2020

Distinct age-related patterns of overweight development to guide school health care interventions

Häkkänen, Paula

Wiley

Tieteelliset aikakauslehtiartikkelit
© Foundation Acta Paediatrica
All rights reserved
http://dx.doi.org/10.1111/apa.15036

https://erepo.uef.fi/handle/123456789/7826
Downloaded from University of Eastern Finland's eRepository
Distinct age-related patterns of overweight development to guide school health care interventions

Paula Häkkänen¹,², Anna But³, Eeva Ketola⁴, Tiina Laatikainen⁵,⁶,⁷

¹School and Student Welfare, Social Services and Health Care Division, City of Helsinki, Finland; ²Department of General Practice and Primary Health Care, University of Helsinki, Finland; ³Department of Public Health, University of Helsinki, Finland; ⁴Information Services, National Institute for Health and Welfare, Helsinki, Finland; ⁵Institute of Public Health and Clinical Nutrition, University of Eastern Finland, Kuopio, Finland; ⁶Siun Sote - the Joint Municipal Authority for North Karelia Social and Health Services, Joensuu, Finland, ⁷Department of Public Health Solutions, National Institute for Health and Welfare, Helsinki, Finland

Short title: Overweight development during primary school

Corresponding author: Paula Häkkänen, School and Student Welfare, Social Services and Health Care Division, City of Helsinki, PL 84301, FI-00099 Helsingin kaupunki, Finland. Tel +358 05 5901819. E-mail: paula.hakkanen@helsinki.fi.
ABSTRACT

Aim: We aimed to identify groups of primary school children with similar overweight development, reveal age-related patterns of overweight development in the resulting groups and analyse overweight-related school health care interventions.

Methods: This retrospective longitudinal register study utilized electronic health records from six primary school years. From a random sample of 2000 sixth graders, we derived a study cohort of 508 children meeting criteria for overweight at least once during primary school. We investigated how many different groups (latent classes) of children with similar weight development would emerge by applying flexible latent class mixed models on body mass index standard deviation score. We also explored the resulting groups with respect to offered overweight-related interventions.

Results: Per child, the data consisted in median 7 growth measurements over 5.4 years. We identified five overweight development groups for girls and four for boys. The groups converged temporarily around age 10 after which only some continued into obesity. School nurses and physicians offered overweight-related interventions to children with obesity, less to children gaining weight or with overweight.

Conclusion: Obesity prevention might benefit from awareness of typical overweight development patterns when designing intervention studies or planning and timing multidisciplinary school health check programs.
**Keywords:** Childhood obesity, intervention, latent class mixed model, primary school children, trajectory.

**Key notes:**
- This retrospective register-based cohort study evaluated overweight development and overweight-related interventions during six primary school years.
- We identified five distinct overweight development patterns for girls and four for boys and summarized these into developmental curves of which all but one were in overweight area around the age of 10, and only some continued into obesity.
- Overweight development patterns should be considered when timing multidisciplinary school health checks.
INTRODUCTION

Prevention of childhood obesity calls for various efforts from the society (1). School health care, a part of primary health care, is one of the actors in prevention and treatment of obesity and its limited resources should be used effectively and timed well. School health care could make a difference with improved understanding of the subgroups and the ideal moments to offer overweight-related interventions.

In Finland school nurses meet children annually, as obligated by the Finnish decree (2), and therefore are a valuable resource for detecting overweight and obesity and offering evidence-based interventions (3). Over six primary school years, multidisciplinary health checks during first grade (age 7) and at fifth grade (age 11) include appointments with school physicians in addition to school nurses and emphasize collaboration with parents. Extra appointments with school physicians are organised when preventive health concerns are observed, overweight or obesity as one example. Treatment of acute or long-term diseases takes place in community health centres.

Although several countries, like Finland, have national guidelines (3, 4) and local operating models, obesity treatment in primary care is often suboptimal (5-7). International studies show that various treatment programs can be effective (8, 9), also those realised in primary care settings (10). Multicomponent interventions seem to have the best results, yet knowledge on beneficial practices remains incomplete (9).

We have insufficient knowledge on the ways in which the resources in school health care are de facto used and how treatments actualise. We also lack the knowledge whether the Finnish approach, with health checks by a school physician at first and fifth grades (ages 7 and 11), is ideal with respect to timing when aiming to prevent and treat obesity. For example, treatment results in paediatric outpatient clinics were clearly better if interventions were started before the age of 10 (11).

Childhood obesity, especially during adolescence, predicts adult obesity even though most adults with obesity have been in normal-weight area during childhood (12). Childhood obesity does not always continue after puberty and therefore the usefulness of targeting interventions to children with overweight and obesity can been speculated (12). Thus, identifying distinct overweight development patterns could help school health care to target children most likely to continue gaining weight.
Obesity treatment and research could do with a clearer focus on gender differences. Gender affects the causes and consequences of obesity through related biological and social factors (13, 14) and timing and secular trend of pubertal development differ between sexes (15).

