



# Growing up in Scotland: Obesity from early childhood to adolescence

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Medical  
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Commissioned by Obesity Action Scotland



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## Foreword

In Scotland we value children's rights and have been proud to become the first country in the UK to incorporate those rights into legislation. That position comes with responsibility. We must ensure we are doing our best for their health and wellbeing. At the moment we are failing our children when it comes to providing an environment that helps them achieve and maintain a healthy weight.

As a nation we have an ambition to reduce childhood obesity prevalence to 7%. It is currently at 18% and that marks a rise since the ambition itself was announced in 2018. This is not good enough and has unacceptable health consequences.

Since Obesity Action Scotland was set up in 2015 I have always been acutely aware that the data we hold for children only tells us part of the story and that there is still a lot to learn. Whilst we need policy and legislative action to tackle the poor food environment in which we live, we can also use data to understand the challenge and the drivers.

I commissioned this report in the hope that the valuable longitudinal data held within the Growing Up in Scotland cohort would allow us to better understand how children's weight changes throughout childhood. We only have one population wide measurement of all children in Scotland and that is in Primary 1. This study provides us with a unique understanding of whether that is a good predictor of weight in the rest of childhood..... it isn't.

It also gives us the opportunity to look at the relationship with many other factors. The unsurprising but still shocking conclusion is that food insecurity in the early years of childhood impacts on children's weight for the rest of their childhood and makes them 4 times more likely to be living with persistent obesity between age 4 and 14. The damage caused by food insecurity goes way beyond the short term impact that we are all acutely aware of.

I hope that this report will add to the valuable evidence we have on childhood health and will provide an urgent incentive for action. We can turn this around with brave and bold policy action that is outlined in much of Obesity Action Scotland's work but we need it to happen soon if we are to give Scotland's children the very best chance of realising their right to health and wellbeing.



**Lorraine Tulloch**

**Programme Lead, Obesity Action Scotland**

## Executive summary

In this analysis we have used the Growing Up in Scotland Study to reveal how children born in 2004-05 experience changes in BMI category (underweight, healthy weight, overweight, obesity) between ages 4, 10 and 14, and how this differs depending on the socio-economic circumstances they have experienced in the early years. This provides important new insights into how children experience overweight and obesity across childhood into adolescence and the social patterning of these experiences.

The prevalence of obesity was already high at the start of Primary school, with 10% of 4-year-olds living with obesity, and 25% living with overweight (including obesity). These respective figures rose to 22% and 37% by age 14 years. The prevalence of obesity and overweight was similar among boys and girls.

Half of GUS children (49.9%) were a healthy weight at both age 4 *and* age 14. However, 16% were living with overweight (including obesity) at both age 4 *and* age 14, and 6% lived with obesity at *both* ages. More than a third (40%) of children moved BMI category between age 4 and 14, the majority of whom moved into a higher weight category.

When we focus only on children who experienced obesity at 14, and consider what pattern of BMI they experienced at the beginning and end of Primary school (i.e. at ages 4 and 10 years), we see that one in four (25%) experienced 'persistent' obesity in primary school. A further 22.5% experienced persistent overweight or moves between overweight and obesity in Primary school. However, 48% of children who experienced obesity at 14 started Primary school at a healthy weight. Due to these changes in BMI status between ages 4 and 14, BMI measurements taken at age 4 in Scotland (corresponding to the Primary 1 population-wide monitoring of childhood BMI) only provide a crude predictor of BMI-status at age 14. Using obesity at age 4 as a predictor misses 71% of children who go on to experience obesity at 14. Furthermore 37% of children who experienced obesity at age 4 did not go on to experience obesity at age 14. Using a longitudinal measure of obesity at ages 4 and 10 improves predictions. However, even with this additional BMI measure, over one third (35%) of 14-year-olds experiencing obesity did not experience obesity at 4 or 10.

Children who experienced socio-economic disadvantage in the early years were more likely to experience obesity (as opposed to underweight, healthy weight or overweight), and this inequality widened with age. For example, after adjustment for sex, children who were in the lowest household income quintile at age 4 were 1.7 times as likely to experience obesity at age 4 and 2.4 times as likely to experience obesity at age 14 when compared to children in the highest income quintile. Area deprivation, lone parenting, lower maternal education, maternal unemployment and not owning the family home at the start of Primary school were also all associated with increased obesity at age 14. Children who both lived in the most deprived areas and in the lowest income households were at increased risk of obesity compared to experiencing either of these disadvantages in isolation.

Furthermore, socio-economic disadvantage is associated with increased risk of experiencing obesity at more than one time point. For example, after adjusting for sex, children in the lowest household income quintile were 2.6 times as likely to experience obesity at both 4 and 14 (as opposed to no obesity at either age) when compared to children living in the highest income households.

The cost-of-living crisis is exacerbating levels of social disadvantage, in particular food insecurity has risen dramatically since the COVID-19 pandemic. Just 6% of the GUS children were reported to be living in households that were affected by food costs 'more than

a little', far lower than food insecurity currently being experienced in Scotland and the UK. Nevertheless, those children were four times more likely to experience obesity at the start of Primary school *and* at age 14 than children who did not experience food insecurity, after accounting for area deprivation, maternal education and lone parenting.

In this report we draw on the longitudinal nature of the Growing Up in Scotland cohort, to understand how experiences of overweight and obesity, and their social determinants, vary throughout childhood. The findings highlight a limited value of using BMI in the early years to target interventions, since many of these children would not be expected to continue to experience overweight and obesity, while many others would only go on to develop obesity at later ages. Nevertheless, tackling child poverty and disadvantage in the early years is essential to avoid rates of obesity rising further among children in Scotland, increasing the risk of poor health and premature mortality among future generations of adults and widening inequalities further. Addressing food insecurity, which is far higher now than it was when the GUS children were growing up, is one essential area for action.

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## Obesity from early childhood to adolescence in Scotland

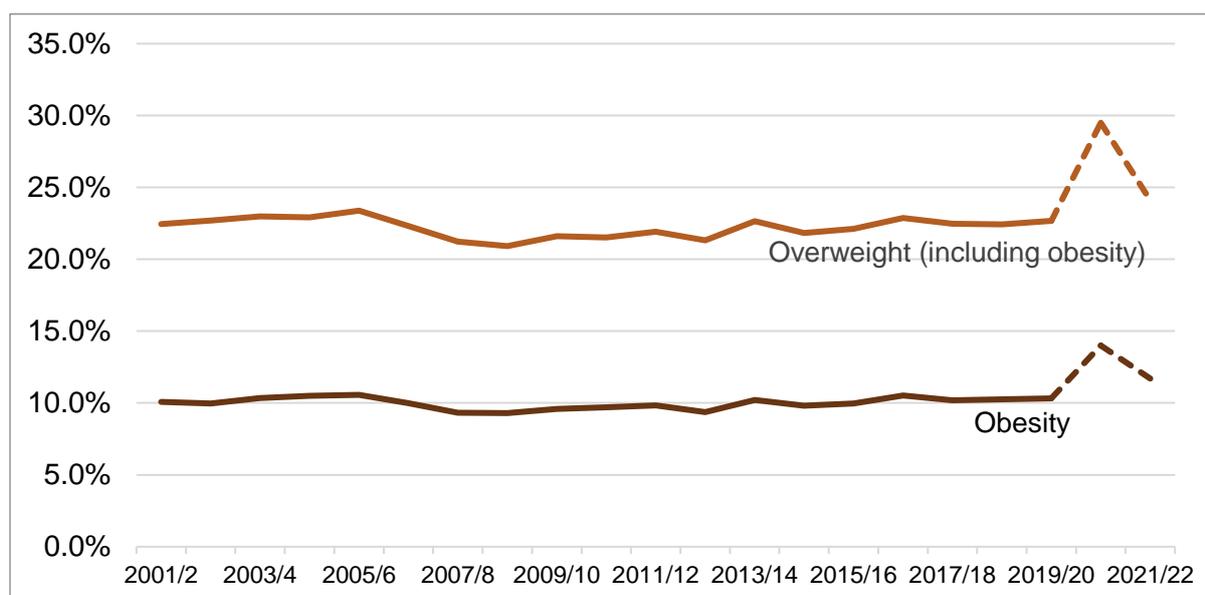
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## Introduction

Overweight and obesity are highly preventable conditions, yet over the past 20 years there has been little progress in reducing the prevalence of overweight and obesity among children in Scotland (Figure 1)<sup>1</sup>.

**Figure 1: Prevalence of overweight and obesity between 2001/2 and 2021/22 in Scotland, using Public Health Scotland Primary 1 BMI statistics (school-year 2021 to 22)<sup>1</sup>.**

*Note that coverage of child BMI monitoring dropped during the pandemic so figures from 2020/21 and 2021/22 (dotted lines) have greater uncertainty.*



There has been a concerning widening of socio-economic inequalities in childhood overweight and obesity during this period<sup>2</sup>. Prior to the pandemic, the prevalence of childhood obesity was increasing in the most deprived areas, while declining in the least deprived areas. A similar pattern has also been seen in England<sup>3</sup>. Following a spike in prevalence during COVID-19 pandemic lockdowns, the most recent monitoring round at the time of writing (2021/22) suggests that obesity has risen among all SIMD quintiles in Scotland compared to before the pandemic, but with the largest rise in the most deprived quintile. It is not yet clear to what extent the 2021/22 estimates reflect temporary changes in prevalence in the wake of the pandemic, or more persistent trends.

Experiencing overweight and obesity in childhood has wide ranging ramifications across the lifecourse. For example, it has negative impacts on child mental health, is associated with obesity in adulthood and is a risk factor for type 2 diabetes and hypertension<sup>4 5</sup>. Furthermore, obesity in childhood is associated with premature mortality<sup>6</sup>. These risks can be heightened among children who experience persistent obesity throughout childhood<sup>7</sup>. The high prevalence of childhood obesity and high inequalities in Scotland is therefore a major public health concern and may mean that we are storing up problems for the future.

It is increasingly recognised that childhood obesity and inequalities in obesity cannot be solved by attempts to change individual behaviours alone. Interventions which target only behaviours can widen inequalities, as families with the resources, including time, income, and social supports, are more likely to benefit<sup>8</sup>. Moreover, an emphasis only on individual

behaviours can exacerbate the stigma faced by children living with overweight and obesity<sup>9</sup>. Therefore, action to address the social, environmental, and commercial determinants of obesity are also essential. Policies across all sectors and all levels of decision-making can be leveraged to ensure that the environment in which children grow up promotes and prioritises their health<sup>10</sup>.

Understanding how the risk of overweight and obesity changes across childhood, and how this varies according to deprivation, is important for informing the design and delivery of policies and interventions. This requires longitudinal data and rich socio-economic information. This report therefore aims to explore a) how overweight and obesity change throughout childhood to early adolescence, and b) how inequalities in overweight and obesity develop with age, using the Growing Up in Scotland cohort study.

The results are presented across four chapters. Chapter 1 asks “How do overweight and obesity change throughout early childhood to mid-adolescence?”. It describes the cross-sectional prevalence of overweight and obesity at key points in childhood, and how much change in weight children experience between these ages.

Chapters 2 and 3 ask “How do inequalities in overweight and obesity change with age?”. To do this, chapter 2 describes socio-economic inequalities in obesity and overweight at key ages, and Chapter 3 describes inequalities in the way that weight changes in childhood and adolescence.

Finally, Chapter 4 explores the impact that food insecurity, a severe symptom of socio-economic disadvantage, experienced at a young age can have on overweight and obesity in later childhood.

Prior to this, there is a short section describing the methods used throughout the report.

## Methods:

### *The Growing Up in Scotland Study*

The data in this report are from the first birth cohort in the Growing Up in Scotland Study. This is a nationally representative study of over 5000 children born in Scotland between 2004-5, who have been followed up regularly since they were aged 10 months<sup>11</sup>. Detailed information is collected from primary care givers about the child's health and development, their family structure and socio-economic circumstances, and the child's wider environment such as their childcare and social networks. This gives a detailed and rich insight into the lives of children as they age in Scotland.

### *Who is included in the analysis?*

Of the 5217 children who entered the study, 2238 were successfully followed up to age 14 and are the focus of our analysis, with some analyses focussing on children who were present at multiple surveys making the sample size slightly lower. For example, our analyses using BMIs measured at ages 4, 10 and 14 include 1697 children. These children are weighted to account for the sampling strategy and attrition over the course of the study, so that the final results should be representative of all children living in Scotland at the time. A description of the characteristics of the study sample is provided in Appendix 1.

### *How is overweight and obesity measured?*

Participating children's height and weight are measured by the person administering the survey when they were aged 4, 6, 8, 10, and 14<sup>12</sup>. In this report we focus on the measurements taken at ages 4, 10 and 14. The measurements at 4 and 10 years represent the beginning and end of Primary School, and are the nearest equivalents to the ages at which child height and weight is measured in the National Measurement Programme in England (4-5 and 10-11 years)<sup>13</sup>. The measurement at age 14 is analysed as the most recent measurement available, which can give insight into how experiences in early childhood impact on later overweight and obesity.

Objective measures of height and weight are used to calculate body mass index (BMI) z-scores, standardised for age and sex using the 1990 UK BMI reference<sup>14</sup>, and categorised into the following groups referred to collectively as 'BMI Status':

- Underweight: BMI z-score in bottom 5% (where numbers were sufficiently large)
- Healthy weight: BMI z-score between lowest 5% and top 15%
- Overweight (including obesity): BMI z-score in top 15%
- Obesity: BMI z-score in top 5%

A comparison of alternative methods for classifying overweight and obesity, and a discussion of the limitations of using BMI to measure overweight, is presented in Appendix 2.

In some sections, we create a longitudinal measure of BMI status (also referred to as 'trajectories'), using measurements taken at age 4 and 14 years (and, sometimes, also age 10). Groupings which refer to stability between the relevant time points are referred to as 'persistent' obesity, 'persistent' healthy weight, etc. (with others experiencing movement up or down BMI status categories). Please note that this reference to 'persistence' means that this state was experienced only at the time points which were measured. It is possible that there was some movement between these timepoints which we have not taken into account.

To assess the reliability of the GUS data for estimating the prevalence of childhood obesity in Scotland, we have compared the prevalence of obesity at 4 years in GUS (measured in 2008/9) to the Primary 1 weight and height checks that same year. These are part of the national programme aiming to measure the BMI of all children in Primary 1 (aged 4-5). This

shows that GUS children have a very similar prevalence of overweight and obesity at the start of Primary School as population-wide monitoring (Appendix 3). This gives us confidence that GUS is broadly representative and can be used to explore how prevalent overweight and obesity are at older ages, when no Scottish national measurement programmes exist.

### *Measures of socio-economic circumstances*

This report uses several measures of socio-economic circumstances taken at the start of Primary School to examine inequalities in BMI status across childhood. Throughout the analyses, the following measures taken in early childhood (at age 4 unless otherwise stated) are used to describe a child's socio-economic circumstances:

- **Area deprivation:** Measured using the Scottish Index of Multiple Deprivation (SIMD), this measure summarises the characteristics of a local neighbourhood, including the proportion of the community who are experiencing low income, unemployment, poor health, have low education, barriers to accessing services, high crime or poor housing. The measure ranks all local areas in the country to determine their relative deprivation. In this report we use SIMD quintiles.
- **Household income:** The equivalised household income measures are grouped into five equally sized groups. In other words, income quintiles .
- **Family structure:** Whether children live in a household with a single parent, or parents in a couple.
- **Mother's highest educational qualification:** Degree level or above compared to lower than degree level.
- **Mother employment:** Employed compared to not employed.
- **Tenure:** Whether the child's family own (outright or with a mortgage) their home or not.

### *Food insecurity*

In Results Chapter 4 we explore in detail the association between food insecurity (whether the child's mother is affected by food costs 'more than a little' or not, when the child was aged 2), and obesity experience across childhood.

### *Analysis methods*

The prevalence of each BMI status category, and changes in BMI status, when described are weighted using a longitudinal weight accounting for sampling design and attrition between first data collection and age 14.

