention and policy efforts. Even if long-term observation will reinforce this favourable trend of plateauing, the prevalence of childhood overweight remains unacceptably high, putting a serious burden on individual health, health care systems and economies, thus obesity will still remain a major public health concern during the next decades, calling for successful and sustainable means of intervention.

## Aims of the study

The aim of this work is (1) to describe the behaviour of European children for the most important risk factors of childhood obesity, (2) to assess the extent of pre-intervention adherence to the recommended threshold of these selected key behaviours and (3) to evaluate how compliance with these recommendations contributes to a lower prevalence of overweight (including obesity) with respect to each individual behaviour and to a composite compliance score of this pro-health cluster of behaviours. All analyses have been carried out on the baseline survey data, i.e. before the intervention was introduced and disseminated systematically.

## The IDEFICS study

The results of this thesis were based on the data of the IDEFICS (**I**dentification and prevention of **D**ietary-and lifestyle-induced health **EF**fects **I**n **C**hildren and infant**S**) study, a multicentre European cohort study between 2006-2012. The study provided one of the largest European datasets based on children`s cohort, comprising 8 survey centres (Estonia, Sweden, Germany, Belgium, Hungary, Italy, Spain, Cyprus), and contributed to in-depth epidemiological investigation of the childhood overweight/obesity. After the baseline survey, the IDEFICS study launched an intervention programme, its main targets having been identified with the methodological framework of intervention mapping protocol. This revealed six key behaviours in three major areas: (1) diet (a) enhancing daily consumption of water and (b) daily consumption of fruit and vegetables; (2) physical activity (a) reducing TV-viewing and (b)

increasing daily physical activity; (3) ability to cope with stress (a) spending more time together in the family and (b) ensuring adequate sleep duration. In the present work we analysed the pre-intervention, baseline behaviours concerning the above six selected targets.

## Subjects and methods

### Study subjects

For the descriptive statistics of key behaviours, the baseline cohort ($T_0$) of 16,228 children aged 2 to 9 years in the 2007/08 academic year, and additional 2,517 children aged 2 to 10.9 years newly recruited during the next wave of the survey ($T_1$) two years later, comprised the study sample. Though children recruited in $T_1$ survey were not explicitly the subject of the intervention program, due to the school and community modules and media channels of the intervention they still might have been contaminated with these messages. Therefore, only the $T_0$ sample was included for the analysis of the contribution of the selected key lifestyle factors to obesity. The survey followed detailed standard operation procedures (SOPs) being exactly the same at baseline ($T_0$) and at follow-up ($T_1$). The actual age of school enrolment varied in the survey countries, so the school-aged subgroup was defined according to the most frequent date, i.e. being 6-year or older. All survey centres obtained ethical approval according to their national regulations.

### Body mass index assessment

Weight was measured using an electronic scale (Tanita BC 420 SMA, Tanita Europe GmbH, Sindelfingen, Germany) to the nearest 0.1 kg, with the children wearing only underwear. Height was measured barefooted, using a telescopic height measuring instrument (Seca 225 stadiometer, Birmingham, UK) to the nearest 0.1 cm. BMI was calculated as the body weight in kilograms divided by the height in meters squared. BMI was then categorized according to International Obesity Task Force cut-offs, 2012.

### Instruments for assessing indicators of lifestyle

Physical activity was objectively assessed by a uni-axial accelerometer (ActiGraph® or ActiTrainer® n ActiGraph, Pensacola, FL, USA) worn on the child's hip over three consecutive days, including one weekend day, for a minimum duration of six hours monitoring time per day. The duration of moderate to vigorous physical activity (MVPA) was determined according to the cut-offs established by Evenson.

Parental proxy-reported questionnaires provided information on the indicator variables of the other five key behaviours. The 'Children's eating habits questionnaire' (CEHQ) included a 43 item food frequency questionnaire referring to the home dietary habits of the previous

four weeks. Fruit and vegetable consumption was obtained from CEQH, summarising the reported intake frequency of fresh fruits, raw and cooked vegetables. For the descriptive statistics of key behaviour, water consumption frequency was used, assessed as times per day. For the analysis of the contribution of the selected key lifestyle factors to obesity these indicators were modified. In favour of getting a holistic picture of the child' diet, the fruit and vegetable intake was extrapolated to the global diet, based on the number of meals eaten at home and at school. In the IDEFICS intervention, the message was to consume water while in exchange reducing the intake of sugar-sweetened beverages. Taking into account both the direct and indirect part of this key message, water and plain milk were counted as the healthy beverage options, in contrast with sweetened drinks, juices and sweetened milk, categorised as the unhealthy options for the assessment of complying with this key message.

The computer-based 24-hour dietary recall included also a diary, inquiring the child's bedtime and get-up time from which the nocturnal sleep duration was calculated.

The core questionnaire on behavioural factors was the source for proxy-reported daily screen-time of the child, adding the time spent with audio-visual media (TV, video, DVD, computer, game console).

Assuming that high quality of life indicates more balanced family life, a health-related quality of life score was used as an indicator of the key message referring to improved quality of family life, though it covers a broader range of information than the family life. Thus, the parental core questionnaire included 4 modules from the KINDL® (Questionnaire for Measuring Health-Related Quality of Life in Children and Adolescents) questionnaire: emotional self-being, self-esteem, family relations and social contacts. These aspects were evaluated by the parent on a four-point scale (1-4). The results were summed to create a total score that ranged from 12-48, the higher the score value the better the reported well-being.