Analysing patterns of childhood growth in longitudinal settings is recommended over cross-sectional associations in identifying risk factors for abnormal growth (16). Latent class models and other advanced statistical techniques have been used to illustrate distinct weight development patterns (trajectories) of children during primary school and adolescence. Several studies have investigated the association of weight development patterns with child- and parental-related characteristics, such as gender and ethnicity, childhood environment and experiences, as well as maternal factors (17-21). Most above-mentioned studies included girls and boys in one analysis. However, sex-specific weight development patterns were exploited in studies of Canadian (22), Japanese (20) and South-African children (23). Few studies have examined associations of weight development patterns with health-related behaviours (21, 24). To our knowledge, overweight development patterns with respect to overweight-related interventions offered in school health care have not been studied earlier.

Aim

This study aims to identify typical overweight development patterns of primary school children (ages 7 to 12 years) in a longitudinal real-life cohort by identifying groups of children with similar weight development and summarizing these age-related patterns into curves using body mass index standard deviation scores (BMI SDS). We aim to learn how overweight develops under prevailing obesity prevention and treatments offered in school health checks. By studying data from electronic health records (EHR) on offered overweight-related interventions with respect to the identified overweight development groups, we aim to evaluate at whom treatments were targeted in school health care.

METHODS

This retrospective register-based cohort study was based on longitudinal data from primary health care EHRs of six primary school years. From these health check records, we manually retrospectively retrieved available growth measurements and data on overweight-related interventions during primary school.
Study population and growth measurements

From all 4968 sixth graders in Helsinki, Finland, in spring 2013, we selected randomly 2000 children (40%) from which we derived a cohort of children with overweight (Figure S1). As we expected to find 20% to 25% of the sample to fulfil the eligibility criteria of the study, the resulting cohort was considered sufficiently representative yet achievable for retrieving the data manually. The study cohort comprised 518 children (26% of the sample) who, based on growth measurement data, were affected by overweight at least once during six primary school years according to both weight-for-height classification (25) and newer Finnish growth references (26).

During the study period, weight-for-height classification was the Finnish standard for health care professionals to define weight status and plan interventions and therefore our study adopted it to classify overweight. According to the classification, weight status is assessed as a percentage of the median weight-for-height of girls or boys. The cut-off points used for overweight and obesity for under 7-year-olds were 110% and 120% respectively, and upwards from 7 years 120% and 140% (25). Updated Finnish growth references include also BMI-for-age with cut-offs for overweight (girls 1.16, boys 0.78) and obesity (girls 2.11, boys 1.70) (26). BMI is useful in describing weight change over time and is comparable to other studies; therefore, we selected BMI SDS for our main analysis on weight development patterns even though we acknowledged that it may have disadvantages in analysis of severe obesity (27).

The total number of BMI SDS measurements varied between children. We required at least two BMI SDS measurements between 6 and 14 years of age for each child and thus excluded 10 children. In the end, the study population comprised 508 children (Figure S1), and altogether we had 3631 growth measurements available for the analysis.

We also utilized information of pubertal development found in the EHR entries. At school health checks it is customary to record the menarcheal status of girls. Additionally, at fifth-grade multidisciplinary health checks (age 11) school physicians determine the pubertal development of girls and boys by using Tanner staging (28, 29). These records were somewhat incomplete yet by combining all entries on the subject, we were able to form a variable informing if the Pubertal Development of girls was ‘early’, ‘average’, ‘late’ or ‘not known’. Boys were classified as ‘early’ (at least Tanner G3), ‘pubertal development started’ (Tanner G2) or ‘not started’ (Tanner G1) by the time of the fifth-grade health check.

For girls, early pubertal development implied menarche or at least Tanner M4 at fifth grade health check. The class of average Pubertal Development included girls having had menarche before sixth-grade health check but not before fifth grade or, alternatively, M2 or M3 at fifth grade. The
late class covered all girls with M1 at fifth grade, girls over 11.5 years of age with M2 at fifth grade and no experienced menarche before sixth grade and girls aged 13.5 years or more having not yet had menarche. Not known class comprised children whose EHR entries were inadequate for classification.

Weight-related attributes
The follow-up time for each child was determined as the time between the first and last primary school growth measurement in EHR. To form an attribute of the trend of weight development during primary school, we calculated if the BMI SDS increased or decreased between these two time-points. We also defined the highest and lowest BMI SDS measurement during primary school for each child with the corresponding age at these moments and the frequencies of obesity and severe obesity at first and sixth grades and over all six school years.

Overweight-related interventions
We wanted to understand what kind of evidence-based interventions were offered to children with overweight or obesity. Therefore, we formed variables to capture interventions offered during primary school after the first measurement of overweight or obesity. To determine this moment, we used the same weight-for-height criteria as school nurses and school physicians during the study period.

To combine and compare the overall interventions given, we formed a new binary variable called 'Optimal Intervention'. This variable demonstrates whether the total treatments offered and organised by school health care met defined criteria. The variable of Optimal Intervention did not attempt to quantify treatments according to assumed effectiveness.

