Tracking of thinness and overweight in children of Dutch, Turkish, Moroccan and South Asian descent from 3 through 15 years of age: a historical cohort study

Wilde, J.A. de; Middelkoop, B.J.C.; Verkerk, P.H.

Tracking of thinness and overweight in Dutch, Turkish, Moroccan and South Asian children from the age of 3 through 15 years: a historical cohort study

JA de Wilde[1,2], BJC Middelkoop[1,3] and PH Verkerk[2]

[1]Department of Public Health and Primary Care, Leiden University Medical Center, Leiden, the Netherlands; [2]Department of Child Health, TNO, Leiden, the Netherlands; [3]Department of Epidemiology, Community Health Service Haaglanden (GGD Haaglanden), The Hague, the Netherlands.

Address for correspondence:

Jeroen A de Wilde, Department of Public Health and Primary Care, Leiden University Medical Center, PO Box 9600, 2300 RC Leiden, the Netherlands. E-mail: J.A.de_Wilde@lumc.nl

Running title: Tracking of thinness and overweight 3-15 years

Keywords

Adolescent, Child, Epidemiology, Thinness, Overweight, the Netherlands

Conflict of Interests: The authors declare no conflict of interest.

ABSTRACT

BACKGROUND: Overweight is shown to track (= to maintain a relative position in a distribution) from childhood to adulthood, but is mostly studied in preobesogenic cohorts and in single ethnic groups. Little is known about tracking of thinness by ethnic group.

OBJECTIVES: to determine (differences in) tracking of BMI (class) from 3 through 15 years and the prediction of BMI class at 13-15 years of age in contemporary Dutch, Turkish, Moroccan and South Asian children living in the Netherlands.

METHODS: Historical cohort of 7 625 children, born 1994-1997, with 24 376 measurements of BMI. BMI z-score and BMI class was analysed using universal criteria. South Asian children were also assessed using ethnic specific BMI criteria. Diagnostic odds ratios (OR) and test properties were calculated to estimate the ability of BMI class at 3-4 years to predict BMI class at 13-15 years.

RESULTS: Tracking of thinness between 3 and 15 years was generally stronger than that of overweight. BMI trajectories of thin, normal weight and overweight between 3 and 15 years were, although significantly different, similar in Dutch, Turkish, and Moroccan adolescents. The South Asian BMI trajectory deviated considerably from the other ethnic groups, but the differences disappeared when South Asian specific BMI criteria were applied. A considerable proportion of overweight developed between 5-10 years, after which less children shifted to other BMI classes. Sensitivity, specificity, positive predictive value and diagnostic OR of overweight at 3-4 years based on ethnic specific criteria varied between ethnic groups from 0.36-0.47, 0.87-0.94, 0.55-0.78, and 6.8-28.1 respectively; for thinness from 0.25-0.40, 0.96-0.98, 0.10-0.20, and 10.2-283.5, respectively.

CONCLUSIONS: In all ethnic groups, overweight and thinness highly tracked into adolescence. South Asian children differed from the other ethnic groups when universal BMI criteria were applied, but tracking patterns became more concordant with South Asian specific BMI criteria.

INTRODUCTION

In the past decades childhood obesity has grown into a true pandemic that poses a major public health threat in affected populations[1, 2] because of the associated cardiometabolic health risks.[3] Although there are several prevention programmes for overweight and obesity, the significant changes in body mass index (BMI, weight/height^2) or other measures of nutritional status after a life style intervention are generally small and improvements are often not sustained in the long term.[4, 5] Nevertheless, in several developed countries the prevalence of overweight has been shown to stabilize.[6, 7] In the Netherlands in most ethnic groups the rates of overweight and obesity seems to be levelling off. There has even been a decrease found in Dutch children (of European descent) in the prevalence of overweight and obesity since 1999.[8] The exact causes of the stabilising and declining trends in overweight or obesity rates in Dutch children are unclear, but may perhaps be attributed to the increased public awareness as well as to the many prevention programmes and interventions that have been implemented throughout the Netherlands in the past decade.[9]

However, as BMI and overweight have been shown to track (= to maintain a relative position in a distribution)[10] from childhood into adulthood[11-13] the obesity epidemic may not be over. Most of the studies investigating 'tracking' of overweight, involved populations born in a preobesogenic era, when obesity rates were much smaller. Therefore, in contemporary populations, exposed to an obesogenic environment from birth, the tracking pattern may be different,[14] i.e. they might gain more fat from an earlier age, and consequently show a steeper increase in BMI than previous generations. For prevention strategies and interventions to be most effective, it is important to determine which groups are at greatest risk for developing obesity and related diseases. When the natural history of the development of overweight and associated health risks is known, interventions can be targeted particularly at those high-risk groups.

A cohort study of young Dutch adults born in 1977-1986 showed that the BMI increase in the age period 2-6 years was the strongest predictor of adult overweight,[15] as well as of cardiovascular and metabolic risks in adulthood.[16] Other studies showed that children with rapid growth in weight or

BMI during infancy or children that were obese during infancy had a higher risk of developing obesity at subsequent ages.[17] For contemporary generations it is currently unknown in the Netherlands how strong BMI tracks during childhood and to what degree overweight during earlier ages is predictive of overweight at an older age. Considering the large differences in prevalence of obesity among ethnic groups in the Netherlands,[8] tracking patterns are likely to be different between ethnic groups, as was previously demonstrated in the USA.[18] Further reports comparing tracking of overweight in various ethnic groups are scarce. Also, little is known about tracking of thinness in general, and in different ethnic groups living in developed countries in particular.