## Compliance score

A total compliance score was calculated as the sum of those key behaviours where a recommended target value was met. In case of four key behaviours internationally confirmed thresholds were available:

- fruit and/or vegetable consumption: a daily intake of five or more portions;
- sleep duration: 11 hours or more for pre-school children and 10 hours or more for school children;
- screen time: not more than one hour per day for pre-school children and not more than two hours per day for school age children;

- physical activity: at least 60 minutes of moderate to vigorous physical activity per day.

Since water consumption is influenced by season and climate, physical activity, and the water content of the diet, we have not considered the international recommendation but used as target the highest category of intake frequency in CEHQ, i.e. 4 or more times per day. In case of further analysis, the compliance was indicated by consuming only water or plain milk and no sweetened beverages of any sort.

No international treshold could be interpreted for KINDL® questionnaire, since only four modules of the original six have been used; so the 85$^{th}$ percentile, i.e. a generally used threshold, was applied on the scale range, indicating 44 points as cut-off value.

Based on the above thresholds, a compliance score was calculated by summing the number of key behaviours for which the target was met. Hence, the compliance score ranges from zero (no compliance with any of the key behavioural targets) to six (full compliance with all six targets). Achieving at least four points, i.e. complying with more than the half of the key behaviours, was regarded as good compliance.

### Statistical analysis

We assessed country-specific means and standard deviations and prevalence of compliance with each of the six key behaviours as well as country-specific distributions of the compliance score, stratified by age group. All analyses were performed using SAS 9.2 (SAS Institute Inc.). To determine whether compliance with the key behaviours modify the risk of being overweight/obese (outcome variable) we used multilevel logistic regression models (Proc Glimmix, SAS 9.3, Cary, North Carolina, USA) to derive age- and sex-adjusted odds ratios (ORs) with corresponding 95%-confidence intervals (95% CIs), with country modelled as a random intercept. Smoothed age- and gender-specific percentile graphs of certain behaviour prevalence were created by LMSchartmaker ProVersion 2.54.

## Results

### The study population

Baseline descriptive data were obtained from the extended cohort of T0 plus the T1 new recruitment children (total 18,745 children); and the contribution of key behaviours to obesity was assessed only in the T0 – i.e. pre-intervention- cohort (total 16,228 children). The sample size according to reported key behaviour indicators varied in a range of 7444-17212, according to the varying proportions of participation in the various modules; while information on all six elements for calculation of a total compliance score was available for 5,140

and 4,340 children for the descriptive and the inferential statistics, respectively. No noteworthy differences were found regarding the socio-demographic characteristics between the total sample and the various sub-populations according to the availability of data on the various key behaviours (Table 1).

*Table 1. Socio-demographic profile of the total sample and of the various analysis groups*

| Children providing information on… | N | | Girls (%) | | ISCED-Level[1)] Low/High (%) | | Age Mean (SD) | | BMI z-score Mean (SD) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $T_0+T_1$ | $T_0$ | $T_0+T_1$ | $T_0$ | $T_0+T_1$ | $T_0$ | $T_0+T_1$ | $T_0$ | $T_0+T_1$ | $T_0$ |
| Water consumption | 16,250 | 14,992 | 49.6 | 49.2 | 9.8 / 38.7 | 10.7 / 38.5 | 6.14 (1.88) | 5.99 (1.80) | 0.31 (1.19) | 0.32 (1.19) |
| Fruit/vegetable consumption | 14,950 | 14,992 | 49.8 | 49.2 | 9.6 / 39.2 | 10.7 / 38.5 | 6.13 (1.88) | 5.99 (1.80) | 0.31 (1.19) | 0.32 (1.19) |
| Screen-time | 17,212 | 15,084 | 49.6 | 49.2 | 9.9 / 38.7 | 10.2 / 38.2 | 6.15 (1.88) | 5.99 (1.79) | 0.32 (1.19) | 0.32 (1.19) |
| MVPA | 8,302 | 7,444 | 49.8 | 49.5 | 9.9 / 36.8 | 10.0 / 37.1 | 6.40 (1.85) | 6.22 (1.76) | 0.35 (1.17) | 0.36 (1.18) |
| Health-related quality of life | 15,965 | 13,936 | 49.6 | 49.3 | 9.9 / 38.2 | 10.2 / 38.7 | 6.17 (1.88) | 6.01 (1.80) | 0.32 (1.19) | 0.33 (1.18) |
| Sleep duration | 11,559 | 10,494 | 49.7 | 49.5 | 11.4 / 35.2 | 11.7 / 35.9 | 6.18 (1.98) | 6.04 (1.83) | 0.35 (1.18) | 0.35 (1.18) |
| All six key behaviours | 5,140 | 4,340 | 50.1 | 49.4 | 8.4 / 37.0 | 9.8 / 35.6 | 6.33 (1.90) | 6.25 (1.77) | 0.31 (1.16) | 0.38 (1.17) |
| ***Total sample*** | 18,745 | 16,228 | 49.6 | 49.1 | 10.4 / 38.2 | 10.7 / 38.7 | 6.16 (1.88) | 6.01 (1.79) | 0.33 (1.20) | 0.33 (1.19) |

[1)] Educational level of parents, according to the International Standard Classification of Education Low: (Pre-) Primary and lower secondary education (ISCED-level categories 0/1/2)
High: Tertiary education (ISCED-level categories 5/6).
Percentages are calculated related to the number of children with non-missing values for the variable ISCED-level.

The prevalence of overweight and obesity was 19.7% in the baseline population, with a significant increase by age, being 13.8% and 24.7% in kindergarten and school-age, respectively. The country distribution, demonstrating a North-South difference, is shown in Figure1.