We deemed a child to have received optimal intervention if the following had taken place: a school nurse entered an observation of overweight or obesity into EHR, a school physician met the child for this reason or in course of a routine health check, there was a treatment plan made together with parents and a next overweight-related appointment was planned. In addition to these, we required a recorded positive change in health habits or a concrete nutrition or exercise plan. We did not take the count of appointments as a qualifier, as a previous study noticed that children attend overweight-related additional appointments mainly alone (7). All children who attended family centred group interventions lasting one school year or visited paediatricians due to obesity in outpatient clinics were also deemed to have received Optimal Intervention. Our decision was founded on Finnish evidence-based guidelines for prevention and treatment of childhood obesity (3). The chosen central parts of the guidelines reflect the overall effort given by
school health care during all primary school years. This approach was taken as forming a confident relationship with the family and increasing their motivation for behavioural change might take time.

We also compiled information on overweight-related consultations with dietitians or physiotherapists and obesity diagnoses recorded in EHR. To compare the physical activity of children in different groups, we looked at EHR entries on involvement in regular and guided sport activities. Our criterion for involvement was one or more positive entry during primary school.

Statistical methods

We used counts and percentages for categorical variables to describe weight-related attributes and overweight-related interventions of the study population and subgroups. As continuous variables were not normally distributed, we presented them with medians and interquartile ranges (IQR).

To capture heterogeneity in the development of overweight and obesity, in other words to find between-person differences in within-person change, we studied BMI SDS along the children’s age by using the latent class mixed model (LCMM). For this, we did not discern children by overweight-related interventions. Uninfluenced by prior hypotheses we investigated how many distinct sex-specific overweight development patterns would emerge.

Proust-Lima (30) introduced a flexible LCMM method suitable for nonlinear longitudinal outcomes, when the timing and number of measurements vary from one individual to another. We configured the LCMM to allow for curvilinear curves (I-spline with four knots at quartiles as a link function) and included the quadratic polynomial function of age. To identify distinct BMI SDS age-related patterns (trajectories) and explore possible differences by sex, models with 2, 3, 4 or 5 latent classes were fitted separately to the data on boys and girls. Each child was assigned to one latent class based on his/her highest estimated membership probability. The model fit was evaluated by Bayesian Information Criteria (BIC), lower BIC value indicating better fit. In addition, we assessed the relative entropy, an aggregate measure of class discrimination, which varies between zero and one and indicates higher discrimination of classes with values approaching one. Along with the BIC and entropy values, latent class size, average posterior probability (APP) of class membership and visual evaluation of smoothed (loess) of the class-specific developmental curves with 95% confidence intervals (CI) guided the choice between candidate models (31). To allow meaningful comparison between classes and to obtain clinically interpretable results, we required the size of the smallest class to be at least 5% of the total.
sample size considering girls and boys separately. We also produced spaghetti plots of individual level data to visualize the patterns of BMI SDS changes within latent classes.

We explored the distribution of weight-related attributes and overweight-related interventions in the overweight development classes. To check if the distribution of weight-related attributes was congruent with the resulting developmental curves and if overweight-related interventions were associated with the latent classes, we compared categorical data using Fisher’s exact test. For continuous data, the non-parametric Kruskall-Wallis test was applied.

Finally, according to the suggested framework for latent class trajectory modelling (31) we performed sensitivity analyses. To account for the uncertainty of class assignment, we used the case-weight approach, which we considered to be the most appropriate because of the relative entropy being less than 0.80 and the presence of small latent classes (32). We treated children as fractional members of all identified latent classes by allowing each boy and girl to be included in each of the sex-specific classes, when accounting for the corresponding posterior probabilities of class membership by means of weighting. We then calculated the effective sample size and weighted statistics of the key attributes for each class as well as performed statistical comparisons of these attributes.

We set the statistical significance level at 5% and considered results with p values <0.05 as statistically significant. LCMMs were fitted using the lcmm package (30) for R statistical software, version 3.5.0 (33). All statistical comparisons were performed using IBM SPSS version 25 software (IBM corporation, Armonk, New York, USA). Approval to conduct this register-based study was received from The City of Helsinki Department of Health Care in December 2012. Per the Finnish legislation ethical approval is not required for pure register-based studies.

RESULTS

Study population

The study population of 508 children consisted of 225 girls and 283 boys. At the end of primary school (at median age of 12.6), over half of the girls (56%) and boys (55%) had higher BMI SDS than when entering primary school (Table 1). Of the boys, 34% were affected by obesity and 7% by severe obesity at some point during primary school according to the Finnish BMI-for-age classification. For girls the numbers were 15% and 1%, respectively. Of the 265 boys measured at first grade, 17% were affected by obesity and 6% by severe obesity. For the girls (n=205), the
corresponding percentages were 9% and 1%. At sixth grade, 24% and 4% of the boys (n=258) were affected by obesity or severe obesity and of the 214 girls 9% and 0.5%, respectively.

Legislated health checks actualised satisfactorily. School nurses met all the children at least once after the child was affected by overweight or obesity during primary school. The majority of children (girls 93%, boys 88%) met a school physician at fifth grade health check (Table 2). At first grade the percentages were lower, 46% and 50% respectively. During second, third and fourth grades a school physician met less than 10% of the children in additional health checks or overweight-related appointments (Table 2). Over 80% of the children attended regular guided sport activity at some time (Table 2).

