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## Cohort Profile: The Gateshead Millennium Study

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Cohort Profile: The Gateshead Millennium Study

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Key messages

The cohort provides a rich dataset on children’s early eating characteristics, dietary intake, physical activity, and developmental psychopathology.

The study will allow examination of the development of childhood obesity, and the development of preventative strategies.

Word count: 3315 (main body of paper, ie excluding title page, contributor’s list, references and tables)
How did the study come about?

The Gateshead Millennium Baby Study (GMBS) originated from the observation that slower than expected weight gain in infancy, traditionally known as failure to thrive, but more recently as ‘weight faltering’, had never been satisfactorily explained. There were methodological problems associated with much previous research. The first was the use of attained weight criteria to identify slow weight gain in infancy, which confounds poor postnatal weight gain with poor prenatal weight gain. The second was the use of referred samples of children, leading to selection biases. The third was the use of retrospective accounts from parents after poor weight gain had already been identified. The GMBS was thus originally designed to investigate the antecedents of weight faltering in a population based prospective study which addressed the main methodological problems of previous research.

What does it cover?

The original GMBS set out to examine infant feeding behaviour and relate it to subsequent weight gain and weight faltering. It also investigated risk factors for iron deficiency in infancy. Relevant maternal characteristics including feeding style, eating attitudes and depression were also examined. More recently the title of the study has been changed to Gateshead Millennium Study (GMS) to reflect the age of the cohort. The study has continued to focus on feeding and growth, with three additional areas of interest emerging.

First, it investigated aspects of developmental psychopathology using measurements principally taken at 5-6 years of age. A recent UK prevalence survey in 5-19 year olds reported that mental health disorders are common, affecting approximately 8%
and that sub-threshold symptoms were even more common. Eating disorders comprise an important social and medical problem developing over late childhood. Accurate figures on the prevalence of eating disorders have not been easy to establish. Those in a recent comprehensive review suggest a prevalence of 0.28% for anorexia nervosa, 1% for bulimia nervosa, 1.5% for night eating syndrome and 2.3% for binge eating disorder. A much higher proportion of young women report less specifically diagnosable problems such as occasional binge eating or self induced vomiting or score high on tests of abnormal eating attitudes. There is also evidence that sub-threshold eating disorders are commonly associated with depression in adolescents, and there is a strong link between restrictive eating and aggression, attempted suicide and substance misuse. Most longitudinal studies of disordered eating have started in the teenage years, but the strongest predictor of later disordered eating in these studies has always been disordered eating at the start of the study. There is some evidence for continuity between earlier feeding problems and later eating disorder symptoms and we are examining this systematically in this study. The GMS also investigated the child’s emotional and behavioural development, and social communication skills. A topic of particular interest has been the development and prevalence of repetitive behaviours, which are key behaviours in autistic spectrum disorder but are also found in typically developing children. These repetitive behaviours can range from repetitive motor mannerisms, intense special interests or hobbies to more unusual sensory interests in the sight, taste, sound, smell or texture of objects or people. The GMS provided an opportunity to investigate prospectively the relationship between various symptoms of psychopathology in typically developing children, and to identify early risk and protective factors for both eating problems and mental health disorders.
The second new area of interest was the high and rising rates of childhood obesity.\textsuperscript{11-13} It was known that body mass index (BMI; weight/height\textsuperscript{2}) tracks through later childhood into adulthood\textsuperscript{14} and that teenage and adult obesity are associated with increased health risks.\textsuperscript{15-18} It was also suggested that low birth weight and subsequent underweight in infancy are related to an increased risk of a number of chronic diseases in adulthood, including obesity.\textsuperscript{19} However, detailed normative data are scarce and little was known about how lean and fat mass vary between individual children and how far early weight gain is associated with early childhood fatness. In addition, risk factors for early adiposity, such as dietary intake, physical activity and sedentary behaviour, needed to be investigated. Finally, there was the potential for intervention to reduce new cases of obesity in childhood. Evidence suggested that family-based interventions offered potential for success in prevention of obesity,\textsuperscript{20} yet little information is available on what the content and approach of interventions should be and which would be acceptable to families. The GMS was able to investigate these issues when the cohort was aged 6-8 years.

The third new area of interest was the mechanisms by which early life exposures may influence health in later life. It has been postulated that nutrition during pregnancy as well as early feeding behaviours may alter mitotically heritable markings on DNA, so called epigenetic markings, which can influence body composition and other phenotypic characteristics in children through altering gene expression.\textsuperscript{21, 22} Epigenetics provide a biologically plausible mechanism to explain developmental programming and this area is currently the focus of much research activity. The GMS
was able to investigate the association between early life exposure and epigenetic patterns in childhood when the cohort was aged 6-8 years.

Who is in the sample?

The GMBS recruited participants shortly after birth in Gateshead, an urban district in north east England. All infants born to mothers resident in Gateshead in 34 pre-specified weeks between June 1999 and May 2000 were eligible. From the 1252 eligible mothers, 1011 mothers joined the study; 116 (12%) were under 20 years of age, 518 (51%) were over 20 and under 30 and 377 (37%) were 30 or over. A total of 1029 infants were recruited (18 sets of twins). Full details of recruitment are reported elsewhere. The current GMS sample consists of any traceable survivor of the original cohort whose family have not asked to be withdrawn.

How often have they been followed up?

The cohort was recruited by study researchers and baseline data were collected in an interview shortly after the baby was born. This was followed up by data collected by midwives at hospital discharge and six days, and by health visitors at ten days and three months. Parents were sent postal questionnaires at 6 weeks, and 4, 8, 12 months. Families were invited to a clinic appointment at 13 months where the child and mother were measured for height and weight. A case-control study of children who failed to thrive had two lunchtime meals directly observed at 13-21 months. There were further parent completed postal questionnaires at 30 months and 5-6 years. A data sweep at age 6-8 years collected information from parents at home visits, and for the first time since 13 months children were assessed directly at school and/or home visits. At the 6-8 year data sweep parents were followed up with qualitative
focus groups and one-to-one interviews. At 8-10 years data were collected data from parents postally, and from children directly at school.

What has been measured?

