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Title: Prevalence of Severe Childhood Obesity in England: 2006-2013.

Running Title: Prevalence of Severe Childhood Obesity in England

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Abstract:

Background: International evidence shows that severe paediatric obesity results in an increased risk of ill health, and may require specialised weight management strategies, yet there remains a lack of data on the extent of the problem.

Objective: To examine the prevalence of severe obesity in children aged 4-5 and 10-11 years, attending English schools between 2006/07 and 2012/13.

Design: A retrospective analysis of National Child Measurement Programme (NCMP) data.

Setting: Maintained schools in England.

Participants: All children aged 4-5 and 10-11 years included in the NCMP dataset.

Main outcome measures: Prevalence of severe childhood obesity, defined using the 99.6th centile of the UK90 growth reference for BMI, analysed by sex; geography; ethnic group; and deprivation.

Results: The key findings show that in 2012/13, severe obesity (BMI \geq UK90 99.6th centile) was found in 1.9% of girls and 2.3% of boys aged 4-5 years, and 2.9% of girls and 3.9% of boys aged 10-11 years. Severe obesity prevalence varies geographically and is more prevalent in children from deprived areas, and among those from Black ethnic groups.

Conclusions: The findings from this study should help to raise awareness of the prevalence of severe obesity and support the provision of adequate treatment and prevention services both to support children who are already severely obese, and reduce the prevalence of extreme weight in the future.

Key Words: severe obesity, child, prevalence, England

Introduction:

In children the relation between body mass index (BMI) and adiposity varies with age and sex, so BMI thresholds are usually defined in terms of specific centiles on a growth reference. There is, however, currently no universal definition of severe paediatric obesity. In England the British 1990 (UK90) growth charts for BMI are frequently used to define paediatric weight status according to age and sex, with the highest centile shown on the charts being the 99.6th [1]. The International Obesity Task Force (IOTF) has recently published a definition for 'morbid obesity' in children, which they define as corresponding to a BMI value of 35kg/m² at age 18 [2]. In the United States (US), an expert committee proposed a classification of severe childhood obesity in 2007 as a BMI greater than or equal to the 99th centile of the Centers for Disease Control (CDC) growth reference [3]. This classification has subsequently been challenged and a new classification of BMI greater than or equal to 120% of the 95% centile proposed [4-6]. Using the new definition, analysis of the US National Health and Nutrition Examination Survey (NHANES) 1999-2012 identified an upward trend in the rates of severe obesity over time, with the latest 2011-2012 data showing a prevalence of 5.9% in children aged 2-19 years [7]. This study also demonstrated that severe obesity prevalence was highest amongst older children, and those from Hispanic and non-Hispanic Black populations. These data complement an earlier study which also reported an association between severe obesity and the development of hypertension [8]. Further US studies show that severe obesity is associated both with increased paediatric cardiovascular risk factors, and risk of severe obesity in adulthood [9][10]. These studies complement similar findings from a Dutch paediatric surveillance survey [11], which found that two out of three severely obese children (defined using the Dutch age and sex specific cut points corresponding to an adult BMI of 35 or more) have cardiovascular risk factors.

A 2013 scientific statement from the American Heart Association [6] highlighted the associated immediate and long term cardiovascular, metabolic and other health consequences (obstructive sleep

apnoea, non alcoholic fatty liver disease, muscular-skeletal and psychological problems) of severe paediatric obesity, suggesting the need for specialised treatment services. As these children may require a range of interventions, accurate prevalence data are essential to inform the appropriate planning, delivery and commissioning of such services. These data are also valuable for international comparisons. This paper builds on analyses conducted for the recent Chief Medical Officer's report [12], and provides the first detailed description of the prevalence of severe obesity in children in England.

Methods:

Objective

To examine the prevalence and trends for severe obesity in children aged 4-5 and 10-11 years, attending English schools between 2006/07 and 2012/13.