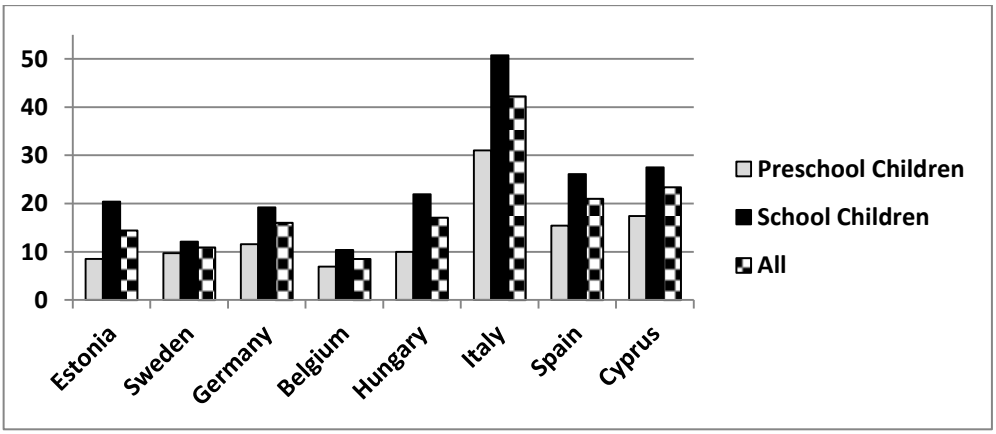



*Figure 1. Prevalence of overweight and obesity by age group and country*

## Descriptive statics of key behaviours

We characterized the observed behaviours by mean (SD) stratified by country and age group (Table 2). The higher amount of water consumption in the South countries was most probably a climate effect, while age didn't play a role. Fruit and vegetable intake was below the recommended level in all countries, but despite the geographical/agricultural possibilities, some Northern countries achieved better results than the Southern counties. Older children spent more time in front of the TV or computer. In all countries total screen-time was higher for boys than girls. The mean daily duration of MVPA was higher for boys than for girls and in school age than in kindergarten children. Health-related quality of life score was lower in older children in all countries. Nocturnal sleep duration decreased by age, while the shorter duration in Southern countries may reflect the influence of climate.

*Table 2. Means and standard deviations of key behaviour indicators by country and age group*

| | **Pre-school children** | | | **School children** | | | **All** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **N** | **Mean** | **SD** | **N** | **Mean** | **SD** | **N** | **Mean** | **SD** |
| **Water consumption (times per day)** | | | | | | | | | |
| **Estonia** | 932 | 2.72 | 1.45 | 1,042 | 2.57 | 1.46 | 1,974 | 2.64 | 1.46 |
| **Sweden** | 881 | 2.55 | 1.37 | 861 | 2.40 | 1.42 | 1,742 | 2.47 | 1.39 |
| **Germany** | 836 | 2.70 | 1.66 | 1,160 | 2.57 | 1.70 | 1,996 | 2.62 | 1.68 |
| **Belgium** | 986 | 2.31 | 1.44 | 1,034 | 2.30 | 1.48 | 2,020 | 2.31 | 1.46 |
| **Hungary** | 1,160 | 2.97 | 1.55 | 1,882 | 2.93 | 1.58 | 3,042 | 2.94 | 1.57 |
| **Italy** | 899 | 3.96 | 0.90 | 1,235 | 3.90 | 0.98 | 2,134 | 3.92 | 0.95 |
| **Spain** | 676 | 3.99 | 0.80 | 781 | 3.97 | 0.82 | 1,457 | 3.98 | 0.81 |
| **Cyprus** | 804 | 3.92 | 0.84 | 1,081 | 3.81 | 0.97 | 1,885 | 3.86 | 0.92 |
| ***All*** | ***7,174*** | ***3.09*** | ***1.46*** | ***9,076*** | ***3.05*** | ***1.51*** | ***16,250*** | ***3.07*** | ***1.49*** |
| **Fruit/vegetable consumption (times per day)** | | | | | | | | | |
| **Estonia** | 822 | 2.80 | 1.68 | 941 | 2.81 | 1.78 | 1,763 | 2.80 | 1.73 |
| **Sweden** | 830 | 3.09 | 1.64 | 809 | 3.18 | 1.69 | 1,639 | 3.13 | 1.66 |
| **Germany** | 763 | 3.13 | 1.80 | 1,010 | 2.89 | 1.70 | 1,773 | 2.99 | 1.75 |
| **Belgium** | 924 | 2.19 | 1.13 | 1,008 | 2.25 | 1.07 | 1,932 | 2.22 | 1.10 |
| **Hungary** | 1,069 | 2.40 | 1.53 | 1,725 | 2.16 | 1.42 | 2,794 | 2.25 | 1.47 |
| **Italy** | 842 | 2.13 | 1.56 | 1,156 | 2.13 | 1.57 | 1,998 | 2.13 | 1.57 |
| **Spain** | 638 | 2.40 | 1.51 | 719 | 2.58 | 1.65 | 1,357 | 2.50 | 1.59 |
| ***All*** | ***6,601*** | ***2.63*** | ***1.66*** | ***8,349*** | ***2.54*** | ***1.65*** | ***14,950*** | ***2.58*** | ***1.66*** |
| **Total screen-time (hours/per day)** | | | | | | | | | |
| **Estonia** | 957 | 1.63 | 0.95 | 1,092 | 2.49 | 1.18 | 2,049 | 2.09 | 1.16 |
| **Sweden** | 887 | 1.35 | 0.69 | 863 | 1.92 | 0.85 | 1,750 | 1.63 | 0.82 |
| **Germany** | 852 | 1.22 | 0.91 | 1,191 | 1.72 | 1.03 | 2,043 | 1.51 | 1.01 |
| **Belgium** | 1,057 | 1.37 | 0.92 | 1,148 | 1.85 | 1.05 | 2,205 | 1.62 | 1.02 |
| **Hungary** | 1,186 | 1.51 | 1.02 | 1,923 | 1.75 | 1.01 | 3,109 | 1.66 | 1.02 |
| **Italy** | 995 | 1.59 | 1.12 | 1,346 | 2.03 | 1.20 | 2,341 | 1.84 | 1.19 |
| **Spain** | 677 | 1.16 | 0.76 | 782 | 1.61 | 0.91 | 1,459 | 1.40 | 0.87 |
| **Cyprus** | 938 | 1.64 | 1.03 | 1,318 | 1.90 | 0.99 | 2,256 | 1.79 | 1.01 |
| ***All*** | ***7,549*** | ***1.45*** | ***0.96*** | ***9,663*** | ***1.90*** | ***1.07*** | ***17,212*** | ***1.71*** | ***1.05*** |
| **Moderate-to-vigorous physical activity (minutes per day)** | | | | | | | | | |
| **Estonia** | 690 | 33.87 | 16.46 | 751 | 46.1 | 22.07 | 1,441 | 40.24 | 20.51 |
| **Sweden** | 210 | 39.77 | 20.55 | 343 | 50.00 | 22.54 | 553 | 46.11 | 22.35 |
| **Germany** | 411 | 37.86 | 20.88 | 754 | 47.29 | 23.44 | 1,165 | 43.97 | 23.01 |
| **Belgium** | 213 | 32.55 | 17.72 | 445 | 43.30 | 18.42 | 658 | 39.82 | 18.87 |
| **Hungary** | 574 | 31.37 | 17.82 | 1,213 | 39.70 | 19.73 | 1,787 | 37.03 | 19.52 |
| **Italy** | 261 | 32.38 | 18.55 | 649 | 28.35 | 18.36 | 910 | 29.51 | 18.50 |
| **Spain** | 619 | 36.55 | 20.18 | 656 | 46.40 | 22.00 | 1,275 | 41.62 | 21.69 |

