BMI development and early adolescent psychosocial well-being: UK Millennium Cohort Study

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Abbreviations:

A-BIC	Adjusted Bayesian information criterion
A-levels	Advanced level (a school based examination taken around age 18)
AIC	Akaike information criterion
BMI	Body Mass Index
FIML	Full Information maximum likelihood
GCSE	General Certificate of Secondary Education (a school based examination taken around age 16)
LMR-LRT	Lo-Mendell-Rubin likelihood ratio test
NS-SEC	National Statistics Socio-economic Classification
OR	Odds Ratio
SDQ	Strengths and Difficulties Questionnaire
TV	Television
UK	United Kingdom
US	United States

What's Known on This Subject

Distinct patterns of BMI development exist over the childhood years

What This Study Adds

Several potentially modifiable early life factors are linked to BMI growth patterns in the overweight and obese range through childhood. BMI growth trajectories in the overweight

and obese range through childhood are associated with worse psychosocial well-being in early adolescence.

Contributor's statement:

Prof Kelly conceptualized and designed the study, drafted the initial manuscript, and approved the final manuscript as submitted.
Dr Patalay carried out the analyses, reviewed and revised the manuscript, and approved the final manuscript as submitted.
Prof Montgomery critically reviewed the manuscript and approved the final manuscript as submitted.
Prof Sacker assisted in the design of the study, advised on data analysis, critically reviewed the manuscript and approved the final manuscript as submitted.

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Abstract

Background and objectives: The underlying influences on different patterns of BMI development are not well understood and psychosocial outcomes linked to BMI development have been little investigated. Objectives were to: 1. identify BMI developmental trajectories across the first decade of life; 2. examine early life predictors of trajectory membership; 3. investigate whether being on a particular BMI trajectory is associated with markers of psychosocial well-being.

Methods: We employed latent class analysis to derive BMI trajectories using data collected at ages 3, 5, 7 and 11 years on 16936 participants from the Millennium Cohort Study. Regression models were used to estimate predictors of BMI trajectory membership, and their psychosocial correlates.

Results: Four trajectories were identified: i. 83.8% had an average 'stable' non-overweight BMI; ii. 0.6% were in a 'decreasing' group; iii. 13.1% had 'moderate increasing' BMIs; iv. 2.5% had 'high increasing' BMIs. Predictors of 'moderate' and 'high' increasing group membership were smoking in pregnancy (OR=1.17 and 1.97 respectively), maternal BMI (OR=1.10 and 1.14), skipping breakfast (1.66 and 1.76), non-regular bedtimes (1.22 and 1.55). Children in the 'moderate' and 'high' increasing groups had worse scores for emotional symptoms, peer problems, happiness, body satisfaction and self-esteem, and those in the 'high increasing' group were more likely to have tried alcohol and cigarettes.

Conclusion: Several potentially modifiable early life factors including smoking in pregnancy, skipping breakfast, and bedtime routines were important predictors of BMI development in the overweight and obese range, and high BMI growth was linked to worse psychosocial well-being.

Introduction

Overweight and obesity are linked to health throughout the lifecourse. A growing body of research suggests the existence of distinct BMI development trajectories through childhood.[1-12] Prior studies have identified three broad types of trajectories: a majority group with 'healthy' BMI throughout childhood; groups who develop BMI in the overweight range at some point during childhood; and those with BMI in the overweight/obese range throughout their childhoods.[1-6] Underlying influences on different patterns of BMI development are not well understood, but factors reported to predict childhood BMI trajectories include mothers' BMI,[1,3,5,6,8,10,11] smoking during pregnancy,[1,5,6] and sociodemographic background.[1-5,12] Prior work suggests a range of early life factors including infant feeding, diet, physical activity and family routines are associated with child overweight and obesity.[13] However, comparison of study findings is often hampered for two main reasons. Firstly, differences in study design used, for example representative population[1-6] versus convenience samples.[7-9] Secondly, studies often consider different potential influences for BMI growth, overweight or obesity.