Descriptions of the data collected are shown in Table 1.

[Insert Table 1 about here]

Throughout infancy and early childhood detailed information was collected using questionnaires completed by the child’s carer, usually the mother. Characteristics assessed included growth, feeding behaviour, temperament, illness and social behaviour in children. Information about parent characteristics including eating attitudes and depression was also collected. The GMBS mothers were given a special edition of the Personal Child Health Record (PCHR) which is issued routinely to all new mothers. The special edition PCHR included extra forms for health staff and parents to record details about the child on the study’s behalf; in particular mothers were asked to get their baby weighed regularly and to transcribe the weights onto the questionnaires they received and send them to the study office. The children and parents were also measured directly at clinics run by study nurses at 13 months. School-entry child height and weight measurements were retrieved from NHS records.

When the children were aged 5-6 years a postal questionnaire collected information about the child’s eating behaviour and maternal approach to feeding their child.

Information was also collected on the child’s social communication skills, repetitive
behaviours and common symptoms related to psychopathology, especially anxiety, emotional and conduct related symptoms.

When the children were aged 6-8 years information collected by parental questionnaire included the child’s eating behaviour, the child’s food and physical activity environment, parental eating characteristics and food intake, and socio-economic status. The children completed questionnaires on their food knowledge and eating behaviour. The child’s dietary intake was observed, and physical activity levels and sedentary behaviour were measured using accelerometry. The children’s and mothers’ anthropometric measurements were taken as well as saliva samples for the purposes of DNA extraction and subsequent epigenetic analysis. After the quantitative data collection had finished, for parents who expressed an interest, views on childhood obesity were sought using focus groups and one-to-one interviews to explore knowledge, perceptions of childhood overweight and potential strategies for intervention.

A data sweep when the children were 8-10 years old took direct measures of children’s habitual physical activity and sedentary behaviour (using accelerometry) and anthropometric measurements. Additionally, questionnaire data were collected from the children on their home environment, sports club activities and eating attitudes, and from parents on the children’s home environment.

**What is attrition like?**

The children have received a birthday card in the mail every year since birth with a letter including a reply slip for parents to return if they no longer wish to participate in
the research. Unless parents have let the study know that they would prefer not to be contacted again, every effort is made to trace, contact and recruit the child for follow-up data sweeps regardless of whether they remain in the area of birth or have relocated. At the start of the 8-10 year data sweep two children were known to have died and the parents of 161 children had asked to leave the study leaving a sample of 866 children eligible to be contacted.

Non-participation for individual data sweeps has been substantial, but different families have participated in different data sweeps and consequently the study has retraced and collected data from 697 families over the last 3 years.

The original sample was comparable to the northern region of England in terms of socio-economic deprivation apart from slight under-representation of the most affluent quintile, assessed using the Townsend deprivation index from the 1991 census (Table 2). Overall, non-participation has been higher in the least affluent families than in the most affluent. Thus only 15% of families were in the most affluent quintile at birth, but 70% of them participated up to 6-8 years; 19% were in the least affluent quintile but only 56% participated at 6-8 years. This means that by 6-8 years the distribution across all the deprivation quintiles was fairly even (Table 2) and the current sample is representative of the north of England. Non-participation patterns according to maternal qualification are similar to the Townsend deprivation index, with non-participation being higher in less educated mothers, particularly for postal data sweeps (Table 2).

[Insert Table 2 about here]
Tracing and tracking of the GMS children is ongoing and they are being flagged with the UK National Health Service Central Register.

**What has it found? Key findings and publications**

*Weight loss, weight gain and feeding in the first year of life*

Postnatal weight loss was less than previous studies have shown. At five days, the mean weight loss was 50g, only just over 1% below birth weight, and 3% of babies were 10% below, none showing any signs of serious illness. One third had already regained their birth weight. More frequent feeding in the first week was related to higher weight gain at 6 weeks of age for breast-feeders, but not for bottle-feeders. Babies who were fed by both breast and bottles were less likely to continue to be fed by breast at 6 weeks of age than those who received only breast milk.

Nearly one quarter of the babies started eating solids before 3 months of age. Characteristics associated with early weaning were fast weight gain to 6 weeks, lower socioeconomic status, parents’ perceptions that their baby was hungry, and being bottle fed. Babies weaned before 3 months, compared with those weaned after 4 months of age, had increased risk of diarrhoea.

Appetite at 6 weeks and 12 months was positively related to weight gain to 12 months, and encouraging a child to eat was associated with poorer weight gain. Children’s appetite appeared to be related to how well or poorly they eat and grow. Mothers’ characteristics such as their eating behaviour, mood, and social characteristics were not strongly associated with children’s weight gain over the first
year. Postnatal depression was associated with slower weight gain and increased rates of weight faltering in the infants up to 4 months, especially if they came from deprived families, but by 12 months they were no different from the remainder of the cohort.  

Data from this cohort as well as the Avon Longitudinal Study of Parents and Children (ALSPAC) have been used to assess how the growth of UK infants compares to newly published WHO standards. Analysis showed that in both cohorts infants were heavier than infants in the WHO growth study from about the age of 6 months but showed very similar linear growth.

**Mealtime energy intake and feeding behaviour**

Video observations were used to identify types of feeding behaviour in children aged 13-21 months. Two meals were observed for each of 30 children who had shown weight faltering in the first year and 57 controls. Energy intake and weight of food eaten were also measured. The children who gained less weight were offered and accepted food at the same rate as children with normal weight gain but had a lower energy intake.