| | Pre-school children | | | School children | | | All | | |
|---|---|---|---|---|---|---|---|---|---|
| | **N** | **Mean** | **SD** | **N** | **Mean** | **SD** | **N** | **Mean** | **SD** |
| **Cyprus** | 197 | 32.76 | 18.54 | 316 | 35.36 | 18.13 | 513 | 34.36 | 18.31 |
| ***All*** | ***3,175*** | ***34.57*** | ***18.89*** | ***5,127*** | ***41.91*** | ***21.75*** | ***8,302*** | ***39.10*** | ***21.01*** |
| **Health-related quality of life score (points)** | | | | | | | | | |
| **Estonia** | 919 | 41.89 | 4.26 | 1,045 | 39.84 | 4.76 | 1,964 | 40.80 | 4.64 |
| **Sweden** | 861 | 42.41 | 3.69 | 848 | 41.75 | 4.31 | 1,709 | 42.08 | 4.02 |
| **Germany** | 765 | 40.61 | 4.29 | 1,103 | 40.07 | 4.86 | 1,868 | 40.29 | 4.64 |
| **Belgium** | 1,002 | 41.50 | 4.32 | 1,101 | 40.24 | 4.95 | 2,103 | 40.84 | 4.71 |
| **Hungary** | 1,142 | 38.21 | 3.92 | 1,878 | 37.38 | 4.12 | 3,020 | 37.69 | 4.07 |
| **Italy** | 951 | 39.97 | 4.47 | 1,302 | 38.75 | 4.93 | 2,253 | 39.27 | 4.78 |
| **Spain** | 644 | 40.49 | 3.94 | 760 | 39.95 | 4.25 | 1,404 | 40.20 | 4.12 |
| **Cyprus** | 618 | 38.08 | 4.91 | 1,026 | 37.87 | 4.77 | 1,644 | 37.95 | 4.82 |
| ***All*** | ***6,902*** | ***40.41*** | ***4.47*** | ***9,063*** | ***39.22*** | ***4.81*** | ***15,965*** | ***39.73*** | ***4.70*** |
| **Sleep duration (hours per night)** | | | | | | | | | |
| **Estonia** | 932 | 9.58 | 0.77 | 1,005 | 9.38 | 0.72 | 1,937 | 9.48 | 0.75 |
| **Sweden** | 688 | 11.00 | 0.82 | 697 | 10.50 | 0.66 | 1,385 | 10.75 | 0.78 |
| **Germany** | 790 | 11.29 | 0.85 | 1,134 | 10.79 | 0.72 | 1,924 | 11.00 | 0.81 |
| **Belgium** | 388 | 11.28 | 0.62 | 504 | 10.84 | 0.51 | 892 | 11.03 | 0.60 |
| **Hungary** | 552 | 10.05 | 0.55 | 990 | 10.00 | 0.61 | 1,542 | 10.01 | 0.59 |
| **Italy** | 793 | 9.85 | 0.88 | 1,153 | 9.53 | 0.71 | 1,946 | 9.66 | 0.80 |
| **Spain** | 469 | 10.37 | 0.57 | 452 | 10.02 | 0.40 | 921 | 10.20 | 0.52 |
| **Cyprus** | 350 | 10.19 | 0.52 | 662 | 10.12 | 0.53 | 1,012 | 10.14 | 0.53 |
| ***All*** | ***4,962*** | ***10.39*** | ***0.99*** | ***6,597*** | ***10.09*** | ***0.83*** | ***11,559*** | ***10.22*** | ***0.92*** |

Percentile charts (Figure 2) of those behaviours for which international recommendations are available depict an at-a-glance overview (with details in the next section) where the distribution and age-related trend of these behaviours can be observed. Fruit and vegetable