Study design

A retrospective analysis of the National Child Measurement Programme (NCMP) was performed for school years 2006/07-2012/13. The NCMP data were analysed in Microsoft Access, Excel and R, with 95% confidence intervals (CI) for the prevalence estimates calculated using the Newcombe method [13]. When analysing severe obesity prevalence within ethnic groups and at Local Authority (LA) level, the last three years of data were combined for the LA analysis, and the last four years combined for the ethnic group analysis, to avoid any small number disclosure and improve statistical strength.

Binary logistic regression was used to assess the relation between NCMP year of measurement and Index of Multiple Deprivation (IMD)¹ decile, and the probability of being severely obese. Four separate models were produced, one for each of the school year and sex combinations. The Generalised Linear

¹ <https://www.gov.uk/government/publications/english-indices-of-deprivation-2010>

Models (GLM) function in the statistical software R² was used to fit the models. The models are based on the assumption that the log of the odds of being severely obese is linearly related to the two explanatory variables: year of measurement and IMD decile. IMD decile was considered as a categorical variable. The variables were assessed for significance using the chi-square test. Significance in other data presented was assessed using 95% confidence intervals, with significant differences assumed when intervals did not overlap.

Setting

The NCMP was established in 2006 and annually collects measured height and weight, sex, age, ethnicity and postcode data from all children in Reception (ages 4-5 years) and Year 6 (ages 10-11 years), from every maintained (state funded) school across England. Data collection at privately funded and special needs schools is not mandatory. Because coverage of data collection in these schools is low, data from them have been excluded from this analysis. A full description of the methods for the NCMP has been previously published [14]. The programme is co-ordinated by Public Health England and is used to inform local planning and delivery of children's services, gather population level surveillance data, and increase awareness of weight issues in children.

Participants

Participants are school children in the Reception year (aged 4-5) and year 6 (aged 10-11). The numbers measured in previous years were: n=873,584 in 2006/07 (80% participation); n=972,479 in 2007/08 (88% participation); n=1,003,866 in 2008/09 (90% participation); n=1,026,368 in 2009/10 (91%

² R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>.

participation); n=1,036,608 in 2010/11 (93% participation), n=1,056,780 in 2011/12 (93% participation); n=1,076,824 in 2012/13 (93% participation).³

Main outcome measures

The primary outcome of this study was the prevalence of severe childhood obesity, defined using the 99.6th centile of the UK90 Body Mass Index growth reference charts (this equates to a BMI at age 18 of approximately 31.93 for boys and 32.6 for girls⁴). Prevalence was also analysed by sex; geography; ethnic group; and deprivation (calculated IMD 2010). As commissioners often rely on higher thresholds to define the need for highly specialised service such as bariatric surgery, two further categories for very severe obesity are also presented, based on the 99.87th (which equates to an adult BMI of approximately 34.46 for boys and 35.09 for girls) and 99.98th (which equates to an adult BMI of approximately 39.38 for boys and 39.73 for girls) centiles of the UK90 growth charts. To facilitate international comparisons International Obesity Task Force thresholds [2] were also applied to these data.

Ethical approval for this study was not required as it involved the secondary analysis of routinely collected and anonymised public health data.

Results:

Table 1 presents the first (2006/07) and last available (2012/13) years of prevalence figures for English school children who fell on or above the 99.6th centile of the UK90 growth charts, and met the new IOTF morbid obesity classification.

³ NB due to additional data cleaning these figures may differ slightly from figures previously published by the Health and Social Care Information Centre.

⁴ Analysis utilised LMSgrowth program version 2.77. 2012. Huiqi Pan and Tim Cole. Available as a download from <http://www.healthforallchildren.com>

Severe obesity prevalence classified using the IOTF definition aligns most closely to the prevalence defined using the 99.87th centile of the UK90 reference. For the remainder of this paper, the 99.6th centile of the UK90 reference will be used to define severe obesity. This represents the highest centile line marked on the growth charts, and is thus easily distinguishable by both lay and clinical personnel using the charts with children in the UK.

