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Trajectories of Child Cognitive and Socioemotional Development and Associations with Adolescent Health in the UK Millennium Cohort Study

Michelle Black, PhD[1], Nicholas Kofi Adjei, PhD[2], Mark Strong, PhD[1], Amy Barnes, PhD[1], Hannah Jordan, PhD[1], and David Taylor-Robinson, PhD[2]

Objective To identify and describe distinct trajectories of cognitive and socioemotional development during childhood and to examine their relationships with adolescent health.

Study design We used group-based multitrajectory modeling applied to longitudinal data on 11 564 children up to age 14 years from the UK Millennium Cohort study to identify trajectories of cognitive and socioemotional development measured using validated instruments. We assessed associations between the derived trajectories and baseline socioeconomic, parental, and school factors using multinomial regression. Logistic regression was used to assess associations between trajectory groups and adolescent health at age 14 and 17 years.

Results Four child development trajectories were identified: "no problems" (76.5%); "late socio-emotional problems" (10.1%); "early cognitive and socioemotional problems" (8.6%); and "persistent cognitive and socioemotional problems" (4.8%). Those in the problem trajectories were more socioeconomically disadvantaged. Compared with the "no problem" trajectory, the "late socioemotional problems" trajectory had increased odds of overweight and mental ill-health at age 14 years of 1.50 (95% CI 1.24-1.81) and 2.51 (2.03-3.10), respectively. For the "persistent problems" group, the OR for overweight was 1.41 (1.04-1.91), and for mental ill-health, 3.01 (2.10-3.30). For both groups, the associations persisted to age 17 years.

Conclusions In a representative UK cohort, groups of distinct trajectories of cognitive and socioemotional development were identified. Adverse development, if unresolved, can have a negative impact on weight and mental health in adolescence. Socioemotional development was the main driver of the impact on adolescent health and this requires emphasis in child health policy. *(J Pediatr 2023;263:113611)*.

Improving child and adolescent health and reducing health inequalities is a global priority,[1] yet many countries, including the United Kingdom, do not have a child and adolescent health strategy.[2] This is a missed opportunity, as good health in adolescence is important for future health directly and indirectly by enabling educational opportunities.[3] However, poor health in adolescence is increasingly common. Globally, the prevalence of anxiety and depression has doubled from pre- to postpandemic years and currently affects approximately 1 in 4 of those younger than the age of 18 years,[4] with stark inequalities in high-income settings. Children and adolescents in families with a lower socioeconomic status (SES) are 2-3 times more likely to develop mental health problems than their peers with a greater family SES.[5] Prevalence of and inequalities in childhood obesity is also increasing. For example, in the United Kingdom, 1 in 4 children are obese when they leave primary school at age 10-11 years,[6] the start of their adolescent journey.

Early childhood cognitive and socioemotional skills are important predictors of later mental health problems and obesity. A recent systematic review suggests that socioemotional development, defined as internalizing and externalizing behaviors, emotional and social skills, and temperament on starting school (age 3-7 years), has a strong influence on weight and mental health in adolescence.[7] In addition, cognitive development was associated with subsequent risk of internalizing behaviors such as anxiety and depression.[7] Studies in the United Kingdom and Australia have found that risk factors such as SES, sex, and maternal mental health are associated with trajectories of socioemotional behavior during childhood.[8,9]

Despite these insights, few studies have assessed how early life risk factors influence the codevelopment of cognitive and socioemotional behavior and how different trajectories of development are related to adolescent health outcomes such as mental health and obesity. Studying the evolution of cognitive and socioemotional development together is important as children develop holistically, with their needs changing over time and in relation to their socioeconomic circumstances.[10] Early childhood socioeconomic circumstances have a major influence on both socioemotional behavior and cognitive development.[11] Cognitive ability, particularly language skills, develop and rapidly improve

GBTM	Group-based trajectory modeling
MCS	Millennium Cohort Study
SES	Socioeconomic status

From the [1]School of Health and Related Research, The University of Sheffield, Regent Court, Sheffield, United Kingdom; and [2]Public Health, Policy and Systems, Institute of Population Health, University of Liverpool, Liverpool, United Kingdom

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throughout childhood.[12] Compared with more-affluent peers, however, children living in disadvantaged circumstances are less likely to move up cognitive ability rankings.[13] This highlights the importance of understanding the impact of socioeconomic circumstances on cognitive development in terms of educational attainment and the process of skills development.[10] Socioemotional skills are fundamental to cognitive development as they improve the capacity to learn increasing educational attainment.[14,15] Attainment affects health through greater self-efficacy, self-direction, and the adoption of health behaviors,[16] and it is mediated by skills and personal control.[17] This interplay between cognitive ability and socioemotional behavior may interact over time to influence adolescent health, which may be enhanced or limited by the child's socioeconomic circumstances.

To our knowledge, no studies have analyzed trajectories of concurrent cognitive and socioemotional development in childhood or the socioeconomic, school, and parental factors associated with them. Identifying groups of children following similar developmental paths of antecedent socioemotional behavior and cognitive abilities, and describing the characteristics of those trajectories and their association with later health, could help to inform times and targets for interventions to improve adolescent health. This is an important aim against a background of increasing inequalities and may strengthen cross-sector policy development beyond the early years. Therefore, in a nationally representative UK cohort, this research sought to determine trajectories of socioemotional and cognitive development concurrently in mid-childhood; characterize how these trajectories are influenced by socioeconomic, school, and parent factors; and quantify the associations between any identified developmental trajectories and adolescent health.