Children’s median age at multidisciplinary fifth-grade health checks was 11.5 years (age at school physician’s health check and if not actualised, at school nurse’s health check). Of the girls, 25% had had menarche and of the boys 38% had entered puberty (Tanner G2 or more) by that time. By sixth-grade health check (median age 12.6) 55% of the girls had had menarche. Of all girls, 29% were classified early in their pubertal development, 51% average and 15% late. For boys the percentages for early, started and not started pubertal development were 8%, 30% and 44%, respectively. For 13 girls (5.8%) and for 51 boys (18%) the status of puberty was not recorded.

**Age-related patterns of overweight development**

Table S1 summarizes the fitted LCMMs with 2,3,4 and 5 classes. The resulting weight development patterns from these models were also visually evaluated (results not included). The median period between the first and last growth measurement during primary school was close to 5.4 years (Table 1) and the median number of growth measurements was 7 for both girls and boys (Table S1).

Based on the BIC and by requiring the smallest latent class to be at least 5% of the total sample, we chose the latent class model with five classes for girls and the model with four classes for boys. The smallest class included 5.8% and 11.0% of girls and boys, respectively. All classes had an APP of over 0.8, indicating satisfactory class assignment. Relative entropy was 0.73 for boys and 0.79 for girls, demonstrating a moderately high level of class discrimination. Also, the weight development curves corresponding to the latent classes were found to be clinically reasonable (Figure 1). The effective sample sizes obtained in the sensitivity analysis were very close to the sizes of classes identified by highest posterior probability (Table S2).

The shapes of the curves (Figure 1) contributed to the naming of the latent classes. The two classes of girls with obesity were named as *Fluctuating Obesity* and *Decreasing Obesity*. Namely,
based on 95% CIs, BMI SDS differed at the end but not at the beginning of primary school, indicating a divergence of weight development in these two latent classes. Dissimilarly, the model indicated just one Stable Obesity class for boys with obesity. The remaining three classes for both girls and boys were named as Stable Overweight, Transitory Overweight and Increasing to Overweight. The naming of the classes generally reflected the individual level change of BMI SDS illustrated by the spaghetti plots. More uncertainty remained in small classes, especially in the Fluctuating Obesity class for girls (Figures S2 and S3).

The largest class for both girls and boys was Stable Overweight, covering 50% of the girls and 37% of the boys. Table 1 shows that medians of weight-related attributes of children in different latent classes were congruent with the related curves. In the sensitivity analysis, similar results were obtained for the weight-related attributes (Table S2).

Most curves were in overweight area around the age from 10 to 11, although at the beginning of primary school they had commenced from normal-weight, overweight or obesity areas (Figure 1). The Stable Obesity class for boys was the only exception, remaining above the cut-off point for obesity through primary school. For girls, the otherwise steady curve of Stable Overweight dropped somewhat towards the end of primary school, for boys the trend was opposite.

The age around 10 was an intersection for overweight development curves and they started to disperse later (Figure 1). The girls’ Fluctuating Obesity curve reached its lowest point around the age of 10 and then returned to obesity. For Transitory Overweight class, both girls’ and boys’, the median age for highest BMI SDS was between 10 and 11. In these classes the lowest BMI SDS rested at the end of primary school for girls and in the beginning for boys (Table 1). The Transitory Overweight curve for boys started to separate from the other classes a bit later, around the age of 12. Girls in Decreasing Obesity class and boys in Stable Obesity class had the highest BMI SDS at the beginning of primary school (Table 1). The curve for Increasing to Overweight class, both for girls and boys, rose over the cut-off point for overweight around the age of 10.

We did not find a statistically significant relation between latent classes and pubertal development. For girls we evaluated Pubertal Development, with classification to early, average, late or not known, (p=0.289), and binary variables for menarche by the fifth-grade multidisciplinary health check (median age of 11.5, p=0.336) and for menarche by sixth-grade health check (median age of 12.6, p=0.324). For boys, we assessed the Pubertal Development classifications of early, started, not started or not recorded (p=0.291).

**Overweight-related interventions**
Optimal Intervention and latent classes of both girls and boys were statistically significantly related (p<0.001) (Table 2). Latent classes of obesity had the highest share of children who received Optimal Intervention. Legislated health checks made by school physicians at first and fifth grades were not statistically significantly related to latent classes, unlike the relation between additional checks and latent classes of girls (p=0.004) and boys (p<0.001) (Table 2). Most additional checks were held for girls in Decreasing Obesity or boys in Stable Obesity class.

Children in the latent classes of obesity received more interventions overall than children in other classes. Understandably, visits to paediatricians in outpatient clinics, participation in family centred group interventions (Table S3, Table S4) or consultations with dietitians (Table 2) occurred more often in the obesity latent classes than in others. Table 2 shows that overweight or obesity were seldom reasons for consultations with dietitians or physiotherapists and the frequency of recorded obesity diagnoses varied between 30% and 57% in the latent classes of obesity.

Involvement in regular guided sport activity and latent classes were statistically significantly associated among boys (p=0.002), boys in Increasing to Overweight class having the lowest share of 71.4% (Table 2). These associations retained statistical significance in the sensitivity analysis (Table S5).

