Short and Long-run Effects of Obesity on Cognitive Skills: Evidence from an English Cohort

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Abstract

This paper investigates the consequences of obesity on individuals' cognitive ability using data from the British Cohort Study. Specifically, it focuses on the outcomes of two cognitive tests: the B.A.S. (British Ability Scale), taken when cohort members are 10 years old, and a basic (literacy and numeracy) skills test, sit at age 34.

The analysis is performed using both the individuals' BMI (Body Mass Index) and an indicator for the obesity condition as measures of body weight and, for the test taken in adulthood, the impact of past weight status is also evaluated.

In order to understand whether the influence of obesity is causal, we employ instrumental variables, using both parents' BMI as instruments for cohort members' BMI. Even after controlling for a large set of covariates describing individuals' family environment, our results show that weight excess has a significant negative causal effect on cognitive skills, both in childhood and in adulthood. Moreover, childhood obesity has a long-run impact on skills at age 34.

Keywords: Health, Obesity, Body Mass Index, Cognitive Ability
JEL Classification: I12, I14, J62

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1. Introduction

Recent medical research[1] has proved the existence of a negative relationship between obesity and cognitive skills, finding out that the Intelligent Quotient (IQ) and fatness are negatively correlated.

Also in the economics literature some studies analyzed the consequences of obesity on cognitive ability, measured by standardized tests, and educational outcomes, such as school performance (e.g. Datar, Sturm and Magnabosco, 2004; Kaestner and Grossman, 2009; Cawley and Spiess, 2008).

We investigate this issue using data from the British Cohort Study, which follows a cohort of U.K. individuals from their birth, in 1970, until nowadays. This longitudinal dataset provides information about the results of two cognitive tests: the British Ability Scale (B.A.S.), sit in 1980 when individuals were 10 years old, and a basic skills test, taken in 2004 when they were 34. In the same years data about individuals' BMI are recorded[2]. Therefore, we can study the impact of current BMI levels on both the individuals' test scores. Moreover, we can evaluate the lagged effect of the BMI in 1980 on the basic skills test performed in 2004, and study whether a change in the weight status from childhood to adulthood affect the test result.

The topic has a great relevance since cognitive ability and basic skills are important determinants of individual's productivity and economic outcomes. For this reason, policies targeted to reduce obesity rates may have economic implications that go beyond the well-known savings in health expenditure.

Several studies have indeed highlighted the negative effect of weight excess on wages and employment probability. However, not enough attention has been put on the channels driving these relationships: a decline in cognitive ability caused by obesity might explain part of the wage and employment gap found between obese and non-obese workers.

Therefore, our contribute aims to complement this strand of literature, shedding new light on the potential origins of such disparities.

In turn, the relationship between weight excess and individuals' test scores can be driven by several mechanisms. First of all, obesity could cause a decline in cognitive ability. One possible medical explanation is that the hormones secreted by fat could damage brain's cells (Cournot M. et al., 2006). Cognitive problems can also follow from deficiencies of certain micronutrients such as zinc, iron and iodine (Taras, 2005) for which overweight people may

[1] Archana Singh-Manoux et al. (2012), Cournot M. et al. (2006), Thompson P.M. et al. (2010).

[2] BMI values are self-reported. As shown by O'Neill and Sweetman (2012), self-reported BMI is subject to a significant measurement error that is negatively correlated with the true measure of BMI. This may lead to an overestimation of the relationship between BMI and the outcome under analysis.

be at risk because of the consumption of cheap, energy-rich but nutrient-poor food (Nead et al. 2004). Moreover, it is well known that weight problems are responsible for many chronic diseases (such as cardiovascular diseases, hypertension, sleep disorders, etc.) that could alter cognitive functioning.

Obesity may also have adverse psychological effects. Strauss (2000) found a positive correlation between weight problems and low self-esteem, while Faith, Matz and Jorge (2002) documented a positive association linking depression with obesity. Psychological problems, as well as health disorders, could be responsible for a decline in cognitive functioning.