Methods

Study Design and Sample

We undertook longitudinal analysis of the Millennium Cohort Study (MCS), a nationally representative cohort of children in the United Kingdom. The MCS cohort was selected from all children in the United Kingdom who turned 9 months and were in receipt of child benefit (which at the time was a universal provision) in a 16-month survey window beginning in September 2000. The MCS was designed as a stratified clustered cohort, stratified at ward level in relation to ethnicity and area disadvantage (child poverty index), with similar wards clustered. The sample was then randomly selected from the stratified cluster population, but with overrepresentation of ethnic minorities and disadvantaged children. This resulted in a disproportionately stratified cluster sample, which means, for example, that children born in disadvantaged areas had a greater chance of being selected than children in advantaged areas. Weighting was used to account for differential representation because of the unequal selection probability. Further detail on MCS study design and weighting is detailed elsewhere.[18]

The current total sample size of MCS is 19 243 families. Recruitment started when the child was 9 months old and follow ups took place at ages 3, 5, 7, 11, 14, and 17 years. Due to the structure of the dataset, we used data from surveys at age 9 months to age 17 years, for singleton children only. The number of cohort members at each of these survey points were 18 296, 15 382, 15 042, 13 682, 13 112, 11 564, and 10 500. The details of the number of families, number of cohort members and attrition at each wave is available in Appendix 1. We did not do a formal sample size calculation.

Measures

Development Trajectories. Socioemotional behavior was measured using the Strengths and Difficulties Questionnaire, completed by the parent when cohort members were age 3, 5, 7, 11, and 14 years. The Strengths and Difficulties Questionnaire is a behavioral screening questionnaire with 25 measures of psychological attributes covering 5 subscales (emotional symptoms scale, conduct problems, hyperactive scale, peer problems, and prosocial scale). The respondent classified statements about the child's behavior as either true, somewhat true, or certainly true. All of the subscales apart from prosocial scale are taken together to generate a total difficulty score. A score of 0-13 is "normal," 14-16 is "borderline," and 17-40 is "abnormal."[19] Children were classified into 2 groups to create a binary category using the validated cut-offs of 0-16 for "normal" to "borderline" socioemotional behavior and 17-40 for socioemotional behavior problems.

Cognitive development was measured from the results of standard cognition tests administered individually to cohort members at ages 3, 5, 7, 11, and 14 years. The tests at ages 3-11 years used the British Ability Scales II, which have demonstrated construct validity of cognitive ability and high test retest reliability.[20] The test(s) taken at each age, together with the ability that test is measuring, is illustrated in Appendix 2. T scores were used rather than raw scores, as the t scores are adjusted for age and item difficulty by standardizing against a reference group (norming sample).[21] This is important because it removes the cognitive advantage conferred by older age within sweeps and allows for comparison between children who have been born at different times of the year and/or have tests administered at different times. The test at age 14 years is a subset of the vocabulary assessment in the 1970 British cohort study survey, with no reference sample available. Test scores were used to classify children into 2 groups to create a binary category with children classed as having cognitive problems if they scored –1.25 SDs below the cohort mean score for the sample[22] and classed as no cognitive problems for all other scores.

Adolescent Health Outcomes. Two adolescent health outcomes measured at ages 14 and 17 years: overweight or obese and mental ill health. Classifications of weight were derived from the body mass index (kg/m^2) of children, using the

International Obesity Task Force age- and sex-specific body mass index cut-offs.[23]

Mental ill health was measured at age 14 years using the Short Moods and Feelings Questionnaire,[24] which is a 13-item self-report measure of *Diagnostic and Statistical Manual of Mental Disorders*, 4th ed, depressive symptom severity in the past 2 weeks. Possible scores range from 0 to 26, with the cut-off for symptoms indicative of clinical depression at ≥12.[25] A score of 0-11 was classed as no mental ill health, and a score of 12-26 was classed as mental ill health. At age 17 years, mental ill health was measured using the Kessler 6 scale, a 6-item measure of psychological distress. Participants were asked how often in the last 30 days they felt: so depressed that nothing could cheer you up, hopeless, restless or fidgety, everything was an effort, worthless, and nervous, with response options ranging from "all of the time" to "none of the time." Possible scores range from 0-24, with 13 or more indicating mental illness.[26] A score of 13-24 was classed as mental ill health and 0-12 classed as no mental ill health.

Predictors of Developmental Trajectories. Sociodemographic, school, and parent factors were measured as possible predictors of the developmental trajectories. Sociodemographic factors were child sex (sex at birth), UK country of residence, child ethnicity, maternal education, quintile of deprivation (all at 9 months), quintile of family income (at 9 months), and maternal mental health (at age 3 years).

School factors were experience of being bullied (child-reported), enjoying school (child-reported), and parental involvement with school (parent-reported); all at age 7 years, as a marker of the school environment during the trajectory period of age 3-14 years. Being bullied was measured from the child's own response to "How often do other children bully you?" with the child selecting either "never," "some of the time," or "all of the time." Enjoying school was measured from the child's own response to "How much do you enjoy school?" with the child selecting either "enjoy a lot," "enjoy a bit," or "don't enjoy." Involvement with school was derived (uniquely for this study) from a measure that asks parents what their main involvement with school is. The parent can select from a range of options such as, for example, "help out in class," "help out in fundraising," to "part of governing body" or "none of these." All parents who indicated involvement of any type with school were coded as "involved with school." Those who selected "none of these" were coded as "not involved with school."

Parental factors were frequency of reading with child, frequency of visiting library with child, and frequency of playing games with child; all from parent interviews (parent reported) at age 5 years, as a marker of what parents did with their children during the trajectory period. Responses were recoded into regularly (frequency of at least monthly for library visits, weekly for playing games with child) and not regularly for all other responses. For helping with reading, responses were recoded into every day, several times a week, and less than several times a week.