DISCUSSION

Our study identified nine sex-specific overweight development patterns for primary school children, five for girls and four for boys. Most of the weight development curves illustrating these distinct patterns were in overweight area around the age of 10. For some identified latent classes, this age was also the turning point towards favourable or unfavourable weight development as the curves dispersed and some continued or returned towards obesity. A notable finding was that the Increasing to Overweight class had fewest boys who had been involved in regular guided sport activities during primary school. Additionally, interventions offered in school health care to prevent and treat obesity were targeted mainly at children with obesity, less to individuals with continuous overweight or those who were gaining weight.

In earlier studies, the number of sex-specific latent classes has varied from four to six for girls and from three to five for boys (20, 22, 23). Determinants of weight, methods used to identify different weight development groups as well as age-range and ethnicity of children varied between the studies, sample sizes being between 972 and 1824. As a distinction, our study excluded children.
with normal weight. In line with our findings, abovementioned studies all found more classes for girls than for boys.

School nurses are key persons for screening of overweight and obesity and offering interventions, but a multidisciplinary approach could bring better results. Multidisciplinary treatment has been shown effective (34) and in our earlier study collaboration with families in making treatment plans was more abundant at first and fifth grade than at other grades (7), indicating that multidisciplinary health checks are valuable.

Health care professionals wish for the ability to foretell overweight development and identify children with risk of obesity. Analysis of prior weight development in the context of these detected typical weight development patterns could shine light on other known risk factors. In our study, in Stable Obesity and Increasing to Overweight classes for boys the trend of weight development could be seen early on, during primary school. According to our trajectories, predicting weight development for girls is more challenging. However, there is value also in identifying children with smaller risk. In our study, boys and girls with fairly stable overweight during the first primary school years seemed to be quite safe from obesity development. Pubertal development did not explain overweight development trajectories as latent classes were not associated with the timing of pubertal development.

For all children fifth grade might not be optimal timing for multidisciplinary health checks, being late for some. At fifth grade, children in our study had, already for years, either gained weight or maintained high weight status. All children had access to overweight-related interventions during primary school. Still, for some children weight development continued unfavourably. Few children had met school physicians in health checks or overweight-related appointments between grades one and five. With the assumption that effective interventions can be offered in school health care, earlier multidisciplinary health checks and targeting efforts to those in risk, could enable better results. Flexibility for the timing of health checks, for example by moving a check from fifth to fourth grade, could be one solution.

The idea of acting early agrees with a Dalla-Valle et al study indicating more favourable results when obesity management was started before the age of 10 (11). Still, it is notable that in our study all obesity trajectories, for girls and for boys, declined between the ages of 8 and 10 and therefore at that time any intervention might seem effective. The nature of BMI SDS to detect changes in weight status more sensitively for prepubertal children than in adolescence (27) might explain some of the findings of Dalla-Valle et al and our studies. Age, sex, obesity level and pubertal development all affect to BMI SDS values (27). In adolescence, large differences in BMI
are seen smaller in BMI SDS especially in the case of severe obesity. In our study, only a small proportion of children, 7% of boys and 1% of girls, had severe obesity at some point during primary school.

Our results demonstrate that school health care professionals targeted interventions especially towards children with obesity. This may have been useful as Decreasing Obesity class had the highest proportion of girls receiving Optimal Intervention. Other children undergoing weight gain may have been overlooked during primary school. Ideally, interventions are targeted early enough at individuals most likely to end up into obesity in adulthood. Identification of these children may benefit from paying more attention to patterns of overweight development, as all children with overweight or obesity will not be affected by obesity in adulthood (12).

Physical activity plays an important role in obesity prevention. Boys in the Increasing to Overweight class had the lowest share of children attending regular guided sport activities, reflecting the results of an earlier study where participating less than an hour in organised sports per week was associated with an increasing BMI SDS weight development curve (trajectory) (21). Whether the intensity and duration of the regular guided activities differed in our study population, is unknown. Additionally, EHR entries were insufficiently detailed to reveal overall physical activity and sedentary times. However, our results suggest that boys whose weight is rising towards overweight, and who are uninvolved in organised sports are a potential subgroup to focus on in obesity prevention.

**Weaknesses and strengths**

There are, however, some limitations in this study. Given the relatively small sample size, uncertainty inherent in the posterior probability of class membership can be considerable. By performing a sensitivity analysis, we accounted for the uncertainty related to class assignment. Although the analysis produced similar results, comparisons between the classes can be hampered by uncontrolled uncertainty inherent in the posterior probability of class membership. The model might not detect small latent classes properly (35).

Our study only covers primary school years. To more understand the significance of weight development during primary school, in subsequent studies the weight development curves should proceed to adolescence and early adulthood.

We cannot figure causality from our results. Children with obesity received more interventions, as they probably should, but this study setting did not enable us to deduct whether children
benefitted from more intensive interventions. We also must take into account that we lack knowledge on the quality of our retrospective EHR data. Health care professionals have different record entry styles and entries can be missing or erroneous (36). Still, our results can be useful when planning primary health care interventions and intervention studies on childhood obesity prevention and treatment. The effect of interventions probably depends on the age and, for example, for girls the response to interventions might differ in Fluctuating Obesity and Decreasing Obesity classes. Sample sizes need to be sufficiently large in intervention studies to make the distinction between these groups.