**Diagnosis of borderline iron deficiency**

This therapeutic trial included 462 infants whose parents agreed to have blood taken and were successfully bled during the 13 month assessment. It explored how successful five different blood markers were at identifying iron deficiency, as indicated by a clear response to treatment. Low total and mean cell haemoglobins proved good predictors of a response to treatment, but about half the children who
responded had haemoglobins within the normal range. The three other markers were only associated with a response when two or more were abnormal. Using the above definition 13% of the children tested could be defined as truly iron deficient. These children did not generally show differences in social factors or growth, apart from a moderate association with breast feeding for over 4 months and a greatly increased risk for a small minority of children from ultra orthodox Jewish families. 32

Eating behaviour and repetitive behaviours in toddlers and young children

Eating problems were perceived as common in toddlers and in the majority were associated with normal growth, although weight faltering was more common in such children. Excessive milk-drinking may have been a cause of low appetite at meal times, but was not associated with poor growth. 33

Repetitive behaviours are an essential part of the diagnosis of autism but are also commonly seen in typically developing children. Repetitive behaviours data from this cohort, pooled with data from another local cohort, showed that 2 year old children frequently engage in a range of different types of repetitive behaviours (with boys showing higher scores than girls). These behaviours can be summarised within four subscales: unusual sensory interests; repetitive motor movements; rigidity/adherence to routine; and preoccupations with restricted patterns of interests. These study results support the proposal that repetitive behaviours measured on subscales that closely resemble the repetitive behaviour subtypes within the ICD-10 criteria for autism, represent a continuum of functioning that extends to the typically developing child population. 10 Subsequent analysis of new pooled data looking at the continuity of repetitive behaviours from 2 years to 6 years shows that the predominant repetitive
behaviours change over time and that although the total rates of repetitive behaviours reduce over time, they do not disappear.\textsuperscript{34}

**Surveillance of physical activity in the UK**

Public health surveillance of physical activity in children in the UK has depended on a parent-reported physical activity questionnaire which has not been validated. Physical activity measured objectively using accelerometry in 6-7 year olds showed that levels of habitual physical activity in children are likely to be substantially lower than those reported in UK Health Surveys.\textsuperscript{35}

**Origins and perceptions of childhood adiposity**

Parents’ ability to identify whether their child was overweight was limited when compared to current standards for overweight or obesity. Parents neither used nor trusted current standards of childhood overweight and instead used alternative approaches which heavily relied on extreme cases as a reference point.\textsuperscript{36, 37}

**What are the main strengths and weaknesses?**

Gateshead has a stable population, but even so, maintaining up-to-date contact details and keeping the families involved has been difficult. Direct contact has achieved higher participation than postal contact. For example, 636 families returned postal questionnaires at 12 months whereas 847 attended a clinic run by study nurses at 13 months. Using direct contact for retracing and data collection, the study has managed to maintain a cohort of approximately 700 children.
Gateshead has a higher rate of deprivation than the rest of the northern region of England and this was reflected in the lower proportion of the most affluent families recruited to the study. As is common for community based studies, there has been higher rates of attrition among the most deprived families. However, due to higher retention of the most affluent families compared to the least affluent families, the current sample is socially diverse and representative of the north of England.

The cohort has the benefit of a wealth of data on maternal characteristics and the child’s early eating patterns, developmental psychopathology, dietary intake at 6-8 years, a comprehensive set of body composition measurements, lifestyle behaviours and physical activity at 6-8 and 8-10 years, and DNA samples. It will provide crucial information for investigation of both physical and mental health. Of obvious importance is the examination of the role of fast weight gain in infancy and childhood lifestyle behaviours in the development of later obesity and other chronic disease outcomes in later life. A cohort of this size is only adequately powered to examine variation within the normal range and between major subgroups, but since our current main area of interest, childhood obesity, is now so common, the study is likely to be adequately powered to examine important risk factors.

**Can I get hold of the data? Where can I find out more?**

Most of the data are currently being actively analysed by the existing study team, but we welcome suggestions for collaboration. Potential collaborators should contact Professor Ashley Adamson at the Institute of Health and Society at Newcastle University. The study has a website at http://www.research.ncl.ac.uk/gms/.
Acknowledgements

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Contributor’s list

Dr Kathryn Parkinson contributed to protocol development, and was responsible for co-ordination of the study and writing the manuscript.

Dr Mark Pearce contributed to protocol development and writing the manuscript, and was responsible for the analytical framework and supervision of data analysis.

Dr Anne Dale maintained liaison with Gateshead Children’s Services, and contributed to protocol development and writing the manuscript.

Dr Robert Drewett contributed to protocol development and writing the manuscript.
Dr Paul McArdle contributed to protocol development and writing the manuscript.

Professor Charlotte Wright founded the GMBS cohort and was responsible for
execution of the GMBS study, and contributed to protocol development and writing
the manuscript.

Professor Ann Le Couteur was responsible for execution of the 5-6 year datasweep,
and contributed to protocol development and writing the manuscript.

Dr Caroline Relton was responsible for execution of the epigenetic element of the
study and contributed to the writing the manuscript.

Professor Ashley Adamson had primary responsibility for execution of the GMS
data sweeps, and contributed to protocol development and writing the manuscript.

Conflict of interest

The authors declare no conflict of interest.
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### Table 1. Summary of data collected since birth (n=1029 children)