Covariates. Covariates used in the logistic regression model were child sex, child ethnicity (White, mixed, Indian, Pakistani, Bangladeshi, Black Caribbean, Black African, or other ethnic group), maternal education (diploma/degree plus, A-Levels, GCSE A-C, GCSE D-G/other or none), and maternal mental health (no psychological distress or moderate/high psychological distress at baseline) as guided by the multinominal regression analysis of predictors of the trajectory groups.

Statistical Analysis

First, we used group-based trajectory modeling (GBTM) to determine multitrajectory groups for cognitive and socioemotional development from age 3-14 years. GBTM is an application of finite mixture modeling that allows for populations to be organized into meaningful subgroups that show statistically similar trajectories.[27] It does this by identifying unique features of the data and organizing it into latent strata. These strata represent groups of individuals following similar trajectories for both of the developmental measures under study. Individuals do not belong to a trajectory but are assigned a probability of group membership. GBTM differs from growth curve modeling and growth mixture modeling, which define the number of sample groups a priori. In contrast, GBTM encodes no previous information about the sample distribution of trajectories and allow the data to drive the categorization of trajectories.[28] We determined the number of groups that best represented heterogeneity in the development trajectories based on model fit, model adequacy, and parsimony. We did this by fitting between 1 and 5 trajectory groups using logistic regressions with quadratic and cubic polynomial functions of age (see **Appendix 3** for more details on model specification). Model fit was determined using conditional fit statistics, Bayesian information criteria, and Akaike information criterion. Using these criteria and qualitative judgment, we determined that 4 groups was the optimal fit. As recommended by Nagin and Odgers,[28] model adequacy was further tested by determining the accuracy of individual assignment to trajectories using the average posterior probability with a minimum threshold of 0.7 and odds of correct classification based on the posterior probabilities of group membership greater than 5. Analysis was undertaken using STATA 17 and STATA Traj plug in for GBTM,[29] with full-imputation maximum likelihood used to account for missing data.

Second, to determine predictors of the trajectory groups, we used univariate and multivariable multinomial regression analysis to assess the associations between sociodemographic, parent, and school factors and the derived trajectories. Relative risk ratios and 95% CIs were calculated.

Finally, logistic regression was used to assess associations between trajectory groups and adolescent health outcomes at age 14 and 17 years. The models were adjusted for the main predictors found in the multinomial regression; child sex, ethnicity, maternal mental health, and maternal education. ORs and CIs were calculated. Complete case analysis

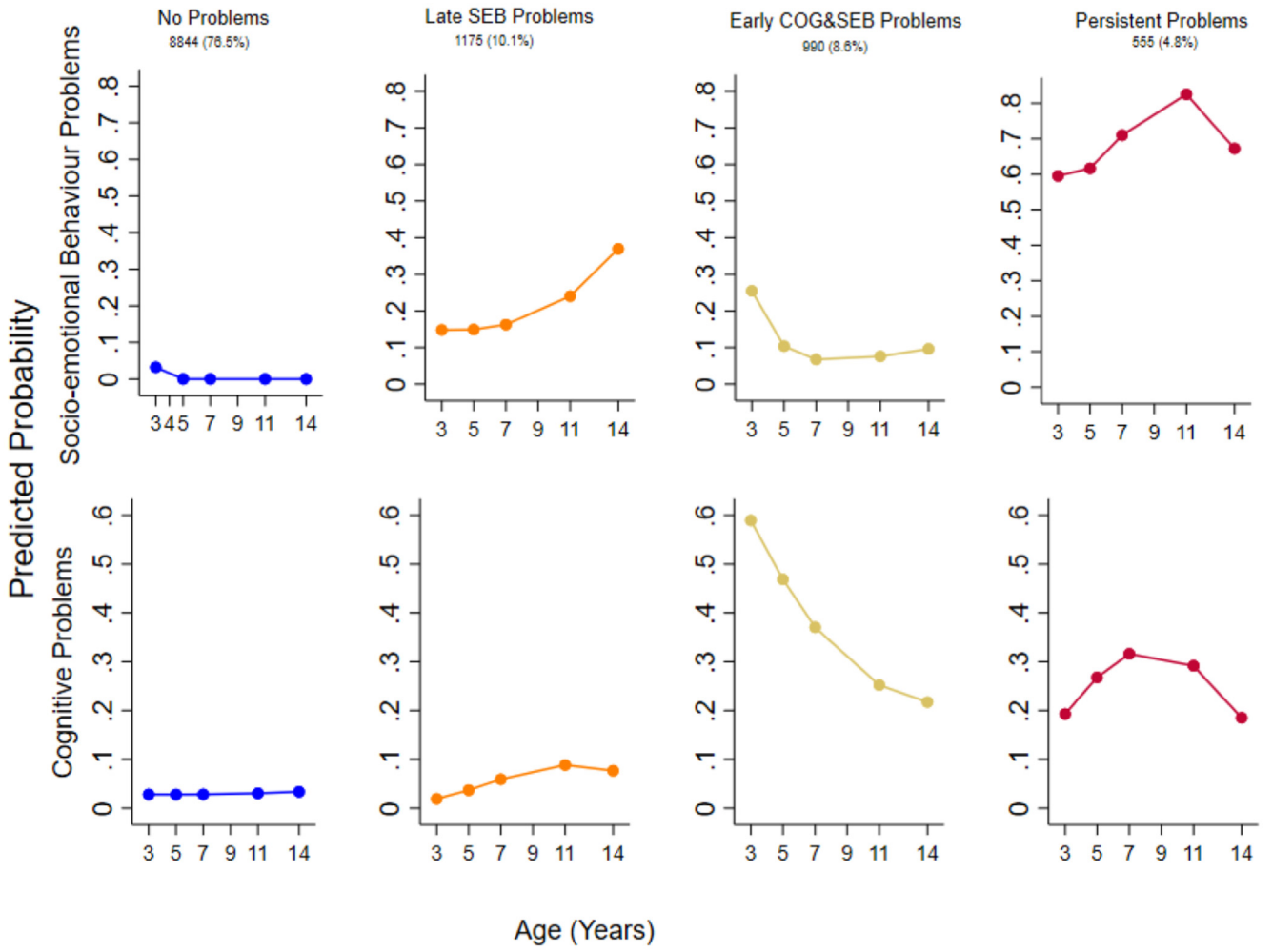

Figure. Predicted probability of socioemotional behavior problems and cognitive problems by age and trajectory group in the Millennium Cohort Study. *COG*, cognitive development; *SEB*, socioemotional behavioral development.

was used with survey weights used to account for response bias and attrition, using the *svy* command in STATA.[30] Results are reported as per the STROBE checklist (Appendix 4).