*Relative* inequalities are described throughout using odds ratios (ORs, with 95% confidence intervals), which are calculated using a logistic regression model, adjusted for sex, and weighted using the same longitudinal weight as the descriptive analyses. When exploring inequalities in the prevalence of obesity at a particular age, these models compare the odds of experiencing obesity relative to the odds of not experiencing obesity (i.e. with underweight, healthy weight or overweight as a combined comparison group).

Children experiencing socio-economic disadvantage are more likely to experience food insecurity, and more likely to experience obesity. Therefore, to estimate the effect of food insecurity on obesity, the association between food insecurity and obesity was estimated after adjusting for sex, area deprivation, lone parenting and maternal education in a logistic regression model. Income was not included as an adjustment variable due to a greater proportion of missing data in GUS (Appendix 1).

When exploring inequalities in persistent obesity, the odds of experiencing obesity at both ages 4 and 14 is compared to the odds of not experiencing obesity at either age (in other words, being underweight, healthy weight or overweight at 4 and 14 years).

*Other methods used in the summarised literature*

In sections where we have summarised what is already known about changes and inequalities in childhood obesity, we have drawn on the results of a literature review of previous research specifically using GUS. These use a range of different analysis methods to explore these topics. In Section 1.2.1, we summarise findings from a study that used growth mixture models to explore trajectories in BMI status over Primary school. This is a data intensive method to group children experiencing similar BMI trajectories. As noted in the variables section above, in our analysis we have instead described the prevalence of each possible trajectory of BMI between ages 4 and 14, which is more intuitive to interpret.

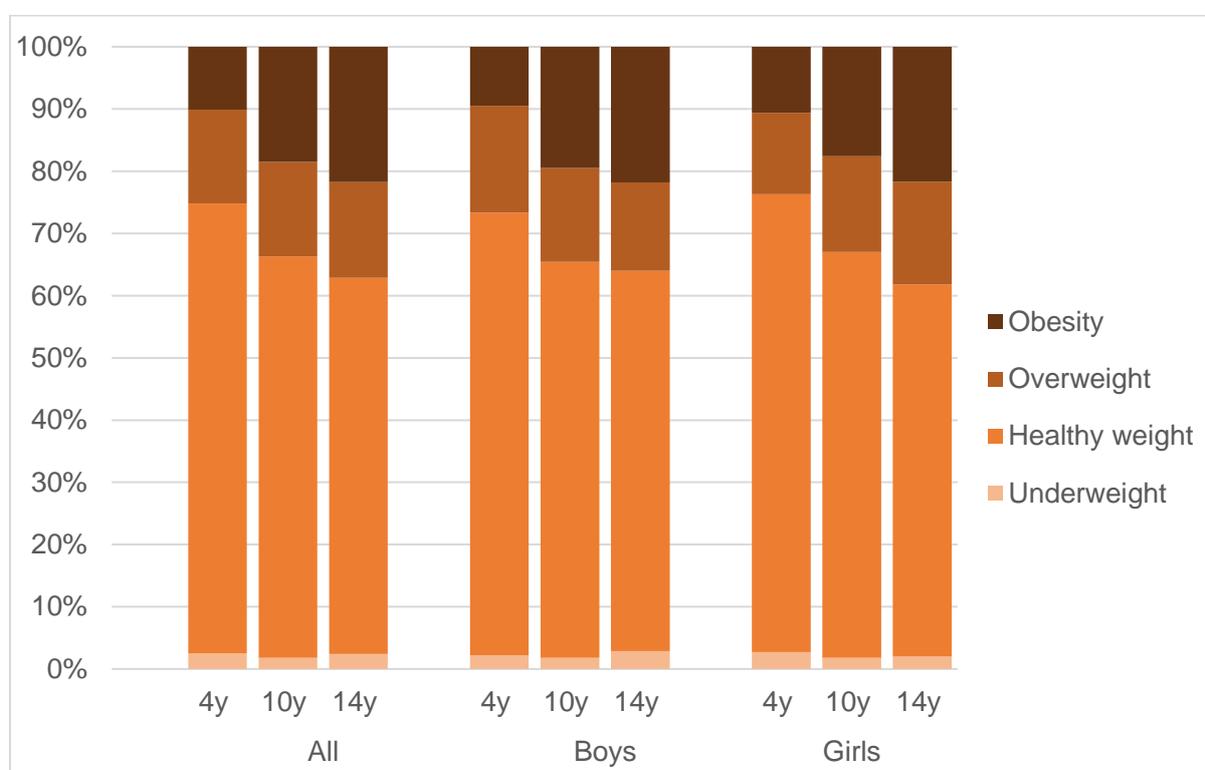
In Section 2.1 we summarise literature which describes socio-economic inequalities in overweight and obesity in *absolute* terms. These absolute inequalities capture the difference in prevalence of obesity between two comparison groups. As noted above, we have quantified inequalities using relative measures adjusted for sex. Relative inequalities are less effected by the overall prevalence of the outcome, and so facilitate the comparison of inequalities at different ages, or between cross-sectional obesity prevalence and persistent obesity. Finally, section 3.1 describes literature which reports relative inequalities, but unlike the results in our report, this is not adjusted for sex.

## Results Chapter 1: How do overweight and obesity change across childhood in Scotland?

### 1.1 The prevalence of overweight and obesity at ages 4, 10 and 14

The prevalence of obesity in GUS children was already high at the start of Primary School, and increased further with age (Figure 2). One in ten children were already living with obesity by age 4 (10%). By age 10 (the end of Primary School), 19% of children were experiencing obesity, which rose to 22% in 14-year-olds. This represents a doubling in the prevalence of obesity between ages 4 and 14. In contrast, the prevalence of overweight (not including obesity) remained at 15% throughout.

**Figure 2: Prevalence of underweight, healthy weight, overweight and obesity at ages 4, 10, and 14, in the Growing Up in Scotland Study, for all children and boys and girls separately.**



	<i>All</i>			<i>Boys</i>			<i>Girls</i>		
<i>Age (sample size)</i>	<i>4y (2101)</i>	<i>10y (2194)</i>	<i>14y (1797)</i>	<i>4y (1053)</i>	<i>10y (1104)</i>	<i>14y (886)</i>	<i>4y (1048)</i>	<i>10y (1090)</i>	<i>14y (911)</i>
<b>Underweight (%)</b>	2.5	1.8	2.4	2.2	1.8	2.9	2.7	1.8	2.0
<b>Healthy weight (%)</b>	72.4	64.5	60.4	71.2	63.7	61.1	73.6	65.3	59.8
<b>Overweight (%)</b>	15.1	15.2	15.4	17.2	15.1	14.2	13.1	15.4	16.5
<b>Obesity (%)</b>	10.1	18.5	21.7	9.5	19.5	21.8	10.6	17.6	21.7
<b>Overweight or obesity (%)</b>	25.2	33.7	37.1	26.7	34.6	36.0	23.7	33.0	38.2

### 1.1.1 Differences between boys and girls

The prevalence of overweight (including obesity) was slightly higher in four-year-old boys (27%) than four-year-old girls (24%). However, by age 14, girls had the slightly higher prevalence (38% compared to 36%). The differences between boys and girls were reasonably small at every age, however, especially in the prevalence of obesity. For example, both 22% of boys and girls experienced obesity at age 14.

## 1.2 What are the most common longitudinal patterns of overweight/obesity throughout childhood for boys and girls?

### 1.2.1 What is already known about changes in BMI status during Primary School?

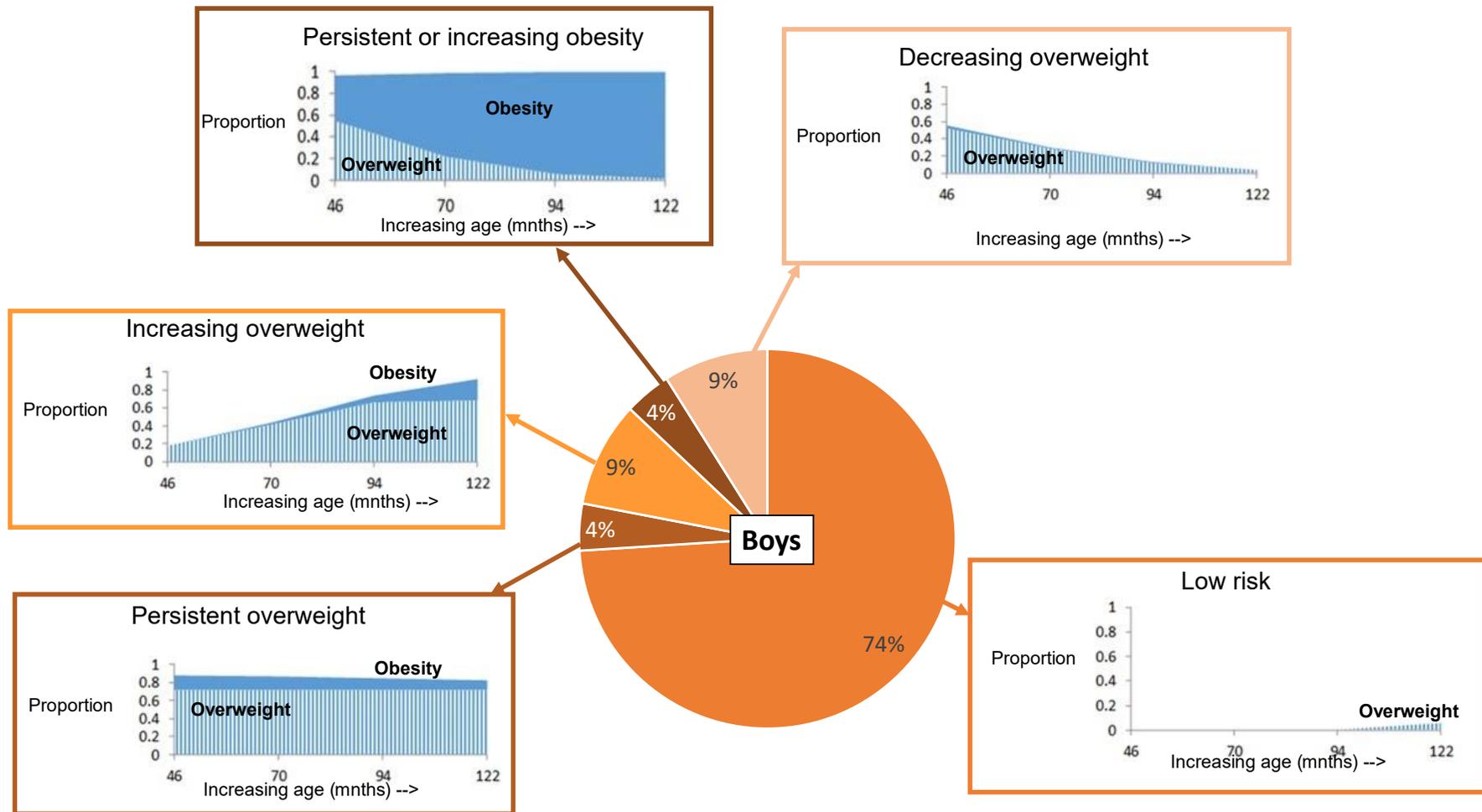
Measurements collected in the Growing Up in Scotland study have previously been used to identify the most common longitudinal patterns (or 'trajectories') of children's risk of overweight and obesity throughout Primary school (using measurements at ages 4, 6, 8 and 10)<sup>15</sup>. Five patterns were identified by Parkes et al: 'Low risk throughout', 'Persistently overweight', 'Increasing overweight', 'Persistent or increasing obesity', and 'Decreasing overweight' (Figure 2). The prevalence of each of these groups, for boys, is shown in the pie chart, at the centre of Figure 3. This shows that, for example, almost three-quarters of boys remained in the 'Low risk' of overweight group throughout childhood. 4% boys are in the 'Persistent or increasing obesity' group (shown in the darkest brown segment of the pie chart).

The blue bar charts show how, for each of the five groups, the proportion of boys who were overweight or had obesity changed with age. For example, as shown in bottom right-hand bar chart, no boys in the 'Low risk' group were overweight throughout the early years, with very few displaying risk of overweight by age 10. The top left hand bar chart shows that nearly all boys in the 'Persistent or increasing obesity' group had already experienced overweight (light blue), with a smaller proportion experiencing obesity (dark blue), by age 4. By age 10, nearly all boys in this group experienced obesity.

The patterns for each group among girls were very similar (Figure 4), although with some differences in their size. Girls were more likely to be categorised into the 'Persistent overweight' or 'Increasing overweight' groups than boys (20% compared to 13%), although the proportions in 'Persistent or increasing obesity' were similar (5% and 4% respectively). Boys are more likely to be classed as 'Low risk' throughout (74%) than girls (65%).<sup>15</sup> It is worth noting that there is some degree of uncertainty when assigning people to different groups using this method.

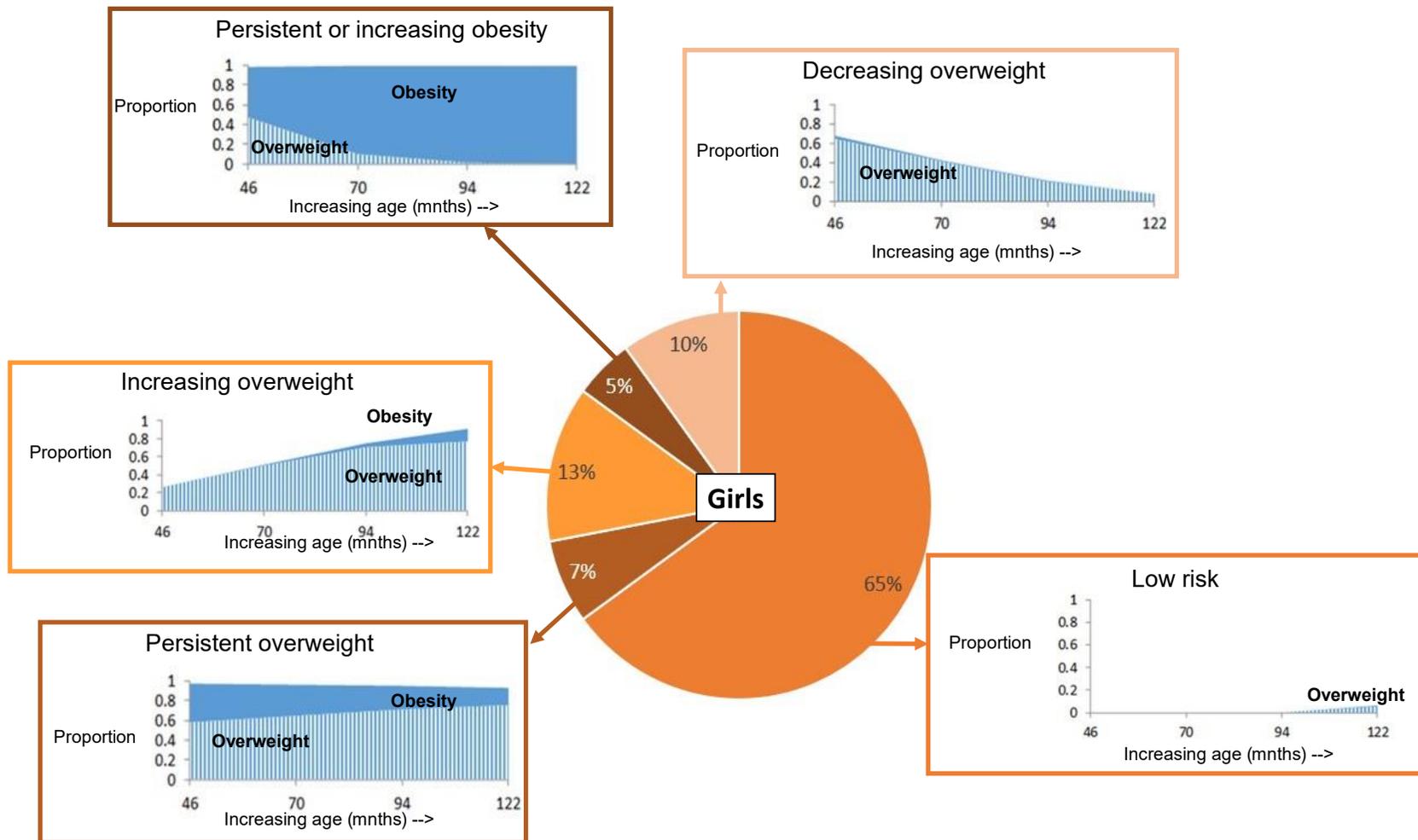
**Figure 3: Five BMI-status trajectories between ages 4 (2008/9) and 10 (2014/15) among boys in the first Growing Up in Scotland birth cohort – their prevalence (see pie chart) and shape (see blue figures).**