Finally, weight excess could harm the human capital accumulation. For example, obese children are more likely to be absent from school than non-obese (Geiner et al. 2007), they can be discriminated by teachers (Redline et al. 1999) and bullied by their peers. This can negatively influence their learning environment, resulting in a lower educational achievement, which is important in determining cognitive ability. Moreover, educational attainment affects the probability of finding a good job, which in turn can influence the level of skills acquired at the workplace.

However, the association between obesity and cognitive skills might be driven also by unobservable confounders, like personal characteristics and the family environment that can simultaneously affect both the individual's weight and cognitive ability. In particular, parental cognitive skills[3], socio-economic position, psychological condition, and attitudes toward education might be important omitted variables.

Part of the relationship linking obesity and cognitive ability could also be explained by reverse causality: differences in cognitive ability might cause differences in adiposity. Individuals with lower IQ and education might be less able to acquire and process health information and can therefore choose unhealthy behaviours and lifestyle that may lead to obesity. In addition, it is possible that they are more likely to suffer from psychological discomfort: discrimination, lower popularity and engagement in social activities could induce depression and over-eating.

We address the unobserved heterogeneity and the reverse causality issues by means of instrumental variables. Following the approach by Sabia (2007) and Averett and Stiefel (2007) we instrument individual's BMI with their relatives' BMI.

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[3] De Coulon, Meschi and Vignoles (2008) showed that parents' basic skills in literacy and numeracy have a positive significant effect on their children's cognitive test scores, over and above the positive effects of parental education.

Parental BMI was previously used as an instrument for offspring's BMI by Cawley (2000, 2004) and Brunello and d'Hombres (2005) that, however, focused on wages and employment disability as outcomes of interest.

The first requirement for the model identification is that parent's BMI is strongly correlated with that of their offspring (conditional on other covariates). This is likely to be the case as showed by recent research[4].

The second identification assumption requires that parental BMI is not correlated with unobservable determinants of children cognitive ability. This hypothesis could be problematic if parental obesity is correlated with some family-level environmental characteristics that can influence children cognitive skills. However, as highlighted by Cawley (2004) there is little empirical evidence of the effect of a common household environment on BMI: genetics rather than the family context is the key factor in explaining body weight. Despite this evidence, in order to enhance the credibility of our instrument, we control for a large set of variables describing parents' socio-economic status, psychological condition and attitudes toward schooling, which are available in our dataset.

We shed new light on the causality of the link existing between weight problems and individual's cognitive skills using for the first time in this kind of literature data from the British Cohort Study of 1970 (BCS70). This dataset contains information about the BMI of *both* the parents of the cohort members: the availability of two instrumental variables guarantees an efficiency gain in the estimation and provides us with an additional element to check their validity, that is, the possibility to perform an over-identification test. This was not possible in the studies mentioned above, using just one relative's BMI as an IV for the individual's BMI. Moreover, the BCS70 allows us to control for many important variables describing the family environment that were often missed in the previous literature.

Another novelty lies in the fact that we focus in the same paper on two different cognitive tests, one taken in childhood and the other in adulthood. The analysis we carry out on the link existing between the weight status and the cognitive skills of adult persons is particularly relevant since, at our knowledge, all of the preceding economic studies about this topic has focused on samples of children and school-aged individuals.

The panel structure of our data provides us with two different observations of individuals' BMI, one in 1980, when cohort members are 10 years old and the other in 2004, when they are 34. Therefore, in addition to the effect of current BMI on each of the tests' score, we can

[4] See Comuzzie and Allison (1998) and Castelnovo (2013)

study both the impact of lagged BMI and the implications of a change in the weight status (from childhood to adulthood) on the test performed in 2004.

The outline of this paper is as follows. Section 2 contains a literature review; the data used are described in section 3, while section 4 presents the empirical models and the estimation strategies employed. In section 5 we show our results. Conclusions follow.