Results

Study Sample Characteristics

When cohort members were aged 14 years, there were 15 415 eligible families, from a sample size of 19 243. Of the eligible families 11 726 responded (overall response rate of 60.9% and a productive response rate from eligible families of 76.1%). After we removed twins and multiple births, 11 564 cohort members remained for the main analysis (study flow diagram available in Appendix 5).

Prevalence of Socioemotional Behavior Problems and Cognitive Problems. The weighted cross-sectional prevalence of socioemotional behavior problems and cognitive problems at ages 3, 5, 7, 11, and 14 years is available in Appendix 6. At each age point, more than 1 in 10 children had either cognitive or socioemotional development problems and approximately 1 in 50 children had problems in both aspects of development.

Analysis Part I: Group-Based Multitrajectory Modeling

Development Trajectories. The multitrajectory model with the best fit had 4 groups (Figure). These 4 groups, based on predicted probabilities, were labeled as "no problems" (76.5%); "late socioemotional problems" (10.1%); "early cognitive and socioemotional problems" (8.6%); and "persistent cognitive and socioemotional problems" (4.8%). Almost 1 in 4 children (23.5%) were in an adverse trajectory group. Population estimates for each group, based on average probabilities, are available in Appendix 3.

Table I shows the characteristic of the cohort by trajectory group. Most of the sample are residents in England and of White ethnicity, with slightly more male than female participants. Notably, the prevalence of children in each of

Table I. Description of sample (observed data, weighted sample)

Characteristics	Trajectory groups, No. (%)				*P* value	Total sample, No. (%)
	No problems n = 8844 (76.5%)	Late SEB problems n = 1175 (10.1%)	Early COG and SEB problems n = 990 (8.6%)	Persistent COG and SEB problems n = 555 (4.8%)		n = 11 564
Country					**<.001**	
England	5682 (81.5)	799 (84.0)	767 (86.6)	384 (85.2)		7632 (82.5)
Wales	1246 (5.2)	164 (4.5)	106 (4.1)	83 (5.1)		1599 (5.0)
Scotland	1028 (8.9)	112 (7.7)	58 (6.0)	38 (5.8)		1236 (8.4)
Northern Ireland	888 (4.4)	100 (3.7)	59 (3.3)	50 (4.0)		1097 (4.2)
Sex					**<.001**	
Male	4219 (49.2)	642 (55.8)	575 (62.7)	368 (69.8)		5804 (52.5)
Female	4625 (50.8)	533 (44.2)	415 (37.3)	187 (30.2)		5760 (47.5)
Ethnicity					**<.001**	
White	7177 (81.2)	903 (76.6)	383 (45.7)	377 (67.7)		8840 (76.7)
Mixed	391 (5.1)	61 (5.6)	46 (4.6)	29 (5.6)		527 (5.2)
Indian	216 (1.9)	22 (2.2)	54 (4.4)	10 (1.3)		302 (2.1)
Pakistani	283 (2.2)	42 (2.2)	211 (15.1)	35 (3.1)		571 (3.4)
Bangladeshi	133 (1.0)	16 (0.7)	96 (5.2)	6 (0.6)		251 (1.3)
Black Caribbean	72 (1.1)	17 (1.6)	20 (3.2)	5 (0.7)		114 (1.3)
Black African	155 (2.1)	6 (0.5)	48 (6.4)	4 (2.2)		213 (2.2)
Other ethnic group	165 (1.8)	32 (2.4)	85 (10.7)	23 (4.2)		305 (2.8)
Missing	252 (3.6)	76 (8.1)	47 (4.3)	66 (14.7)		441 (4.9)
Maternal education					**<.001**	
Degree plus	1985 (16.5)	119 (6.7)	24 (1.7)	19 (1.84)		2147 (13.1)
Diploma	878 (8.2)	98 (5.4)	29 (2.0)	21 (3.0)		1026 (7.0)
A-Levels	918 (8.7)	97 (6.6)	58 (3.8)	25 (3.2)		1098 (7.7)
GCSE A-C	2847 (34.1)	389 (31.2)	222 (21.4)	161 (25.3)		3619 (32.1)
GCSE D-G	749 (10.7)	156 (16.2)	106 (11.0)	98 (19.0)		1109 (11.9)
Other qualifications	197 (2.2)	33 (2.5)	74 (6.7)	12 (1.8)		316 (2.6)
No qualifications	978 (15.2)	236 (25.8)	412 (47.1)	183 (38.9)		1809 (20.8)
Missing	292 (4.3)	47 (5.4)	65 (6.3)	36 (7.0)		440 (4.8)
Quintile of deprivation					**<.001**	
Quintile 1 (most deprived)	2098 (22.8)	401 (32.9)	556 (48.9)	247 (39.6)		3302 (27.4)
Quintile 2	1874 (19.4)	281 (23.2)	179 (18.8)	134 (24.1)		2468 (20.1)
Quintile 3	1589 (19.6)	184 (17.6)	99 (13.3)	63 (13.2)		1935 (18.4)
Quintile 4	1405 (17.3)	133 (11.1)	66 (10.1)	41 (9.5)		1645 (15.4)
Quintile 5 (least deprived)	1600 (16.8)	133 (10.4)	29 (3.0)	36 (6.6)		1798 (14.2)
Missing	278 (4.2)	43 (4.8)	61 (5.9)	34 (6.9)		416 (4.6)
Income at baseline					**<.001**	
Income quintile 1 (lowest)	1365 (19.2)	339 (35.1)	422 (45.2)	223 (45.1)		2349 (25.0)
Income quintile 2	1613 (19.0)	290 (24.5)	298 (27.8)	140 (27.0)		2351 (21.0)
Income quintile 3	1759 (20.2)	188 (14.0)	114 (12.5)	78 (11.8)		2139 (18.3)
Income quintile 4	1914 (18.8)	182 (13.0)	55 (4.7)	42 (6.1)		2193 (16.1)
Income quintile 5 (highest)	1897 (18.4)	129 (8.1)	32 (3.0)	27 (3.0)		2085 (14.8)
Missing	296 (4.4)	47 (5.4)	69 (6.7)	35 (6.9)		447 (4.8)
Maternal mental health (at baseline)					**<.001**	
No psychological distress	5367 (59.3)	489 (38.5)	305 (33.0)	162 (30.0)		6323 (52.7)
Mod/high psychological distress	2164 (25.4)	477 (42.1)	234 (23.3)	242 (40.2)		3117 (28.2)
Missing	1313 (15.3)	209 (19.4)	451 (43.6)	151 (29.8)		2124 (19.2)