*Adapted from Parkes et al<sup>15</sup>*



**Figure 4: Five BMI-status trajectories between ages 4 (2008/9) and 10 (2014/15) among girls in the first Growing Up in Scotland birth cohort – their prevalence (see pie chart) and shape (see blue figures)**

*Adapted from Parkes et al <sup>15</sup>*



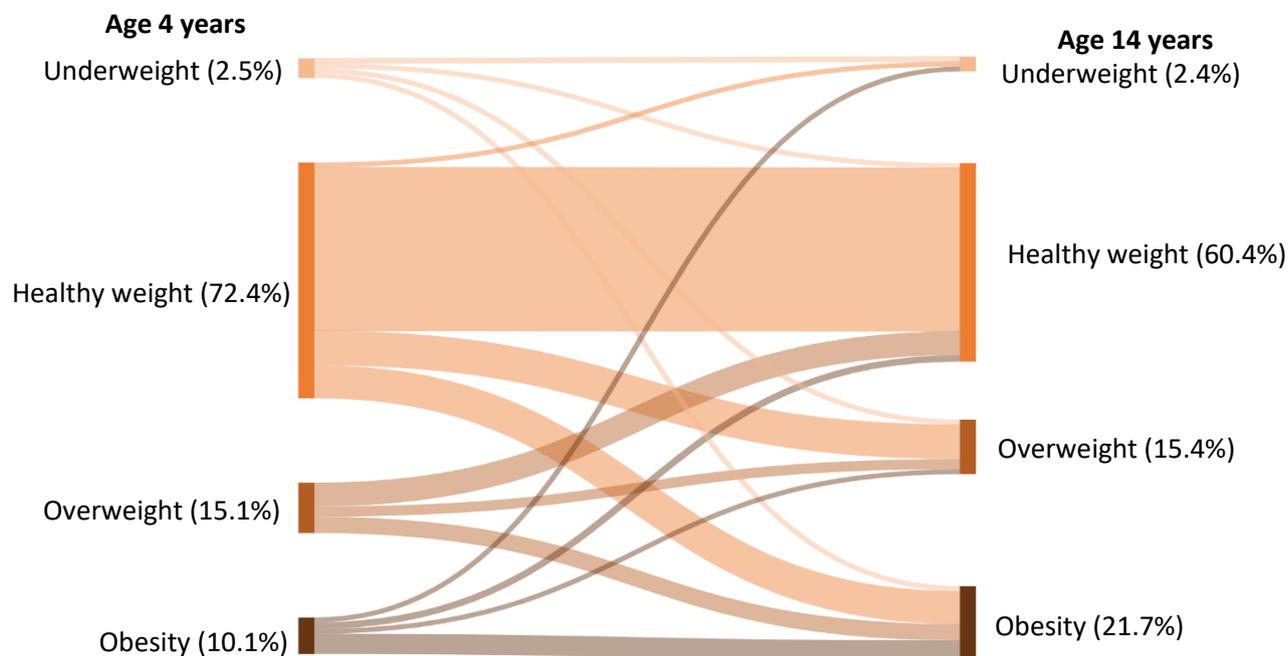
### *1.2.2 How does BMI-status change between age 4 and 14 years?*

In the previous section we saw that the majority of GUS children remained at a healthy weight throughout primary school (up until age 10). Here we examine different patterns of overweight and obesity up until age 14. The longitudinal groupings created by Parkes et al<sup>15</sup> cannot be directly compared to those we have created below (because we have used different methods), but we also find that healthy weight continues to be the most common pattern between ages 4 and 14.

Figure 5 shows the movement of children between BMI categories at ages 4 (left hand side) and 14 (right hand side). This chart shows that the majority of children who were healthy weight at age 4 continued to be a healthy weight at age 14 (shown by the large, continuously orange strip). Similarly, many of those who experienced obesity at age 4 continued to experience obesity at age 14 (shown in the continuously dark red strip at the bottom). However, relatively few children who experienced overweight at age 4 were still experiencing overweight at 14 (shown by the very small, medium orange, strip), with movement from overweight to healthy weight being more common than movement from overweight to obesity. Appendix 4 shows that the prevalence of each trajectory is similar among boys and girls.

**Figure 5: Movement of children between BMI-categories between ages 4 and 14 years, among children in the Growing Up in Scotland Study.**

The width of the bar is proportional to the proportion of children experiencing this trajectory of BMI status. n=1697.



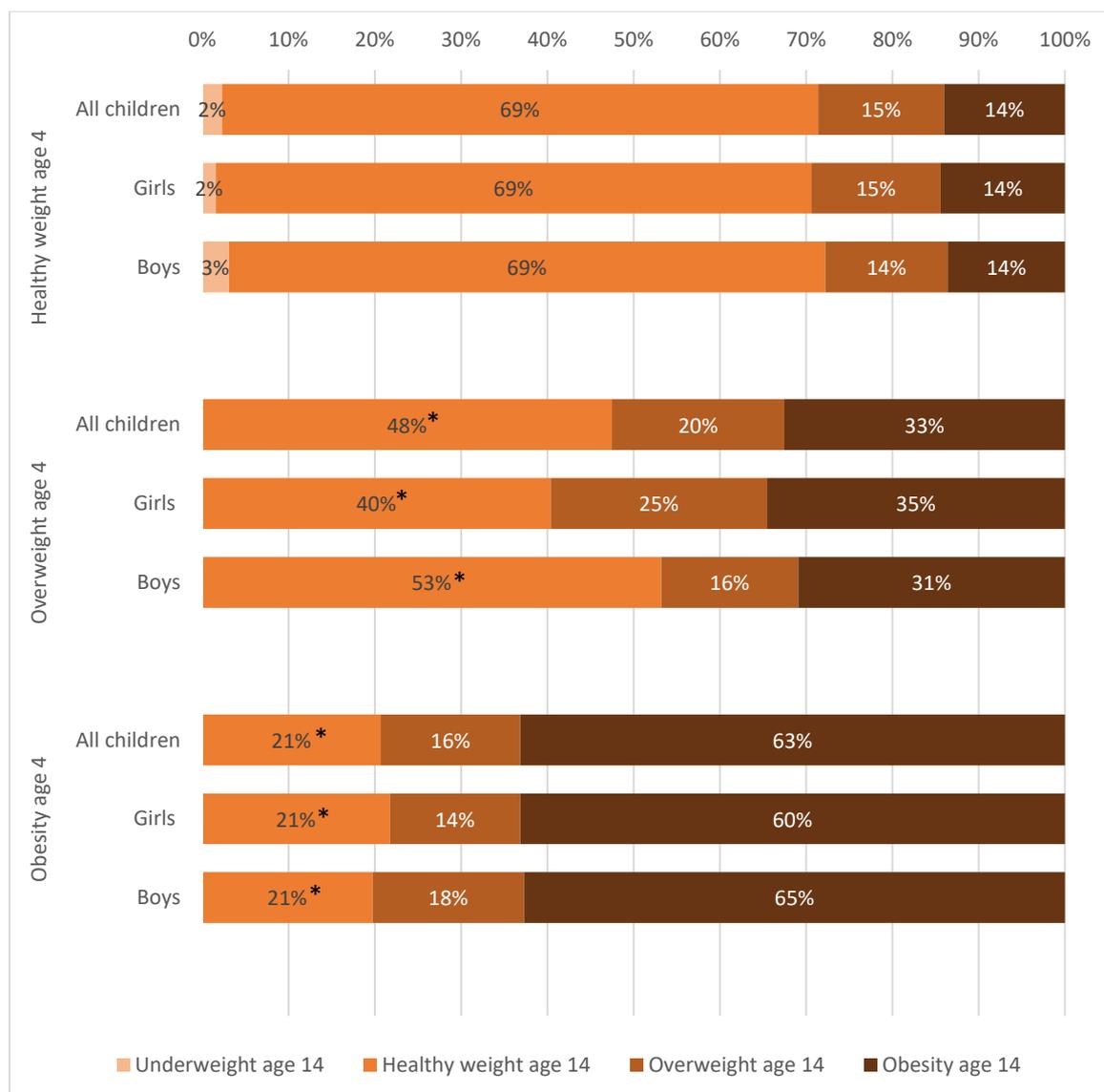
<b>Trajectory between ages 4 and 14 years</b>	<b>Prevalence</b>
<i>Underweight to Underweight</i>	<2%
<i>Underweight to Healthy weight</i>	<2%
<i>Underweight to Overweight</i>	<2%
<i>Underweight to Obesity</i>	<2%
<i>Healthy weight to Underweight</i>	2%
<i>Healthy weight to Healthy weight</i>	50%
<i>Healthy weight to Overweight</i>	11%
<i>Healthy weight to Obesity</i>	10%
<i>Overweight to Underweight</i>	<2%
<i>Overweight to Healthy weight</i>	7%
<i>Overweight to Overweight</i>	3%
<i>Overweight to Obesity</i>	5%
<i>Obesity to Underweight</i>	<2%
<i>Obesity to Healthy weight</i>	2%
<i>Obesity to Overweight</i>	2%
<i>Obesity to Obesity</i>	6%
<b>Total</b>	<b>100%</b>

Figure 5 showed the prevalence of all of these different longitudinal combinations at the population level. Figure 6 below shows the prevalence of each BMI status at 14 years, according to children’s BMI status at 4 years. This shows that 69% of GUS children who were healthy weight at age 4 continued to be a healthy weight at age 14 and 63% of those who experienced obesity at age 4 continued to experience obesity at age 14. Just one in five children who experienced overweight at age 4 were still experiencing overweight at 14.

## Obesity from early childhood to adolescence in Scotland

Across the population this means that the majority of children (60%) will have the same BMI status at 14 as they did at age 4. However, 27% of children will move upwards to a heavier BMI group, and the remaining 13% of children will move downwards. In total, half of children experience unhealthy weight (underweight, overweight, or obesity) at either age 4 or 14, or both. Figure 6 also shows that there is little variation between boys and girls.

**Figure 6: The prevalence of underweight, healthy weight, overweight and obesity at age 14, stratified by BMI status at 4, for boys (n=832), girls (n=865), and all children (n=1697) in the Growing Up in Scotland Study<sup>^</sup>**



<sup>^</sup>Data not presented for underweight at age 4 due to small cell sizes. \*underweight and healthy weight combined

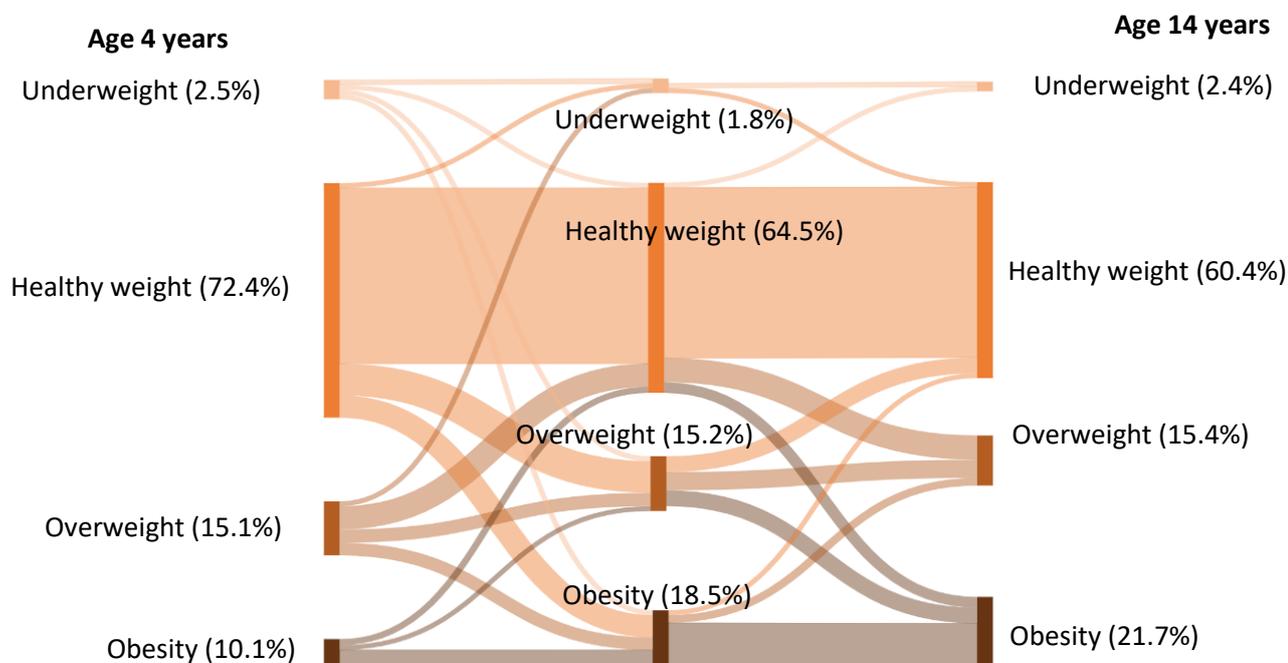
We can explore these movements in BMI-status between ages 4 and 14 in more detail, by incorporating the measures taken at age 10. A similar diagram to Figure 5, including BMI status at age 10 is presented in Figure 7. This shows that movement between BMI categories between ages 4 and 10 is largely similar to movement between ages 10 and 14. The most obvious exception is that a greater proportion of the cohort experienced persistent obesity between ages 10 and 14 years (14%) than between ages 4 and 10 years (6%). Furthermore, the proportion of the cohort moving from a healthy weight into obesity between ages 4 and 10 (7%) is greater than the proportion moving from healthy weight to obesity

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between 10 and 14 (3%). These analyses can shed insight into the age at which obesity develops in children, alongside how persistent it is at these three key ages.