2. Literature Review

It is well known from the medical literature that obesity has important negative consequences on individuals' health. This has in turn relevant economic implications that have drawn the attention of economists, who initially focused on the effect of obesity on outcomes like wages and employment. Within this literature we can distinguish between studies investigating the existence of a simple association between weight excess and economic outcomes and those trying to understand whether such relationship is actually causal.

One of the first papers looking at the consequences of obesity on wages is Sargent and Blanchflower (1994), that showed a negative association between obesity at 16 years and earnings at 23 for British women but not for men. Female adolescents who were in the top 10% of the BMI distribution at age 16 earned 7.4% less than their non-obese peers and those in the top 1% earned 11.4% less, while no statistically significant effect is found for males.

Han, Norton and Powell (2009) highlight the existence of a negative correlation between late teen BMI and future wages also in the U.S. and distinguish between the direct BMI wage penalty, operating through employers' discrimination, and the indirect effects driven by poor educational and occupational choices. Their results show a total 0.96% decrease in wages for each additional unit of late teen BMI among women. A significant portion of the total wage penalty is due to the indirect effects of BMI that occurs prior to employment. As in Sargent and Blanchflower (1994), they didn't find a significant direct effect of BMI on wages for men. However, they showed that higher levels of late teen BMI for men slightly decrease hourly wages via the indirect pathways of education and occupational choice.

Focusing on several economic outcomes (employment probability, hours worked and earnings), Cawley and Danziger (2005) found that high body weight is a great barrier to labor market success for white women but not for African-American women.

All of the studies cited until now established the existence of a negative correlation between weight and labor market outcomes, but provide no evidence of a causal effect, since they do not account for the potential endogeneity of individuals' BMI.

Cawley (2000) is probably the first one facing this issue, using a sibling's BMI as an instrument for individual's own BMI. His outcome of interest was the employment disability and his results revealed that the body weight had no causal effect on it.
The same IV approach was used in Cawley (2004), where the author studied the effect of BMI on wages. Using data from the National Longitudinal Survey of Youth (NLSY) he showed that weight had a negative causal impact only on white females' wages. No evidence was instead found for males and black females.
On the contrary, using data from 9 E.U. countries and the average of relatives' BMI as an instrument, Brunello and d'Hombres (2005) concluded that the causal impact of obesity on wages is independent of gender dimension. It is negative and statistically significant for countries belonging to the "olive belt" and positive for Northern and Central Europe States.
A different instrument, that is the genetic markers (whose validity will be discussed later on in this paper), is employed in Norton and Han (2008), that found no causal effect of obesity on neither employment probability nor wages.

More recently, economists have focused their research also on the potential relationship existing between weight excess and academic or cognitive achievements. This issue has been investigated at different points of individuals' life, from early childhood to university-age students. Also in this case, it is possible to distinguish between studies establishing a simple correlation and those looking for a causal effect, which are a small minority. As made clear in the following, the evidence provided is unclear.
Cawley and Spiess (2008) evaluated skill attainment in children from 2 to 4 years old, finding that, among boys, obesity is associated with reduced verbal, social and motor skills, while for girls it is associated only with reduced verbal skills.
The link between weight excess and the academic performance of U.S. elementary school children was examined by several authors. Datar, Sturm and Magnabosco (2004) showed that overweight children had significantly lower math and reading test scores compared with non-overweight peers in kindergarten and at the end of grade 1. However, these differences, except for boys' math scores became insignificant after controlling for socioeconomic and behavioral variables, suggesting that overweight is a marker but not a causal factor.
Datar and Sturm (2006) focused on several outcomes (math and reading standardized test scores, school absences, grade repetition) showing that becoming overweight during the first 4 years in school is a significant risk factor for adverse school outcomes among girls but not among boys.

Different findings are obtained by Kaestner and Grossman (2009) using a sample of U.S. children's aged 5-12 years and the Peabody Individual Achievement Tests in math and reading as an outcome. Their results suggest that, in general, overweight and obese children get achievement test scores that are about the same as children with average weight.