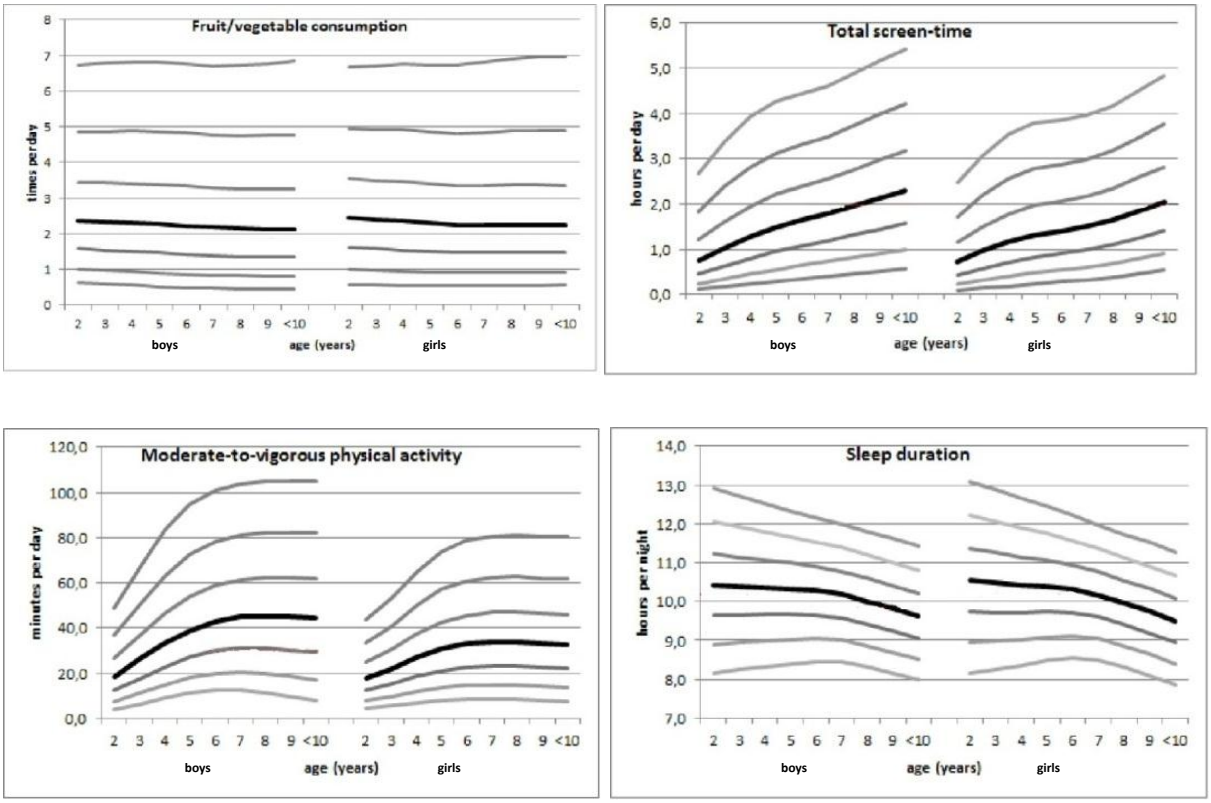



*Figure 2. Percentile (3rd, 10th, 25th, 50th, 75th, 90th and 97th) distribution of certain lifestyle factors*

consumption doesn't demonstrate characteristic differences by age or gender, though it is remarkable that only the 90$^{th}$ percentile reaches the recommended level of consumption. Total screen time, being higher in boys, increased rapidly by age, where roughly the 50$^{th}$ percentile corresponds with the recommendations. Regarding physical activity, by school age the 75$^{th}$ percentile in boys and the 90$^{th}$ percentiles in girls equals with the recommended threshold. Sleep duration decreased by age, which is physiological, but this speeds up by school enrolment. In both sexes, roughly the 75$^{th}$ percentile fulfils the recommendations.