**Figure 7: Movement of children between underweight, healthy weight, overweight and obesity between ages 4 and 10, and between ages 10 and 14.**

*The thickness of the connecting flow is proportional to the percentage of children who experience this weight trajectory among the Growing Up in Scotland Study.*

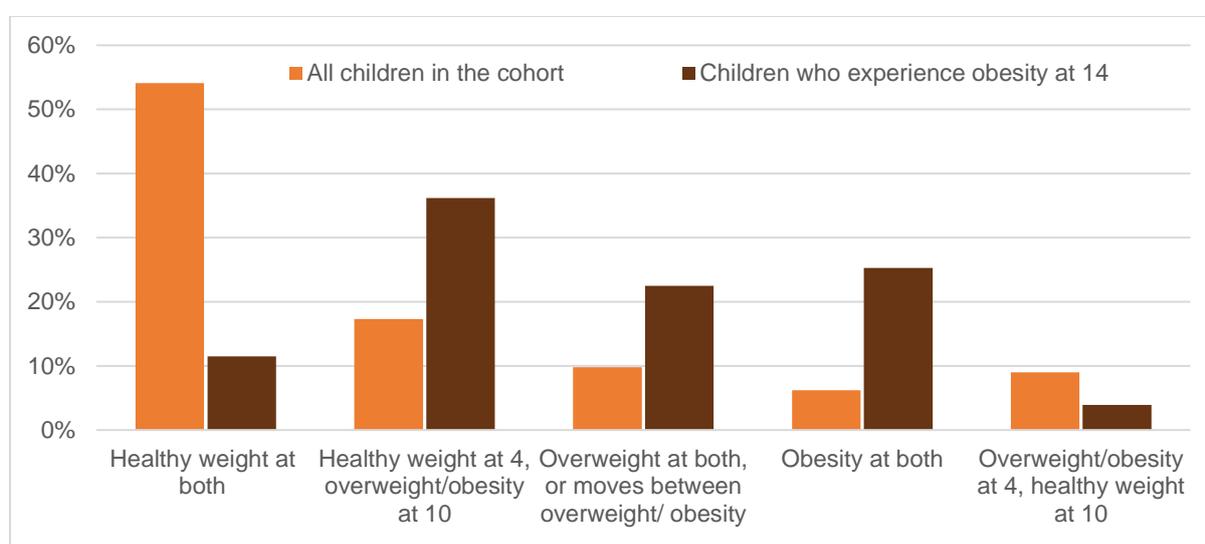


<b>Trajectory between ages 4 &amp; 10y</b>		<b>Trajectory between ages 10 &amp; 14y</b>	
	<b>%</b>		<b>%</b>
<i>Underweight to Underweight</i>	21%	<i>Underweight to Underweight</i>	<2%
<i>Underweight to Healthy weight</i>	2%	<i>Underweight to Healthy weight</i>	<2%
<i>Underweight to Overweight</i>	21%	<i>Underweight to Overweight</i>	<2%
<i>Underweight to Obesity</i>	21%	<i>Underweight to Obesity</i>	<2%
<i>Healthy weight to Underweight</i>	<2%	<i>Healthy weight to Underweight</i>	2%
<i>Healthy weight to Healthy weight</i>	55%	<i>Healthy weight to Healthy weight</i>	53%
<i>Healthy weight to Overweight</i>	10%	<i>Healthy weight to Overweight</i>	8%
<i>Healthy weight to Obesity</i>	7%	<i>Healthy weight to Obesity</i>	3%
<i>Overweight to Underweight</i>	21%	<i>Overweight to Underweight</i>	<2%
<i>Overweight to Healthy weight</i>	7%	<i>Overweight to Healthy weight</i>	5%
<i>Overweight to Overweight</i>	4%	<i>Overweight to Overweight</i>	6%
<i>Overweight to Obesity</i>	4%	<i>Overweight to Obesity</i>	5%
<i>Obesity to Underweight</i>	<2%	<i>Obesity to Underweight</i>	21%
<i>Obesity to Healthy weight</i>	2%	<i>Obesity to Healthy weight</i>	2%
<i>Obesity to Overweight</i>	<2%	<i>Obesity to Overweight</i>	2%
<i>Obesity to Obesity</i>	6%	<i>Obesity to Obesity</i>	14%

1.2.3 Trajectories of BMI status during Primary School for children who go on to experience obesity at 14.

Figure 8 shows that if we focus on the children who experienced obesity at age 14 (dark orange bars; right hand column of the accompanying table), one quarter had experienced obesity persistently throughout primary school (i.e. at ages 4 and 10). This is far higher than the entire cohort, 6% of whom experienced obesity at both ages (light orange bars). Just over a fifth (23%) of children who experienced obesity at age 14, experienced persistent overweight or movement between overweight and obesity between 4 and 10 years. This means that almost half children who had obesity at age 14 had not been a healthy weight at either ages 4 or 10.

**Figure 8: Prevalence of each weight trajectory between ages 4 and 10, among all children in the Growing Up in Scotland Study (n=2064), and just those who experienced obesity at 14 years old (n=307).**



<b>Change in BMI between ages 4 and 10</b>	<b>%, all children (n=2064)</b>	<b>%, children experiencing obesity at 14 (n=307)</b>
<i>Healthy weight at both ages</i>	54	12
<i>Moved from healthy weight into overweight</i>	10	15
<i>Moved from healthy weight into obesity</i>	8	22
<i>Overweight at both</i>	4	7
<i>Moved from overweight into obesity</i>	4	15
<i>Moved from obesity into overweight</i>	<2	<2
<i>Obesity at both</i>	6	25
<i>Moved into healthy weight from overweight/obesity</i>	9	4

A large proportion (37%) of children who had obesity at age 14 had been healthy weight at the start of Primary school but moved into higher weight groups by age 10. This group was made up of children who had been a healthy weight at 4 and were overweight at 10 (a trajectory experienced by 15% of children with obesity at 14), and children who had been a healthy weight at 4 and were living with obesity at 10 (22% of children living with obesity at 14). Only 12% of children experiencing obesity at age 14 had been healthy weight throughout Primary school (at ages 4 and 10), compared to 54% of the total cohort.

### *1.3 Can BMI-status at age 4 be used to predict BMI-status at age 14?*

One option in Scotland for targeting childhood weight interventions is to identify and offer interventions to children who are experiencing high weight when routinely measured during Primary 1 (P1; when children are aged 4-5). It is therefore important to know how well these measures taken at an early age can identify (or predict) those children who will go on to experience overweight and obesity.

Here we consider how well BMI status in P1 would perform if used to target interventions aiming to reduce adolescent obesity, based on the experiences of GUS children. We assess this in two ways. Firstly, we consider how many children who experienced obesity at 14 also experienced obesity at age 4. In other words, what proportion of adolescents with obesity would not have been eligible for an intervention, because they did not have obesity at age 4? The second way is to consider what proportion of children who would be offered the hypothetical intervention based on their BMI-status at the start of primary school would have gone on to be healthy weight at later ages anyway. In other words, who would 1) not receive the intervention even though they could have benefited, and 2) who would unnecessarily be offered the intervention. If an intervention is costly, stigmatising or has other limitations, then minimising the number of children who are offered the intervention unnecessarily is important.

#### *1.3.1 How well does obesity at age 4 predict obesity at 14?*

Of GUS children experiencing obesity at 14 years, less than one third (29%) also experienced obesity at age 4 years. Therefore, if new, hypothetical interventions (i.e. not already being used in Scotland when the GUS children were growing up) to reduce obesity were to be targeted at children who experienced obesity aged 4 years, we might expect 71% of 14-year-olds who live with obesity to be missed (because they were not experiencing obesity at age 4). This is a high proportion of children who could benefit from additional intervention who would be missed if their eligibility were based only on their obesity experience at age 4.

Furthermore, 37% of 4-year-olds with obesity did not experience obesity at age 14. Therefore, over a third of those who would have been eligible for the hypothetical intervention (on the basis of their obesity experience) would have no longer experienced obesity by age 14 anyway.

#### *1.3.2 How well does overweight (including obesity) at age 4 predict obesity at 14?*

Using the larger group of children who were experiencing overweight (including obesity) at age 4 to define eligibility means that a smaller proportion (48%) of 14-year-olds living with obesity would have been missed (compared to 71% when only using obesity). However, this still misses out half of those who could benefit.

Furthermore, this improvement in the reach comes at a cost - 56% of children who would hypothetically be targeted based on their BMI status at age 4 would not go on to experience obesity at age 14 years (compared to 37% when using obesity only as a measure).

#### *1.3.3 Does adding additional measures at age 10 improve predictions?*

Adding a later BMI measurement at age 10 (equivalent to the second National Child Weight Measurement programme in England) improves the prediction of obesity at 14 substantially.

If children who experienced obesity at either 4 or 10 years old were targeted, fewer (35%) 14-year-olds currently living with obesity would have been missed. Moreover, the proportion of children who would be incorrectly targeted is also reduced to 32%. Therefore, including measurements at later ages improves the prediction of obesity at 14, although still with relatively large proportions of children unnecessarily targeted or overlooked.

#### *1.4 Chapter 1: Summary of findings*

The prevalence of overweight and obesity is very high among Scottish children. Already by age 4, one in four children are experiencing overweight (including obesity). The prevalence increases with age, especially for obesity, which doubles between ages 4 and 14. The prevalence of overweight and obesity are broadly similar for boys and girls.

Experiences of overweight and obesity vary throughout childhood. Two in five children changed BMI status between ages 4 and 14, the majority of whom moved upwards to a heavier BMI status group. One quarter of children experiencing obesity in adolescence (age 14) had been experiencing obesity since by the start of Primary school. However, the rest of this group will have started to experience obesity for the first time after this point, or moved in and out of the obesity group.

These varied experiences in overweight and obesity throughout childhood makes it hard to predict who will experience obesity as a young person. Using only a single measure of BMI status at the start of primary school to predict future BMI will mean many children who would benefit from new, targeted interventions would be missed. Using data from ages 4 and 10 can improve predictions and thus the targeting of interventions to prevent adolescent obesity. However, even using a longitudinal measure such as this to predict adolescent obesity misses over one third of 14-year-olds with obesity.

## Results Chapter 2: Inequalities in obesity at single ages

### 2.1 What is already known: Inequalities in primary school:

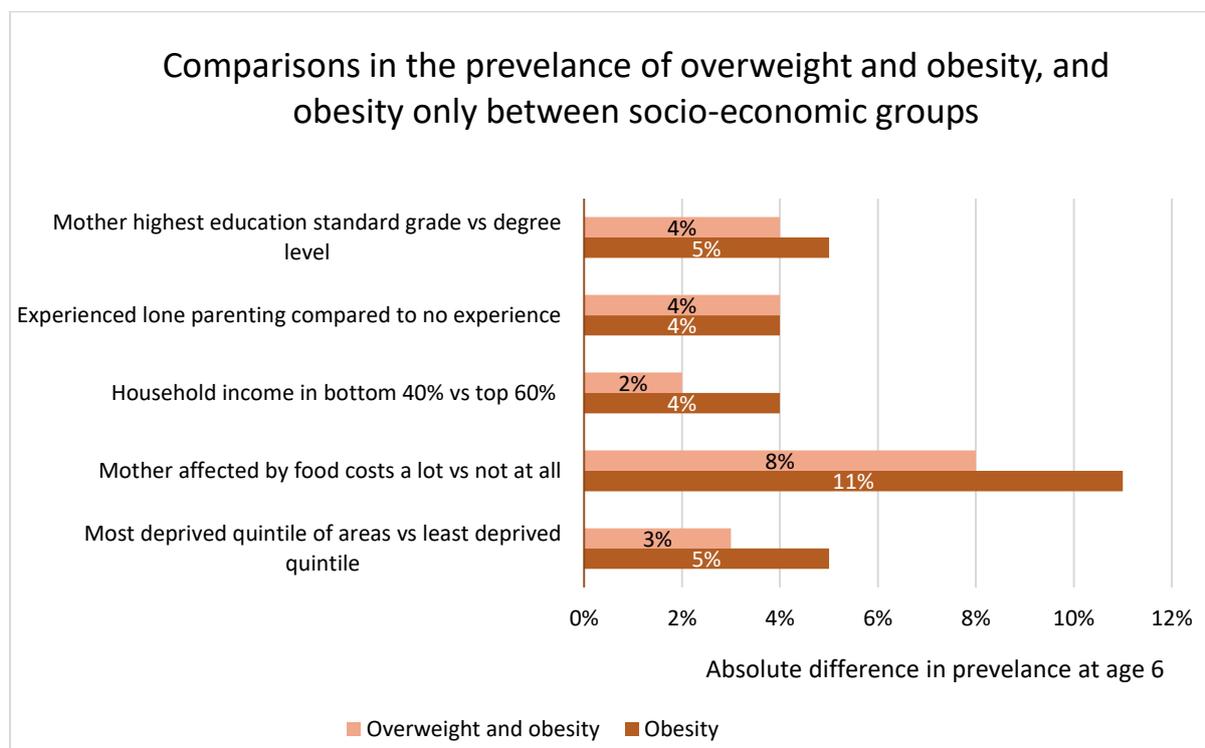
There are substantial social inequalities in overweight and obesity among primary age children. <sup>16 17</sup>. For example, the prevalence of overweight and obesity is higher at age 6 among children who, compared to their more advantaged peers: <sup>16 17</sup>

- Have mothers who have lower educational qualifications.
- Have experienced lone parenting.
- Experienced persistent poverty in the early years.
- Experience food insecurity.
- Live in more deprived areas.

Moreover, more severe outcomes show wider inequalities. In other words, absolute inequalities in the prevalence of obesity at age 6 (2010/11) are larger than inequalities in overweight (including obesity) (Figure 9).<sup>17</sup>

**Figure 9: Absolute difference in the prevalence of overweight and obesity, or obesity only, at age 6 (2010/11) between children in the most and least disadvantaged groups according to several measures of socio-economic circumstances.**

*Adapted from Parkes et al <sup>17</sup>*



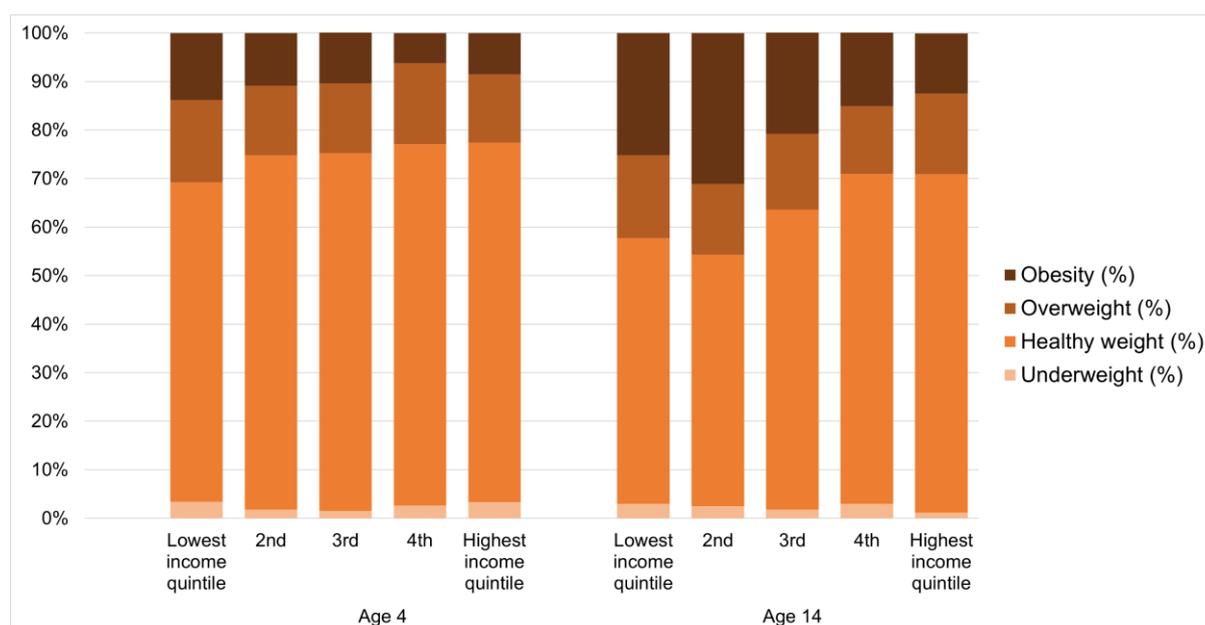
## 2.2 Inequalities in obesity at 4 and 14

Our new GUS analyses show that these inequalities in obesity at the start of Primary school persist and widened with age.

### 2.2.1 Inequalities in obesity according to household income.

Living in the lowest household income quintile at age 4 was associated with increased obesity throughout childhood, however the strength of the association increased with age (Figure 10). After adjustment for sex, children in the lowest household income quintile were 1.7 times as likely to experience obesity at age 4 compared to the highest income household quintile (adjusted odds ratio [aOR]: 1.7, 95% CI 1.0-2.9, data not shown). By age 14, children who lived-in low-income households at age 4 are more than twice as likely to experience obesity (aOR 2.4, 95% CI 1.5-3.8, Table 1). In comparison, inequalities in overweight were relatively low at both ages (see Figure 10). Note that children in the second lowest income quintile at age 4 appeared to experience the highest obesity prevalence at age 14. This is discussed in section 2.2.2 below.