Another strength of our study is that by applying LCMM to estimate weight development patterns, we could exploit all available weight and height measurements regardless of their varying count and timing. By this method, as no growth measurements had to be left out and we were able to observe real-life situations, we may have gained a more detailed picture of weight fluctuations and we revealed more developmental patterns than some earlier studies. We followed a suggested framework to construct the modelling and to present the results (31, 35).

As we used a random sample from an unselected cohort, our results can be generalised for other Finnish urban areas. The fairly small sample size as well as national differences in school systems and in coordination of school health care restrain doing so for other populations. Once growth measurement and intervention data can be retrieved automatically from advanced EHRs, the method used has potential to show weight development patterns for large populations and longer follow-up periods and the associations of patterns with interventions applied.

CONCLUSIONS

Our main finding was that primary school children with overweight followed different sex-specific weight development patterns and the age from 10 to 11 was decisive for later obesity development. Secondly, our study indicated that interventions were mostly offered to children with obesity and therefore more could be done for children experiencing weight gain and prone to obesity.

When planning and timing multidisciplinary school health checks, awareness of distinct weight development patterns and more thorough observation of the earlier weight development of children could help to target the efforts in school health care and might be beneficial for obesity prevention. If a multidisciplinary health check, where both the child and parents will be met, takes place early enough, unfavourable health habits of the family, psychosocial risk factors and the

This article is protected by copyright. All rights reserved
earlier weight development of the child could be noticed. The risk of developing obesity consists of multiple factors. The analysis of prior weight development in the context of the typical overweight development patterns offers additional information. As a consequence, children with overweight and with an observed risk of obesity would get support before they might continue into obesity.

Flexible timing of health checks and early interventions on children gaining weight, especially on boys not taking part in organized sport activities, may increase benefit for children with overweight. For example, moving a fifth-grade multidisciplinary school health check (at the age of 11) to fourth grade, before the age of 10, could be useful in obesity prevention.

ABBREVIATIONS

APP, average posterior probability; BIC, Bayesian Information Criteria; BMI SDS, Body mass index standard deviation score; CI, Confidence interval; EHR, Electronic health record; IQR, Interquartile range; LCMM, Latent class mixed model

ACKNOWLEDGEMENTS

We thank Cecile Proust-Lima for consulting us on the use of the lcmm package and providing us with the additional functions for the lcmm. We also thank Juhana Häkkänen for language revision and Lotta Häkkänen for technical support in generating the figures.

FINANCE

This work was partly supported by the State Research Funding (projects 3900104028 and 390010403403), the Finnish Medical Foundation and the Foundation of Outpatient Care (Avohoidon tutkimussäätiö).

CONFLICTS OF INTEREST

EK reports working in National Institute for Health and Welfare, Finland with the register data. The other authors have stated that there are no conflicts of interest in connection with this article.
References


11. Dalla Valle M, Laatikainen T, Lehikoinen M, Nykanen P, Jaaskelainen J. Paediatric obesity treatment had better outcomes when children were younger, well motivated and did not have acanthosis nigricans. *Acta Paediatr* 2017; 106: 1842-50.


36. Turer CB, Barlow SE, Montano S, Flores G. Discrepancies in Communication Versus Documentation of Weight-Management Benchmarks: Analysis of Recorded Visits With
Legends for figures

Figure 1 Developmental patterns with 95% CIs of BMI SDS of the 225 girls and 283 boys with overweight or obesity during primary school between ages of 6 and 14. BMI SDS, body mass index standard deviation score. Cut-offs for overweight (girls 1.16, boys 0.78) and obesity (girls 2.11, boys 1.70) according to the Finnish BMI-for-age references (26).

Figure S1 Flow chart of the study population.

Missing data (n = 10): incomplete social security number (n = 2), not in electronic health records (n = 2), birth year not matching the target sample (n = 5), already 8th grader in April 2013 (n = 1).

Figure S2 Spaghetti plots of BMI SDS of 225 girls by latent classes.

Figure S3 Spaghetti plots of BMI SDS of 283 boys by latent classes.
Table 1 | Weight-related attributes in distinct latent classes of overweight development for girls (n = 225, five latent classes) and boys (n = 283, four latent classes) during primary school (from 6 to 14 years of age)