Apparent links between overweight and obesity and psychosocial well-being exist although the direction of association is not clear, and may be bidirectional in nature. Several studies indicate that early psychosocial stress and adverse family environments are associated with an increased risk of obesity,[14-17] and many others suggest that being overweight or obese is linked to increased risks of poor psychosocial well-being, including low self esteem and depressive symptoms.[16,17] One prior study examined BMI development trajectories and adolescent psychosocial well-being and showed that the exploration of risky behaviors such as tobacco smoking was more common for those who were obese throughout childhood.[18] Given that healthy development early in life has long lasting consequences, improving our understanding of the factors influencing BMI development, and of how particular BMI trajectories relate to markers of well-being, could have important implications for health throughout the lifecourse.

To our knowledge this is the first paper, using nationally representative data from the UK to address the following research objectives:

1. identify BMI developmental trajectories across the first decade of life. We derive trajectories empirically using latent class analysis to group individuals with similar patterns of BMI development. We hypothesise there will be distinct BMI growth trajectories, including BMI growth patterns in the overweight/obese range, and a non-overweight trajectory.

2. examine early life predictors of trajectory membership. We hypothesise that some factors including cigarette smoking, factors linked to family routines including skipping breakfast and non-regular bedtimes, delayed infant motor development, low levels of physical activity, and dietary indicators such as low fruit consumption and intake of sugary drinks will increase

the risk of having BMI growth in the overweight and obese range, whilst breastfeeding will have a protective role.

3. investigate whether BMI trajectory membership is associated with markers of psychosocial well-being including socioemotional difficulties, self esteem, happiness and risky behaviors in early adolescence. Here, we hypothesise that having BMI growth in the overweight or obese range will correlate with poorer psychosocial well-being, an umbrella term that here encompasses socioemotional difficulties, low self esteem, unhappiness and risky behaviors such as cigarette smoking and alcohol consumption.

Methods

Participants

Data were from the first five sweeps of the UK Millennium Cohort Study, a prospective study of children born into 19244 families, sampled from all live births in the UK between September 2000 and January 2002.[19] The first sweep of data was collected when cohort members were around 9 months and the subsequent four sweeps of data were collected at ages 3, 5, 7, and 11 years. We used data from the latter four sweeps (ages 3, 5, 7 and 11 years) to estimate trajectories of BMI development.

A total of 17601 families participated in at least 1 of the 4 sweeps, of which 479 multiple births (234 sets of twins and 11 sets of triplets) were excluded from analysis. A further 186 participants had no BMI data at any sweep and were excluded from our analyses. After dealing with outlier BMI values (described below) there were 14205, 14790, 13457 and 12697 participants with BMI data at sweeps 2 to 5 respectively. 16936 participants were included in the trajectory analysis of which 9523 (56.2%) had data in all four sweeps, 3810 (22.5%) any three, 2024 (12.0%) any two and the remaining 1579 (9.3%) had data at one sweep.

Body Mass Index (BMI)

At ages 3, 5, 7 and 11 years children were weighed and had their height measured without shoes or outdoor clothing. Weights in kilograms to one decimal place and heights to the nearest millimetre were recorded.[20] These measures were used to calculate Body Mass Index (kg/m^2). Values were considered to be outliers if BMI was <10 or >50 resulting in 6, 0, 3 and 5 values from each of sweeps 2-5 being removed, respectively. Mean (SD) values at each sweep were 16.5 (2.1), 16.4 (1.9), 16.7 (2.4) and 19.3 (3.7).

Socio-demographic characteristics

Cohort members were classified into 7 groups based on their ethnicity as reported by their mothers: white, Indian, Pakistani, Bangladeshi, Black Caribbean, Black African and other.[21] Household income was categorised into equivalised quintiles. Occupational class was indicated using the standard National Statistics Socio-economic Classification (NS-SEC) 3-group categorisation (Higher managerial, administrative and professional; intermediate; routine and manual; and an additional category - never worked and long term unemployed). Highest maternal education attained at sweep 1 was grouped into 6 categories (higher education including degree/professional diploma or higher; Advanced levels (A-levels), which are UK school leaving exams at age 17-18 years; General Certificate of Secondary Education (GCSEs), which are UK school exams at age 15-16 years, broken down into A-C grades and D-G grades; other qualifications including overseas qualifications; and none).