**Figure 10: The prevalence of underweight, healthy weight, overweight and obesity at ages 4 (n=2004) and 14 (n=1708), by household income quintile measured at age 4, among children in the Growing Up in Scotland Study.**



	Age 4 (n=2,004)*					Age 14 (n=1,708)*				
	Lowest income quintile	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	Highest income quintile	Lowest income quintile	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	Highest income quintile
<i>Underweight</i>	3%	2%	2%	3%	3%	3%	3%	2%	3%	<2%
<i>Healthy weight</i>	66%	73%	74%	75%	74%	55%	52%	62%	68%	70%
<i>Overweight</i>	17%	14%	14%	17%	14%	17%	15%	16%	14%	17%
<i>Obesity</i>	14%	11%	11%	6%	9%	25%	31%	21%	15%	12%

%s are rounded; \*sample size varies from some other analyses due to missingness in the income variable

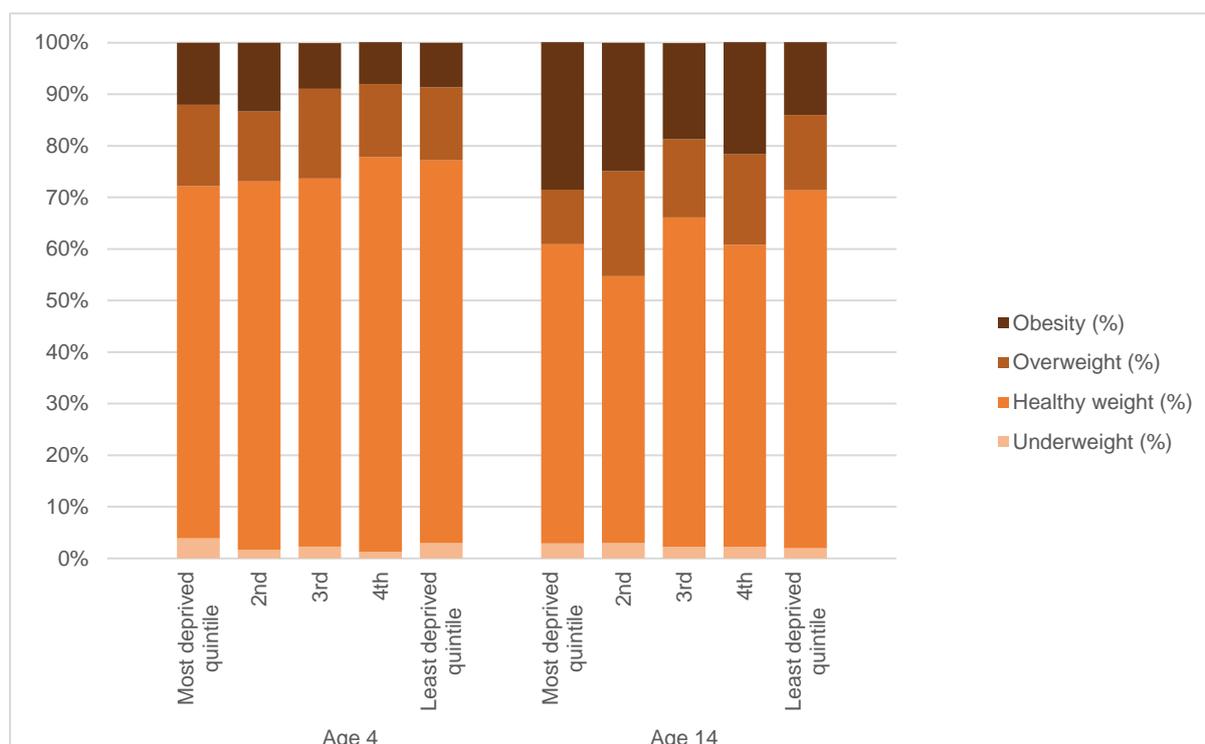
Among all income quintiles, there was little change in the prevalence of overweight between ages 4 and 14, although the prevalence of obesity increased in every group. This does not

necessarily mean that, at the individual-level, this was driven by healthy children moving into the obesity group. Section 1.2 (and figures 1.5 and 1.7 in particular) provides more detail on the different trajectories which led to this overall change.

**2.2.2 Inequalities in obesity related to area deprivation.**

A similar pattern of inequality is seen for children living in the most deprived quintile of areas (based on the Scottish Index of Deprivation) at age 4 compared to the least deprived quintile (Figure 11). At age 4 this was associated with a 1.4-times elevated risk of obesity after adjustment for sex (aOR 1.4, 95% CI 0.8-2.8, data not shown), which by age 14 had risen to a 2.4 times elevated risk (aOR 2.4, 95% CI 1.5-4.1, Table 1).

**Figure 11: The prevalence of underweight, healthy weight, overweight and obesity at ages 4 (n=2101) and 14 (n=1797), by area deprivation quintile measured at age 4, among children in the Growing Up in Scotland Study.**



	Age 4 (n=2101)*					Age 14 (n=1797)*				
	Most deprived quintile of areas	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	Least deprived quintile of areas	Most deprived quintile of areas	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	Least deprived quintile of areas
<i>Underweight</i>	4%	2%	2%	<2%	3%	3%	3%	2%	2%	2%
<i>Healthy weight</i>	68%	71%	71%	77%	7%	58%	52%	64%	59%	69%
<i>Overweight</i>	16%	14%	17%	14%	14%	11%	20%	15%	18%	15%
<i>Obesity</i>	12%	13%	9%	8%	9%	29%	25%	19%	22%	14%

\*sample size varies from some other analyses due to missingness in the deprivation variable

Figures 10 and 11 show that for both income and area deprivation, the second most disadvantaged groups (measured at age 4) had the highest prevalence of overweight (including obesity) at age 14, and the second lowest household income quintile had the

highest prevalence of obesity (only) compared to other income quintiles. This is in contrast to the results for BMI status at age 4 and also the national P1 measurement programme, which found that the most deprived areas consistently see the highest prevalence of both obesity and overweight (including obesity), although differences between the most and second most deprived quintiles were small<sup>13</sup>. In Appendix 5, the cohort's BMI status at 14 is shown by socio-economic circumstances measured at 14 (concurrently). Children in the lowest income quintile at 14 had the highest obesity prevalence. When area deprivation (SIMD) was measured at 14, the prevalence of adolescent obesity in the most and second most deprived SIMD quintiles was similar, and slightly higher in the second most deprived quintile. This suggests that the especially high prevalence of obesity among 14 year olds who were in the *second* lowest income quintile at age 4 might partly be explained by changes in socio-economic circumstances between 4 and 14.

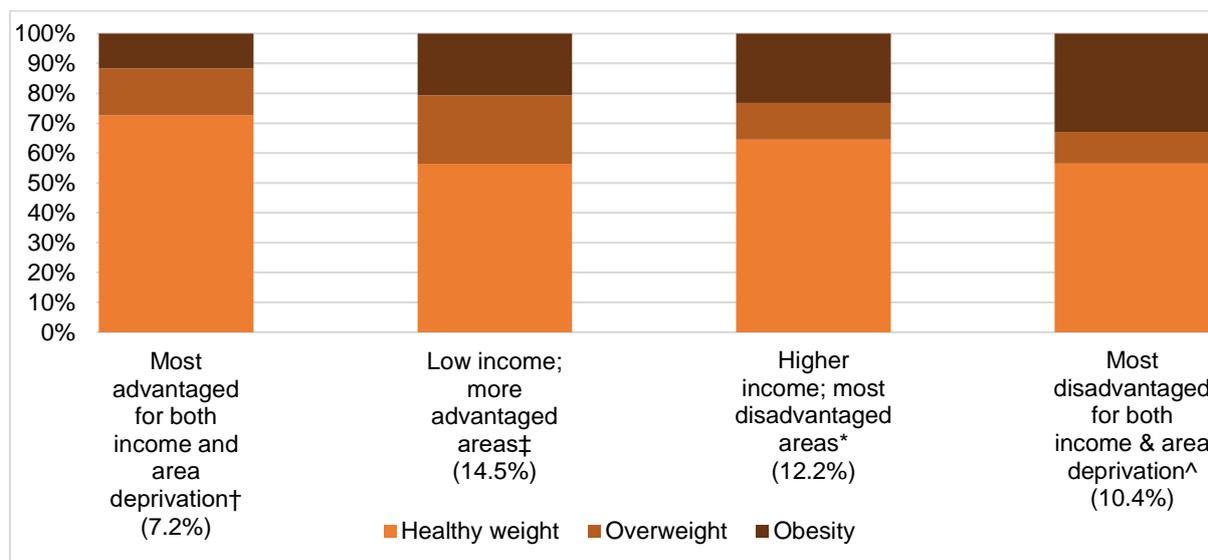
Overall, these findings suggest that the association between disadvantage and obesity is not confined to the most deprived groups, but occurs across a gradient of disadvantage.

### *2.2.3 The impact of combined low income and area-deprivation on adolescent obesity*

So far, we have explored inequalities in childhood obesity according to household income and area deprivation separately. However, the impact of one socio-economic factor is likely to differ depending on the presence of the other. For example, in 2008/9 when children in the Growing Up in Scotland Study were aged 4, one in ten were living in the most deprived quintile of areas and were *also* in a household in the lowest income quintile. Experiencing these two factors together may have an even greater impact on obesity.

Below we divide the GUS children into four groups based on their experience of low income (lowest household income quintile) or area deprivation (living in the most deprived quintile of areas) at age 4. Children who experienced both types of disadvantages had a substantially elevated risk of obesity at age 14 than those experiencing one type of disadvantage alone (Figure 12). The prevalence of obesity at 14 among these children was 32%, compared to 23% among children living in the most deprived areas but on higher incomes, 20% among children living on low incomes but in less deprived areas, and 12% among children in both the least deprived quintile of areas and the highest household income quintile. This corresponds to children living in both the most deprived quintile of areas and the lowest income quintile at age 4 experiencing a 3.5 times higher risk of obesity at age 14 than children in the most advantaged income quintile and the most advantaged quintile of areas.

**Figure 12: The prevalence of healthy weight (or underweight), overweight and obesity at age 14, according to combinations of income and area deprivation, at age 4 among children in the Growing Up in Scotland Study (n=2136).**



	Prevalence of this socio-economic circumstance (%)	Proportion experiencing obesity at 14 (%)	Odds ratio adjusted for sex (95% CI)
<i>Most advantaged for both income and area deprivation †</i>	7	12	1.0 (ref)
<i>Most disadvantaged income quintile, more advantaged area ‡</i>	15	20	1.9 (1.0-3.7)
<i>Most deprived deprivation quintile, more advantaged income quintile*</i>	12	23	2.3 (1.2-4.3)
<i>Most disadvantaged for both income and area deprivation ^</i>	10	32	3.5 (1.7-7.3)
<i>Other</i>	56	21	2.0 (1.2-3.4)

†Child lives in the least deprived quintile of areas (SIMD 1) and in the highest household income quintile. ‡Child in the lowest household income quintile but not the most deprived area quintile (ie. SIMD 1-4). \*Child lives in the most deprived area quintile (SIMD 5) but not the lowest household income quintile. ^Child in the lowest household income quintile and the most deprived quintile of areas (SIMD 1).

#### 2.2.4 Other inequalities in adolescent obesity, in addition to area deprivation and household income

As shown in Table 1, alongside household income and area deprivation, the following factors (measured at age 4) were associated with an increased risk (odds ratio, OR) of obesity at age 14, after adjustment for sex:

- Mother's highest educational qualification was lower than degree level (aOR 2.3).
- The family did not own their home (aOR 2.0).
- Children lived in a single parent household (aOR 1.9).
- Maternal unemployment (aOR 1.3).

**Table 1: Association between six measures of socio-economic circumstances, measured at age 4, with obesity prevalence at age 14.**

	Size of group (n)	Proportion living with obesity at 14 (%)	Sex-adjusted odds ratio (95% CI)
<b>Area deprivation</b>			
<i>Least deprived quintile</i>	567	14.1	1 (ref)
2 <sup>nd</sup>	531	21.7	1.7 (1.0-2.7)
3 <sup>rd</sup>	501	18.6	1.4 (0.9-2.3)
4 <sup>th</sup>	325	24.9	2.0 (1.2-3.4)
<i>Most deprived quintile</i>	314	28.6	2.4 (1.5-4.1)
<b>Household income</b>			
<i>Highest income quintile</i>	317	12.4	1 (ref)
4 <sup>th</sup>	375	15.2	1.3 (0.8-1.9)
3 <sup>rd</sup>	470	20.9	1.9 (1.2-2.8)
2 <sup>nd</sup>	478	31.1	3.2 (2.0-4.9)
<i>Lowest income quintile</i>	496	25.2	2.4 (1.5-3.8)
<b>Lone parenting</b>			
<i>Coupled parents (reconstituted or natural)</i>	2008	19.4	1 (ref)
<i>Lone parent</i>	230	31.6	1.9 (1.3-2.9)
<b>Mother education</b>			
<i>At least degree level</i>	880	12.8	1 (ref)
<i>Lower than degree</i>	1345	25.3	2.3 (1.7-3.1)
<b>Mother employment</b>			
<i>Employed</i>	1643	20.1	1 (ref)
<i>Unemployed</i>	585	25.1	1.3 (1.0-1.8)
<b>Tenure</b>			
<i>Owns home</i>	1772	17.3	1 (ref)
<i>Rents home or other tenure situation</i>	465	29.7	2.0 (1.5-2.8)

### 2.3 Chapter 2: Summary of findings

Experiencing socio-economic disadvantage in the early years is associated with higher obesity prevalence, although differences in overweight are small. For example, a very similar proportion of 14 year olds who were living in lowest and highest income quintile households at age 4 were overweight (~17%), whereas for obesity the difference in proportions was far larger (25% vs. 12%).

Inequality in obesity increases with age. For example, the percentage point difference in obesity between the low and high income households rose from 5% at age 4 to 13% at 14 years.

Nevertheless, inequalities are seen across the entire socio-economic gradient, meaning that childhood obesity is by no means confined to the most disadvantaged households or areas. Furthermore, disadvantages experienced in combination, such as living in the lowest income

## Obesity from early childhood to adolescence in Scotland

households in the most deprived quintile of areas, are associated with a particularly high obesity prevalence at age 14 (31%).

## Results Chapter 3: Inequalities in longitudinal patterns of overweight and obesity

### 3.1 What is already known?

Alongside inequalities in the prevalence of obesity at different ages, seen in the previous chapter, there are inequalities in the way in which BMI changes over childhood.

#### 3.1.1 Inequalities in the persistence of overweight and obesity before Primary school

This is true for changes in weight during toddlerhood. For example, among children born between 2009 and 2013, children in the most deprived quintile of areas were 1.5 times as likely to be at risk of overweight (including obesity) at both their 27-30 month health check, and their P1 measure, than children in more affluent areas<sup>18</sup>.

#### 3.1.2 Inequalities in the persistence of overweight and obesity during Primary school

Inequalities are also clear in the persistence of overweight (including obesity) during primary school. Children who experienced longer durations of household poverty and lone parenting, or whose mothers had no educational qualifications, were more likely to experience persistently high or increasing risk of overweight and obesity between ages 4 and 10.<sup>15</sup> Furthermore, GUS children in the most deprived quintile of areas were 50% more likely to experience persistently high or increasing overweight between ages 6 and 10 than children in the least deprived areas.<sup>16</sup>

New analyses of GUS allow us to look in more detail at inequalities in how BMI status changes over childhood and to extend these analyses into adolescence.