In the Netherlands, children of South Asian descent have received increased attention from youth health care nurses and physicians, and other public health workers such as health promotion professionals. This is not only because South Asian children have a generally higher risk of cardiometabolic disease compared with populations of European descent,[19, 20] but also because the BMI distribution and the relation between BMI and fat mass was shown to be different from other ethnic groups.[21, 22]

The first aim of this study is to investigate if the longitudinal development (trajectory) of mean BMI z-scores from 3 to 15 years of age differs between Dutch, Turkish, Moroccan and South Asian children. The second aim is to determine the ability of BMI class at a younger age to predict thinness or overweight at 13-15 years. And thirdly, in South Asian children differences in tracking based on universal BMI criteria versus ethnic specific BMI criteria will be investigated.

METHODS

Data collection

In the Netherlands, all children are invited periodically for a general health assessment by a Youth Health Care nurse or physician, as part of the national child health surveillance programme. Children between 3 and 15 years of age are invited four times for a voluntary health assessment. Participation rates are generally high (80-90%).[23] Incompleteness of health records can generally be attributed to non-participance and the moving of families into and out of the city during the follow up period.

The Youth Health Care organisation of the city of The Hague (the Netherlands) has kept a digital record system since 1998 in which details of the preventive health assessments of all children are registered. For this study, growth data on height and weight, and background data such as sex, date of birth, the child's surname, and parental country of birth were extracted from the digital records of a cohort of children born 1994-1997. Height and weight data of all standard health assessments at the ages of 3-4, 5-6, 7-10 and 13-15 years of age were subsequently selected. Data from younger ages were not available. Measurements were taken between January 1998 and November 2013. All children with a measurement at 13-15 years of age and at least one measurement at a younger age were included in the study.

As this study involved the analysis of routinely collected data, under Dutch law ethical consent was not needed,[24] provided that regulations regarding privacy are met. Therefore, after determining ethnicity and age, identifying personal information was removed from the research database.

Ethnic groups

Ethnicity was firstly based on country of birth of both parents. If the mother and father were both born outside the Netherlands but in different countries, the country of birth of the mother prevailed. If one of the parents was born in the Netherlands and the other outside the Netherlands the country

of birth of the non-Dutch parent determined the ethnicity of the child. In cases where both parents were born in the Netherlands the child's surname was matched with lists of typically Dutch, Turkish and Moroccan surnames to distinguish Dutch parents from Dutch second generation Turkish and Moroccan parents (of whom parents were born in the Netherlands but grandparents in Turkey or Morocco). As most South Asians in the Netherlands originate from the former Dutch colony Suriname, South Asian ethnicity was determined both by parental country of birth (Suriname) and the presence of a Surinamese South Asian surname of the child.

Anthropometric measurements and cut-off values

Height and weight of children were measured by trained youth health care physicians, nurses and physician's assistants; height with a stadiometer (Seca 202; Hamburg, Germany) or height measuring tape (Seca 206 or equivalent), rounded to the nearest 0.1 cm, and weight with a calibrated mechanical step scale (Seca 761 or equivalent), rounded to the nearest 0.5 kg. Up till the age of 7 years, children were measured in underclothes, and from that age in light clothes without shoes. Body mass index was calculated with the formula [weight in kg]/[height in meters]^2. BMI z-scores and BMI categories were calculated with the latest international BMI references and cut-offs for children.[25] BMI categories were determined with the z-scores that correspond to the adult BMI cut-offs of <17 kg/m^2 for thinness, ≥17 but <25 kg/m^2 for normal weight, and ≥25 kg/m^2 for overweight (including obesity). A recently developed South Asian specific BMI reference for South Asian children in the Netherlands, including a new BMI classification,[26] was also used but only for South Asian children. This reference was based on the BMI distribution of a population of South Asian children in the Netherlands born in a preobesogenic era with BMI cut-offs for thinness corresponding to a BMI of <15 kg/m^2 at 18 years of age, and cut-offs for overweight to a BMI of ≥23 kg/m^2 at 18 years of age.[26]

Statistical analyses

The term tracking is firstly used to describe a variable's longitudinal development and the maintenance of a relative position or ranking of the variable within the variable's distribution. Secondly, tracking also involves the ability to predict subsequent measures from previous measures.[10] For this article both concepts of tracking were studied using BMI z-scores and the BMI classification (thinness, normal weight, and overweight).

All variables were tested for normality. The longitudinal development of the mean BMI z-score (=dependent) over time was analysed by ethnic group and age (=covariate) with a linear mixed-effects model (repeated measures). Sex was added to the model as a potential confounder. Estimated Marginal Mean BMI z-scores were calculated by ethnic group and age from the fitted model while adjusting for the other variables in the model. For the graphs in the article the EMM for the ages 11-12 were interpolated.