Pregnancy and infancy factors

Health related behaviors during and after pregnancy that were included were whether the mother smoked during pregnancy, ever breastfed the child and introduced solid foods before four months of age. Motor delay in infancy (9 months) was estimated based on delay compared to the rest of the cohort in any key motor skills - sitting, crawling and standing.[22]

Early childhood factors

Mother's BMI at age 3 (sweep 2) was estimated from self-reported height and weight. Early childhood factors included markers of diet, physical activity and sleep at age 5 years. Dietary factors were: whether the child mainly drank sugary drinks (e.g. cola, milkshakes, fruit juice) in between meals; ate less than 3 portions of fruit a day; and regularly skipped breakfast. Sports participation (less than once per week) was included as a marker of physical activity. TV viewing for more than 3 hours a day was included as a marker of sedentary behavior. Whether the cohort member had regular bedtimes and if they did whether this bedtime was late (9pm or later at age 5 years) were included as markers of sleep.

Psychosocial well-being outcomes

At age 11 markers of psychosocial well-being were as follows: socioemotional difficulties and skills (parent reported Strengths and Difficulties Questionnaire (SDQ)[23]) including: emotional symptoms; conduct problems; hyperactivity; peer problems; prosocial behavior. Higher emotional symptoms, conduct problems, hyperactivity and peer problems scores indicate more difficulties, whilst high prosocial scores indicate better outcomes. Cohort members themselves reported on anti-social activity (stealing, being noisy/rude in public spaces, damaging public property), exploratory health behaviors (ever having smoked cigarettes and ever having drank alcohol), self-esteem (Rosenberg self-esteem scale with lower scores indicating worse outcomes)[24] and happiness (6-item measure of 'happiness' with school work, appearance, family, friends, school, life as a whole with responses to each item on a 7-point scale from completely happy to not at all happy, α=0.83).[25] Additionally,

the marker of body satisfaction (happiness with appearance) from the happiness scale was examined as a separate item.

Analysis

Trajectories of BMI development were identified using Latent Class Growth Analysis in Mplus[26] with full Information maximum likelihood (FIML) estimation to account for missing BMI data at any time point. The selection of the number of trajectories to explore in further analysis was based on a range of criteria including model comparison (Lo-Mendell-Rubin likelihood ratio test, LMR-LRT; likelihood ratio difference), improvement in information criteria (Akaike information criterion, AIC; adjusted Bayesian information criterion, A-BIC), neatness of classification (entropy index) and theoretical interest.[27,28] The 4-trajectory model was chosen for further analysis (A-BIC plot indicated a clear flattening of A-BIC subsequent to the 4-trajectory model, entropy of 0.88 suggested satisfactory neatness of classification, likelihood ratio difference indicated highly significant improvement in model fit ($p<0.001$) and LMR-LRT indicated that 4- versus 3-class was an improvement ($p<0.10$) whereas 5-class and above was not ($p>0.50$)).

Once trajectories had been derived, in the next stage, multiple imputation was carried out to ensure no data were excluded in analysis due to missingness on the predictors of interest while also maintaining the survey structure in the data. During imputation the trajectory group of individuals was also included alongside all the other covariates to inform the imputation. Overall, 14.6% of data points across the entire sample including the socio-demographic, infancy, childhood and age 11 outcome variables were missing. The proportion of data missing varied by variable, e.g. no cases missing for gender, 0.1% missing income, 0.6% missing ethnicity (not imputed) on the lower end, through to 28.5% missing SDQ and 29.6% self-esteem at age 11 years on the higher end. Missingness on markers of psychosocial well-being was consistently lowest for individuals in the moderate increasing BMI group (average missing 18.9%), followed by the stable group (average missing 28.7%), the high increasing BMI group (average missing 30.2%) and the highest missingness was observed in children in the smallest group with decreasing BMI over childhood (average missing 35.8%).

Guided by best practice,[29] 25 imputations were carried out and used in subsequent analysis. Supplementary Table 1 provides information on the non-imputed and imputed descriptive statistics for all the variables in the study.

Predictors of membership to different trajectory groups were investigated using multivariate multinomial logistic regressions comparing the decreasing and increasing trajectories to the reference group (the largest, ‘stable’ trajectory). Psychosocial outcomes at age 11 – socioemotional difficulties and skills, antisocial behaviors, exploratory risky behaviors, self-esteem and ‘happiness’ were examined by trajectory group to ascertain whether different

trajectories were associated with different outcomes. Socio-demographic variables were adjusted for in these analyses, and we present odds ratios for potential predictors that are independent of all factors. In addition we carried out sensitivity analysis for participants with data on markers of puberty but this did not alter estimates and is not reported.