COG, cognitive development; *SEB*, socioemotional behavioral development.
P values in bold indicate statistically significant.

the adverse trajectory groups decreased as socioeconomic factors of maternal education and income level increase and deprivation decreased. There is variation between groups in relation to all the characteristics and this difference is statistically significant.

Analysis Part II: Multinomial Regression

Predictors of Development Trajectories. Results of the univariate and multivariable multinomial regression model are illustrated in Table II. The income variable was removed from the multivariable analysis to reduce multicollinearity. Compared with the "no problems" group; male sex, lower maternal education qualifications, being in the most deprived quintile of deprivation, poor maternal mental health, and school factors of being bullied "all the time," and parents not involved with school, were common risk factors for all of the adverse trajectory groups.

In addition, school factors increased the risk of being in the "late socioemotional behavior problems" group, such as any frequency of bullying and not enjoying school. For this group, parenting factors were not a statistically significant factor. Non-White ethnic group, increasing deprivation, and parenting factors were additional risk factors for the "early cognitive and socioemotional problems" group.

Table II. Univariate and multivariable multinomial regression analysis—predictors of multitrajectory development groups in the Millennium Cohort Study

	Univariate analyses				Multivariable analyses			
	Relative risk ratio (95% CI)				Relative risk ratio (95% CI)			
Predictors	Late SEB problems	Early COG and SEB problems	Persistent COG and SEB problems	No problems	Late SEB problems	Early COG and SEB Problems	Persistent COG and SEB problems	No problems
Sex								
Female	–	–	–	–	–	–	–	–
Male	1.32 (1.17-1.49)	1.52 (1.33-1.73)	2.16 (1.80-2.58)	Ref	1.26 (1.07-1.49)	1.59 (1.25-2.02)	2.05 (1.53-2.75)	Ref
Country								
England	–	–	–	–				–
Wales	0.94 (0.78-1.12)	0.63 (0.51-0.78)	0.98 (0.77-1.26)	Ref	0.93 (0.74-1.17)	1.59 (1.15-2.20)	0.88 (0.59-1.32)	Ref
Scotland	0.77 (0.63-0.95)	0.42 (0.32-0.55)	0.55 (0.29-0.77)	Ref	0.95 (0.72-1.24)	1.44 (0.93-2.24)	0.83 (0.47-1.46)	Ref
Northern Ireland	0.80 (0.64-0.99)	0.49 (0.37-0.65)	0.83 (0.62-1.13)	Ref	0.71 (0.53-0.97)	1.28 (0.84-1.98)	1.18 (0.74-1.88)	Ref
Ethnicity								
White	–	–	–	–			–	–
Mixed	1.24 (0.94-1.64)	2.20 (1.60-3.04)	1.41 (0.95-2.09)	Ref	1.05 (0.72-1.54)	1.93 (1.15-3.22)	1.14 (0.60-2.19)	Ref
Indian	0.81 (0.5-1.26)	4.68 (3.42-6.42)	0.88 (0.46-1.67)	Ref	0.86 (0.47-1.60)	2.45 (1.20-4.98)	0.86 (0.29-2.50)	Ref
Pakistani	1.18 (0.85-1.64)	13.97 (11.37-17.16)	2.35 (1.63-3.39)	Ref	0.58 (0.31-1.12)	9.14 (5.95-14.04)	1.51 (0.73-3.10)	Ref
Bangladeshi	0.96 (0.57-1.61)	13.53 (10.20-17.93)	0.85 (0.37, 1.96)	Ref	0.48 (0.11-2.07)	12.03 (5.63-25.72)	1.44 (0.32-6.63)	Ref
Black Caribbean	1.87 (1.10.3.20)	5.21 (3.14, 8.63)	1.32 (0.53-3.29)	Ref	1.38 (0.65-2.94)	3.42 (1.43-8.16)	1.29 (0.37-4.45)	Ref
Black African	0.31 (0.14-0.70)	5.80 (4.13, 8.15)	0.49 (0.18-1.3)	Ref	0.60 (0.23-1.53)	3.08 (1.36-6.98)	0.36 (0.05-2.71)	Ref