## Descriptive statistics of the composite compliance score

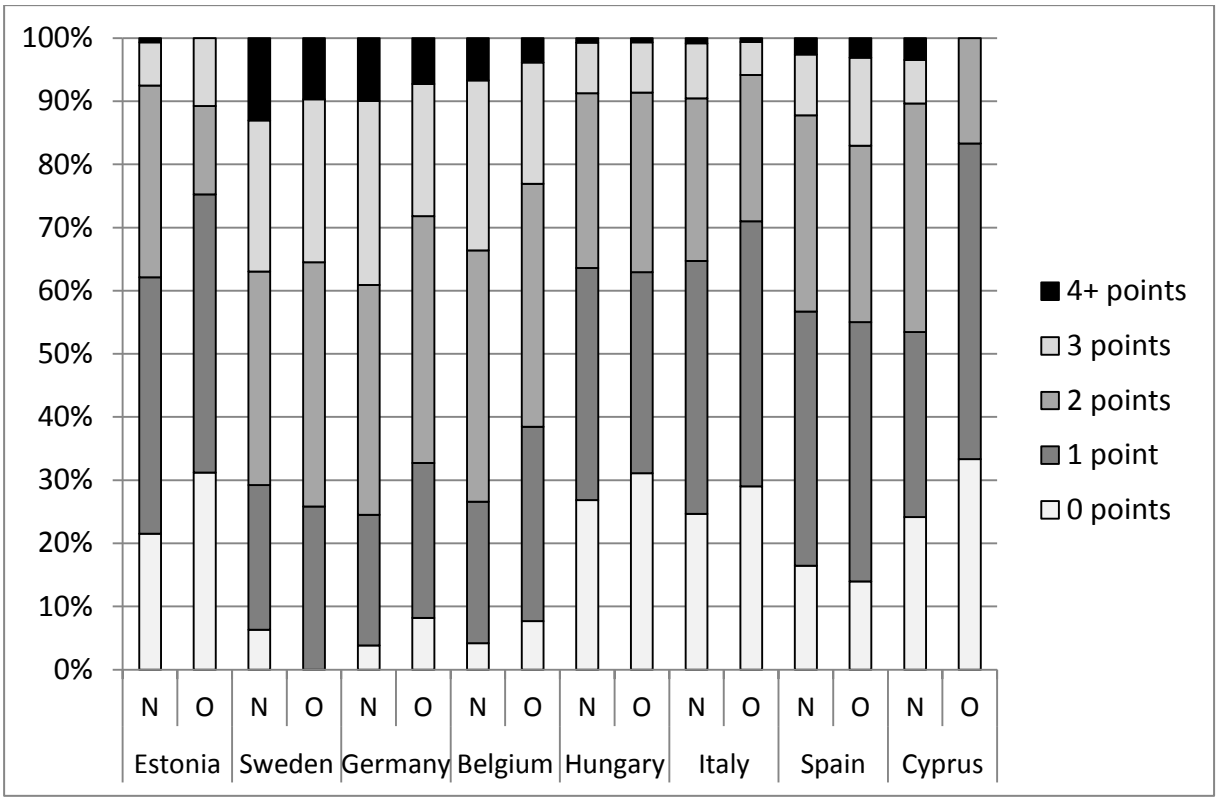
Results for the composite compliance score are shown in Table 3. Only a minor proportion of the overall sample demonstrated adherence to at least four key behaviours (3.8%), and among this small group almost twofold better results were observed among normal weight children compared to overweight children. Overall, compliance was better in older age in both weight groups. On the opposite side of the spectrum, the non-compliance (score value 0-1) also reinforced the observed lifestyle differences, being more prevalent in overweight children than in normal weight children.

*Table 3. Distribution of compliance score value according to age and weight group*

| | Preschool Children | | | | School Children | | | | All | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Normal* | | Overweight** | | Normal* | | Overweight ** | | Normal* | | Overweight* * | |
| | N | % | N | % | N | % | N | % | N | % | N | % |
| **0 point** | 346 | 23.0 | 72 | 34.1 | 211 | 10.8 | 133 | 19.8 | 557 | 16.1 | 205 | 23.2 |
| **1 point** | 551 | 36.7 | 88 | 41.7 | 580 | 29.7 | 242 | 36.1 | 1131 | 32.7 | 330 | 37.4 |
| **2 points** | 420 | 28.0 | 41 | 19.4 | 682 | 34.9 | 194 | 28.9 | 1102 | 31.9 | 235 | 26.6 |
| **3 points** | 156 | 10.4 | 10 | 4.7 | 364 | 18.6 | 83 | 12.4 | 520 | 15.0 | 93 | 10.5 |
| **4+ points** | 29 | 1.9 | 0 | 0.0 | 119 | 6.1 | 19 | 2.8 | 148 | 4.3 | 19 | 2.2 |
| **All** | 1502 | 100.0 | 211 | 100.0 | 1956 | 100.0 | 671 | 100.0 | 3458 | 100.0 | 882 | 100.0 |

* including also underweight
** including also obese

Figure 3. shows the distribution of compliance score by survey centre country and weight status (normal vs. overweight). It reveals significant inter-country differences with a characteristic North-South contrast, with the exception of Estonia. Overall, the Northern European countries reported better compliance with the key behaviours, while also having lower obesity prevalence. In most countries the normal weight children demonstrated better compliance with key behaviours than the obese children with the exceptions of equally low compliance in Hungary and Italy and a reversed direction in Spain.




N: normal weight including underweight; O: overweight including obese

*Figure 3. Distribution of compliance score value according to country and weight group*

## Adherence to the recommended thresholds

In the following, we investigated the compliance with each of the key behaviours (Table 4). Overall, 52.5% of the children were in the highest category of water intake, which represented the recommended level of consumption. The recommended "5-a-day" portion of fruit and vegetable consumption was met only by a minor proportion of the children, being especially low in Italy, Spain and Belgium. None of these diet-related key behaviours showed major differences by age. Total screen-based activities were below the recommended maximum threshold in half of all children with no major regional differences, girls having better compliance than boys. The recommended 60 minutes MVPA was achieved in only 15.2% of the children, with threefold difference in the prevalence between countries. The same order of magnitude in difference was observed according to sex, being higher among boys than among girls, improving by age in both groups. The health-related quality of life score demonstrated far better results in the Northern region than in the Southern region, especially among girls, while a lower result at school age was observable. The recommendation on sleep duration was fulfilled in 37.9% of our study sample. In both age groups and in all countries except Estonia, the adherence was better in girls.

*Table 4. Country-, age- and weight-specific proportions (in percent) of children complying with the key behavioural targets*