The longitudinal development of the mean BMI z-score was determined for each BMI class at 13-15 years and tested with a linear mixed-effects model (repeated measures) analysis, with the BMI z-score of each BMI class as dependent factor, and age, sex, and ethnic group as covariates. Trends in the prevalence of overweight (vs no overweight) or thinness (vs no thinness) by age were tested with a generalised estimating equations logistic model, as this model takes the correlation between repeated measures into account. Additionally, when overweight or thinness status at a younger age considered a test for overweight or thinness respectively at 13-15 years of age, the test properties (sensitivity, specificity, positive predictive value) were calculated for ages 3-4, 5-6, and 7-10 years by ethnic group. The 95% Confidence interval (CI) was determined by calculating the Wilson score interval with continuity correction.[27, 28]

As test of discriminatory performance the diagnostic odds ratio (DOR with 95% Confidence interval) was calculated for every age group by ethnicity. This single indicator combines sensitivity and specificity (which are not easily interpreted when comparing tests) and is independent of the prevalence.[29] The resulting odds ratio represents the ratio of the odds of the test being positive if the

child has the condition (overweight/thinness), divided by the odds of the test being positive if the child does not have the condition.

The statistical significance level was set at P<0.05 (two-sided). IBM SPPS Statistics v22 software was used for all statistical tests.

RESULTS

In this study, 7 625 children were included, with a total of 25 604 registered measurements. Though the study population involved a dynamic cohort participating in a routine health surveillance programme yet 71% of the children had all follow-up check-ups registered (Figure 1). The population characteristics were similar between the ethnic groups (Table 1).

Prevalence of overweight and thinness

The highest prevalence of overweight was found in South Asian children (ethnic specific reference) followed by Turkish, Moroccan and Dutch children. Overweight rates significantly increased with age in all ethnic groups (P<0.001), with the largest increase between 5-6 and 7-10 years of age. The prevalence of thinness was generally very low in all ethnic groups, except in South Asian children (universal BMI cut-offs) (Table 2). When South Asian specific BMI cut-offs were applied thinness prevalences were concordant with those found in the other ethnic groups.

Tracking: the maintenance of a relative position of BMI

The trajectory of the estimated marginal mean (EMM= the mean value, adjusted for repeated measures and the other variables in the model) BMI z-score for age (Figure 2) differed between the ethnic groups (P<0.001). Within each ethnic group there were no significant differences in BMI z-score between males and females. Turkish and Moroccan children had the highest initial (at 3 years) BMI z-score (0.4) whereas South Asians had the lowest when based on the universal BMI reference (-0.6). In Dutch, Moroccan and Turkish children the overall BMI z-score followed a similar pattern

between 3 and 15 years of age: between 3 and 5 years the mean BMI z-score remained fairly stable, increased between 6 and 7 years, and reached a plateau at 7 years of age. The BMI trajectory of South Asian children deviated considerably when based on the universal BMI reference. The BMI z-scores in this group were very low until 4 years of age, increased sharply between 4 and 7 years by 1.1 SD, and from then on remained fairly stable. However, when applying the South Asian specific reference the BMI z-score trajectory was concordant with the other ethnic groups, approximating the BMI trajectory of Moroccan children.

The BMI z-score trajectory of thin, normal weight, and overweight 13-15 year old adolescents shows how on average the final BMI z-score was reached from the age of 3-4 years (Figure 3). No differences were found between the sexes within each ethnic group by BMI class. The BMI z-score trajectories of overweight adolescents of Dutch, Moroccan and Turkish origin, although statistically significantly different ($P<0.001$), followed similar patterns. For thin and normal weight adolescents of these ethnic groups, the BMI trajectory showed more variation ($P<0.001$), but also here the trend of the pattern was quite similar. In general, thin children at age 13-15 years had been already relatively thin (<-0.9 SD) in earlier years, whereas normal weight adolescents had a mean BMI z-score that started at 3-4 years around a value of 0 and remained largely stable. Overweight adolescents on average had already considerably higher mean BMI z-scores at younger ages (around +1 SD), that increased by 0.8-0.9 SD between 3-4 years and 13-15 years of age.

The BMI trajectory of thin, normal weight and overweight South Asian children, when based on the universal BMI reference, deviated considerably with a sharp increase in BMI z-scores from 3-4 up to 7-10 years of age, both in normal weight and overweight 13-15 year olds. When applying the South Asian specific reference the BMI tracking pattern in this group was again largely consistent with the pattern found in the other ethnic groups.

Prediction of BMI class by testing BMI class at a younger age

When the presence of overweight (vs. no overweight) or thinness (vs no thinness) at a younger age is considered a positive test for overweight or thinness at 13-15 years respectively, the test properties sensitivity, specificity, positive predictive value and diagnostic odds ratio (Tables 2 and 3) are informative of tracking (prediction) of overweight or thinness based on the previous BMI class. Low values (<90%) of one of the test properties sensitivity, specificity and positive predictive value indicate that children with thinness or overweight at a younger age shifted to another BMI class at 13-15 years of age. The diagnostic OR shows the degree of tracking with higher values signifying a stronger tracking compared to lower diagnostic OR.