### 3.2 Inequalities in BMI-trajectory beyond Primary school

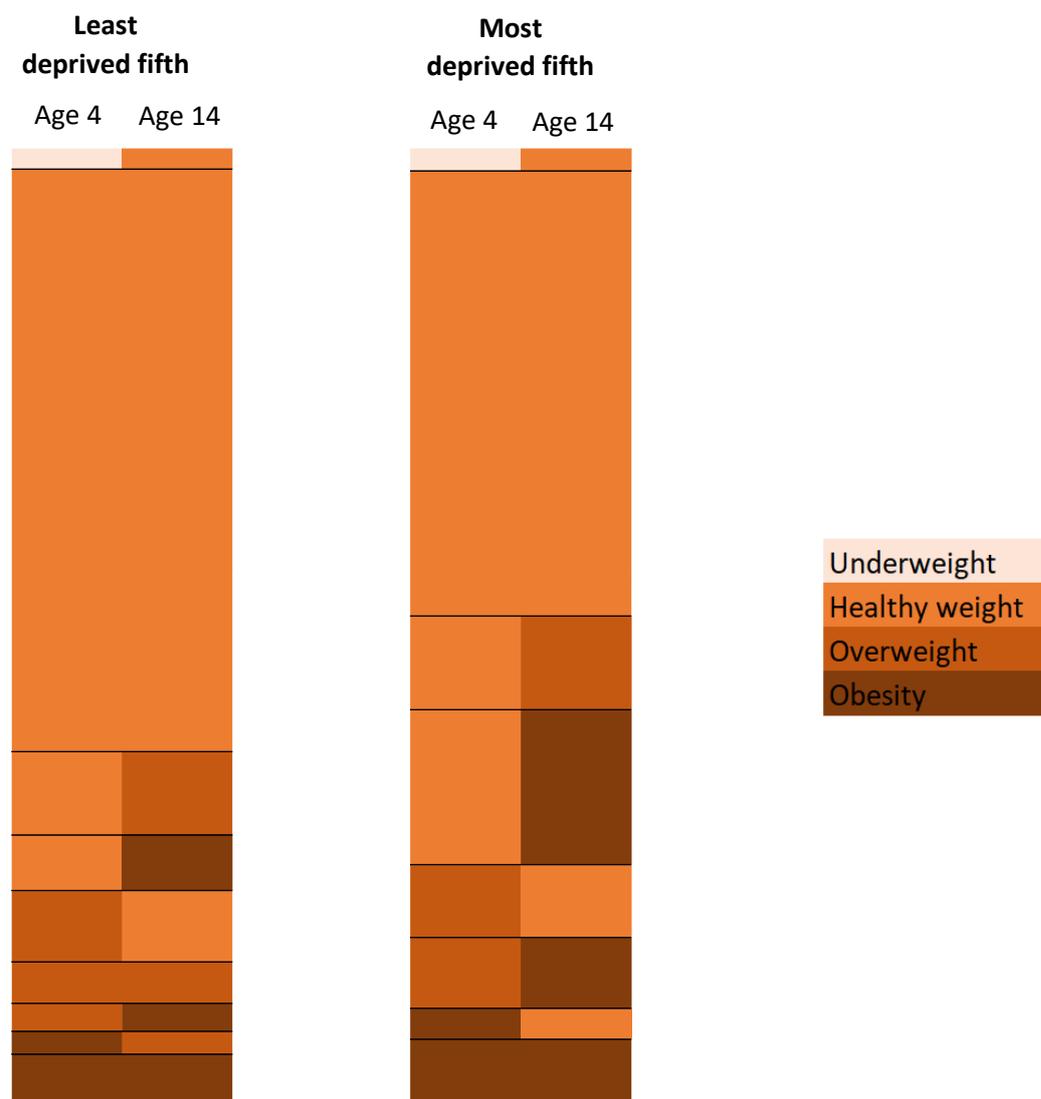
Children living in the most deprived quintile of areas at the start of primary school (age 4) were more likely to experience obesity at age 14 than children in the least deprived areas, no matter what BMI status they experienced at the start of Primary school.

The barchart in Figure 13 shows the proportion of children living in the least deprived areas (left hand bar) and most deprived areas (right hand bar), based on their experiences of overweight and obesity, at age 4 (the left half of each bar) and 14 (the right half of each bar). The proportions in each combination of weight status at age 4 and 14, accept for very rare combinations, are shown, in order of appearance, in the table at the foot of the figure. This shows, for example, that 44% children in the most deprived areas were experiencing healthy weights at both ages compared to 58% in least deprived areas.

Inequalities in obesity at age 14, between more and less deprived areas, were largely driven by more children having moved into obesity between the ages of 4 and 14 in the most deprived areas (Figure 13). The larger proportion of children moving into obesity between ages 4 and 14 in more, compared to less, disadvantaged areas additionally means that measures of BMI taken at the start of Primary school (age 4) are even less sensitive predictors of obesity at age 14 in deprived areas than they are in the overall cohort. While this was not formally explored in Chapter 1, this implies that interventions targeting children based on their BMI status at age 4 could widen inequalities (with all else [e.g. intervention uptake and effectiveness] being equal).

The proportion of children who experienced persistent obesity was only moderately higher in the most compared to the least deprived quintile of areas (5% and 6% respectively, sex-adjusted odds ratio 1.4, 95% CI 0.5-4.4, see Appendix 6).

**Figure 13: Movements between underweight, healthy weight, overweight and obesity\*, ages 4 and 14, children in the least (n=437) and most (n=229) deprived area quintiles**



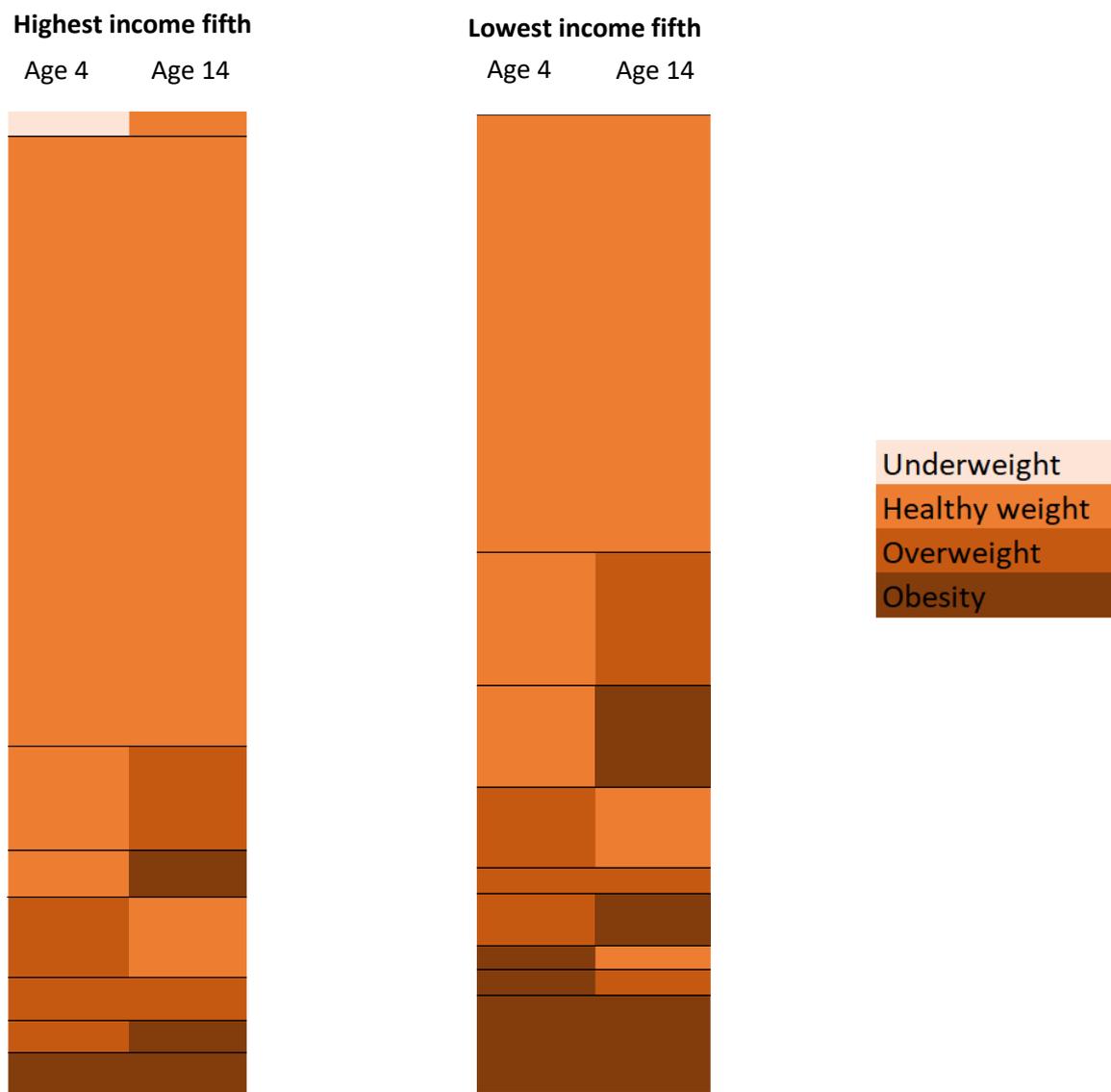
	Most deprived quintile (%)	Least deprived quintile (%)
<i>Underweight at both</i>	<2	<2
<i>Underweight to healthy weight</i>	2	2
<i>Underweight to overweight</i>	<2	<2
<i>Underweight to obesity</i>	<2	<2
<i>Healthy weight to underweight</i>	<2	<2
<i>Healthy at both</i>	58	44
<i>Healthy to overweight</i>	8	9
<i>Healthy to obesity</i>	6	15
<i>Overweight to underweight</i>	<2	<2
<i>Overweight to healthy weight</i>	7	7
<i>Overweight at both</i>	4	<2
<i>Overweight to Obesity</i>	3	7
<i>Obesity to underweight</i>	<2	<2
<i>Obesity to healthy weight</i>	<2	3
<i>Obesity to overweight</i>	2	<2
<i>Obesity at both</i>	5	6

\*combinations which were rare (<2%) are not shown in the graphic

## Obesity from early childhood to adolescence in Scotland

When we look at household income, both the proportion of children moving into obesity, and the proportion of children experiencing persistent obesity, is considerably higher among the lowest income quintile than the highest income quintile (Figure 14). Children in the lowest income quintile have 2.6 times greater odds of experiencing persistent obesity than children in the highest income quintile (aOR 2.6, 95% CI 1.2-5.6).

**Figure 14: Movements between underweight, healthy weight, overweight and obesity ages 4 and 14\*, children in the highest (n=376) and lowest (n=233) income quintiles.**



	Highest income quintile (%)	Lowest income quintile (%)
<i>Underweight at both</i>	<2	<2
<i>Underweight to healthy weight</i>	2	<2
<i>Underweight to overweight</i>	<2	<2
<i>Underweight to obesity</i>	<2	<2
<i>Healthy weight to underweight</i>	<2	<2
<i>Healthy at both</i>	58	42
<i>Healthy to overweight</i>	10	13
<i>Healthy to obesity</i>	4	10
<i>Overweight to healthy weight</i>	8	8
<i>Overweight at both</i>	4	3
<i>Overweight to Obesity</i>	3	5
<i>Obesity to underweight</i>	<2	<2
<i>Obesity to healthy weight</i>	2	2
<i>Obesity to overweight</i>	<2	2
<i>Obesity at both</i>	4	10

\*combinations which were rare (<2%) are not shown in the graphic

These analyses have focused on the most and least disadvantaged groups. More detailed analysis of trajectories of BMI-status change across the gradient of area deprivation and household income are described in Appendix 7.

### *3.2.1 Other inequalities in persistent obesity between ages 4 and 14*

Other socio-economic inequalities in the prevalence of persistent obesity between ages 4 and 14, compared to no experience of obesity at either age (those who are healthy weight, overweight and underweight at 4 and 14), are largely of similar magnitude to the inequalities in obesity measured at age 14, after adjusting for sex, described in section 3.2.5 (Appendix 6):

- Children whose mother's highest educational qualification were lower than degree level were 2.5 times as likely to experience persistent obesity (compared to no obesity) than children whose mothers had degree level qualifications.
- Children whose families did not own their home at age 4 were 1.8 times as likely to experience persistent obesity.
- Children living in a single parent household at age 4 were 1.8 times as likely to experience persistent obesity.
- Children whose mothers were not employed when they were 4 years old were 1.5 times as likely to experience persistent obesity.

### *3.3 Chapter 3: Summary of findings*

Children living in more deprived circumstances experience different trajectories of overweight and obesity across Primary school into adolescence. For example, the proportion of children experiencing healthy weight at age 4 and obesity at age 14 was 6% in the least deprived areas and 15% in the most.

A large part of the income and area deprivation inequalities in obesity seen at age 14 were driven by greater movements into obesity among these groups, although persistent obesity was also more common among children in disadvantaged circumstances, especially those from the lowest income households (10% compared to 4% in the highest income households).

The greater movement into obesity between age 4 and 14 in disadvantaged groups means that measures of BMI taken at the start of Primary school in Scotland are less sensitive predictors of adolescent obesity for more deprived groups than more affluent groups.

## Results Chapter 4: Food insecurity

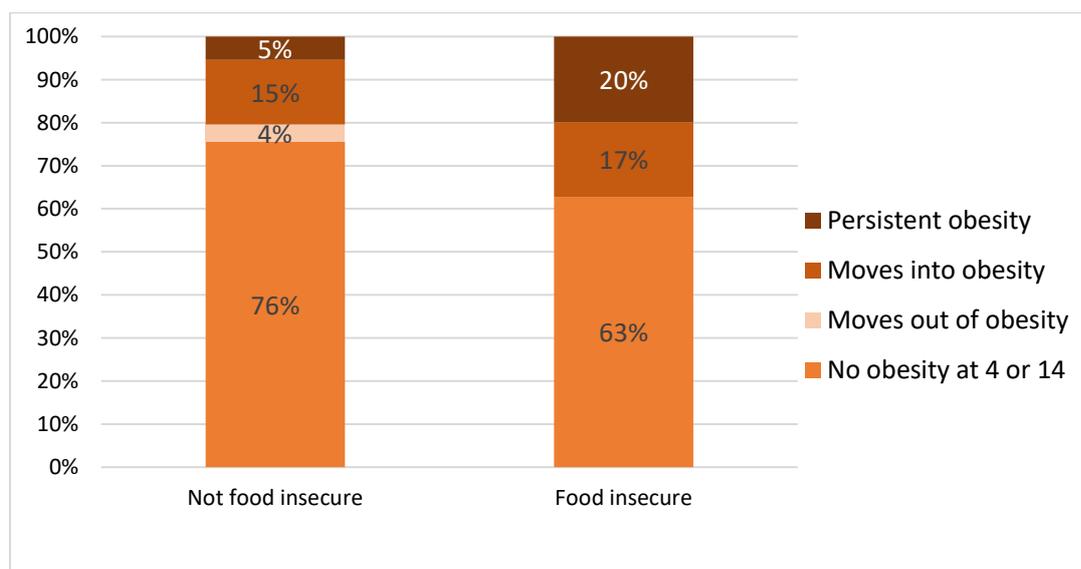
As noted in Chapter 3, there are large socio-economic inequalities in childhood overweight and obesity in Scotland. Food insecurity, which is concentrated in less advantaged groups, is a growing concern for the health and wellbeing of children in Scotland. Food insecurity describes a lack of reliable access to sufficient, nutritious food to meet an individual or household’s needs and preferences<sup>19</sup>. Experiencing food insecurity can mean worrying about food costs or about running out of food, eating less or skipping meals, or relying on low-cost foods or unbalanced meals<sup>20</sup>.

Food insecurity is high in Scotland. Data from 2019/20 suggest that 16% of Scottish households have marginal, low or very low food security, and this rises to 48% of single parent families<sup>21</sup>. A third (34%) of single parents, and over 10% of all families in the 2019-21 Scottish Health Surveys, were worried they would run out of food<sup>22</sup>. These figures likely underestimate current levels of food insecurity, which has been exacerbated by the cost-of-living crisis. Across the UK, food insecurity has doubled among households with children in 2022<sup>23</sup>. One in five UK households with children were forced to rely on low-cost food and imbalanced meals, or did not have enough to eat, due to food and cooking costs in January 2023, affecting 3.7 million children<sup>23</sup>.

Some studies have suggested that food insecurity is a cause of obesity in childhood<sup>24</sup>, however the evidence for this remains mixed<sup>25</sup>. Here we examine the association between food insecurity in childhood and changes in obesity in the Growing Up in Scotland Study.

Food insecurity in toddlerhood (age 2) was experienced by 6% of participating households. Figure 15 shows that 20% of children in food insecure households at age 2 experienced persistent obesity between ages 4 and 14, compared to only 5% of those who were not food insecure at age 2. The proportions experiencing moves into obesity between ages 4 and 14 were similar (17% of those who experienced food insecurity at 2 compared to 15% of those who did not experience food insecurity at 2).