Results

Of the 16936 participants with BMI data in any of the sweeps, 48.8% (n=8259) were girls. Most of the sample (83.8%) had an average non-overweight BMI - the 'stable' trajectory. The smallest 'decreasing' trajectory group (0.6%) had BMIs in the obese range at age 3 but were similar to the stable group by age 7. The 'moderate increasing' group (13.1%) had average BMIs in the non-overweight range at age 3 and subsequent average BMIs that increased throughout the rest of childhood into the overweight, but not obese range. The 'high increasing' trajectory (2.5%) had average BMIs in the obese range at age 3 and their BMIs continued to increase throughout childhood (Figure 1).

<Figure 1 around here>

What factors predict BMI trajectory membership?

Table 1 shows the distribution of predictor variables by BMI trajectory group. Fully adjusted estimates, simultaneously taking account of all variables are shown in Table 2. Sociodemographic variations in trajectory membership were seen. Girls were more likely to be in the 'moderate increasing' group (OR=1.36), and less likely to be in the 'decreasing' trajectory (OR=0.44). Indian, Pakistani and Black African children were significantly more likely to have a 'moderate increasing' trajectory (OR=1.66, 1.29 and 2.01 respectively) and Pakistani, Black Caribbean and Black African children were more likely to belong to the 'high increasing' group (OR=1.83, 3.44 and 3.39 respectively). Compared with cohort members in the affluent income quintile, those in the other four income groups had higher odds of being in the 'moderate increasing' BMI group. Low maternal educational attainment compared with degree or higher levels predicted membership of increasing trajectories (GCSE grades A-C and D-G 'moderate increasing' OR=1.32 and 1.42 respectively; GCSE grades A-C, and no qualifications 'high increasing' OR=1.79 and 1.74 respectively).

Cohort members whose mothers smoked during pregnancy had higher odds of being in both the 'moderate increasing' and 'high increasing' trajectories (OR=1.17 and 1.97 respectively). Breastfeeding and the early introduction of solid food were not independently associated with trajectory membership. Having motor (sitting, standing, crawling) delays in infancy were associated with higher odds of being in the 'high increasing' group (OR=1.47). A unit increase in maternal BMI was associated with a 10% increase in the odds of being in the 'moderate increasing' and 'high increasing' trajectories. Skipping breakfast or having non-

regular bedtimes in early childhood were associated with higher odds of increasing trajectory membership ('moderate increasing' – skipping breakfast OR=1.66, non-regular bedtimes OR=1.22; 'high increasing' OR=1.76 and 1.55 respectively). Sugary drink consumption, fruit intake, TV viewing and sports participation appeared not to be predictive of trajectory membership.

<Table 1 around here>

<Table 2 around here>

Are BMI trajectories linked to psychosocial well-being at the start of adolescence?

Compared to the 'stable' group, cohort members in the 'moderate increasing' group had worse scores for emotional symptoms, peer problems, and happiness, body satisfaction and self-esteem, but had better pro-social behavior scores. Cohort members in the 'high increasing' group had worse scores for emotional symptoms, peer and conduct problems, happiness, body satisfaction, self-esteem and were more likely to have drank alcohol and smoked cigarettes. In addition cohort members in the moderate increasing group were more likely to have scores in the clinical range for emotional and peer problems, and those in the high increasing group were more likely to have scores in the clinical range for emotional, peer and conduct problems (data not shown). Belonging to the decreasing trajectory did not appear to predict any significantly different outcomes at age 11 years. The distribution of psychosocial well-being markers are shown in Table 1 and fully adjusted estimates by BMI trajectory are shown in Table 3.

<Table 3 around here>

Discussion

In this large population based sample of children we identified four BMI development trajectories. The majority of children belonged to a stable non-overweight group. About one in seven belonged to a group with increasing BMIs with average BMIs just under the overweight range at age 3 and subsequent average BMIs increasing throughout the rest of childhood into the overweight, but not obese range. A smaller group (2.5%) had average BMIs in the obese range at age 3 and their BMIs continued to increase throughout childhood. A small group (less than 1%) of children had BMIs in the obese range at age 3 but by age 7 their BMIs were in the non-overweight range. Factors that predicted membership of the two increasing BMI trajectories included socioeconomic disadvantage, being from certain ethnic

minority backgrounds, maternal smoking during pregnancy, maternal BMI and family routines, such as skipping breakfast and not having regular bedtimes. We found that, in general having BMIs in the overweight and obese range throughout childhood was associated with worse psychosocial well-being at 11 years of age.