Other	1.54 (1.05-2.27)	9.65 (7.29, 12.79)	2.65 (1.69-4.15)	Ref	1.73 (0.94-3.17)	6.45 (3.62-11.47)	2.93 (1.31-6.56)	Ref
Maternal education								
Dip/degree	–	–	–	–	–	–	–	–
A-Levels	1.39 (1.08-1.79)	3.41 (2.33-4.99)	1.95 (1.18-3.23)	Ref	1.36 (1.00-1.83)	2.47 (1.45-4.22)	1.44 (0.67-3.12)	Ref
GCSE A-C	1.80 (1.51-2.14)	4.21 (3.11-5.71)	4.05 (2.85-5.74)	Ref	1.53 (1.23-1.89)	2.60 (1.72-3.94)	3.14 (1.91-5.15)	Ref
GCSE D-G/other	2.64 (2.14-3.25)	10.28 (7.50-14.08)	8.32 (5.75-12.04)	Ref	2.02 (1.53, 2.66)	5.21 (3.33-8.16)	5.36 (3.11-9.26)	Ref
None	3.18 (2.61-3.88)	22.76 (16.94-30.57)	13.39 (9.44-18.99)	Ref	2.58 (1.94-3.43)	7.66 (4.93-11.91)	7.48 (4.34-12.88)	Ref
IMD quintile of deprivation								
Q5 (least)	–	–	–	–	–	–	–	–
Q4	1.14 (0.88-1.46)	2.59 (1.66-4.03)	1.29 (0.82-2.04)	Ref	1.01 (0.75-1.37)	2.76 (1.41-5.42)	0.82 (0.44-1.55)	Ref
Q3	1.39 (1.10-1.76)	3.44 (2.26-5.23)	1.76 (1.16-2.67)	Ref	1.10 (0.83-1.46)	2.99 (1.57-5.69)	0.90 (0.51-1.59)	Ref
Q2	1.80 (1.45-2,24)	5.27 (3.54-7.85)	3.18 (2.18-4.61)	Ref	1.39 (1.06-1.83)	3.25 (1.73-6.09)	1.25 (0.74-2.12)	Ref
Q1 (Most)	2.29 (1.87-2.83)	14.62 (10.01-21.36)	5.23 (3.66-7.47)	Ref	1.53 (1.16-2.01)	4.44 (2.39-8.25)	1.72 (1.03-2.86)	Ref
Maternal mental health at baseline								
No psychological distress	–	–		–	–	–	–	–
Mod/high psychological distress	2.42 (2.11-2.77)	1.90 (1.59-2.27)	3.70 (3.02-4.55)		2.22 (1.88-2.61)	1.50 (1.81-1.90)	2.99 (2.25-3.98)	
School environment								
Bullied (age 7)								
Never	–	–	–	–	–	–	–	–
Sometimes	1.34 (1.16-1.54)	1.23 (1.04-1.44)	1.79 (1.42-2.27)	Ref	1.36 (1.15-1.62)	1.20 (0.93-1.55)	1.65 (1.21-2.27)	Ref
All the time	2.97 (2.41-3.66)	2.87 (2.28-3.63)	5.99 (4.53-7.95)	Ref	2.35 (1.82-3.04)	2.25 (1.58-3.20)	3.78 (2.56-5.58)	Ref
Enjoys school (age 7)								
A lot	–	–	–	–	–	–	–	–
A bit	1.01 (0.86-1.17)	0.69 (0.58-0.83)	0.88 (0.68-1.12)	Ref	1.15 (0.96-1.39)	0.67 (0.50-0.89)	0.96 (0.69-1.34)	Ref
Don't enjoy	1.62 (1.36-1.94)	1.02 (0.82-1.26)	2.11 (1.65-2.71)	Ref	1.36 (1.09-1.70)	1.23 (0.91-1.69)	1.40 (0.98-2.01)	Ref
Parental involvement with school (age 7)								
Involved	–	–	–	–	–	–	–	–
Not involved	1.63 (1.44-1.86)	2.90 (2.50-3.37)	2.53 (2.09-3.06)	Ref	1.33 (1.12-1.56)	1.46 (1.14-1.86)	1.63 (1.22-2.18)	Ref
Parenting								
Reads to child (age 5)								
Every day	–	–	–	–	–	–	–	–
Several/week	1.14 (0.98-1.32)	1.28 (1.09-1.50)	1.09 (0.87-1.37)	Ref	1.11 (0.93-1.33)	1.27 (0.97-1.66)	1.22 (0.88-1.70)	Ref
Less than several/week	1.68 (1.38-2.04)	2.83 (2.33-3.42)	2.54 (1.96-3.29)	Ref	1.25 (0.97-1.63)	1.66 (1.18-2.33)	1.65 (1.11-2.45)	Ref
Visits library (age 5)								
Regularly	–	–	–	–	–	–	–	–
Not regularly	1.13 (0.99-1.29)	1.68 (1.44-1.96)	1.95 (1.57-2.41)	Ref	0.92 (0.77-1.09)	1.47 (1.12-1.93)	1.40 (1.01-1.95)	Ref
Plays games with child (age 5)								
Regularly	–	–	–	–	–	–	–	–
Not regularly	1.23 (1.05-1.47)	2.13 (1.81-2.50)	1.79 (1.44-2.24)	Ref	1.04 (0.83-1.31)	0.98 (0.72-1.34)	1.22 (0.85-1.74)	Ref

IMD, index of multiple deprivation; *VIF*, variance inflation factor.
Model details: Bayesian information criteria 8943.63, Akaike information criterion: 8322.76, and VIF: 1.2.
Variables in italics indicate reference values.