<table>
<thead>
<tr>
<th>Cohort age</th>
<th>Where</th>
<th>By whom</th>
<th>Number of participants (%)</th>
<th>Data collected</th>
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<tr>
<td>After birth</td>
<td>Hospital/home</td>
<td>Mother</td>
<td>1029 (100%)</td>
<td>Birth weight&lt;br&gt;Milk feeding behaviour&lt;br&gt;Mode of milk feeding&lt;br&gt;Socio-economic status**</td>
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<td>Day 3</td>
<td>Hospital</td>
<td>Midwife</td>
<td>633 (62%)</td>
<td>Feeding ratings**</td>
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<tr>
<td>Day 6</td>
<td>Hospital/home</td>
<td>Midwife</td>
<td>801 (78%)</td>
<td>Feeding ratings**</td>
</tr>
<tr>
<td>Day 10</td>
<td>Home</td>
<td>Health visitor</td>
<td>944 (92%)</td>
<td>Feeding ratings**</td>
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<tr>
<td>6 weeks</td>
<td>Home</td>
<td>Parent</td>
<td>832 (80%)</td>
<td>Milk feeding behaviour&lt;br&gt;Cessation of breast feeding, weaning etc&lt;br&gt;Illness**&lt;br&gt;Infant temperament 40&lt;br&gt;Weights (from Personal Child Health Record (PCHR))</td>
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<tr>
<td>3 months</td>
<td>Home</td>
<td>Health visitor</td>
<td>792 (77%)</td>
<td>Feeding ratings**&lt;br&gt;Maternal depression 41</td>
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<tr>
<td>4 months</td>
<td>Home</td>
<td>Parent</td>
<td>762 (74%)</td>
<td>Milk feeding behaviour&lt;br&gt;Cessation of breast feeding, weaning etc&lt;br&gt;Illness**&lt;br&gt;Accidents**&lt;br&gt;Adverse family life events 42, 43&lt;br&gt;Weights (from PCHR)</td>
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<tr>
<td>8 months</td>
<td>Home</td>
<td>Parent</td>
<td>675 (65%)</td>
<td>Solid feeding behaviour&lt;br&gt;Cessation of breast feeding, weaning etc&lt;br&gt;Illness**&lt;br&gt;Accidents**&lt;br&gt;Infant temperament 40&lt;br&gt;Weights (from PCHR)</td>
</tr>
<tr>
<td>12 months</td>
<td>Home</td>
<td>Parent</td>
<td>636 (61%)</td>
<td>Solid feeding behaviour&lt;br&gt;Cessation of breast feeding&lt;br&gt;General behaviour&lt;br&gt;Illness**&lt;br&gt;Accidents**&lt;br&gt;Maternal eating behaviour 44&lt;br&gt;Maternal childhood 45&lt;br&gt;Weights (from PCHR)</td>
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<td>13 months</td>
<td>Clinic</td>
<td>Study nurse</td>
<td>847 (82%)</td>
<td>Child’s height and weight (measured)&lt;br&gt;Blood for full blood count, ferritin, zinc protoporphyrin&lt;br&gt;Mother’s height and weight (measured)</td>
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<td>30 months</td>
<td>Home</td>
<td>Parent</td>
<td>492 (47%)</td>
<td>General feeding&lt;br&gt;Food preferences 46, 47&lt;br&gt;Drinks**&lt;br&gt;General behaviour&lt;br&gt;Repetitive Behaviour Questionnaire 48, 49&lt;br&gt;Difficulties with child 50&lt;br&gt;Illness**&lt;br&gt;Weights (from PCHR)</td>
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<tr>
<td>4-5 years</td>
<td>School</td>
<td>School nurse</td>
<td>724 (70%)</td>
<td>Child’s height and weight (measured)</td>
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<tr>
<td>5-6 years</td>
<td>Home</td>
<td>Parent</td>
<td>506 (49%)</td>
<td>Child’s height and weight (measured)&lt;br&gt;Child’s appetite, mealtimes, problems&lt;br&gt;General child health and education&lt;br&gt;Mother’s approach to feeding her child 50&lt;br&gt;Child’s eating behaviour 41&lt;br&gt;Repetitive Behaviour Questionnaire 48, 49&lt;br&gt;Common symptoms of psychopathology 52&lt;br&gt;Social communication problems 53&lt;br&gt;Parental employment (self-coded method) 54&lt;br&gt;Socio-economic status**</td>
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<td>6-8 years</td>
<td>Home</td>
<td>Parent</td>
<td>617 (60%)</td>
<td>Child’s eating behaviour **</td>
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<td>Child’s risk factors for eating disorders ***</td>
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<td>Family health status **</td>
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<td></td>
<td>Parental employment (self-coded method) **</td>
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<td></td>
<td>Socio-economic status **</td>
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<tr>
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<td></td>
<td></td>
<td>Parents’ body measurements; height, weight, waist, hip, bioelectrical impedance **</td>
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<td></td>
<td></td>
<td></td>
<td>DNA biomarkers (saliva sample) **</td>
</tr>
<tr>
<td>6-8 years</td>
<td>School</td>
<td>Teacher</td>
<td>576 (56%)</td>
<td>Common symptoms of psychopathology **</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Attitudes and knowledge about food **</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Restrained eating **</td>
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<td></td>
<td>Body image **</td>
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<td></td>
<td>Habitual physical activity (accelerometry) **</td>
</tr>
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<td></td>
<td></td>
<td>Habitual sedentary behaviour (accelerometry) **</td>
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<td></td>
<td></td>
<td>Body measurements; height, weight, waist, skinfolds (biceps, triceps, subcapular and supra-iliac), bone frame (knee, wrist, shoulders, hips and elbow) and bioelectrical impedance **</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DNA biomarkers (saliva sample) **</td>
</tr>
<tr>
<td>6-8 years</td>
<td>Home and school</td>
<td>Parents and observers</td>
<td>486 (47%)</td>
<td>Child’s food intake over 4 days **</td>
</tr>
<tr>
<td>6-8 years</td>
<td>Community premises</td>
<td>Parents and interviewers (Qualitative study)</td>
<td>37 (16)</td>
<td>Parent focus groups on childhood obesity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Parent one-to-one interviews on childhood obesity **</td>
</tr>
<tr>
<td>8-10 years</td>
<td>Home</td>
<td>Parent</td>
<td>495 (48%)</td>
<td>Child’s sedentary opportunities in the home **</td>
</tr>
<tr>
<td>8-10 years</td>
<td>School</td>
<td>Child</td>
<td>590 (57%)</td>
<td>Habitual physical activity (accelerometry) **</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Habitual sedentary behaviour (accelerometry) **</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sports activity and how they feel physically **</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sedentary opportunities in the home **</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Eating patterns ** and appetite **</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Body image **</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Body measurements; height, weight, waist, and bioelectrical impedance **</td>
</tr>
</tbody>
</table>

* Influenced by previous work or developed for the GMS
** Items developed for the GMS
*** Non-validated, based on previous work
† Items relevant to six week infants used
$ Interviewer led
Table 2. Socio-economic characteristics of mothers (based on data collected at birth)