When taking South Asian children (ethnic specific criteria) as an example, the low sensitivity of 47% of having overweight at 3-4 years means that 53% of the South Asian children classified as having overweight as 13-15 year old did not have overweight at the age of 3-4 years. In the other ethnic groups the sensitivity was even lower, which signifies that most children with overweight at 13-15 years developed overweight at an older age. But as expected, the sensitivity increases by age, indicating a larger proportion maintaining their overweight. The high specificity of overweight at ages 3-10 years in South Asian children (and in the other ethnic groups) means that most children without overweight as 13-15 year old did not have overweight at a younger age. On the other hand, the high positive predictive value of 71-77% at ages 3-10 in South Asian children (ethnic specific criteria) indicates that, once overweight is present at a younger age, in 71-77% of cases their overweight is maintained up till 13-15 years of age.

In addition, a statistically significant diagnostic OR >1 means that there is tracking. The higher the diagnostic OR the better the test (overweight or thinness at a younger age) predicts overweight or thinness at 13-15 years of age. The highest diagnostic OR's for overweight were found for overweight at 7-10 years in all ethnic groups, ranging between 23 and 31. For thinness the OR's were

considerably higher, even up to a value of 319 in Turkish 7-10 year olds, indicating a strong ability of thinness at the age of 7-10 years to predict thinness at 13-15 years of age.

DISCUSSION

Main findings

In this study two concepts of tracking were studied. Firstly, the longitudinal development of BMI over time, and secondly the predictive ability of the BMI class at younger age for thinness and overweight as 13-15 year old. Dutch, Turkish and Moroccan children showed, although significantly different, quite similar tracking patterns of BMI z-score and BMI classes from 3 through 15 years of age. Tracking of BMI in South Asian children when based on universal BMI criteria showed large discrepancies compared with other ethnic groups, which disappeared to a great extent when South Asian specific BMI criteria were applied. In all ethnic groups the presence of overweight and especially thinness at 3-4 years of age highly tracked into adolescence, although a considerable proportion of thinness and overweight at 13-15 years developed after that age.

Strengths of this study are the large sample size, the longitudinal and population-based design, the inclusion of children from different ethnic groups, and measurements performed by trained professionals. Another strength is the high follow-up rate. For that reason, selection bias by non-participance is unlikely to have influenced the results of our study.

Meaning of findings & practical implications

Considerable ethnic differences in thinness and overweight rates were found. Strikingly, South Asian children had the highest thinness rates of 16% at 3-4 years of age and also the lowest overweight rate at that age (8%) based on the universal BMI criteria. However, when applying South Asian specific BMI cut-offs (based on the BMI of an affluent cohort of South Asian children born before the

obesity epidemic), the thinness rates were concordant with those found in other ethnic groups, but simultaneously the overweight prevalence increased to the highest level of all ethnic groups, 27% at 3-4 years up to 45% at 7-10 years. This indicates that in this ethnic group universal BMI cut-offs highly overestimate thinness and underestimate overweight rates.[21] Although previously, an expert panel from the UK did not yet recommend separate BMI definitions for South Asian children and adolescents, [30] our findings support the use of South Asian specific BMI criteria.

Based on diagnostic odds ratios, thinness tracked generally stronger than overweight. An explanation is that these thin children represent the lower end of the normal BMI distribution. As BMI during infancy and childhood was shown to be highly correlated with lean body mass in adolescence and adulthood, and not with fat mass,[31, 32] thin children of our study are likely to have a predisposition for a smaller lean body mass.

The very high prevalence of overweight at age 3 in Turkish, Moroccan and South Asian children (17-27%) implies that factors before that age are also important determinants of overweight.

A recent Dutch study showed that weight gain in the first 6 months of life and maternal pre-pregnancy BMI explained most of the differences in overweight rates between 2 year old Turkish, Moroccan and Dutch children.[33] In the current study overweight prevalence remained fairly stable from 3 to 6 years in all ethnic groups, followed by a considerable increase, and a plateau in the overweight prevalence from the age of 7-10 years.

Previously, overweight at the age of 9-11 years was shown to track into adulthood.[34] However, many adults with overweight were not affected by overweight as a child. In the Netherlands, the prevalence of adult overweight is currently levelling off but the rates are considerably higher than in Dutch adolescents of our study. In 2015 almost 29% of 20-30 year old Dutch adults were affected by overweight and 42% of 30-40 year olds.[35] It is likely that a large proportion of adolescents with overweight will maintain their overweight, but most overweight in this group is likely to develop

during adulthood. Those who ultimately will be affected by overweight as an adult is still difficult to predict and depends on many life style factors and personal circumstances.

In all ethnic groups a considerable proportion of 3-4 year olds already had overweight, and most of these children maintained their overweight as an adolescent (positive predictive values of 55-78%), indicating that once children have become overweight it is difficult to gain a 'normal weight'. Therefore, preventive interventions should preferably start before that age, possibly already during the first year of life. And because of the increase in overweight prevalence between the age of 5-6 years and 7-10 years, also 3-10 year olds should be targets of preventive activities. Furthermore, for a proper assessment of BMI in South Asian children ethnic specific criteria are recommended.

Conclusion

In this study, the mean BMI z-score of both overweight and thin Dutch, Turkish, Moroccan and South Asian children followed a similar pattern between 3 and 15 years of age (provided that South Asian specific BMI criteria were applied). The different tracking pattern found in South Asian children compared with the other ethnic groups raises doubts over the use of universal BMI criteria for all ethnic groups. Although at 3-4 years of age already a large proportion of Turkish, Moroccan and South Asian children had overweight, between 5 and 10 years many children gained overweight, stabilising from the age of 10 years. Once a child is affected by overweight, in most cases this is maintained during adolescence. These findings may enable health care providers to early intervene in children at increased risk of developing or maintaining overweight or obesity, especially children of South Asian descent. Preventive interventions and strategies should preferably start during infancy and continue throughout childhood.