**Figure 15: The prevalence of four BMI-trajectory groups between ages 4 and 14: persistent obesity, moving into obesity, moving out of obesity, and does not have obesity at either time point, by food security measured at age 2 (n=1,695).**



After adjustment for sex and socio-economic circumstances which could confound the relationship (area deprivation, lone parenting and maternal education), children with higher food insecurity were 1.9 times as likely to experience obesity (as opposed to underweight, healthy weight or overweight) at age 4 than those who did not experience food insecurity (95% confidence interval 0.9-3.8) (n= 2086). They were also 1.9 times as likely to experience obesity at age 14 (95% CI 1.1-3.4) (n= 1784). Shockingly, children experiencing food insecurity at age 2 were 4 times as likely to experience obesity at both ages 4 and 14 (compared to at neither age) than children not experiencing food insecurity at age 2 (95% CI 1.8-8.9), after adjustment (n=1684).

#### *4.1 Chapter 4: Summary of findings*

6% of GUS children were classified as being 'food insecure' (mother reported being affected by food costs 'more than a little') at age 2, far lower than levels seen in Scotland the UK today. Nevertheless, we found it to be strongly associated with persistent childhood obesity throughout childhood and adolescence, even after adjustment for area deprivation, lone parenthood and maternal education. For example, children living in food insecure households were four times more likely to be experiencing obesity at both ages 4 and 14.

The cost-of-living crisis has exacerbated barriers to accessing healthy, nutritious food. Therefore, interventions to tackle childhood food insecurity are likely to be particularly pressing in order to address inequalities in obesity during childhood.

## Limitations and Gaps

The Growing Up in Scotland study provides rich information on the circumstances in which children grow up and their health and development during childhood. In this report we have explored how obesity and overweight in Primary school relate to experiences of obesity into adolescence.

### *Other types of inequality: ethnicity and disability*

There are other factors which are known to be important for health in Scotland, but our understanding of how these are related to childhood obesity is limited by shortcomings in the available data. These under researched factors include disability and ethnicity. Studies using the Growing Up in Scotland study to explore inequalities related to ethnicity have previously shown that the association with obesity trajectories is not straightforward, with minority ethnicities overrepresented in the high/increasing obesity group but underrepresented in the high and increasing overweight groups<sup>15</sup>. However small sample sizes necessitate aggregating minority ethnicities into White versus Non-white, which may mask important differences between groups.

### *Co-occurrence of disadvantage*

Furthermore, we know that the co-occurrence of different types of social disadvantage is important in determining health outcomes. In this report we have explored the co-occurrence of area deprivation and low income to some extent, looking at how the experience of living in both the most deprived quintile of areas, and in the lowest income quintile differs to experiencing one of these disadvantages alone. However, this type of analysis focuses heavily on just the most deprived groups, which misses the experiences across the gradient of disadvantage. Furthermore, exploring the co-occurrence of just these two types of disadvantage simplifies the question of how different elements of children's socio-economic circumstances may combine to impact on childhood obesity.

### *Accumulation of disadvantage*

Finally, socio-economic circumstances in this report have been described using measurements taken at age 4 (unless otherwise stated). This does not capture changes in disadvantage with age. For some measures of social disadvantage, such as maternal education, it is unlikely that there will be many changes while the child is at primary school. However, other measures such as household income or maternal unemployment can potentially change substantially over the course of a decade.

We have chosen to focus large on early years' socio-economic measures, to demonstrate the impact that disadvantage experienced early in childhood had well into adolescence. Transient experiences of disadvantage are likely to have different impacts on health to persistent disadvantage, as the impacts of disadvantage accumulate over time. Future research could explore the impacts of persistent poverty over time on childhood obesity and overweight in Scotland.

## Conclusions

In this report we make the most of GUS's longitudinal study design, providing new and important evidence around children's experiences of overweight and obesity up until adolescence.

We find that the prevalence of obesity is already concerningly high by the start of Primary school amongst children in Scotland (as already known from routine reports from PHS). This increases further into adolescence. By age 14, more than one in five GUS children were living with obesity.

Half of GUS children were a healthy weight at both age 4 and age 14. Two in five experienced changes in BMI category between age 4 and 14, the majority of whom increased in BMI.

Focusing on children living with obesity at age 14 shows that one quarter had experienced obesity persistently throughout primary school (at ages 4 and 10) as well as 14. In contrast, nearly half of children living with obesity at age 14 started primary school at a healthy weight and moved into obesity in later childhood or adolescence.

These changes in BMI status between age 4 and age 14 mean that solely using the Primary 1 BMI measures to target interventions or policies may miss as many as seven in ten children who go on to experience obesity in adolescence.

Including a second measure of BMI at age 10 improves the ability to predict obesity at later ages. Targeting an intervention at children who experienced obesity at either ages 4 or 10 captured 40 percentage points more adolescents with obesity than targeting only children who experienced obesity at 4. However, even with this additional BMI measure at age 10, over one third of 14-year-olds experiencing obesity were missed.

Experiencing socio-economic disadvantages in the early years is associated with increased risk of obesity at every age, and inequalities widen for older age groups. The risk of experiencing obesity at age 14 was at least twice as high for those: living in the lowest household income quintile compared to the highest quintile, in the most deprived quintile of areas compared to the least deprived quintile, having a mother with lower than degree level education, living in a rented home, or experiencing lone parenting at age 4. The risk is especially raised for children experiencing both income *and* area-based deprivation at the start of Primary school, who experienced a 3.5 times higher risk of obesity at age 14 than children in the most affluent income and area-deprivation quintiles.

Socio-economic disadvantage was additionally associated with increased risk of experiencing persistent obesity over Primary school and into adolescence. For example, children in the lowest household income quintile at age 4 were 2.6 times as likely to experience obesity at both age 4 and age 14 compared to no obesity at either age.

Food insecurity among children is of growing concern, with increasing numbers of families facing financial barriers to accessing sufficient, good quality food. The 6% of GUS participants who experienced food insecurity (being affected 'more than a little' by food costs) as a toddler had a quadrupled risk of living with persistent obesity between ages 4 and 14, even after accounting for sex and socio-economic circumstances (area deprivation, lone parenting and maternal education).

Without action to address high rates of obesity, especially among children living in disadvantaged circumstances, Scotland risks establishing health conditions and health inequalities at early ages that are likely to persist and widen into adulthood.

The findings from this report highlight the limited value of using BMI in the early years to target interventions, since many of these children would not be expected to continue to experience overweight and obesity, while many others would only go on to develop obesity at later ages. Preventative measures are required at the population level, while providing greater support to those experiencing social disadvantage. Addressing food insecurity, which is far higher now than it was when the GUS children were growing up, is one essential area for action.

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## Appendices

### 1. Description of GUS sample at age 4:

**Table A1: Characteristics of the Growing Up in Scotland Study sample included in the study (who were followed up to age 14).**

Characteristic	n (Unweighted)	% (Weighted)
<b>Sex</b>		
Male	1130	50.9
Female	1108	49.1
Missing	0	0
<b>Area deprivation</b>		
Least deprived quintile	567	19.2
2 <sup>nd</sup>	531	20.4
3 <sup>rd</sup>	501	20.9
4 <sup>th</sup>	325	16.7
Most deprived quintile	314	22.7
Missing	0	0
<b>Household income quintile</b>		
Highest quintile (£>37,500)	496	16.0
4 <sup>th</sup> (£25,625-37,500)	478	16.6
3 <sup>rd</sup> (£19,444-25,625)	470	19.3
2 <sup>nd</sup> (£11,875-19,444)	375	19.4
Bottom quintile (£<11,875)	317	23.6
Missing	102	5.0
<b>Family structure</b>		
Lone parent household	230	18.8
Parent in couple in household	2008	81.2
Missing	0	0
<b>Tenure</b>		
Owns home	1772	64.7
Rents home or other	465	35.2
Missing	1	<0.1
<b>Highest maternal education</b>		
Degree or higher	880	28.3
Lower than degree	1345	71.0
Missing	13	0.8
<b>Maternal employment</b>		
Employed	1643	65.5
Not employed	585	34.0
Missing	10	0.6
<b>Total</b>	<b>2238</b>	<b>100</b>

## 2. Comparing systems for defining overweight and obesity.

Body Mass Index (BMI) is a simple measure of weight adjusted for height that is commonly used to compare risk of overweight and obesity among children. BMI is difficult to interpret in isolation but becomes useful when compared to the distribution of scores of a standardised reference population<sup>26</sup>. This method measures how far a child's BMI is from the average given their sex and age, and so creates a relative measure of overweight and obesity.

There are multiple possible systems for categorising BMI measures into underweight, healthy weight, overweight and obesity which have been developed for use among children. In this study we have used children's BMI standardised using the BMI distribution for 37,000 British children measured in 1990. An alternative system uses thresholds termed the International Obesity TaskForce (IOTF) cut-offs. These use a different reference population, that includes children and young adults aged 0-25 from six different countries including the UK. There is no consensus over which measure gives the most accurate reflection of overweight and obesity among the population using BMI, and both have been used in published literature.

When we apply these two systems to data in the Growing Up in Scotland Study, we see that the UK 1990 reference system suggests a prevalence of obesity that is more than double the prevalence suggested by the international reference thresholds (Table A2). This is a substantial difference that may explain some differences in published literature exploring the prevalence and risk factors for obesity using the Growing Up in Scotland Study.

**Table A2: Prevalence of each weight category in the Growing Up in Scotland Study using the UK 1990 population as a reference or the International Obesity Taskforce as a reference.**

	Prevalence at age 4 (%)		Prevalence at age 10 (%)		Prevalence at age 14 (%)	
	UK 1990 reference	IOTF reference	UK 1990 reference	IOTF reference	UK 1990 reference	IOTF reference
Underweight	2.5	*	1.8	*	2.4	*
Healthy weight	72.4	80.5	64.5	73.3	60.4	71.0
Overweight	15.1	15.6	15.2	20.0	15.4	19.2
Obesity	10.1	3.9	18.5	6.7	21.7	9.8

\*combined with healthy weight

For the main results of this report, we have used the UK 1990 reference curves for two key reasons. Firstly, this measurement allowed the identification of children experiencing underweight in the Growing Up in Scotland Study, whereas using the international reference system meant that underweight BMI z-scores were aggregated with healthy weight z-scores in the comparison group. Secondly, the 1990 UK reference curves are used in the reporting of the national Primary One measurements in Scotland<sup>27</sup>, so using this threshold makes our data more comparable to that national dataset.

BMI measures have received some criticism for being less accurate in predicting poor health and adiposity than alternative measures assessing body fat composition<sup>28</sup>. For example, an athlete with a high muscle percentage can be classed as overweight despite having low body fat. This limits the utility of BMI at an individual level for diagnosing obesity or predicting health risks, however BMI remains the preferred, non-invasive method to assess trends in overweight and obesity in children at a population level<sup>26 29</sup>. Nevertheless, a study compared the accuracy estimating obesity using BMI and 1990 UK reference data to a method assessing body fat composition (measuring skinfold thickness) and found that BMI may

## Obesity from early childhood to adolescence in Scotland

underestimate obesity at a population level<sup>30</sup>. Therefore, it is important to note that figures presented in this report may be conservative estimates for the prevalence of obesity and overweight among Scottish children.

### 3. Comparing P1 and GUS measures:

National weight measurements are taken among children in Primary 1 (aged 4-5 years) annually in Scotland. These measures aim to cover the entire population of children in Scotland, and therefore has the potential to act as a gold standard reference for the prevalence of obesity and overweight in Scotland. For this reason, we have compared the prevalence of obesity at age 4 in the Growing Up in Scotland (GUS) study (measurements which were taken in 2008/9) to the P1 measurements of similarly aged children in the same year. However, it is important to note that the national P1 measure had reasonably low coverage in 2008/9 (62.2%)<sup>31</sup> and may not be representative of children in Scotland. It is likely that the same children who are less likely to be represented in the GUS study are less likely to be measured in the P1 dataset, and therefore any agreement between the surveys does not mean that they are completely free from bias.

Overall, the prevalence of obesity is similar between the P1 measures and the GUS measures (9.3% compared to 10.1%), although the prevalence of overweight in GUS is higher (15.1% compared to 11.6%). The magnitude of these differences is similar when divided into the most and least deprived quintiles of areas (table A3).

**Table A3: Prevalence of underweight, healthy weight, overweight, and obesity, among the whole population and different area deprivation quintiles, comparing estimates from the 2008/09 school year Primary 1 (P1) national measurement programme and the Growing Up in Scotland Study.**

	All areas		Most deprived quintile of areas		Least deprived quintile of areas	
	P1 measure in 2008/09 (4 to 5-year-old children) <sup>2</sup>	GUS measure in 2008/09 (4-year-old children)	P1 measure in 2008/09 (4 to 5-year-old children) <sup>2</sup>	GUS measure in 2008/09 (4-year-old children)	P1 measure in 2008/09 (4 to 5-year-old children) <sup>2</sup>	GUS measure in 2008/09 (4-year-old children)
<b>Underweight</b>	*	2.5%	*	3.9%	*	3.0%
<b>Healthy weight</b>	79.1%	72.4%	77.2%	68.3%	82.6%	74.2%
<b>Overweight</b>	11.6%	15.1%	11.6%	15.8%	10.4%	14.2%
<b>Obesity</b>	9.3%	10.1%	11.2%	12.0%	7.0%	8.6%

\*Combined with healthy weight

4. Movements in BMI status between age 4 and age 14, stratified by sex.

**Table A4: The prevalence of each BMI status trajectory between ages 4 and 14, for all children, boys and girls.**

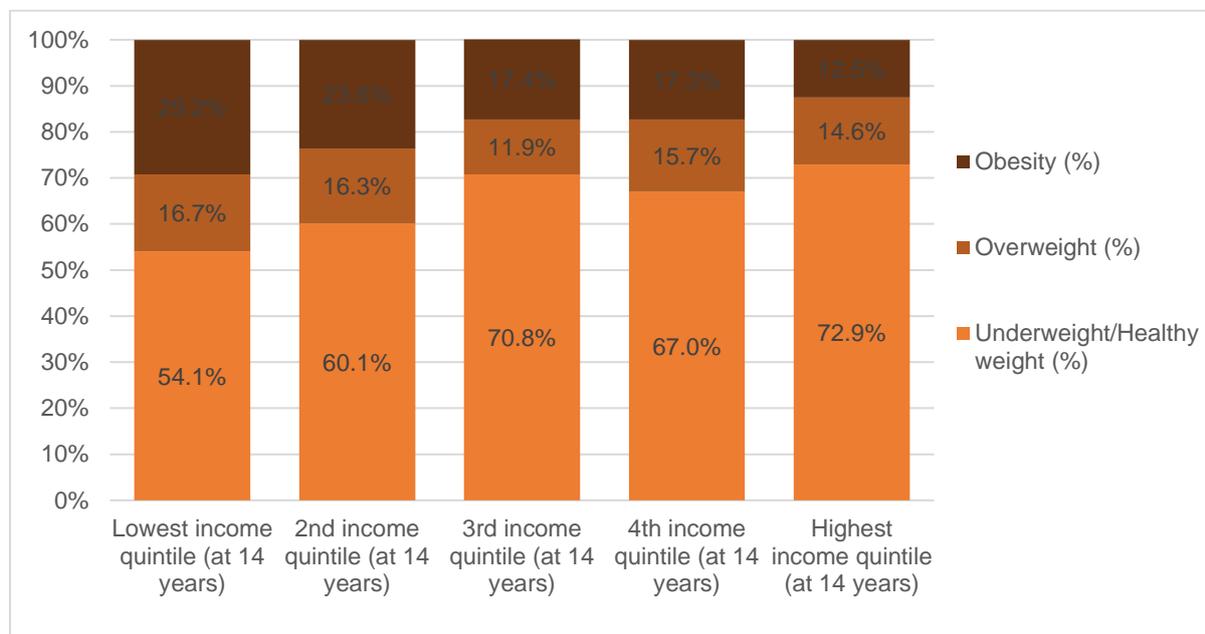
The left-hand side of the table shows the prevalence of each BMI status at age 4, for all children and for boys and girls in the Growing Up in Scotland Study. The right hand four columns show the prevalence of each trajectory in weight from BMI at age 4 to BMI at age 14.