<table>
<thead>
<tr>
<th>Townsend quintile*</th>
<th>Baseline N=1011</th>
<th>12 months N=624</th>
<th>13 month health check N=830</th>
<th>30 months N=482</th>
<th>5-6 years N=495</th>
<th>6-8 years N=605</th>
<th>8-10 years N=576</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>1 (most affluent)</td>
<td>156</td>
<td>15</td>
<td>129</td>
<td>21</td>
<td>137</td>
<td>17</td>
<td>110</td>
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<tr>
<td>2</td>
<td>204</td>
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<td>146</td>
<td>23</td>
<td>178</td>
<td>21</td>
<td>111</td>
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<td>3</td>
<td>227</td>
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<td>140</td>
<td>22</td>
<td>189</td>
<td>23</td>
<td>107</td>
</tr>
<tr>
<td>4</td>
<td>226</td>
<td>22</td>
<td>121</td>
<td>19</td>
<td>177</td>
<td>21</td>
<td>88</td>
</tr>
<tr>
<td>5 (least affluent)</td>
<td>192</td>
<td>19</td>
<td>83</td>
<td>13</td>
<td>143</td>
<td>17</td>
<td>61</td>
</tr>
<tr>
<td>Missing</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>0.1</td>
<td>6</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Qualification</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>A levels or above</td>
<td>243</td>
<td>24</td>
<td>186</td>
<td>30</td>
<td>213</td>
<td>26</td>
<td>150</td>
</tr>
<tr>
<td>GCSEs or equivalent</td>
<td>495</td>
<td>49</td>
<td>325</td>
<td>52</td>
<td>415</td>
<td>50</td>
<td>255</td>
</tr>
<tr>
<td>NVQ's or none</td>
<td>194</td>
<td>19</td>
<td>83</td>
<td>13</td>
<td>144</td>
<td>17</td>
<td>55</td>
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<td>Missing</td>
<td>79</td>
<td>8</td>
<td>30</td>
<td>5</td>
<td>58</td>
<td>7</td>
<td>22</td>
</tr>
</tbody>
</table>

Percentages do not add up to 100 in all cases due to rounding.
* Based on Townsend deprivation index from 1991 census, using enumeration districts as the unit of analysis with the Northern Region of England as the population for comparison for the calculation of the quintiles.
Cohort Profile: The Gateshead Millennium Study

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Key messages


The cohort provides a rich dataset on children’s early eating characteristics, dietary intake, physical activity, and developmental psychopathology.

The study will allow examination of the development of childhood obesity, and the development of preventative strategies.

Word count: 3315 (main body of paper, ie excluding title page, contributor’s list, references and tables)
How did the study come about?

The Gateshead Millennium Baby Study (GMBS) originated from the observation that slower than expected weight gain in infancy, traditionally known as failure to thrive, but more recently as ‘weight faltering’, had never been satisfactorily explained. There were methodological problems associated with much previous research. The first was the use of attained weight criteria to identify slow weight gain in infancy, which confounds poor postnatal weight gain with poor prenatal weight gain. The second was the use of referred samples of children, leading to selection biases. The third was the use of retrospective accounts from parents after poor weight gain had already been identified. The GMBS was thus originally designed to investigate the antecedents of weight faltering in a population based prospective study which addressed the main methodological problems of previous research.

What does it cover?

The original GMBS set out to examine infant feeding behaviour and relate it to subsequent weight gain and weight faltering. It also investigated risk factors for iron deficiency in infancy. Relevant maternal characteristics including feeding style, eating attitudes and depression were also examined. More recently the title of the study has been changed to Gateshead Millennium Study (GMS) to reflect the age of the cohort. The study has continued to focus on feeding and growth, with three additional areas of interest emerging.

First, it investigated aspects of developmental psychopathology using measurements principally taken at 5-6 years of age. A recent UK prevalence survey in 5-19 year olds reported that mental health disorders are common, affecting approximately 8%
and that sub-threshold symptoms were even more common. Eating disorders comprise an important social and medical problem developing over late childhood.

Accurate figures on the prevalence of eating disorders have not been easy to establish. Those in a recent comprehensive review suggest a prevalence of 0.28% for anorexia nervosa, 1% for bulimia nervosa, 1.5% for night eating syndrome and 2.3% for binge eating disorder. A much higher proportion of young women report less specifically diagnosable problems such as occasional binge eating or self-induced vomiting or score high on tests of abnormal eating attitudes. There is also evidence that sub-threshold eating disorders are commonly associated with depression in adolescents, and there is a strong link between restrictive eating and aggression, attempted suicide and substance misuse. Most longitudinal studies of disordered eating have started in the teenage years, but the strongest predictor of later disordered eating in these studies has always been disordered eating at the start of the study. There is some evidence for continuity between earlier feeding problems and later eating disorder symptoms and we are examining this systematically in this study. The GMS also investigated the child’s emotional and behavioural development, and social communication skills. A topic of particular interest has been the development and prevalence of repetitive behaviours, which are key behaviours in autistic spectrum disorder but are also found in typically developing children. These repetitive behaviours can range from repetitive motor mannerisms, intense special interests or hobbies to more unusual sensory interests in the sight, taste, sound, smell or texture of objects or people. The GMS provided an opportunity to investigate prospectively the relationship between various symptoms of psychopathology in typically developing children, and to identify early risk and protective factors for both eating problems and mental health disorders.

Deleted: it was possible to collect information from parents about the child’s emot
The second new area of interest was the high and rising rates of childhood obesity.

It was known that body mass index (BMI; weight/height$^2$) tracks through later childhood into adulthood$^{14}$ and that teenage and adult obesity are associated with increased health risks.$^{15-18}$ It was also suggested that low birth weight and subsequent underweight in infancy are related to an increased risk of a number of chronic diseases in adulthood, including obesity.$^{19}$ However, detailed normative data are scarce and little was known about how lean and fat mass vary between individual children and how fat early weight gain is associated with early childhood fatness. In addition, risk factors for early adiposity, such as dietary intake, physical activity and sedentary behaviour, needed to be investigated. Finally, there was the potential for intervention to reduce new cases of obesity in childhood. Evidence suggested that family-based interventions offered potential for success in prevention of obesity,$^{20}$ yet little information is available on what the content and approach of interventions should be and which would be acceptable to families. The GMS was able to investigate these issues when the cohort was aged 6-8 years.