Contrasting results are obtained also by the studies focusing on adolescents and high school students. Sigfusdottir, Kristjansson and Allegrante (2007) explored the relationship between health behaviours and academic achievement in Icelandic 14- and 15-year old students. They showed that, even after controlling for several covariates (gender, parental education, family structure and absenteeism), BMI, diet and physical activity still explained up to 24% of the variance in academic achievement

As highlighted by Fuxa and Fulkerson (2011), overweight and obese U.S. adolescents are significantly less likely to plan to go to college and more likely to report skipping school and to have lower academic grades than non-overweight peers. Similarly, Karnehed et al. (2006) found that in Sweden 18 years old obese students are 50% less likely to get into higher education. On the contrary, Kaestner, Grossman and Yarnoff (2009) found that overweight or obese U.S. adolescents aged 14-18 years have levels of attainment (measured by the highest grade attended, the highest grade completed and the drop out status) that are about the same as teens with average weight.

Finally, Okunade, Hussey, Karakus (2009) suggested no adverse impact of overweight or obesity on timely high school completion for males, but a significant average negative effect on females, in particular white and Asian females.

Even if several authors have focused on the link between weight problems and educational or cognitive achievements, only few of them have investigated the causality of this relationship. Those who did, typically faced the endogeneity problem that is likely to affect individuals' BMI employing an instrumental variable approach. Specifically, we can distinguish between studies using as instrument the BMI of a relative and those exploiting genetic markers.

In the former category we include Sabia (2007) and Averett and Stiefel (2007). Sabia (2007) explored the relationship between the body weight of U.S. adolescent and their academic achievement, finding consistent evidence of a significant negative causal effect of BMI on grade point average in math and English language for white females aged 14-17. For non-white females and males, the evidence of a causal link is less convincing after controlling for unobserved heterogeneity.

The main issue with this paper is the use of subjective and self-reported measures of parental obesity. Indeed, the variables used as instruments are neither parents' BMI levels nor dummies indicating whether they actually are overweight or obese, but rather variables stating whether they *feel* obese or not. Therefore, they inform about parents' *perceived* obesity, and they are not objective measures of their real weight status. Moreover, also grade point averages are self-reported by students, which may have an incentive to over-report their grades.

Averett and Stiefel (2007) employed maternal BMI as an IV for individuals' BMI, focusing on two types of childhood malnutrition: not only over- but also under-weight. They use a sample of 5-years old children from the NLSY79 to investigate the cognitive consequences of child malnutrition, concluding that malnourished children tend to have lower cognitive abilities when compared to well-nourished children.

The literature using genetic markers in order to identify the causal effect of obesity on cognitive ability includes Fletcher and Leherer (2008), Ding et al. (2009) and Von Hinke Kessler Scholder et al. (2010). The latter is the only study using a U.K. dataset, the Avon Longitudinal Study of Parents and Children[5] (ALSPAC), and moves a critique to the preceding works. As the authors pointed out, there is a week and inconsistent evidence in the medical literature that the genetic variants employed in the prior studies are robustly associated with fatness in large population samples. This is a serious problem since weak association may result in biased estimates. Moreover, even if a suitable and robust genetic instrument is available, it may explain little of the variation in observed phenotype: if the alleles shift the adiposity distribution by a very small amount, the effect of fatness on test scores is identified only by this small difference in mean adiposity. The variants used by Von Hinke Kessler Scholder et al. (2010) are currently the best candidates to be used as genetic markers, since they have been shown to be associated with adiposity in large population samples. However, the authors admit that, while their instruments are not weak in a statistical sense, their effects may be "too small to impact on the possible pathways to academic performance", concluding that genetic instruments should be used with care. At the light of this evidence, it is not surprising that none of these studies have found a significant effect of fatness on academic performance.