Although maternal mental health was a risk factor, it was lower than for the other 2 adverse development groups. All non-White ethnicities, all quintiles of deprivation (compared with the least-deprived quintile), parenting factors such as being read to less than several times a week (compared with every day), and not regularly visiting the library with the child increased the risk of being in this group. For the "persistent problems" group, additional to the common risk factors were school factors such as any frequency of bullying and not enjoying school, and parenting factors such as reduced frequency of reading with child and not visiting library with child.

Analysis Part III: Logistic Regression

Association between Development Trajectories (Exposure) and Child Health Outcomes. Results for the associations between the development groups and weight and mental health outcomes at age 14 and 17 years are shown in Table III. All of the adverse development groups were associated with overweight or obesity at age 14 and 17 years, compared with the "no problems" group, in the crude model (Model 1). The associations remain (slightly attenuated) in the adjusted model (Model 2) apart from the "early cognitive and socioemotional problems" group, thereby leaving 15% of the study sample (the "late socioemotional behavior problems" and "persistent problems" group) with increased odds of overweight or obesity. For both groups, the odds increased from age 14 to 17 years. For example, in the late-onset trajectory group the odds (aOR) of overweight or obesity at age 14 were 1.50 (1.24-1.81) and increased to 1.62 (1.32-2.00) by age 17 years. For the "persistent problems" group, the ORs were 1.41 (1.04-1.91) and increased to 1.51 (1.07-2.14) by age 17 years.

In relation to mental ill health outcomes, we observed similar patterns with the "late socioemotional behavior problems" and "persistent problem" groups having increased odds of mental ill-health at ages 14 and 17 years, but not the "early cognitive and socioemotional problems" group. The late and persistent problems group had over twice the odds of mental ill health in adolescence compared with the "no problems" group. Unlike weight, the odds of the association reduced slightly from age 14 to 17 years for both groups.

Discussion

Using the MCS, a large nationally representative UK cohort, we showed that it is possible to identify characteristic trajectories of children's socioemotional and cognitive development concurrently, which is a novel contribution to this field. One in 4 children (23.5%) were in an adverse development trajectory, with problems in either or both aspects of development during childhood. These trajectories were "late socioemotional problems," "early cognitive and socioemotional problems," and "persistent cognitive and socioemotional problems." The common risk factors for the adverse trajectories were socioeconomic (maternal education, maternal mental health and the most deprived quintile of deprivation), demographic (male sex), and school factors (bullying and low parental involvement). Compared with those with no problems, the late and persistent problems trajectories had increased odds of overweight or obesity and mental ill health at age 14 and 17 years, whereas those with early problems did not.

Socioemotional development during childhood appears to be the main driver of adolescent health rather than cognitive development, as indicated by our finding that the trajectory groups with increased odds of overweight and mental ill health in adolescence were those with socioemotional behavior problems with or without cognitive problems. This is coherent with, and builds upon, other research that highlights that socioemotional development in early childhood is strongly associated with adolescent health whereas cognitive development has weaker associations.[7] We showed that the persistence of or emergence of socioemotional problems during childhood, even in the absence of any cognitive problems, has an adverse impact on adolescent health. Additional research is needed to further identify the interactions between these aspects of development over time. The possibility that socioemotional behavior and cognitive development interact over time to affect health, akin to the evidence for their effect on attainment,[14,15] is not fully supported by the analysis. Further research would help to ascertain how one aspect of development affects or informs the other, the main direction of effect, and the impact that has on health.

Table III. Associations of predicted multidevelopment trajectory groups and child health outcomes at age 14 and 17 years in the UK Millennium Cohort Study

ORs	Model*	No problems	Late SEB problems	Early COG and SEB problems	Persistent COG and SEB problems
Age 14 y Overweight or obese	1	Ref	1.56 (1.30-1.87)	1.38 (1.12-1.70)	1.63 (1.27-2.09)
	2	Ref	1.50 (1.24-1.81)	0.92 (0.67-1.27)	1.41 (1.04-1.91)
Age 17 y Overweight or obese	1	Ref	1.64 (1.36-1.97)	1.36 (1.10-1.69)	1.41 (1.05-1.88)
	2	Ref	1.62 (1.32-2.00)	0.94 (0.67-1.32)	1.51 (1.07-2.14)
Age 14 y: Mental ill health	1	Ref	2.28 (1.89-2.74)	0.55 (0.41-0.75)	2.33 (1.74-3.11)
	2	Ref	2.51 (2.03-3.10)	0.89 (0.58-1.35)	3.01 (2.10-3.30)
Age 17 y: Mental ill health	1	Ref	2.03 (1.63-2.52)	0.92 (0.70-1.19)	1.82 (1.32-2.51)
	2	Ref	2.13 (1.62-2.80)	1.17 (0.78-1.78)	2.24 (1.55-3.23)

*Model 1: Crude model; model 2: adjusted for confounders (child sex, child ethnicity, Maternal Mental Health, and maternal education).

The trajectories of development that we identified showed that the timing of emergence or resolution of developmental problems has implications for health in adolescence. The early problems trajectory (8.6%), in which socioemotional problems resolved and cognitive problems reduced by age seven, was not associated with adverse health outcomes. This concurs with other research around the importance of acting early to optimize development.[31] It suggests that enhanced support to children who start school (perhaps identifiable as not "school ready"), to improve their socioemotional and cognitive development, may be beneficial for their weight and mental health in adolescence. The group of children who develop socio-emotional behavior problems in later childhood with no coemergence of cognitive problems is an important group to monitor because of their increased risk of becoming overweight and of mental ill health.