The third new area of interest was the mechanisms by which early life exposures may influence health in later life. It has been postulated that nutrition during pregnancy as well as early feeding behaviours may alter mitotically heritable markings on DNA, so called epigenetic markings, which can influence body composition and other phenotypic characteristics in children through altering gene expression.$^{21, 22}$ Epigenetics provide a biologically plausible mechanism to explain developmental programming and this area is currently the focus of much research activity. The GMS
was able to investigate the association between early life exposure and epigenetic patterns in childhood when the cohort was aged 6-8 years.

Who is in the sample?

The GMBS recruited participants shortly after birth in Gateshead, an urban district in north east England. All infants born to mothers resident in Gateshead in 34 pre-specified weeks between June 1999 and May 2000 were eligible. From the 1252 eligible mothers, 1011 mothers joined the study; 116 (12%) were under 20 years of age, 518 (51%) were over 20 and under 30 and 377 (37%) were 30 or over. A total of 1029 infants were recruited (18 sets of twins). Full details of recruitment are reported elsewhere. The current GMS sample consists of any traceable survivor of the original cohort whose family have not asked to be withdrawn.

How often have they been followed up?

The cohort was recruited by study researchers and baseline data were collected in an interview shortly after the baby was born. This was followed up by data collected by midwives at hospital discharge and six days, and by health visitors at ten days and three months. Parents were sent postal questionnaires at 6 weeks, and 4, 8, 12 months. Families were invited to a clinic appointment at 13 months where the child and mother were measured for height and weight. A case-control study of children who failed to thrive had two lunchtime meals directly observed at 13-21 months. There were further parent completed postal questionnaires at 30 months and 5-6 years. A data sweep at age 6-8 years collected information from parents at home visits, and for the first time since 13 months children were assessed directly at school and/or home visits. At the 6-8 year data sweep parents were followed up with qualitative
focus groups and one-to-one interviews. At 8-10 years data were collected data from parents postally, and from children directly at school.

What has been measured?

Descriptions of the data collected are shown in Table 1.

[Insert Table 1 about here]

Throughout infancy and early childhood detailed information was collected using questionnaires completed by the child’s carer, usually the mother. Characteristics assessed included growth, feeding behaviour, temperament, illness and social behaviour in children. Information about parent characteristics including eating attitudes and depression was also collected. The GMBS mothers were given a special edition of the Personal Child Health Record (PCHR) which is issued routinely to all new mothers. The special edition PCHR included extra forms for health staff and parents to record details about the child on the study’s behalf; in particular mothers were asked to get their baby weighed regularly and to transcribe the weights onto the questionnaires they received and send them to the study office. The children and parents were also measured directly at clinics run by study nurses at 13 months. School-entry child height and weight measurements were retrieved from NHS records.

When the children were aged 5-6 years a postal questionnaire collected information about the child’s eating behaviour and maternal approach to feeding their child. Information was also collected on the child’s social communication skills, repetitive
behaviours and common symptoms related to psychopathology, especially anxiety, emotional and conduct related symptoms.

When the children were aged 6-8 years information collected by parental questionnaire included the child’s eating behaviour, the child’s food and physical activity environment, parental eating characteristics and food intake, and socio-economic status. The children completed questionnaires on their food knowledge and eating behaviour. The child’s dietary intake was observed, and physical activity levels and sedentary behaviour were measured using accelerometry. The children’s and mothers’ anthropometric measurements were taken as well as saliva samples for the purposes of DNA extraction and subsequent epigenetic analysis. After the quantitative data collection had finished, for parents who expressed an interest, views on childhood obesity were sought using focus groups and one-to-one interviews to explore knowledge, perceptions of childhood overweight and potential strategies for intervention.

A data sweep when the children were 8-10 years old took direct measures of children’s habitual physical activity and sedentary behaviour (using accelerometry) and anthropometric measurements. Additionally, questionnaire data were collected from the children on their home environment, sports club activities and eating attitudes, and from parents on the children’s home environment.

What is attrition like?

The children have received a birthday card in the mail every year since birth with a letter including a reply slip for parents to return if they no longer wish to participate in
the research. Unless parents have let the study know that they would prefer not to be
contacted again, every effort is made to trace, contact and recruit the child for follow-
up data sweeps regardless of whether they remain in the area of birth or have
relocated. At the start of the 8-10 year data sweep two children were known to have
died and the parents of 161 children had asked to leave the study leaving a sample of
866 children eligible to be contacted.

Non-participation for individual data sweeps has been substantial, but different
families have participated in different data sweeps and consequently the study has
retraced and collected data from 697 families over the last 3 years.

The original sample was comparable to the northern region of England in terms of
socio-economic deprivation apart from slight under-representation of the most
affluent quintile, assessed using the Townsend deprivation index from the 1991
census (Table 2). Overall, non-participation has been higher in the least affluent
families than in the most affluent. Thus only 15% of families were in the most
affluent quintile at birth, but 70% of them participated up to 6-8 years; 19% were in
the least affluent quintile but only 56% participated at 6-8 years. This means that by
6-8 years the distribution across all the deprivation quintiles was fairly even (Table 2)
and the current sample is representative of the north of England. Non-participation
patterns according to maternal qualification are similar to the Townsend deprivation
index, with non-participation being higher in less educated mothers, particularly for
postal data sweeps (Table 2).

[Insert Table 2 about here]
Tracing and tracking of the GMS children is ongoing and they are being flagged with the UK National Health Service Central Register.

What has it found? Key findings and publications

**Weight loss, weight gain and feeding in the first year of life**

Postnatal weight loss was less than previous studies have shown. At five days, the mean weight loss was 50g, only just over 1% below birth weight, and 3% of babies were 10% below, none showing any signs of serious illness. One third had already regained their birth weight. More frequent feeding in the first week was related to higher weight gain at 6 weeks of age for breast-feeders, but not for bottle-feeders. Babies who were fed by both breast and bottles were less likely to continue to be fed by breast at 6 weeks of age than those who received only breast milk.

Nearly one quarter of the babies started eating solids before 3 months of age. Characteristics associated with early weaning were fast weight gain to 6 weeks, lower socioeconomic status, parents’ perceptions that their baby was hungry, and being bottle fed. Babies weaned before 3 months, compared with those weaned after 4 months of age, had increased risk of diarrhoea.

Appetite at 6 weeks and 12 months was positively related to weight gain to 12 months, and encouraging a child to eat was associated with poorer weight gain.