The latest available measurement year (2012/13), shows a prevalence of severe obesity of 1.9% (95% CI: 1.81 to 1.92%) for girls and 2.3% (95% CI: 2.26 to 2.37%) for boys aged 4-5, and 2.9% (95% CI: 2.82 to 2.95%) for girls and 3.9% (95% CI: 3.86 to 4.01%) for boys aged 10-11. This equates to a total of 12,316 of 4-5 year olds and 16,775 of 10-11 year olds children with severe obesity at the time of measurement in 2012/13. In addition to the differences in severe obesity between age and sex, there is also significant variation by geography (Figure 1). Using combined data from the last three years, the prevalence of severe obesity across English local authorities varies from 0.7 to 4.3% for the younger age group and 0.4 to 7.5% for the older children. Furthermore, there is also significant variation in severe obesity prevalence among ethnic groups (Figure 2). Data from the last four years combined show that the Black ethnic group has higher prevalence than White, Mixed, Asian, Chinese and Other ethnic groups. The highest prevalence levels are seen in 10-11 year old Black Caribbean children, whilst the lowest rates are seen in Chinese girls of both age groups (Table 2).

Prevalence of severe obesity by sex, age group and Index of Multiple Deprivation 2010 decile over time is shown in Figure 3, with the supporting logistic regression analysis shown in Table 3. These results indicate that both year of measurement and deprivation decile are significant predictors of severe obesity. Table 3 shows that after adjustment for IMD decile the odds of being severely obese have on average increased over time for the older girls and boys, by 1.02 times for each additional

year of measurement. In contrast the odds of being severely obese have decreased over time for younger girls and boys, with odds ratios of 0.99 (95% CI 0.99-0.998) and 0.98 (95% CI 0.97-0.98) respectively. The 10-11 year old girls in the most deprived IMD decile have odds of being severely obese which are 4.35 times those in the least deprived reference category (95% CI 4.13-4.58) (Table 3). The difference in severe obesity prevalence between the least deprived and most deprived IMD deciles is less marked for the other age and sex groups (older boys, younger girls and boys), with odds of severe obesity of between 3.17 and 3.64 times those in the least deprived decile. It was not possible to examine yearly trends by ethnic group, as ethnicity reporting was poor in the first few years of the programme and several years of data need to be aggregated to avoid small number disclosure.

Discussion:

This study provides the first detailed analysis of the measured prevalence of severe obesity in school children across England. Severely obese children are at risk of developing a number of serious acute and chronic health problems [6]. These children therefore pose a significant concern in terms of their health and wellbeing, and may require the provision of specialist services.

Nearly 30,000 severely obese ($\geq 99.6^{\text{th}}$ UK90 centile) children in the two primary school year groups were identified in 2012/13. This is an order of magnitude greater than the number of children falling within the very thin category ($< 0.4^{\text{th}}$ UK90 centile) (in 2012/13, 2860 [children aged 4-5: 1311, 0.2% children aged 10-11: 1549, 0.3%] were classified as very thin). Whilst the strength of this study is the large population size and high participation rate, it is worth noting that the presented figures may underestimate the prevalence of severe obesity, for two main reasons: 1) a small number of children with severe obesity may also have other conditions, such as Prader Willi syndrome, that may lead to them attending schools for children with special needs, most of which do not submit measurements

to the NCMP; 2) analysis of previous years' data, and extensive anecdotal evidence, suggest that heavier children are more likely to opt out of the measurement programme, especially in the older age group. This is not possible to quantify accurately, and it is possible that some of the increase noted in severe obesity over time is a consequence of the commensurate rise in response rate.

When compared to data from the US, [7] English school children showed similar severe obesity prevalence patterns, with higher rates in boys, older children and Black ethnic groups. However, the use of different thresholds, reference populations, and age groups in the two countries makes direct comparisons difficult [15]. Wider use of the new IOTF classification could avoid this problem. A higher prevalence in the younger age group is also observed when the very high 99.98th centile cut point is applied. The reasons for this remain unknown, although it might result from elevated opt out rates in very overweight older children, who may be more sensitive to the risks of obesity-related stigma than their younger counterparts. Whilst it would be very interesting to formally assess the impact of opt out, unfortunately the data that would be required for this analysis are not available.