3. Data and summary statistics

We use data from the British Cohort Study (BCS70), a longitudinal dataset collecting information on the births and families of babies born in England, Scotland, Wales and

[5] The ALSPAC dataset collects information about a cohort roughly 14.000 children born in one geographic area of England, the Avon, between April 1991 and December 1992.

Northern Ireland in a particular week in April 1970 and following their lives until nowadays. Since the birth survey there have been eight "sweeps" of cohort members at ages 5, 10, 16, 26, 30, 34, 38 and 42. The strength of the BCS70 is the vast amount of data it provides about cohort members' family background, educational attainment, socio-economic and health status. For example, it contains relevant information about the parents' attitudes toward children education, the availability of books and newspapers at home, the psychological condition of cohort members' mothers, which are important features of the family environment that are often unobservable. Controlling for these characteristics help us to deal with the endogeneity issues and, as we will see in the next section, to enhance the credibility of our instruments.

In our analysis we focus on the 2nd (age 10) and 6th (age 34) sweeps. In the 2nd, carried out in 1980, cohort members are required to sit the British Ability Scale (B.A.S.) test, while in the 6th sweep (2004) they take a basic skills examination.

The B.A.S. has long been established as a leading standardized test in the UK for assessing a child's cognitive ability and educational achievement across a wide age range. The version of the test taken by individuals in 1980 was organized into four sections, for a total of 120 questions: 1) word definition (explain the meaning of some given words); 2) verbal similarities (tell a word that is related to three words told by the examiner); 3) recall of digits (remember a progressively increasing number of digits); 4) matrices (complete some patterns drawing the appropriate picture in an empty square).

On the contrary, the basic skills test sit in 2004 aimed at assessing individuals' literacy and numeracy skills and was part of a bunch of initiatives carried out to understand and tackle the problem of poor basic skills in a substantial minority of the U.K. adult population. It was divided into two sections for a total of 60 questions: a literacy part, made up of 37 questions, and a numeracy one, composed by 23 questions. The total score is given by the number of correct answers (there is no penalty for wrong answers). Hence, the test score is an integer number between zero and 60.

From what has been said, it is clear that even if they measure some kind of cognitive ability, the two tests have different aims and focus on different skills, therefore their outcome is hardly comparable.

Our sample consists of 6667 individuals, among which 3208 are males and 3459 females.

As it can be seen from Table 1, weight problems are more common in adulthood than in childhood and they are more severe among men: in 2004, average BMI level, overweight and obesity rates are substantially greater for males. The data presented in the table could appear

surprisingly high (more than 60% of the male population is overweight) but they are perfectly in line with those from "The Health Interview Surveys", carried out by Eurostat in 2008.
The situation is different during childhood: when we look at the weight statistics in 1980, we can notice that the average BMI levels, the overweight and obesity rates are very similar across genders.

Table 1 – Weight conditions

	Mean	**Std. Dev.**	**Observations**
2004			
Full Sample			
BMI	25.79	4.83	6667
Overweight rate	49.93%		3329
Obesity rate	15.76%		1051
Males			
BMI	26.51	4.39	3208
Overweight rate	60.50%		1941
Obesity rate	16.65%		534
Females			
BMI	25.13	5.10	3459
Overweight rate	40.13%		1388
Obesity rate	14.95%		517
1980			
Full Sample			
BMI	16.88	2.08	6667
Males			
BMI	16.74	1.91	3208
Overweight rate	15.71%		504
Obesity rate	5.11%		164
Females			
BMI	17.02	2.22	3459
Overweight rate	15.81%		547
Obesity rate	5.06%		175
Weight Trends			
Males			
Non-overweight in 1980 but overweight in 2004	47.07%		1521
Overweight in 1980 and in 2004	13.44%		431
Non-overweight in 1980 and in 2004	37.22%		1194
Overweight in 1980 but not in 2004	2.28%		73

Females		
Non-overweight in 1980 but overweight in 2004	28.79%	996
Overweight in 1980 and in 2004	11.33%	392
Non-Overweight in 1980 and in 2004	55.39%	1916
Overweight in 1980 but not in 2004	4.48%	155

Note that the classification into the overweight and obesity categories for individuals' below 18 years is not the same as for adults: the assignment to a weight category is not simply done by comparing individuals' BMI with the thresholds provided by the WHO, but it is necessary to distinguish between males and females and look at the relative position in the sample weight distribution[6]. That's why, in Table 1, we don't provide overweight and obesity rates for the full sample of individuals in 1980.