| | Preschool Children | | School Children | | All | |
|---|---|---|---|---|---|---|
| | **Normal*** | **Overweight**** | **Normal*** | **Overweight**** | **Normal*** | **Overweight**** |
| **No sweetened drink** | | | | | | |
| **Estonia** | 40.9 | 40.8 | 26.5 | 26.4 | 34.3 | 30.8 |
| **Sweden** | 39.3 | 40.7 | 27.4 | 34.6 | 33.5 | 37.3 |
| **Germany** | 20.7 | 18.6 | 19.5 | 18.8 | 20.0 | 18.7 |
| **Belgium** | 22.5 | 22.4 | 17.8 | 9.4 | 20.3 | 15.1 |
| **Hungary** | 14.9 | 9.9 | 15.8 | 16.8 | 15.4 | 15.1 |
| **Italy** | 28.4 | 28.1 | 19.8 | 20.1 | 24.3 | 22.6 |
| **Spain** | 19.6 | 17.3 | 13.2 | 11.9 | 16.4 | 13.8 |
| **Cyprus** | 39.8 | 32.7 | 37.1 | 40.6 | 38.3 | 38.4 |
| ***All*** | **27.7** | **26.0** | **21.8** | **22.1** | **24.7** | **23.3** |
| **Fruit/vegetable consumption ≥"five a day"** | | | | | | |
| **Estonia** | 35.6 | 42.3 | 16.4 | 22.1 | 26.8 | 28.2 |
| **Sweden** | 37.5 | 44.4 | 40.4 | 43.3 | 38.9 | 43.8 |
| **Germany** | 22.5 | 23.7 | 15.1 | 14.2 | 18.5 | 17.1 |
| **Belgium** | 3.6 | 6.0 | 4.0 | 9.4 | 3.8 | 7.9 |
| **Hungary** | 28.0 | 22.8 | 19.3 | 18.0 | 23.2 | 19.1 |
| **Italy** | 5.2 | 5.1 | 4.7 | 4.4 | 5.0 | 4.6 |
| **Spain** | 9.0 | 8.7 | 9.1 | 7.0 | 9.1 | 7.5 |
| **Cyprus** | 24.5 | 24.5 | 19.7 | 26.1 | 21.8 | 25.6 |
| ***All*** | **21.1** | **18.0** | **16.7** | **14.4** | **18.9** | **15.5** |
| **Total screen-time <1 hour in pre-school and <2 hours in school children** | | | | | | |
| **Estonia** | 29.7 | 22.9 | 40.8 | 30.7 | 34.8 | 28.3 |
| **Sweden** | 36.2 | 37.8 | 61.1 | 54.5 | 48.2 | 47.0 |
| **Germany** | 55.6 | 42.2 | 71.5 | 55.3 | 64.3 | 51.4 |
| **Belgium** | 44.6 | 36.8 | 64.4 | 49.4 | 53.5 | 43.7 |
| **Hungary** | 40.9 | 24.5 | 66.8 | 60.9 | 55.2 | 52.4 |
| **Italy** | 38.7 | 31.0 | 62.0 | 56.7 | 50.0 | 48.6 |
| **Spain** | 56.5 | 46.0 | 72.0 | 69.2 | 64.2 | 61.5 |
| **Cyprus** | 32.4 | 29.6 | 63.1 | 59.9 | 49.7 | 51.3 |
| ***All*** | **41.5** | **33.3** | **63.3** | **56.5** | **52.6** | **49.2** |
| **Moderate-to-vigorous physical activity >60 min** | | | | | | |
| **Estonia** | 5.2 | 9.1 | 26.7 | 17.5 | 14.6 | 14.5 |
| **Sweden** | 17.0 | 25.0 | 31.9 | 23.7 | 26.0 | 24.1 |
| **Germany** | 12.9 | 10.0 | 30.3 | 20.4 | 23.7 | 17.6 |
| **Belgium** | 5.9 | 0.0 | 14.8 | 17.9 | 11.2 | 12.8 |
| **Hungary** | 8.4 | 5.3 | 15.5 | 10.2 | 12.8 | 9.2 |
| **Italy** | 9.6 | 12.8 | 5.8 | 4.7 | 7.2 | 6.3 |
| **Spain** | 12.6 | 10.0 | 24.0 | 16.5 | 18.0 | 14.3 |
| **Cyprus** | 7.4 | 11.4 | 10.8 | 2.9 | 9.3 | 5.7 |
| ***All*** | **9.6** | **10.2** | **20.8** | **11.7** | **15.9** | **11.3** |
| **Health-related quality of life score ≥44 points** | | | | | | |
| **Estonia** | 41.8 | 43.1 | 26.5 | 25.6 | 34.8 | 30.7 |
| **Sweden** | 44.7 | 45.6 | 40.3 | 43.8 | 42.5 | 44.6 |
| **Germany** | 27.7 | 25.3 | 27.6 | 25.1 | 27.7 | 25.2 |
| **Belgium** | 38.0 | 41.2 | 31.2 | 30.7 | 34.9 | 35.7 |
| **Hungary** | 6.2 | 8.4 | 4.3 | 3.9 | 5.2 | 5.0 |
| **Italy** | 22.0 | 23.9 | 18.5 | 17.0 | 20.3 | 19.2 |
| **Spain** | 23.8 | 22.1 | 21.2 | 16.9 | 22.5 | 18.6 |
| **Cyprus** | 15.0 | 9.1 | 12.2 | 9.8 | 13.3 | 9.6 |
| ***All*** | **28.2** | **25.7** | **21.9** | **17.4** | **25.0** | **19.9** |
| **Sleep duration ≥11 hours in pre-school and ≥10 hours in school children** | | | | | | |
| **Estonia** | 3.3 | 1.5 | 12.4 | 11.5 | 7.3 | 8.4 |
| **Sweden** | 40.2 | 39.3 | 76.3 | 67.5 | 58.0 | 55.1 |
| **Germany** | 59.9 | 54.9 | 86.4 | 80.8 | 74.7 | 72.7 |
| **Belgium** | 69.9 | 76.2 | 96.0 | 93.8 | 82.5 | 86.8 |
| **Hungary** | 1.8 | . | 43.1 | 34.4 | 25.6 | 26.7 |

| | Preschool Children | | School Children | | All | |
|---|---|---|---|---|---|---|
| | Normal* | Overweight** | Normal* | Overweight** | Normal* | Overweight** |
| **Italy** | 7.0 | 4.0 | 18.1 | 13.7 | 12.6 | 10.8 |
| **Spain** | 7.9 | 4.9 | 44.3 | 52.7 | 24.2 | 35.7 |
| **Cyprus** | 3.7 | 7.9 | 52.7 | 56.3 | 34.3 | 43.0 |
| ***All*** | **24.9** | **16.8** | **54.2** | **37.9** | **40.1** | **31.4** |