Although in relative terms the prevalence of severe obesity remains low, in absolute terms this represents a very large number of children across the country, many of whom might benefit from top tier service provision. This is a particularly important service consideration when over 4,000 children in just the two school years measured by the NCMP in 2012/13, had a BMI falling on or above the exceptionally high 99.98th centile. Whilst the NCMP only provides data on two year groups, simple extrapolation of these findings to all school age children would suggest that tens of thousands of children may potentially be suffering from severe obesity.

When examining prevalence using the 99.6th centile the observed higher prevalence in boys and older children echoes the raised prevalence of general obesity in these groups: in 2012/13, 20.4% of boys and 17.4% of girls aged 10-11 were classified as obese ($\geq 95^{\text{th}}$ centile of the UK90 reference), compared

to 9.7% of boys and 8.8% of girls aged 4-5 [14]. Severe obesity prevalence patterns also mirror the prevalence patterns for general obesity in the correlation with health inequalities. As reported for general obesity [14], severe obesity prevalence varies significantly by geography, and is highest in the most deprived children and those from Black ethnic groups. Therefore suggesting a need for the development and evaluation of more targeted interventions.

The findings from this study should help to raise awareness of the prevalence of severe obesity and support the provision of adequate treatment and prevention services both to support children who are already severely obese, and reduce the prevalence of extreme weight in the future. However there remain several gaps which would benefit from future research: 1) further investigation of the role of the disproportionate drivers of severe obesity in deprived and ethnic minority groups; 2) linkage to other health outcome data to assess short and long term health impacts; 3) longitudinal analyses tracking individual children over time, to further understanding of the natural history of this condition and identify any potential predictive factors; and 4) exploration of other international data sources using the new IOTF definition of morbid obesity, to support international data comparisons.

What is already known on this topic

- Severe paediatric obesity is associated with a number of serious immediate and long term health problems.
- Prevalence of severe paediatric obesity has increased in the United States over time.
- Data from the United States demonstrate inequalities in the prevalence of severe paediatric obesity, with significant socio demographic variation.

What this study adds

- This is the first detailed analysis of severe paediatric obesity prevalence in English school children.

- 1.9% of girls and 2.3% of boys aged 4-5; and 2.9% of girls and 3.9% of boys aged 10-11 were classified as severely obese (falling on or above the 99.6th centile of the UK90 growth charts) in England in 2012/13.
- In England, prevalence of severe obesity varies significantly across the country and is highest in children living in the most deprived areas, and from Black ethnic groups.

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Competing interests:

None declared.

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Contributorship statement:

This paper was conceived by Ells, Mead, Viner, Kinra, and Rutter. The analyses were carried out by Hancock, Copley and Dinsdale. All authors contributed to the paper design, data interpretation, revisions and final approval for publication. All authors are therefore accountable for the work presented.

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Table 1: Prevalence of severe obesity by international and UK90 proposed definitions. Data source: National Child Measurement Programme 2006/07 and 2012/13

Sex	Boys				Girls			
Age Group	4-5		10-11		4-5		10-11	
	%	n	%	n	%	n	%	n
2006/7								
IOTF morbid obesity (boys 2.93 sds, girls 2.822 sds)	1.7%	3685	0.8%	1737	2.0%	4203	0.9%	1838
≥99.6 th centile UK90 (2.67 sds)	2.7%	5903	3.6%	8107	2.0%	4267	2.5%	5330
≥99.87 th centile UK90 (3 sds)	1.7%	3810	1.3%	3020	1.2%	2487	1.0%	2124
≥99.98 th centile UK90 (3.5 sds)	0.8%	1837	0.1%	312	0.4%	941	0.2%	339
2012/13								
IOTF morbid obesity (boys 2.93 sds, girls 2.822 sds)	1.5%	4400	0.8%	2102	1.8%	5287	1.0%	2503
≥99.6 th centile UK90 (2.67 sds)	2.3%	6956	3.9%	9886	1.9%	5360	2.9%	6889
≥99.87 th centile UK90 (3 sds)	1.5%	4435	1.5%	3729	1.1%	3113	1.2%	2742
≥99.98 th centile UK90 (3.5 sds)	0.7%	2152	0.2%	392	0.4%	1194	0.2%	428