For the trajectory groups associated with adverse health, the strength of the relationship between trajectory of development and weight increased from age 14 to 17 years. However, for mental health, the strength of the relationship reduced. This suggests that weight problems are rooted in childhood and mental ill health might be more amenable to interventions in adolescence. This may reflect the strong relationship between weight and regulation behaviors (as captured in socioemotional behaviors)[32] with unresolved regulation problems in childhood (which may stem from the familial and wider environments) having lasting effects on weight.[33] By contrast, mental ill health may be affected by more external factors throughout adolescence.[34] This finding could have important implications for the timing of interventions and warrants further research to integrate developmental trajectories into the multitude of risk factors for overweight and mental ill health throughout childhood and adolescence.

The adverse development trajectories were socioeconomically patterned in relation to neighborhood deprivation, maternal education, and maternal mental health. This concurs with much research on the negative impact of adverse socioeconomic circumstances on child health and development.[11] Specifically, minority ethnicity (particularly Bangladeshi and Pakistani children) and/or living in more deprived areas were predictive of early development problems which could implicate the role of socioeconomic conditions and disadvantages experienced by particular children and their families.[35] School and parental factors were less strongly associated with the adverse trajectories and which may be because the measures used were simply markers of school and parental factors during the trajectory period. Nonetheless, our findings suggest that school environments that tackle bullying, involve parents, and increase the enjoyment of pupils may help to limit the development of socioemotional behavior problems in late childhood. For those with "persistent problems," our findings build on the evidence that school factors together with parenting factors (such as encouraging reading with children) are beneficial for optimizing development.[36]

Earlier, we highlighted the crisis in adolescent health and the lack of policy to address it. Drawing on the current research, we suggest there is value in developing child and adolescent health policies that continue beyond the early years. Policies that are focused and realistic about what individual child/family/school interventions can achieve against the backdrop of adverse socioeconomic conditions driving adolescent health inequality. Policy that builds upon and extends "best start" is needed, as children continue to develop as they age and their trajectory of development matters for later health. Policy to improve adolescent health should prioritize supporting children's socioemotional development. This raises questions for the education sector in terms of further focusing on and resourcing this aspect of development. It also raises questions for the health sector in terms of prevention efforts and identifies a clear area of focus for collaboration with the education sector to improve adolescent health. Policy needs to be targeted and informed by trajectories of development. We suggest that who to target and how to intervene are different in those with early development problems as opposed to those with development problems in later childhood. For example, minority ethnicity and neighborhood deprivation appear to be important targets in the early years whereas a continued focus on socioeconomic factors such as maternal mental health and maternal education is required throughout the school years. Policy needs to place a strong emphasis on socioeconomic factors which drive adverse development and subsequent health. The effectiveness of parental and school interventions may be limited without much broader structural interventions to improve the socioeconomic context of the child and family.

The strengths and limitations of our study highlight further areas for research. Although many studies have analyzed socioemotional and cognitive development trajectories separately,[8,9,37] ours is the first to analyze these aspects of development concurrently. These trajectories can now be tested in further analyses of other population-based cohorts and perhaps using alternate measures of socioemotional or cognitive development to see if the same trajectories are found. As with any observational study we cannot determine causality of the relationships between risk factors, development trajectory and health as we could not control for unknown confounders. More causally informed analyses are needed to better understand these relationships. Our results are strengthened as we used the most contemporary UK cohort and as such the findings are generalizable to UK policy. The modeling technique allowed for complex longitudinal data to be summarized by grouping individuals together. Although reducing data to groups introduces bias, as the groups will not be completely homogenous, this type of modeling enables us to improve our understanding of groups of people over time.[27] Our model adequacy results provide

reassurance of the model in classifying group membership with a high degree of confidence.

Although we used validated measures where possible, the measures used to measure bullying, enjoying school, and parental involvement with school are not empirically validated measures. Measures of bullying and enjoyment of school rely on children's perceptions of these concepts rather than any formal definitions. However, they are used in a multitude of MCS published research articles. Parental involvement with school is a unique measure derived for this research and as such would need to be further tested. As these measures are self-report, there is a possibility of bias impacting the results. A further limitation was in relation to the measurement of cognitive problems whereby different tests of cognitive ability were used at different ages as determined by the dataset. However, the derived cognitive development trajectories reassure us that the trends we found are as expected.[12]

In summary, in a representative UK cohort, we identified groups of distinct trajectories of cognitive and socioemotional development. Trajectories of persistent cognitive and socioemotional problems and late-onset socioemotional problems were strongly associated with overweight and mental ill-health in adolescence, with socioemotional development an important driver of adverse health. Policies to improve adolescent health should emphasize socioemotional development and account for the mix of factors that drive early, late onset, and persistent developmental problems during childhood.

Ethics Approval and Consent to Participate

Ethical approval for the Millennium Cohort Study was sought from a UK National Health Service research ethics committee before each survey.[38] Written consent was obtained from all participating parents at each survey; MCS1: South West MREC (MREC/01/6/19); MCS2 and MCS3: London MREC (MREC/03/2/022, 05/MRE02/46); MCS4: Yorkshire MREC (07/MRE03/32); MCS5: Yorkshire and The Humber-Leeds East (11/YH/0203); MCS6: London MREC (13/LO/1786), MCS7: REC North East–York (REC ref: 17/NE/0341). This study does not require additional ethical approval. ■

Declaration of Competing Interest

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Credit Author Statement

MB: Conceptualization, Methodology and Writing-Original Draft. All authors supported the conceptualization and methodology. MB (supported by MS, HJ and NA): Formal Analysis, Software, Investigation and Visualisation. NA: Validation. AJ, MS and DTR: Supervision. All authors: Writing-Reviewing and Editing.

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Reprint requests: Michelle Black, PhD, School of Health and Related Research, The University of Sheffield, Regent Court, 30 Regent St, Sheffield, S1 4DA, United Kingdom. E-mail: michelle.black@sheffield.ac.uk

Data Statement

Data sharing statement available at www.jpeds.com.

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