Similar to other reports a large proportion of our study sample had BMIs in the non-overweight range throughout childhood,[1-5,9,11] and we identified groups of children belonging to BMI trajectories in the overweight/obese range. We found a small proportion of children in a decreasing trajectory which has been seen elsewhere.[7] We did not identify a group of children with BMIs consistently in the underweight range. In comparison with other reports there were differences too, for example some studies have identified groups of children who develop overweight/obesity at different points in the childhood years, including a late onset group.[1-4,9,11] Dissimilarities in observed trajectories might not be surprising given different study settings, for example the US,[2-4,7,8] Canada,[5,6,11,12] Australia,[1,9,10] and different empirical approaches used to identify groups.

Our findings suggest a range of early life factors to be associated with children being on particular BMI trajectories. Similar to elsewhere we show sociodemographic factors including socioeconomic position[1,2,4,12,30] and ethnicity[2-4,12] to be linked to membership of trajectories in the overweight and obese range. Other work from the UK has shown variations in the risk of overweight and obesity for children from Black and South Asian groups, and for children living in economically disadvantaged circumstances.[13,31] In keeping with prior reports, 'behavioral' influences appeared important, including smoking in pregnancy,[3,5,6,32] maternal BMI,[1-3,5,6,8,10,11,30,32] and markers of family routines such as skipping breakfast and sleep schedules.[11] Exposure to tobacco products during fetal life has long been thought to increase the risk of overweight in childhood,[33] hypothesised pathways include via altered growth and weight gain, metabolic processes, and epigenetic mechanisms. Prior work suggests links between fetal tobacco exposure and infant motor co-ordination[34] and this in turn could be on a developmental pathway to BMI growth.[35] Maternal BMI appears strongly predictive of children's BMI growth, probably reflecting the wider obesogenic environment along with genetic predisposition. Disrupted routines, exemplified here by non-regular sleep schedules and skipping breakfast, are hypothesised to influence weight gain via increased appetite and consumption of energy dense foods. Interestingly skipping breakfast was also associated with being in the 'decreasing' trajectory, but the potential mechanisms at play here are not clear. We cannot rule out, and neither were we able to tease out, a bidirectional relationship between BMI growth and psychosocial well-being. Similar to prior work,[14,16,17] our findings suggest that trajectories in the overweight and obese range correlate strongly with worse psychosocial outcomes and it may be that the strength of these associations increases as adolescence proceeds as suggested elsewhere.[14,15] Social stigmatisation, isolation and victimisation are factors hypothesised to form links between overweight and negative psychosocial outcomes and the exploration of risky health behaviors. In keeping with this we found common psychosocial correlates of 'moderate increasing' and 'high increasing' BMI trajectories were socioemotional difficulties, low self esteem, low overall happiness and body

dissatisfaction. In addition children with BMIs in the obese range through childhood (the 'high increasing' group) were more likely to report having drunk alcohol and smoked cigarettes.

This paper has distinct strengths, being the first to examine nationally representative UK data with repeated measures allowing for the empirical derivation of BMI trajectories across the first decade of life. We estimated associations between a wide range of early life factors, including mother's health behaviors (smoking during pregnancy, infant feeding and BMI), infant motor skills, family routines, diet and physical activity in relation to different patterns of BMI development. Another strength is that we examined identified BMI trajectories in conjunction with a range of markers of psychosocial well-being, for example socioemotional difficulties, self esteem, happiness and risky behaviors. Our paper has important potential limitations too, for example, even though we included in our analyses a wide range of potential risk factors we were not able to fully characterise influences (including gestational diabetes and growth in infancy) that might play a role. Imperfect measurement was a feature too for some of our early life predictor variables, for example sugary drinks, fruit consumption and markers of physical activity including sports participation and TV viewing all of which had no apparent link with BMI trajectories, however, these markers are crude and conclusions based on null findings should be avoided. Furthermore, these data on early life predictors were mother reported. However, data were collected contemporaneously thus minimising problems of recall bias.