Children’s appetite appeared to be related to how well or poorly they eat and grow. Mothers’ characteristics such as their eating behaviour, mood, and social characteristics were not strongly associated with children’s weight gain over the first
year. Postnatal depression was associated with slower weight gain and increased rates of weight faltering in the infants up to 4 months, especially if they came from deprived families, but by 12 months they were no different from the remainder of the cohort.29

Data from this cohort as well as the Avon Longitudinal Study of Parents and Children (ALSPAC) have been used to assess how the growth of UK infants compares to newly published WHO standards. Analysis showed that in both cohorts infants were heavier than infants in the WHO growth study from about the age of 6 months but showed very similar linear growth.30

**Mealtime energy intake and feeding behaviour**

Video observations were used to identify types of feeding behaviour in children aged 13-21 months. Two meals were observed for each of 30 children who had shown weight faltering in the first year and 57 controls. Energy intake and weight of food eaten were also measured. The children who gained less weight were offered and accepted food at the same rate as children with normal weight gain but had a lower energy intake.31

**Diagnosis of borderline iron deficiency**

This therapeutic trial included 462 infants whose parents agreed to have blood taken and were successfully bled during the 13 month assessment. It explored how successful five different blood markers were at identifying iron deficiency, as indicated by a clear response to treatment. Low total and mean cell haemoglobins proved good predictors of a response to treatment, but about half the children who were also less likely to sit in a high chair throughout the meal.
responded had haemoglobins within the normal range. The three other markers were only associated with a response when two or more were abnormal. Using the above definition 13% of the children tested could be defined as truly iron deficient. These children did not generally show differences in social factors or growth, apart from a moderate association with breast feeding for over 4 months and a greatly increased risk for a small minority of children from ultra orthodox Jewish families.  

**Eating behaviour and repetitive behaviours in toddlers and young children**

Eating problems were perceived as common in toddlers and in the majority were associated with normal growth, although weight faltering was more common in such children. Excessive milk-drinking may have been a cause of low appetite at meal times, but was not associated with poor growth.  

Repetitive behaviours are an essential part of the diagnosis of autism but are also commonly seen in typically developing children. Repetitive behaviours data from this cohort, pooled with data from another local cohort, showed that 2 year old children frequently engage in a range of different types of repetitive behaviours (with boys showing higher scores than girls). These behaviours can be summarised within four subscales: unusual sensory interests; repetitive motor movements; rigidity/adherence to routine; and preoccupations with restricted patterns of interests. These study results support the proposal that repetitive behaviours measured on subscales that closely resemble the repetitive behaviour subtypes within the ICD-10 criteria for autism, represent a continuum of functioning that extends to the typically developing child population.  

Subsequent analysis of new pooled data looking at the continuity of repetitive behaviours from 2 years to 6 years shows that the predominant repetitive
behaviours change over time and that although the total rates of repetitive behaviours reduce over time, they do not disappear.\textsuperscript{34}

\textbf{Surveillance of physical activity in the UK}

Public health surveillance of physical activity in children in the UK has depended on a parent-reported physical activity questionnaire which has not been validated. Physical activity measured objectively using accelerometry in 6-7 year olds showed that levels of habitual physical activity in children are likely to be substantially lower than those reported in UK Health Surveys.\textsuperscript{35}

\textbf{Origins and perceptions of childhood adiposity}

Parents’ ability to identify whether their child was overweight was limited when compared to current standards for overweight or obesity. Parents neither used nor trusted current standards of childhood overweight and instead used alternative approaches which heavily relied on extreme cases as a reference point.\textsuperscript{36, 37}

\textbf{What are the main strengths and weaknesses?}

Gateshead has a stable population, but even so, maintaining up-to-date contact details and keeping the families involved has been difficult. Direct contact has achieved higher participation than postal contact. For example, 636 families returned postal questionnaires at 12 months whereas 847 attended a clinic run by study nurses at 13 months. Using direct contact for retracing and data collection, the study has managed to maintain a cohort of approximately 700 children.
Gateshead has a higher rate of deprivation than the rest of the northern region of England and this was reflected in the lower proportion of the most affluent families recruited to the study. As is common for community based studies, there has been higher rates of attrition among the most deprived families. However, due to higher retention of the most affluent families compared to the least affluent families, the current sample is socially diverse and representative of the north of England.

The cohort has the benefit of a wealth of data on maternal characteristics and the child’s early eating patterns, developmental psychopathology, dietary intake at 6-8 years, a comprehensive set of body composition measurements, lifestyle behaviours and physical activity at 6-8 and 8-10 years, and DNA samples. It will provide crucial information for investigation of both physical and mental health. Of obvious importance is the examination of the role of fast weight gain in infancy and childhood lifestyle behaviours in the development of later obesity and other chronic disease outcomes in later life. A cohort of this size is only adequately powered to examine variation within the normal range and between major subgroups, but since our current main area of interest, childhood obesity, is now so common, the study is likely to be adequately powered to examine important risk factors.

Can I get hold of the data? Where can I find out more?

Most of the data are currently being actively analysed by the existing study team, but we welcome suggestions for collaboration. Potential collaborators should contact Professor Ashley Adamson at the Institute of Health and Society at Newcastle University. The study has a website at http://www.research.ncl.ac.uk/gms/.

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Acknowledgements

The cohort was first established with funding from the Henry Smith Charity and Sport Aiding Research in Kids (SPARKS) and followed up with grants from Gateshead NHS Trust R&D, Northern and Yorkshire NHS R&D, Northumberland, Tyne and Wear NHS Trust, the National Prevention Research Initiative (incorporating funding from British Heart Foundation; Cancer Research UK; Department of Health; Diabetes UK; Economic and Social Research Council; Food Standards Agency; Medical Research Council; Research and Development Office for the Northern Ireland Health and Social Services; Chief Scientist Office, Scottish Government Health Directorates; Welsh Assembly Government and World Cancer Research Fund), the Children’s Foundation and the Scottish Government Health Directorates Chief Scientist Office.