Authors contribution

JdW, BJCM and PHV conceived the idea for the study. JdW managed and analysed the data. All authors were involved in writing the paper, and approved of the submitted and published version.

Acknowledgements

We thank Ron Smit and Marion Groeneveld for their help in retrieving the required data from the youth health care database.

References

1. Ebbeling CB, Pawlak DB, Ludwig DS. Childhood obesity: public-health crisis, common sense cure. *Lancet* 2002; **360**(9331)**:** 473-482.

2. Wang Y, Lobstein T. Worldwide trends in childhood overweight and obesity. *Int J Pediatr Obes* 2006; **1**(1)**:** 11-25.

3. Friedemann C, Heneghan C, Mahtani K, Thompson M, Perera R, Ward AM. Cardiovascular disease risk in healthy children and its association with body mass index: systematic review and meta-analysis. *BMJ* 2012; **345:** e4759.

4. Flynn MA, McNeil DA, Maloff B, Mutasingwa D, Wu M, Ford C *et al.* Reducing obesity and related chronic disease risk in children and youth: a synthesis of evidence with 'best practice' recommendations. *Obes Rev* 2006; **7 Suppl 1:** 7-66.

5. Waters E, de Silva-Sanigorski A, Hall BJ, Brown T, Campbell KJ, Gao Y *et al.* Interventions for preventing obesity in children. *Cochrane Database Syst Rev* 2011; (12)**:** CD001871.

6. Olds T, Maher C, Zumin S, Peneau S, Lioret S, Castetbon K *et al.* Evidence that the prevalence of childhood overweight is plateauing: data from nine countries. *Int J Pediatr Obes* 2011; **6**(5-6)**:** 342-360.

7. Rokholm B, Baker JL, Sorensen TI. The levelling off of the obesity epidemic since the year 1999--a review of evidence and perspectives. *Obes Rev* 2010; **11**(12)**:** 835-846.

8. de Wilde JA, Verkerk PH, Middelkoop BJ. Declining and stabilising trends in prevalence of overweight and obesity in Dutch, Turkish, Moroccan and South Asian children 3-16 years of age between 1999 and 2011 in the Netherlands. *Arch Dis Child* 2014; **99**(1)**:** 46-51.

9. Schonbeck Y, Talma H, van Dommelen P, Bakker B, Buitendijk SE, Hirasing RA *et al.* Increase in prevalence of overweight in Dutch children and adolescents: a comparison of nationwide growth studies in 1980, 1997 and 2009. *PLoS One* 2011; **6**(11)**:** e27608.

10. Foulkes MA, Davis CE. An index for tracking of longitudinal data. *Biometrics* 1981; **37:** 439-446.

11. Aarestrup J, Bjerregaard LG, Gamborg M, Angquist L, Tjonneland A, Overvad K *et al.* Tracking of body mass index from 7 to 69 years of age. *Int J Obes (Lond)* 2016; **40**(9)**:** 1376-83.

12. Magarey AM, Daniels LA, Boulton TJ, Cockington RA. Predicting obesity in early adulthood from childhood and parental obesity. *Int J Obes Relat Metab Disord* 2003; **27**(4)**:** 505-513.

13. Power C, Lake JK, Cole TJ. Body mass index and height from childhood to adulthood in the 1958 British born cohort. *Am J Clin Nutr* 1997; **66**(5)**:** 1094-1101.

14. Singh AS, Mulder C, Twisk JW, van MW, Chinapaw MJ. Tracking of childhood overweight into adulthood: a systematic review of the literature. *Obes Rev* 2008; **9**(5)**:** 474-488.

15. de Kroon ML, Renders CM, van Wouwe JP, van Buuren S, Hirasing RA. The Terneuzen birth cohort: BMI changes between 2 and 6 years correlate strongest with adult overweight. *PLoS One* 2010; **5**(2)**:** e9155.

16. de Kroon ML, Renders CM, van Wouwe JP, van Buuren S, Hirasing RA. The Terneuzen Birth Cohort: BMI change between 2 and 6 years is most predictive of adult cardiometabolic risk. *PLoS One* 2010; **5**(11)**:** e13966.

17. Baird J, Fisher D, Lucas P, Kleijnen J, Roberts H, Law C. Being big or growing fast: systematic review of size and growth in infancy and later obesity. *BMJ* 2005; **331**(7522)**:** 929.

18. Freedman DS, Khan LK, Serdula MK, Dietz WH, Srinivasan SR, Berenson GS. Racial differences in the tracking of childhood BMI to adulthood. *Obes Res* 2005; **13**(5)**:** 928-935.

19. Whincup PH, Gilg JA, Papacosta O, Seymour C, Miller GJ, Alberti KG *et al.* Early evidence of ethnic differences in cardiovascular risk: cross sectional comparison of British South Asian and white children. *BMJ* 2002; **324**(7338)**:** 635.

20. Misra A, Khurana L. Obesity-related non-communicable diseases: South Asians vs White Caucasians. *Int J Obes (Lond)* 2011; **35**(2)**:** 167-187.