* including also underweight
** including also obese

## Contribution of adherence to certain individual lifestyle factors to obesity

Table 5. shows the contribution of complying with each behaviour to the risk of obesity. There was no significant correlation between diet-related behaviours and overweight; but

*Table 5. Contribution of key behaviours to BMI by age group: odds ratios and 95% CIs for overweight/obesity by age group*

| Key behaviour | Pre-school children | School children | All |
|---|---|---|---|
| **No sweetened drink** | 0.93 (0.78-1.09) | 1.03 (0.91-1.18) | 0.99 (0.90-1.10) |
| **Fruit/vegetable consumption ≥"five a day"** | 1.06 (0.88-1.29) | 1.10 (0.95-1.28) | 1.07 (0.95-1.21) |
| **Total screen-time <1 hour in pre-school and <2 hours in school chil-** | *0.73 (0.62-0.85)* | *0.74 (0.66-0.82)* | *0.77 (0.70-0.83)* |
| **Moderate-to-vigorous physical activity >60 min** | 0.97 (0.67-1.41) | *0.63 (0.51-0.78)* | *0.70 (0.58-0.84)* |
| **Health-related quality of life score ≥44 points** | 1.00 (0.84-1.20) | 0.90 (0.78-1.04) | 0.94 (0.84-1.05) |
| **Sleep duration ≥11 hours in pre-school and ≥10 hours in school** | 0.83 (0.63-1.08) | *0.84 (0.73-0.98)* | *0.85 (0.74-0.96)* |

we can't exclude reporting bias. The compliance with the recommended screen time and MVPA level proved to be the most beneficial regarding the maintenance of normal weight. Health-related quality of life showed no association with overweight, probably due the mathematically derived threshold, being not confirmed by international recommendations. Children with optimal sleep duration had a decreased risk of overweight.

## Contribution of compliance score to obesity

Table 6. demonstrates the effect of compliance with the recommended set of behaviours on obesity: increasing score decreased clearly and consequently the chance of obesity. With improved compliance score a gradual decreasing risk of obesity is observable, and within the good compliance category the risk of obesity is almost halved (OR 0.54, 95% CI 0.37 - 0.80).

*Table 6. Contribution of compliance score to BMI by age group: odds ratios and 95% CIs for overweight/obesity by age group*

| Score value | Pre-school children | School children | All |
|---|---|---|---|
| | **Odds Ratio (95% CI)** | **Odds Ratio (95% CI)** | **Odds Ratio (95% CI)** |
| **0 point** | 1.00 reference | 1.00 reference | 1.00 reference |
| **1 point** | 0.75 (0.53-1.06) | 0.80 (0.61-1.06) | 0.81 (0.65-1.01) |
| **2 points** | 0.47 (0.32-0.70) | 0.68 (0.52-0.91) | 0.65 (0.52-0.82) |
| **3 points** | 0.66 (0.40-1.07) | 0.63 (0.45-0.87) | 0.66 (0.51-0.86) |
| **4 + points** | 0.69 (0.32-1.48) | 0.48 (0.30-0.75) | 0.54 (0.37-0.80) |

## Conclusion

This work investigated the adherence of European children to selected health behaviours known to be associated with childhood obesity and being essential for children´s optimal and healthy development. The results demonstrate that strikingly low proportions of these children meet the recommended target values of the investigated health behaviours. This work directs the attention to the gap between the present and the required situation. However, the respective contribution of the individual six elements of this score was different.

The compliance score, an indicator of a set of pro-health behaviours, was significantly correlated with body weight, and as the number of pro-health behaviours increased a gradual reduction for the odds of being overweight was observed. This finding supports the importance of the selected intervention target areas and the six key lifestyle elements. It demonstrates that these messages can be potent and relevant elements of future intervention and prevention programs. The proven favourable effect of guideline adherence underpins that these guidelines represent an important anchor point and an easy-to-use heuristic for all actors – children, parents, schools, stakeholders – to tackle obesity effectively.

The other important finding was the general low prevalence of pro-health behaviours. Almost none of the children achieved full compliance with the six key behaviours selected during intervention mapping. Even the compliance with more than half of the key behaviours was dramatically low. This demonstrates that there is an enormous reserve in the intervention tackling the obesity epidemic, and confirms the potential of obesity intervention. Our results demonstrated that even a slight improvement in lifestyle, i.e. complying with just one more of these pro-health behaviours, provides a meaningful and statistically significant benefit, which is an encouraging message for both the target population and the health promotion professionals.

## New findings of the study

This work contributes to the intervention of childhood obesity by

- providing data on spontaneous (pre- intervention) adherence to the most important international recommendations combatting childhood obesity;
- creating the compliance score, an indicator as composite measure of adherence to relevant pro-health lifestyle contributing to obesity;
- proving the potential of the intervention through demonstrating that even a small increment in the adherence regarding the recommended set of behaviours creates a detectable improvement, an encouraging message in tackling the obesity epidemic. The combining elements of behaviour –though contributing unequally to obesity- may influence and partly compensate each other, which, expressed by the score, is a supportive message motivating compliance.

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I dedicate this work to the memory of my father; and to my mother who transferred me his message.

# Publications

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## Publications in the topic of the thesis

### *Papers, international*

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