We acknowledge the support of an External Reference Group in conducting the study. We appreciate the support of Gateshead Health NHS Foundation Trust, Gateshead Education Authority and local schools. We warmly thank the research team for their effort. Thanks are especially due to the Gateshead Millennium Study families and children for their participation in the study.

Contributor’s list

Dr Kathryn Parkinson contributed to protocol development, and was responsible for co-ordination of the study and writing the manuscript.

Dr Mark Pearce contributed to protocol development and writing the manuscript, and was responsible for the analytical framework and supervision of data analysis.

Dr Anne Dale maintained liaison with Gateshead Children’s Services, and contributed to protocol development and writing the manuscript.

Dr Robert Drewett contributed to protocol development and writing the manuscript.
Dr Paul McArdle contributed to protocol development and writing the manuscript. Professor Charlotte Wright founded the GMBS cohort and was responsible for execution of the GMBS study, and contributed to protocol development and writing the manuscript. Professor Ann Le Couteur was responsible for execution of the 5-6 year datasweep, and contributed to protocol development and writing the manuscript. Dr Caroline Relton was responsible for execution of the epigenetic element of the study and contributed to the writing the manuscript. Professor Ashley Adamson had primary responsibility for execution of the GMS datasweeps, and contributed to protocol development and writing the manuscript.

Conflict of interest

The authors declare no conflict of interest.
References


| Table 1. Summary of data collected since birth (n=1029 children) |
|---|---|---|---|
| **Cohort age** | **Where** | **By whom** | **Number of participants (%)** | **Data collected** |
| After birth | Hospital/home | Mother | 1029 (100%) | Birth weight, Milk feeding behaviour, Mode of milk feeding, Socio-economic status |
| Day 3 | Hospital | Midwife | 633 (62%) | Feeding ratings ** |
| Day 6 | Hospital/home | Midwife | 801 (78%) | Feeding ratings ** |
| Day 10 | Home | Health visitor | 944 (92%) | Feeding ratings ** |
| 6 weeks | Home | Parent | 832 (80%) | Milk feeding behaviour, Cessation of breast feeding, weaning etc **, Illness **, Infant temperament **, Weights (from Personal Child Health Record (PCHR)) |
| 3 months | Home | Health visitor | 792 (77%) | Feeding ratings **, Maternal depression ** |
| 4 months | Home | Parent | 762 (74%) | Milk feeding behaviour, Cessation of breast feeding, weaning etc **, Illness **, Accidents **, Weights (from PCHR) |
| 8 months | Home | Parent | 675 (65%) | Solid feeding behaviour, Cessation of breast feeding, weaning etc **, Illness **, Accidents, Weights (from PCHR) |
| 12 months | Home | Parent | 636 (61%) | Solid feeding behaviour, Cessation of breast feeding, Illness **, Accidents **, Maternal eating behaviour, Maternal childhood =, Weights (from PCHR) |
| 13 months | Clinic | Study nurse | 847 (82%) | Child's height and weight (measured), Blood for full blood count, ferritin, zinc protoporphyrin, Mother's height and weight (measured) |
| 4-5 years | School | School nurse | 724 (70%) | Child's height and weight (measured), Child's appetite, mealtimes, problems, General child health and education **, Mother’s approach to feeding her child, Child's eating behaviour **, Repetitive Behaviour Questionnaire **, Common symptoms of psychopathology, Social communication problems **, Parental employment (self-coded method) **, Socio-economic status ** |
| 5-6 years | Home | Parent | 506 (49%) | Child's height and weight (measured), Mother's height and weight (measured), Child’s appetite, mealtimes, problems, General child health and education **, Mother’s approach to feeding her child, Child's eating behaviour **, Repetitive Behaviour Questionnaire **, Common symptoms of psychopathology, Social communication problems **, Parental employment (self-coded method) **, Socio-economic status ** |

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<tbody>
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<td>6-8 years</td>
<td>Home</td>
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<td>Parental attitude and knowledge about food</td>
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<td>Parents’ body measurements: height, weight, waist, hip, bone frame (knee, wrist, shoulders, hips and elbow) and bioelectrical impedance</td>
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<td>DNA biomarkers (saliva sample)</td>
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<tr>
<td>6-8 years</td>
<td>School</td>
<td>Teacher</td>
<td>576 (56%)</td>
<td>Common symptoms of psychopathology</td>
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<tr>
<td>6-8 years</td>
<td>School</td>
<td>Child</td>
<td>619 (60%)</td>
<td>Attitudes and knowledge about food</td>
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<td>Habitual physical activity (accelerometry)</td>
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<td>Habitual sedentary behaviour (accelerometry)</td>
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<tr>
<td>6-8 years</td>
<td>Home</td>
<td>Parents and observers</td>
<td>486 (42%)</td>
<td>Child’s food intake over 4 days</td>
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<tr>
<td>6-8 years</td>
<td>Community premises</td>
<td>Parents and interviewers (Qualitative study)</td>
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<td>Parent focus groups on childhood obesity</td>
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<td>Parent one-to-one interviews on childhood obesity</td>
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<td>8-10 years</td>
<td>Home</td>
<td>Parent</td>
<td>495 (43%)</td>
<td>Child’s sedentary opportunities in the home</td>
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<tr>
<td>8-10 years</td>
<td>School</td>
<td>Child</td>
<td>543 (53%)</td>
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Table 2. Socio-economic characteristics of mothers (based on data collected at birth)

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<thead>
<tr>
<th>Townsend quintile*</th>
<th>Baseline N=1011</th>
<th>12 months N=624</th>
<th>13 month health check N=830</th>
<th>30 months N=482</th>
<th>5-6 years N=495</th>
<th>6-8 years N=605</th>
<th>8-10 years N=576</th>
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Qualification

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Percentages do not add up to 100 in all cases due to rounding.

* Based on Townsend deprivation index from 1991 census, using enumeration districts as the unit of analysis with the Northern Region of England as the population for comparison for the calculation of the quintiles.
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<thead>
<tr>
<th>Townsend quintile*</th>
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| Totals            | 10    | 10    | 9     | 9     | 61     | 100    |        |        |        |        |        |        |
|                   | 29    | 0     | 9     | 0     | 0      |        |        |        |        |        |        |        |