Looking at the weight evolution over time it can be noticed that 47% of males who were normal-weight when 10 years old switch to the overweight status at the age of 34, while among females this percentage is less than 29%.

Moreover, weight problems are more persistent among males: overweight male children are more likely to remain overweight when adults (13.44% of male individuals suffer from weight problems both in childhood and in adulthood, against 11.3% of females) and less likely to slim down (2.28% vs 4.48%).

These different trends in the weight evolution across genders explain the gap in the adult overweight and obesity rates, starting from a situation of almost equality in 1980.

Table 2 – Test Scores

	Mean	**Std. Dev.**	**Observations**
BASIC SKILL TEST, 2004			
Test Score (out of 60pts)	50.46	7.31	6667
Males Test Score	51.21	7.24	3208
Females Test Score	49.77	7.30	3459
Score per Weight Categories in 2004			
Males			
Test Score if Normal-weight	51.59	7.36	1267
Test Score if Overweight	50.97	7.15	1941
Test Score if Obese	50.86	7.24	534
Difference in mean: Normal vs Overweight	0.62***		
Difference in mean: Normal vs Obese	0.73**		
Females			
Test Score if Normal-weight	50.43	6.95	2071
Test Score if Overweight	48.78	7.70	1388
Test Score if Obese	48.29	7.88	517

[6] Specifically, a child is classified as overweight (obese) if his/her BMI belongs to the 85^{th} (95^{th}) percentile or higher.

Difference in mean: Normal vs Overweight	1.65***		
Difference in mean: Normal vs Obese	2.14***		
Score per Weight Categories in 1980			
Males			
Test Score if Normal Weight	51.24	7.25	2704
Test Score if Overweight	51.08	7.19	504
Test Score if Obese	50.63	7.25	164
Difference in mean: Normal vs Overweight	0.16		
Difference in mean: Normal vs Obese	0.61		
Females			
Test Score if Normal Weight	49.83	7.24	2912
Test Score if Overweight	49.40	7.64	547
Test Score if Obese	49.50	7.94	175
Difference in mean: Normal vs Overweight	0.43*		
Difference in mean: Normal vs Obese	0.33		
B.A.S., 1980			
Test Score (out of 120pts)	63.19	11.73	5321
Males Test Score	63.47	12.03	2533
Females Test Score	62.93	11.45	2788
Score per Weight Categories in 1980			
Males			
Test Score if Normal-weight	63.36	12.02	2140
Test Score if Over-weight	64.10	12.10	393
Test Score if Obese	64.90	12.63	124
Difference in mean: Normal vs Over-weight	-0.74		
Difference in mean: Normal vs Obese	-1.54*		
Females			
Test Score if Normal-weight	63.13	11.44	2365
Test Score if Over-weight	61.86	11.48	423
Test Score if Obese	61.63	12.20	131
Difference in mean: Normal vs Over-weight	1.27**		
Difference in mean: Normal vs Obese	1.50*		

Significance level of the t-test: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.001$

Looking at the average test scores in Table 2, we can see that males performed on average slightly better than females in both the tests. However, what is interesting in our context is to compare the score obtained across different weight categories. As expected, in the basic skills test, the score decreases as the BMI increases: overweight and obese cohort members perform on average worse than normal-weight peers. The inverse relationship between BMI and the test score holds for both the genders and for both current and past BMI levels. However, when considering lagged BMI values, the difference in mean between normal- and over-weight individuals' scores is statistically significant only for females.

Concerning the B.A.S, we can observe that girls suffering from weight excess get poorer results, while boys with higher BMI tend to perform better than their normal-weight peers.