Conclusions

The vast majority of children in this contemporary UK study belonged to BMI trajectories in the non-overweight range. Several potentially modifiable early life factors including smoking in pregnancy and family routines - skipping breakfast and not having a regular bedtime appeared important in predicting membership of BMIs in the overweight and obese range. These findings support the need for intervention strategies aimed at multiple spheres of influence on BMI growth. In general having BMI growth in the overweight and obese range was linked to poorer psychosocial well-being supporting the need for health care providers to monitor the occurrence of these in children with high BMI growth. Given continuities in overweight/obesity and mental health from childhood into adolescence and adulthood, intervening early could alter trajectories and have important implications for physical health, psychosocial well-being and health behaviors across the lifecourse.

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References

1. Magee CA, Caputi P, Iverson DC. Identification of distinct body mass index trajectories in Australian children. *Pediatric Obesity.* 2013;8(3):189-198.
2. Danner FW, Toland MD. The Interactive Role of Socioeconomic Status, Race/Ethnicity, and Birth Weight on Trajectories of Body Mass Index Growth in Children and Adolescents. *The Journal of Early Adolescence.* 2013;33(3):293-314.
3. Li C, Goran MI, Kaur H, Nollen N, Ahluwalia JS. Developmental Trajectories of Overweight During Childhood: Role of Early Life Factors. *Obesity.* 2007;15(3):760-771.
4. Balistreri KS, Van Hook J. Trajectories of Overweight Among US School Children: A Focus on Social and Economic Characteristics. *Matern. Child Health J.* 2011;15(5):610-619.
5. Pryor LE, Tremblay RE, Boivin M, et al. Developmental trajectories of body mass index in early childhood and their risk factors: An 8-year longitudinal study. *Arch. Pediatr. Adolesc. Med.* 2011;165(10):906-912.
6. Carter MA, Dubois L, Tremblay MS, Taljaard M, Jones BL. Trajectories of Childhood Weight Gain: The Relative Importance of Local Environment versus Individual Social and Early Life Factors. *PLoS ONE.* 2012;7(10):e47065.
7. O'Brien M, Nader PR, Houts RM, et al. The ecology of childhood overweight: a 12-year longitudinal analysis. *Int. J. Obes.* 2007;31(9):1469-1478.
8. Ventura AK, Loken E, Birch LL. Developmental Trajectories of Girls' BMI Across Childhood and Adolescence. *Obesity.* 2009;17(11):2067-2074.
9. Garden FL, Marks GB, Simpson JM, Webb KL. Body Mass Index (BMI) Trajectories from Birth to 11.5 Years: Relation to Early Life Food Intake. *Nutrients.* 2012;4(10):1382-1398.
10. Giles LC, Whitrow MJ, Davies MJ, Davies CE, Rumbold AR, Moore VM. Growth trajectories in early childhood, their relationship with antenatal and postnatal factors, and development of obesity by age 9 years: results from an Australian birth cohort study. *Int. J. Obes.* 2015;39(7):1049-1056.
11. Pryor LE, Brendgen M, Tremblay RE, et al. Early Risk Factors of Overweight Developmental Trajectories during Middle Childhood. *PLoS ONE.* 2015;10(6):e0131231.
12. Tu AW, Mâsse LC, Lear SA, Gotay CC, Richardson CG. Body mass index trajectories from ages 1 to 20: Results from two nationally representative canadian longitudinal cohorts. *Obesity.* 2015;23(8):1703-1711.
13. Goisis A, Sacker A, Kelly Y. Why are poorer children at higher risk of obesity and overweight? A UK cohort study. *Eur. J. Public Health.* 2016;26(1):7-13.
14. Heerman WJ, Krishnaswami S, Barkin SL, McPheeters M. Adverse family experiences during childhood and adolescent obesity. *Obesity.* 2016;24(3):696-702.
15. Stenhammar C, Olsson G, Bahmanyar S, et al. Family stress and BMI in young children. *Acta Paediatr.* 2010;99(8):1205-1212.
16. Griffiths LJ, Parsons TJ, Hill AJ. Self-esteem and quality of life in obese children and adolescents: a systematic review. *Int. J. Pediatr. Obes.* 2010;5(4):282-304.
17. Sanders RH, Han A, Baker JS, Cobley S. Childhood obesity and its physical and psychological co-morbidities: a systematic review of Australian children and adolescents. *Eur. J. Pediatr.* 2015;174(6):715-746.
18. Huang DYC, Lanza HI, Wright-Volel K, Anglin MD. Developmental trajectories of childhood obesity and risk behaviors in adolescence. *J. Adolesc.* 2013;36(1):139-148.
19. Millennium Cohort Study, A Guide to the Datasets (Eighth Edition) First, Second, Third, Fourth and Fifth Surveys. http://www.cls.ioe.ac.uk/shared/get-file.ashx?id=1806&itemtype=document. Accessed 21 July 2016.
20. Kathryn Gallop, Nickie Rose, Emma Wallace, et al. Millennium Cohort Study Fifth Sweep (MCS5) Technical Report. Centre for Longitudinal Studies, Institute of Education; 2013:

http://www.cls.ioe.ac.uk/shared/get-file.ashx?id=1655&itemtype=document. Accessed 21 July 2016.
21. Kelly Y, Sacker A, Schoon I, Nazroo J. Ethnic differences in achievement of developmental milestones by 9 months of age: The Millennium Cohort Study. *Dev. Med. Child Neurol.* 2006;48(10):825-830.
22. Sacker A, Quigley MA, Kelly YJ. Breastfeeding and developmental delay: findings from the millennium cohort study. *Pediatrics.* 2006;118(3):e682-689.
23. Information for researchers and professionals about the Strengths & Difficulties Questionnaires. http://www.sdqinfo.org/. Accessed 21 July 2016.
24. Rosenberg M. *Society and the adolescent self-image.* Middletown, Conn.: Wesleyan University Press; 1989.
25. Booker CL, Skew AJ, Sacker A, Kelly YJ. Well-Being in Adolescence—An Association With Health-Related Behaviors: Findings From Understanding Society, the UK Household Longitudinal Study. *The Journal of Early Adolescence.* 2014;34(4):518-538.
26. Muthén LK, Muthén BO. *Mplus User's Guide. Seventh Edition.* Los Angeles, CA: Muthén & Muthén; 1998-2015.
27. Nylund KL, Asparouhov T, Muthén BO. Deciding on the Number of Classes in Latent Class Analysis and Growth Mixture Modeling: A Monte Carlo Simulation Study. *Structural Equation Modeling: A Multidisciplinary Journal.* 2007;14(4):535-569.
28. Jung T, Wickrama KAS. An Introduction to Latent Class Growth Analysis and Growth Mixture Modeling. *Social and Personality Psychology Compass.* 2008;2(1):302-317.
29. White IR, Royston P, Wood AM. Multiple imputation using chained equations: Issues and guidance for practice. *Statistics in Medicine.* 2011;30(4):377-399.
30. Börnhorst C, Siani A, Russo P, et al. Early Life Factors and Inter-Country Heterogeneity in BMI Growth Trajectories of European Children: The IDEFICS Study. *PLoS ONE.* 2016;11(2):e0149268.
31. Zilanawala A, Davis-Kean P, Nazroo J, Sacker A, Simonton S, Kelly Y. Race/ethnic disparities in early childhood BMI, obesity and overweight in the United Kingdom and United States. *Int. J. Obes.* 2015;39(3):520-529.
32. Robinson SM, Crozier SR, Harvey NC, et al. Modifiable early-life risk factors for childhood adiposity and overweight: an analysis of their combined impact and potential for prevention. *The American Journal of Clinical Nutrition.* 2015 2015;101(2):368-375.
33. Oken E, Levitan EB, Gillman MW. Maternal smoking during pregnancy and child overweight: systematic review and meta-analysis. *Int. J. Obes.* 2007;32(2):201-210.
34. Larsson M, Montgomery SM. Maternal smoking during pregnancy and physical control and coordination among offspring. *Journal of Epidemiology and Community Health.* 2011;65(12):1151-1158.
35. Osika W, Montgomery SM, Longitudinal Birth Cohort S. Physical control and coordination in childhood and adult obesity: Longitudinal Birth Cohort Study. *BMJ.* 2008;337:a699.

Figure legend

Figure 1. Average BMI for each of the identified trajectories at ages 3, 5, 7, and 11 years