<table>
<thead>
<tr>
<th>Girls</th>
<th>Overall</th>
<th>Fluctuating Obesity</th>
<th>Decreasing Obesity</th>
<th>Stable Overweight</th>
<th>Transitory Overweight</th>
<th>Increasing to Overweight</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>225</td>
<td>14</td>
<td>13</td>
<td>113</td>
<td>20</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow-up time (years), median (IQR)</td>
<td>5.34 (5.11, 5.54)</td>
<td>5.39 (4.93, 5.54)</td>
<td>5.48 (5.07, 5.81)</td>
<td>5.34 (5.12, 5.59)</td>
<td>5.29 (5.19, 5.51)</td>
<td>5.31 (5.03, 5.48)</td>
<td></td>
</tr>
<tr>
<td>BMI SDS increased during primary school, n (%)</td>
<td>126 (56.0)</td>
<td>7 (50.0)</td>
<td>0 (0.0)</td>
<td>47 (41.6)</td>
<td>8 (40.0)</td>
<td>64 (98.5)</td>
<td>&lt;0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Highest BMI SDS, median (IQR)</td>
<td>1.62 (1.39, 1.98)</td>
<td>2.54 (2.03, 2.72)</td>
<td>2.32 (2.17, 2.53)</td>
<td>1.56 (1.34, 1.80)</td>
<td>1.78 (1.49, 2.04)</td>
<td>1.52 (1.36, 1.76)</td>
<td>&lt;0.001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Age at highest BMI SDS, median (IQR)</td>
<td>10.72 (8.30, 12.16)</td>
<td>10.00 (7.17, 12.78)</td>
<td>7.13 (6.89, 7.67)</td>
<td>9.62 (8.07, 11.15)</td>
<td>10.40 (9.38, 10.84)</td>
<td>12.23 (11.58, 12.69)</td>
<td>&lt;0.001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lowest BMI SDS, median (IQR)</td>
<td>0.89 (0.48, 1.27)</td>
<td>1.94 (1.09, 2.15)</td>
<td>1.54 (1.32, 1.93)</td>
<td>0.94 (0.66, 1.25)</td>
<td>0.71 (0.22, 1.06)</td>
<td>0.50 (0.31, 0.88)</td>
<td>&lt;0.001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Age at lowest BMI SDS, median (IQR)</td>
<td>9.67 (7.93, 11.88)</td>
<td>9.65 (8.48, 10.15)</td>
<td>12.35 (10.99, 12.84)</td>
<td>10.78 (8.79, 12.16)</td>
<td>12.21 (7.18, 12.82)</td>
<td>7.94 (7.27, 9.05)</td>
<td>&lt;0.001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Boys</th>
<th>Overall</th>
<th>Stable Obesity</th>
<th>Stable Overweight</th>
<th>Transitory Overweight</th>
<th>Increasing to Overweight</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>283</td>
<td>31</td>
<td>104</td>
<td>99</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Follow-up time (years), median (IQR)</td>
<td>5.39 (5.06, 5.62)</td>
<td>5.52 (5.26, 5.82)</td>
<td>5.32 (5.01, 5.54)</td>
<td>5.37 (5.04, 5.65)</td>
<td>5.45 (5.05, 5.70)</td>
<td></td>
</tr>
<tr>
<td>BMI SDS increased during primary school, n (%)</td>
<td>155 (54.8)</td>
<td>5 (16.1)</td>
<td>31 (29.8)</td>
<td>70 (70.7)</td>
<td>49 (100.0)</td>
<td>&lt;0.001&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Highest BMI SDS, median (IQR)</td>
<td>1.56 (1.22, 1.90)</td>
<td>2.37 (2.20, 2.60)</td>
<td>1.38 (1.19, 1.72)</td>
<td>1.61 (1.31, 1.83)</td>
<td>1.41 (1.04, 1.76)</td>
<td>&lt;0.001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Age at highest BMI SDS, median (IQR)</td>
<td>10.40 (7.91, 12.24)</td>
<td>7.38 (6.94, 8.33)</td>
<td>8.37 (7.22, 11.16)</td>
<td>10.69 (9.52, 11.78)</td>
<td>12.69 (11.91, 12.98)</td>
<td>&lt;0.001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Lowest BMI SDS, median (IQR)</td>
<td>0.81 (0.37, 1.24)</td>
<td>1.89 (1.62, 2.15)</td>
<td>0.82 (0.49, 1.17)</td>
<td>0.87 (0.46, 1.11)</td>
<td>0.04 (-0.42, 0.42)</td>
<td>&lt;0.001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Age at lowest BMI SDS, median (IQR)</td>
<td>9.74 (7.68, 11.69)</td>
<td>11.15 (10.46, 12.61)</td>
<td>10.89 (9.87, 11.83)</td>
<td>7.82 (7.02, 12.24)</td>
<td>7.83 (7.11, 9.09)</td>
<td>&lt;0.001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