21. de Wilde JA, Zandbergen-Harlaar S, van Buuren S, Middelkoop BJ. Trends in body mass index distribution and prevalence of thinness, overweight and obesity in two cohorts of Surinamese South Asian children in The Netherlands. *Arch Dis Child* 2013; **98**(4)**:** 280-285.

22. Hudda MT, Nightingale CM, Donin AS, Fewtrell MS, Haroun D, Lum S *et al.* Body mass index adjustments to increase the validity of body fatness assessment in UK Black African and South Asian children. *Int J Obes (Lond)* 2017.

23. de Wilde JA, van Dommelen P, Middelkoop BJ, Verkerk PH. Trends in overweight and obesity prevalence in Dutch, Turkish, Moroccan and Surinamese South Asian children in the Netherlands. *Arch Dis Child* 2009; **94**(10)**:** 795-800.

24. Dutch Government [Medical Research Involving Human Subjects Act]. The Hague: Dutch Government, 2017.

25. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. *Pediatr Obes* 2012; **7**(4)**:** 284-294.

26. de Wilde JA, van Dommelen P, Middelkoop BJ. Appropriate body mass index cut-offs to determine thinness, overweight and obesity in South asian children in the Netherlands. *PLoS One* 2013; **8**(12)**:** e82822.

27. Newcombe RG. Two-sided confidence intervals for the single proportion: comparison of seven methods. *Stat Med* 1998; **17**(8)**:** 857-72.

28. Wilson EB. Probable Inference, the Law of Succession, and Statistical Inference. *Journal of the American Statistical Association* 1927; **22**(158)**:** 209-212.

29. Glas AS, Lijmer JG, Prins MH, Bonsel GJ, Bossuyt PMM. The diagnostic odds ratio: a single indicator of test performance. *Journal of Clinical Epidemiology* 2003; **56**(11)**:** 1129-1135.

30. Viner RM, Cole TJ, Fry T, Gupta S, Kinra S, McCarthy D *et al.* Insufficient evidence to support separate BMI definitions for obesity in children and adolescents from south Asian ethnic groups in the UK. *Int J Obes (Lond)* 2010; **34**(4)**:** 656-658.

31. Sachdev HS, Fall CH, Osmond C, Lakshmy R, Dey Biswas SK, Leary SD *et al.* Anthropometric indicators of body composition in young adults: relation to size at birth and serial measurements of body mass index in childhood in the New Delhi birth cohort. *Am J Clin Nutr* 2005; **82**(2)**:** 456-466.

32. Johnson W, Choh AC, Lee M, Towne B, Czerwinski SA, Demerath EW. Is infant body mass index associated with adulthood body composition trajectories? An exploratory analysis. *Pediatr Obes* 2017; **12**(1)**:** 10-18.

33. de Hoog ML, van Eijsden M, Stronks K, Gemke RJ, Vrijkotte TG. Overweight at age two years in a multi-ethnic cohort (ABCD study): the role of prenatal factors, birth outcomes and postnatal factors. *BMC Public Health* 2011; **11:** 611.

34. Deshmukh-Taskar P, Nicklas TA, Morales M, Yang SJ, Zakeri I, Berenson GS. Tracking of overweight status from childhood to young adulthood: the Bogalusa Heart Study. *Eur J Clin Nutr* 2006; **60**(1)**:** 48-57.

35. [Height and weight of persons, underweight and overweight, from 1981]. In. The Hague: CBS (Statistics Netherlands), 2016.

Table 1 Study population characteristics

		Ethnicity			
		Dutch	*Turkish*	*Moroccan*	*South Asian*
N		4 528	1 289	958	850
Sex (%)	Boys	48,1	51,6	48,2	48,5
	Girls	51,9	48,4	51,8	51,5
# Measurements per case (%)	2	15,4	16,4	14,2	17,1
	3	31,6	35,1	37	32,8
	4	53	48,5	48,9	50,1
Health checkups by age group (%)	3-4y	78,1	78	81,6	79,2
	5-6y	73,5	66,6	69,6	67,6
	7-10y	86	87,4	83,4	86,2
	13-15y	100	100	100	100

Table 2 Prevalence of overweight, and test properties of overweight (overweight vs. no overweight) at 3-4, 5-6, and 7-10 years of age by ethnic group as a test for overweight at 13-15 years.