Table 2: Prevalence of severe obesity (≥99.6th centile UK90) by broad ethnic group, school year, and sex (including 95% confidence intervals) Data source: National Child Measurement Programme 2009/10-2012/13 combined

School year	Ethnic group	Prevalence %	n	Prevalence lower 95% CI	Prevalence upper 95% CI
10-11 year olds	Asian	4.38%	7353	4.29%	4.48%
	Black	6.39%	5659	6.23%	6.55%
	Chinese	2.27%	129	1.92%	2.69%
	Mixed	4.47%	2920	4.31%	4.63%
	Other	5.00%	1477	4.76%	5.26%
	White	3.12%	40054	3.09%	3.15%
4-5 year olds	Asian	3.41%	6902	3.33%	3.49%
	Black	4.46%	4778	4.34%	4.58%
	Chinese	2.36%	171	2.04%	2.74%
	Mixed	2.58%	2405	2.48%	2.68%
	Other	3.16%	1092	2.98%	3.35%
	White	1.83%	26439	1.81%	1.86%

Note: ethnic groups were combined as follows:

Asian: Any Other Asian Background; Bangladeshi; Indian; Pakistani.

Black: Any Other Black Background; Black – African; Black – Caribbean.

Chinese: Chinese.

Mixed: Any Other Mixed Background; White and Asian; White and Black African; White and Black Caribbean.

Other: Any Other Ethnic Group.

White: Any Other White Background; White – British; White – Irish.

Table 3. Odds ratios for severe obesity from four logistic regression models for each sex and school year.

Variable	Girls Year 6 Odds Ratio (95% CI)	Boys Year 6 Odds Ratio (95% CI)	Girls Reception Odds Ratio (95% CI)	Boys Reception Odds Ratio (95% CI)
NCMP year of measurement	1.02** (1.02-1.03)	1.02** (1.01-1.02)	0.99** (0.99-0.998)	0.98** (0.97-0.98)
IMD Decile 1 (least deprived)	reference**	reference**	reference**	reference**
2	1.33 (1.25-1.42)	1.24 (1.18-1.30)	1.31 (1.22-1.41)	1.23 (1.16-1.31)
3	1.60 (1.51-1.71)	1.42 (1.35-1.49)	1.52 (1.41-1.63)	1.41 (1.33-1.50)
4	1.91 (1.80-2.04)	1.66 (1.58-1.74)	1.71 (1.59-1.83)	1.55 (1.46-1.64)
5	2.16 (2.04-2.30)	1.95 (1.86-2.04)	1.91 (1.79-2.05)	1.79 (1.69-1.89)
6	2.54 (2.40-2.69)	2.28 (2.18-2.38)	2.26 (2.12-2.41)	2.06 (1.95-2.18)
7	2.97 (2.81-3.15)	2.54 (2.43-2.65)	2.57 (2.41-2.74)	2.34 (2.22-2.47)
8	3.47 (3.28-3.66)	2.92 (2.80-3.04)	2.93 (2.75-3.11)	2.63 (2.50-2.77)
9	4.03 (3.82-4.25)	3.21 (3.08-3.35)	3.36 (3.16-3.57)	2.98 (2.84-3.13)
10 (most deprived)	4.35 (4.13-4.58)	3.53 (3.39-3.68)	3.64 (3.43-3.86)	3.17 (3.02-3.33)

** p<0.01

Figure 1: Prevalence of severe obesity ($\geq 99.6^{\text{th}}$ centile UK90) by English lower tier local authority and school year. Data source: National Child Measurement Programme 2010/11-2012/13 combined

Figure 2: Prevalence of severe obesity ($\geq 99.6^{\text{th}}$ centile UK90) by ethnic group, school year, and sex (including 95% confidence intervals) Data source: National Child Measurement Programme 2009/10-2012/13 combined

Figure 3: Trend in severe obesity ($\geq 99.6^{\text{th}}$ centile UK90) prevalence by school year, sex and deprivation decile (including 95% confidence intervals). Data source: National Child Measurement Programme 2006/07-2012/13