This article is protected by copyright. All rights reserved
Testing for associations between weight-related attributes and overweight development classes; *Fisher’s exact test; *Kruskal-Wallis test. BMI SDS, body mass index standard deviation score; IQR, interquartile range.
<table>
<thead>
<tr>
<th>Latent Classes</th>
<th>Overall</th>
<th>Fluctuating Obesity</th>
<th>Decreasing Obesity</th>
<th>Stable Overweight</th>
<th>Transitory Overweight</th>
<th>Increasing to Overweight</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Girls</strong></td>
<td>n = 225 (100.0%)</td>
<td>n = 14 (6.2%)</td>
<td>n = 13 (5.8%)</td>
<td>n = 113 (50.2%)</td>
<td>n = 20 (8.9%)</td>
<td>n = 65 (28.9%)</td>
<td></td>
</tr>
<tr>
<td>School physician met</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
</tr>
<tr>
<td>At first grade health check</td>
<td>104 (46.2)</td>
<td>9 (64.3)</td>
<td>7 (53.8)</td>
<td>50 (44.2)</td>
<td>5 (25.0)</td>
<td>33 (50.8)</td>
<td>0.166</td>
</tr>
<tr>
<td>At fifth grade health check</td>
<td>210 (93.3)</td>
<td>14 (100.0)</td>
<td>11 (84.6)</td>
<td>108 (95.6)</td>
<td>19 (95.0)</td>
<td>58 (89.2)</td>
<td>0.233</td>
</tr>
<tr>
<td>At 2nd, 3rd or 4th grade (health check or overweight-related)</td>
<td>16 (7.1)</td>
<td>2 (14.3)</td>
<td>4 (30.8)</td>
<td>5 (4.4)</td>
<td>3 (15.0)</td>
<td>2 (3.1)</td>
<td>0.004</td>
</tr>
<tr>
<td>Optimal Intervention(^1)</td>
<td>89 (39.6)</td>
<td>11 (78.6)</td>
<td>11 (84.6)</td>
<td>38 (33.6)</td>
<td>7 (35.0)</td>
<td>22 (33.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Consultation with dietitian due to overweight</td>
<td>17 (7.6)</td>
<td>4 (28.6)</td>
<td>2 (15.4)</td>
<td>5 (4.4)</td>
<td>2 (10.0)</td>
<td>4 (6.2)</td>
<td>0.021</td>
</tr>
<tr>
<td>Consultation with physiotherapist</td>
<td>24 (10.7)</td>
<td>1 (7.1)</td>
<td>4 (30.8)</td>
<td>12 (10.6)</td>
<td>2 (10.0)</td>
<td>5 (7.7)</td>
<td>0.220</td>
</tr>
<tr>
<td>Obesity diagnosis recorded</td>
<td>20 (8.9)</td>
<td>8 (57.1)</td>
<td>4 (30.8)</td>
<td>4 (3.5)</td>
<td>0 (0.0)</td>
<td>4 (6.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Involvement in regular, guided sport activity</td>
<td>190 (84.4)</td>
<td>11 (78.6)</td>
<td>11 (84.6)</td>
<td>97 (85.8)</td>
<td>18 (90.0)</td>
<td>53 (81.5)</td>
<td>0.821</td>
</tr>
<tr>
<td><strong>Boys</strong></td>
<td>n = 283 (100.0%)</td>
<td>n = 31 (11.0%)</td>
<td>n = 104 (36.7%)</td>
<td>n = 99 (35.0%)</td>
<td>n = 49 (17.3%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School physician met</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At first grade health check</td>
<td>140 (49.5)</td>
<td>19 (61.3)</td>
<td>47 (45.2)</td>
<td>52 (52.5)</td>
<td>22 (44.9)</td>
<td></td>
<td>0.358</td>
</tr>
<tr>
<td>At fifth grade health check</td>
<td>250 (88.3)</td>
<td>26 (83.9)</td>
<td>94 (90.4)</td>
<td>87 (87.9)</td>
<td>43 (87.8)</td>
<td></td>
<td>0.740</td>
</tr>
<tr>
<td>At 2nd, 3rd or 4th grade</td>
<td>24 (8.5)</td>
<td>10 (32.3)</td>
<td>6 (5.8)</td>
<td>6 (6.1)</td>
<td>2 (4.1)</td>
<td></td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

This article is protected by copyright. All rights reserved.
(health check or overweight-related)

<table>
<thead>
<tr>
<th>Intervention</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
<th>n</th>
<th>%</th>
<th>p-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal Intervention¹</td>
<td>96</td>
<td>(33.9)</td>
<td>24</td>
<td>(77.4)</td>
<td>20</td>
<td>(19.2)</td>
<td>37</td>
<td>(37.4)</td>
<td>15</td>
<td>(30.6)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Consultation with dietitian due to overweight</td>
<td>11</td>
<td>(3.9 )</td>
<td>4</td>
<td>(12.9)</td>
<td>1</td>
<td>(1.0 )</td>
<td>3</td>
<td>(3.0 )</td>
<td>3</td>
<td>(6.1 )</td>
<td>0.021</td>
</tr>
<tr>
<td>Consultation with physiotherapist</td>
<td>30</td>
<td>(10.6)</td>
<td>3</td>
<td>(9.7 )</td>
<td>13</td>
<td>(12.5)</td>
<td>10</td>
<td>(10.1)</td>
<td>4</td>
<td>(8.2 )</td>
<td>0.896</td>
</tr>
<tr>
<td>Obesity diagnosis recorded</td>
<td>30</td>
<td>(10.6)</td>
<td>12</td>
<td>(38.7)</td>
<td>3</td>
<td>(2.9 )</td>
<td>8</td>
<td>(8.1 )</td>
<td>7</td>
<td>(14.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Involvement in regular, guided sport activity</td>
<td>249</td>
<td>(88.0)</td>
<td>28</td>
<td>(90.3)</td>
<td>98</td>
<td>(94.2)</td>
<td>88</td>
<td>(88.9)</td>
<td>35</td>
<td>(71.4)</td>
<td>0.002</td>
</tr>
</tbody>
</table>

¹We considered a child to have received Optimal intervention if a school nurse entered an observation of overweight or obesity into electronic health record, a school physician met the child for this reason or in course of a routine health check, there was a treatment plan made together with parents and the next overweight-related appointment was in the plans. In addition to these, we required a recorded positive change in health habits or a concrete nutrition or exercise plan. All children who attended family centred group interventions lasting one school year or visited paediatricians due to obesity in outpatient clinics were also deemed to have received Optimal Intervention. Testing for associations between background characteristics or interventions offered and overweight development classes using Fisher’s exact test.