Ethnic group	*Age in years*	*Prevalence in %*	*Test properties to determine overweight at 13-15 years*			
			Sensitivity in % (95% CI)	*Specificity in % (95% CI)*	*PPV in % (95% CI)*	*Diagnostic OR (95% CI)*
Dutch	3-4y	10,6	36 (32 to 40)	94 (93 to 95)	55 (50 to 60)	9.5 (8.3 to 10.8)
	5-6y	11,2	45 (41 to 50)	95 (94 to 96)	64 (59 to 69)	16.7 (15.4 to 18.0)
	7-10y	17,3	70 (66- to 73)	92 (91 to 93)	63 (59 to 66)	27.7 (26.5 to 28.9)
	13-15y	15,8				
Turkish	3-4y	22,2	42 (38 to 47)	92 (89 to 94)	78 (73 to 83)	8.3 (6.9 to 9.7)
	5-6y	23,7	49 (43 to 54)	93 (91 to 95)	83 (77 to 87)	13.0 (11.5 to 14.5)
	7-10y	40	81 (77 to 84)	87 (84 to 89)	80 (76 to 83)	27.1 (25.8 to 28.5)
	13-15y	39,8				
Moroccan	3-4y	17,3	38 (32 to 45)	92 (89 to 94)	66 (58 to 73)	6.8 (5.3 to 8.3)
	5-6y	18,9	47 (40 to 54)	93 (90 to 95)	73 (65 to 80)	11.5 (9.9 to 13.1)
	7-10y	26,2	71 (65 to 77)	92 (89 to 94)	78 (72 to 83)	28.1 (26.6 to 29.6)
	13-15y	29,4				
South Asian (universal reference)	3-4y	7,9	27 (21 to 34)	99 (97 to 99)	87 (75 to 93)	26.6 (24.3 to 28.8)
	5-6y	11,8	38 (30 to 46)	97 (95 to 99)	84 (73 to 91)	22.8 (20.8 to 24.7)
	7-10y	27	77 (71 to 83)	90 (87 to 92)	72 (66 to 78)	30.5 (29.0 to 32.1)
	13-15y	25,1				
South Asian (ethnic specific)	3-4y	26,7	47 (41 to 53)	87 (83 to 90)	71 (64 to 77)	5.9 (4.5 to 7.4)
	5-6y	32,9	62 (55 to 68)	87 (83 to 91)	77 (71 to 83)	11.0 (9.5 to 12.5)
	7-10y	45	84 (79 to 88)	82 (78 to 85)	76 (71 to 80)	23.1 (21.6 to 24.6)
	13-15y	40,5				

Table 3 Prevalence of thinness and test properties of thinness (thinness vs. no thinness) at 3-4, 5-6, and 7-10 years of age by ethnic group as a test for thinness at 13-15 years.

Ethnic group	*Age in years*	*Prevalence in %*	*Test properties to determine overweight at 13-15 years*			
			Sensitivity in % (95% CI)	*Specificity in % (95% CI)*	*PPV in % (95% CI)*	*Diagnostic OR (95% CI)*
Dutch	3-4y	2,3	25 (16 to 37)	98 (98 to 99)	20 (12 to 29)	17.2 (15.4 to 19.1)
	5-6y	2,3	25 (16 to 38)	98 (98 to 99)	18 (11 to 29)	17.3 (15.3 to 19.2)
	7-10y	0,8	24 (16 to 36)	100 (99 to 100	52 (35 to 68)	81.4 (79.2 to 83.5)
	13-15y	1,8				
Turkish	3-4y	2,7	38 (14 to 69)	98 (96 to 98)	11 (4 to 28)	24.4 (19.9 to 28.8)
	5-6y	1,7	17 (3 to 56)	98 (97 to 99)	7 (1 to 30)	12.0 (2.8 to 21.1)
	7-10y	0,3	22 (6 to 55)	100 (99 to 100	67 (21 to 94)	319.1 (306.8 to 331.5)
	13-15y	0,8				
Moroccan	3-4y	4	33 (12 to 65)	96 (95 to 97)	10 (3 to 25)	13.3 (9.1 to 17.5)
	5-6y	3	22 (6 to 55)	97 (96 to 98)	10 (3 to 30)	10.2 (5.0 to 15.3)
	7-10y	0,9	14 (3 to 51)	99 (98 to 100)	14 (3 to 51)	21.8 (12.2 to 31.5)
	13-15y	1				
South Asian (universal reference)	3-4y	16,2	63 (41 to 81)	85 (82 to 88)	11 (6 to 18)	9.8 (7.2 to 12.4)
	5-6y	10,1	69 (44 to 86)	92 (89 to 94)	19 (11 to 31)	24.0 (21.0 to 27.0)
	7-10y	3,3	68 (46 to 85)	98 (97 to 99)	54 (35 to 72)	138.5 (135.4 to 141.6)
	13-15y	2,9				
South Asian (ethnic specific)	3-4y	2,2	40 (12 to 77)	98 (97 to 99)	13 (4 to 38)	33.6 (27.1 to 40.1)
	5-6y	1	60 (23 to 88)	99 (98 to 100)	50 (19 to 81)	283.5 (275.2 to 291.8)
	7-10y	1,6	57 (25 to 84)	99 (98 to 99)	33 (14 to 61)	119.7 (114.5 to 124.9)
	13-15y	0,8				

Figure 1 Number of health check-ups at different ages.