Prevalence at age 4				Prevalence at age 14, by prevalence at age 4			
	All	Boys	Girls		All	Boys	Girls
Underweight (%)	3	2	3	<i>Underweight at 4y</i>			
				Underweight (%)	<2	<2	<2
				Healthy weight (%)	<2	<2	<2
				Overweight (%)	<2	<2	<2
				Obesity (%)	<2	<2	<2
Healthy weight (%)	72	71	74	<i>Healthy weight at 4y</i>			
				Underweight (%)	2	2	*
				Healthy weight (%)	50	49	52
				Overweight (%)	11	10	11
				Obesity (%)	10	10	11
Overweight (%)	15	17	13	<i>Overweight at age</i>			
				Healthy weight			
				/Underweight* (%)	7	9	5
				Overweight (%)	3	3	3
				Obesity (%)	5	5	5
Obesity (%)	10	10	11	<i>Obesity at age 4y</i>			
				Underweight (%)	<2	<2	<2
				Healthy weight (%)	2	<2	2.2
				Overweight (%)	<2	<2	<2
				Obesity (%)	6	6	7
Total	100%	100%	100%		100%	100%	100%

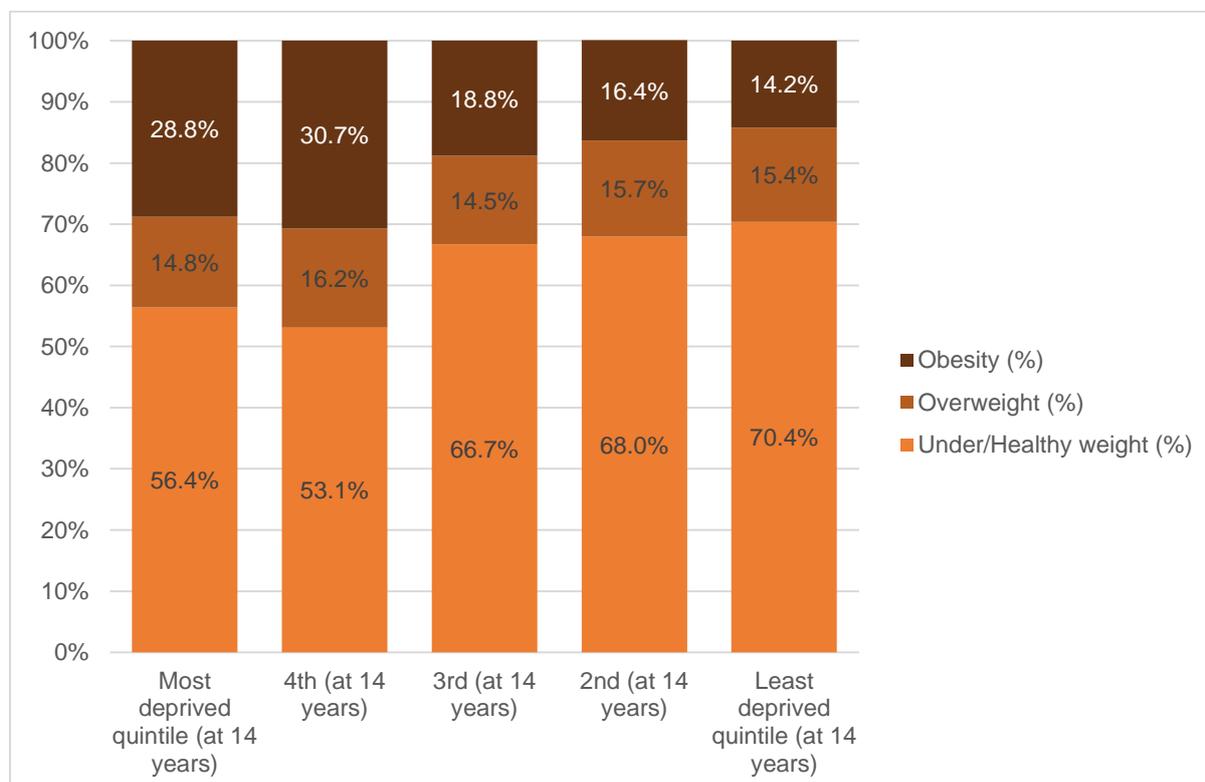
\*Underweight combined with healthy weight due to small cell sizes

5. Association between socio-economic circumstances measured at age 14, and BMI status at age 14.

**Figure A1:** The prevalence of healthy weight (or underweight), overweight and obesity at age 14, by household income quintile measured at age 14, among children in the Growing Up in Scotland Study.



**Figure A2:** The prevalence of healthy weight (or underweight), overweight and obesity at age 14, by SIMD quintile measured at age 14, among children in the Growing Up in Scotland Study.



6. *Associations between socio-economic circumstances in the early years and obesity at 14, or persistent obesity between ages 4 and 14*

Every measure of social disadvantage included is associated with an increased risk of obesity at age 14, and similarly with an increased risk of persistent obesity between ages 4 and 14 compared to no obesity experience, after adjusting for sex. The magnitude of associations is similar for each outcome.

**Table A5: Association between six measures of socio-economic circumstances, measured at age 4, with obesity prevalence at age 14, and persistent obesity between ages 4 and 14 in the Growing Up in Scotland Study.**

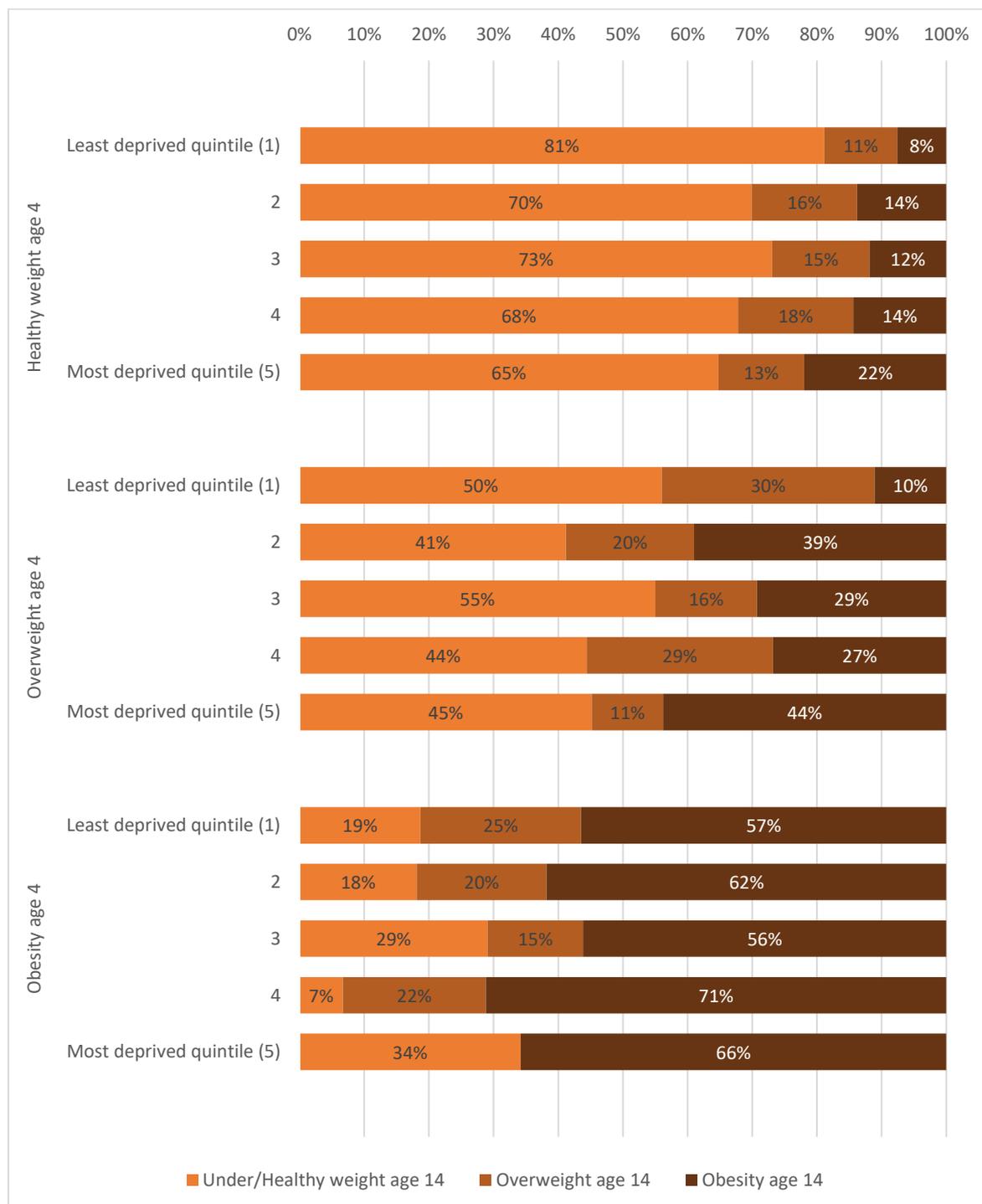
	<b>Association with obesity at age 14 (Sex-adjusted odds ratio (95% Confidence Interval))</b>	<b>Association with persistent obesity between 4 and 14, compared to no experience of obesity (Sex-adjusted odds ratio (95% Confidence Interval))</b>
<b>Area deprivation</b>		
Least deprived quintile	1 (ref)	1 (ref)
2 <sup>nd</sup>	1.7 (1.0-2.7)	1.1 (0.4-3.2)
3 <sup>rd</sup>	1.4 (0.9-2.3)	1.0 (0.4-2.9)
4 <sup>th</sup>	2.0 (1.2-3.4)	2.0 (0.7-5.9)
Most deprived quintile	2.4 (1.5-4.1)	1.4 (0.5-4.4)
<b>Household income</b>		
Highest income quintile	1 (ref)	1 (ref)
4 <sup>th</sup>	1.3 (0.8-1.9)	0.7 (0.3-1.6)
3 <sup>rd</sup>	1.9 (1.2-2.8)	1.6 (0.8-3.3)
2 <sup>nd</sup>	3.2 (2.0-4.9)	1.9 (0.7-5.0)
Lowest income quintile	2.4 (1.5-3.8)	2.6 (1.2-5.6)
<b>Lone parenting</b>		
Coupled parents (reconstituted or natural)	1 (ref)	1 (ref)
Lone parent	1.9 (1.3-2.9)	1.8 (0.8-4.0)
<b>Mother education</b>		
At least degree level	1 (ref)	1 (ref)
Lower than degree	2.3 (1.7-3.1)	2.5 (1.4-4.3)
<b>Mother employment</b>		
Employed	1 (ref)	1 (ref)
Unemployed	1.3 (1.0-1.8)	1.5 (0.8-2.7)
<b>Tenure</b>		
Owns home	1 (ref)	1 (ref)
Rents home or other tenure situation	2.0 (1.5-2.8)	1.8 (1.0-3.4)

*7. Movement between BMI categories between ages 4 and 14, across the gradient of area deprivation and household income*

Children who are experiencing obesity at age 4 are generally more likely to experience persistent obesity if they live in more deprived areas or lower income household, and children who do not experience obesity at age 4 are generally more likely to move into the obesity group by age 14 if they experience these disadvantages.

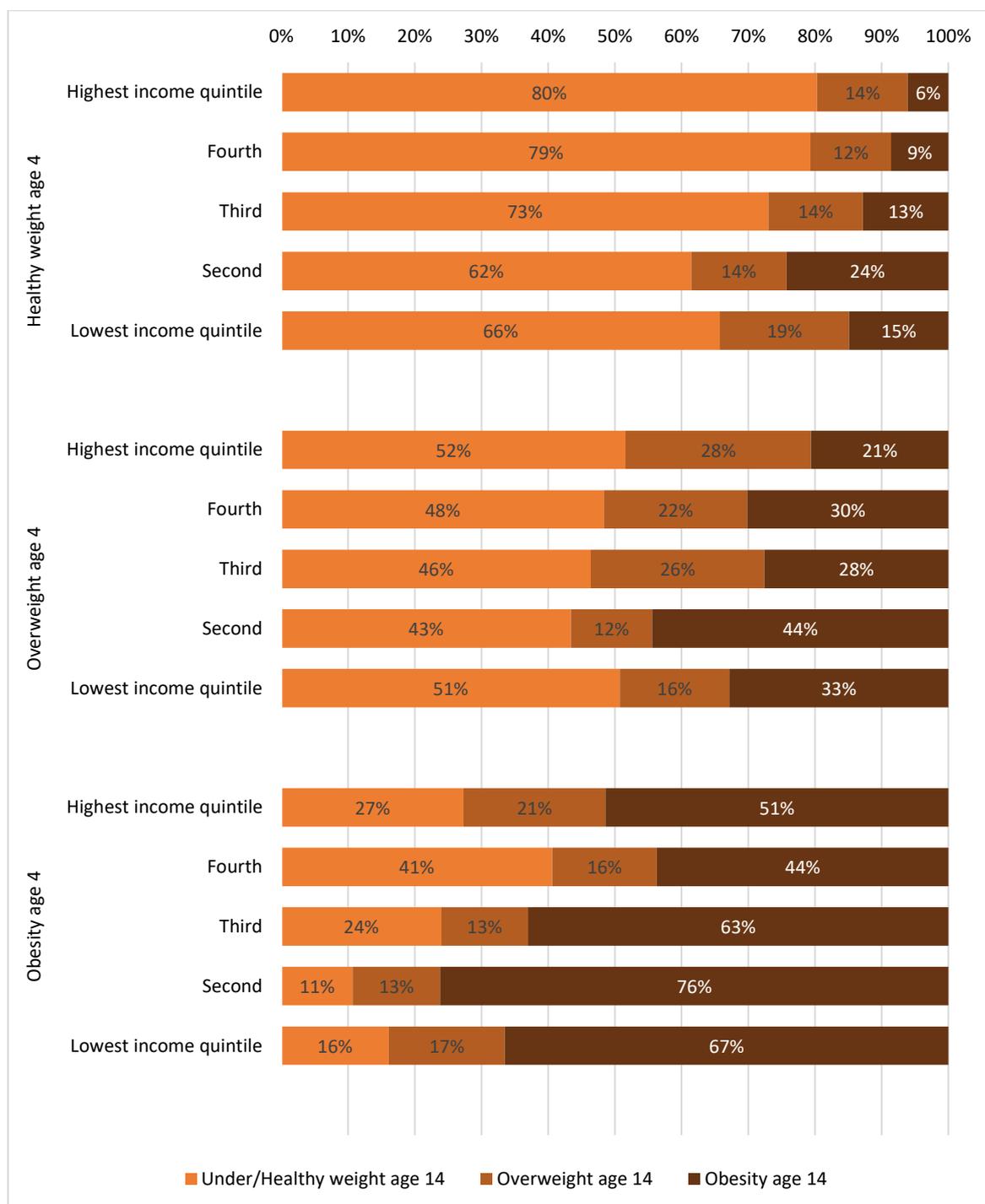
The results in the following two graphs show how the relationship between BMI status at age 14 and area deprivation and income is not strictly linear, with the second most disadvantaged quintile sometimes showing the highest risk, by small margins. This may be the result of sample bias or small numbers.

**Figure A3: The prevalence of healthy weight (or underweight), overweight and obesity at age 14, stratified by area deprivation quintile and BMI status at age 4<sup>^</sup>, among children in the Growing Up in Scotland Study.**



<sup>^</sup>underweight at age 4 not presented due to small numbers

**Figure A4: The prevalence of healthy weight (or underweight), overweight and obesity at age 14, stratified by household income quintile and BMI status at age 4<sup>^</sup>, among children in the Growing Up in Scotland Study.**



<sup>^</sup>Underweight at age 4 not presented due to small numbers

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