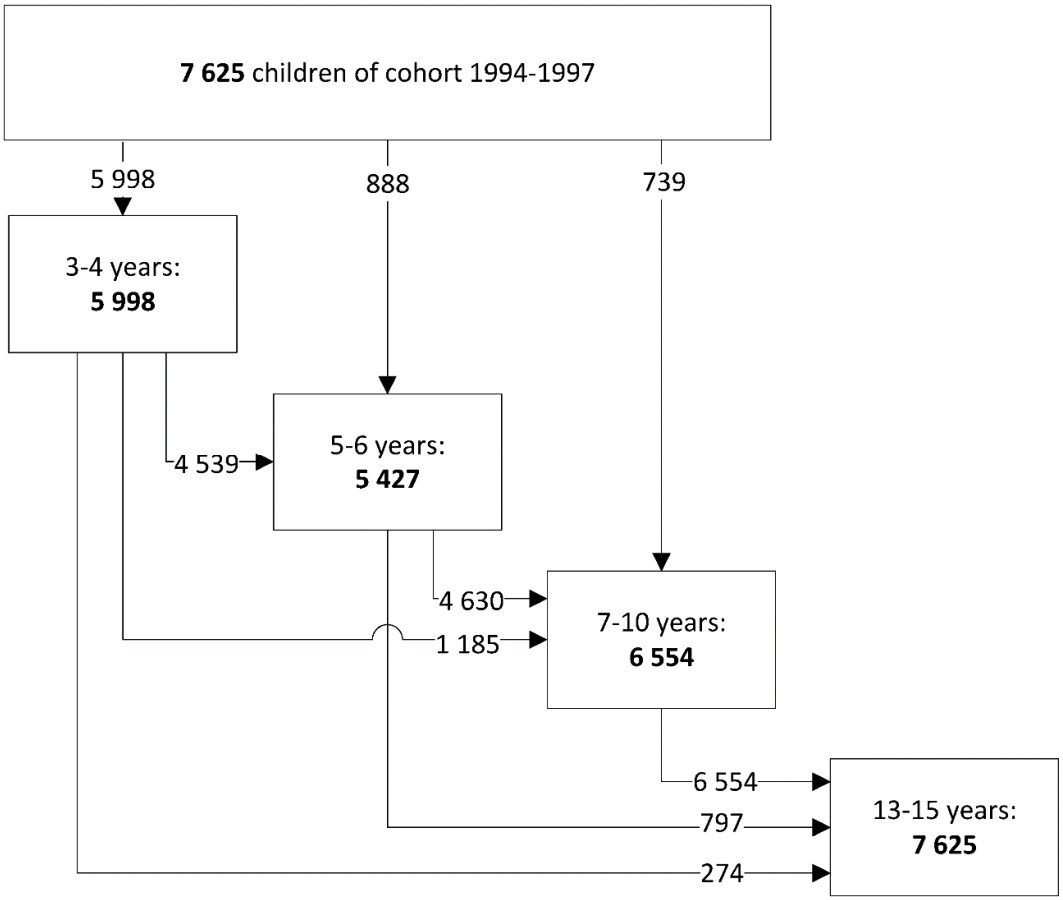

Figure 2 Adjusted mean BMI z-score (Estimated Marginal Mean) by age and ethnic group.

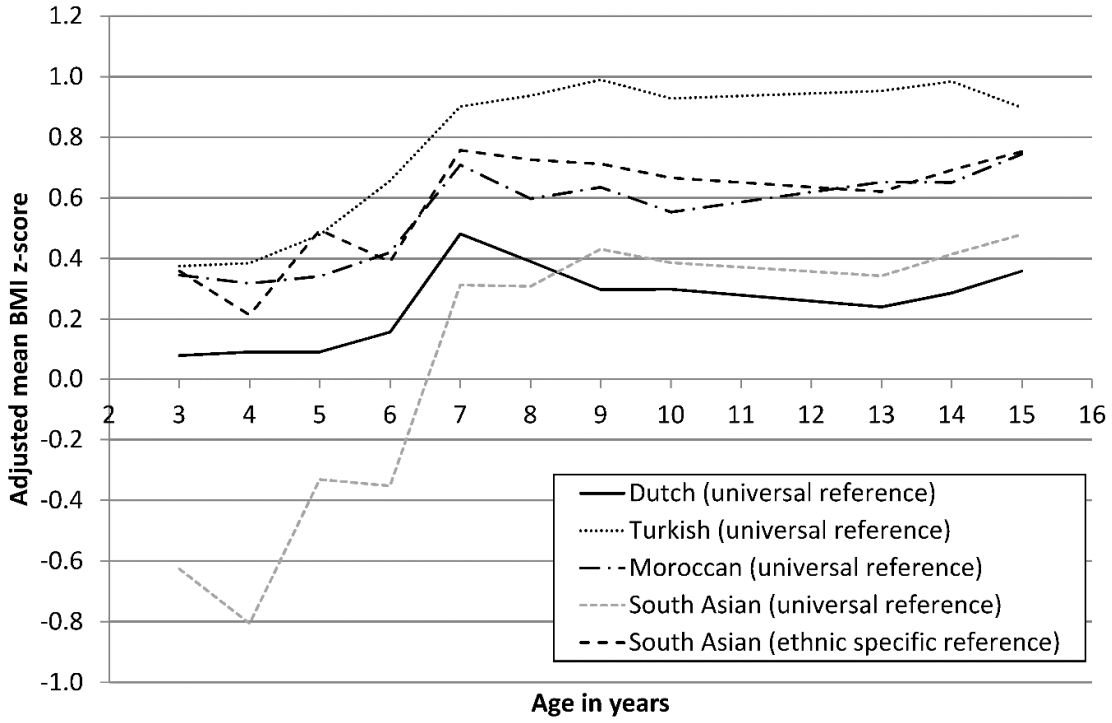

Figure 3 Tracking of adjusted mean BMI z-score (Estimated Marginal Mean) for Dutch, Moroccan, Turkish and South Asian children by BMI category (thinness, normal weight and overweight) at 13-15 years.