4. Empirical Models and Estimation Strategies

4.1 OLS Estimator

Following the literature on the effects of body weight on individuals' outcomes, we assume that our regression of interest takes the form:

$$y_i = \alpha + \beta BMI_i + \gamma X_i + \varepsilon_i \qquad (1)$$

where y_i is the test score reported by individual i in either the B.A.S or the basic skills tests, BMI_i is the cohort member Body Mass Index and X_i is a vector of control variables, including individual- and family-level observable characteristics: the birth and living country, individuals' and their parents' years of schooling[7], the family income in 1980, the number of household members, the social rating of the neighborhood, whether cohort members were breast-fed, their birth-weight, the psychological condition of their mothers in 1980, plus a large set of variables describing the family cultural environment and parental attitudes towards children education.

The complete list of control variables is provided in Appendix 1.

The estimate of β will be an unbiased estimate of the effect of BMI on individuals' cognitive skills only if there are no unobservable characteristics correlated with both BMI and test score, that is $E(\varepsilon|BMI)=0$. If this identification assumption is violated, as it is the case in presence of unobserved heterogeneity and reverse causality, our OLS estimate of β will be biased.

When we focus on the outcome of the basic skills test, we estimate equation (1) for both the values of BMI available (2004 and 1980), in order to study the simultaneous and the lagged effects of weight problems.

In order to account for the potential existence of non-linear effects of weight, we repeat our analysis using, in place of the continuous BMI variable, a dummy variable (OBY_i) indicating whether individuals suffer from weight excess. The equation to be estimated is now:

$$y_i = \alpha + \beta OBY_i + \gamma X_i + \varepsilon_i \qquad (2)$$

Also in this case, for the basic skills test, we focus on the individuals' weight status both at age 10 and 34.

[7] Cohort members' years of schooling are included in the 2004 regression only: since our sample is a cohort of individuals born in 1970 and education in U.K. was compulsory until age 16, in 1980 they all have attended the same years of schooling.

Finally, we investigate the consequences of weight gain from childhood to adulthood. To this aim, we create dummy variables indicating whether individuals changed their weight classification from 1980 to 2004

The model to be estimated becomes:

$$y_i = \alpha + \beta D_i + \gamma X_{1i} + \delta X_{2i} + \varepsilon_i \qquad (3)$$

where y_i is now the outcome of the basic skills test only and D_i is a vector of dummy variables indicating whether the cohort members moved from a normal-weight condition to overweight, slimmed down or remained overweight. Individuals who were normal weight both in 1980 and 2004 are used as the reference category.

Clearly, equations (2) and (3) are subject to the same endogenity issues that affect model (1).

4.2 IV Estimator

As already pointed out, the OLS estimates are unbiased only in the absence of endogeneity issues. This is hardly the case in our context. Reverse causality may take place, since individuals' skills could affect their BMI, influencing their diet and lifestyle choices. Also the presence of unobservable characteristics, both at the individual and family level, can contribute to make the estimates of the BMI influence on skills biased.

Even if we are controlling for a very large set of covariates, including variables describing cohort members' cultural home-environment and socio-economic status, endogeneity concerns may still be an issue.

A common method for addressing these problems is the use of instrumental variables. This requires finding at least one observable variable that provides exogenous variation in individuals' BMI but is uncorrelated with their cognitive skills, except through BMI itself.

Following the existing literature[8] we use relatives' BMI as an instrument for individuals' BMI. Contrary to previous studies, we can exploit information about both parents' BMI. This allows us to perform an over-identification test, which supports the validity of our choice.

Parental BMI is likely to satisfy the first requirement for IVs, since it is strongly correlated with that of their offspring: Comuzzie and Allison (1998) estimated that 40 to 70 percent of the variation in obesity-related phenotypes in humans is heritable, while Castelnovo (2014) highlighted the strong positive association existing between parental and offspring's BMI and computed intergenerational elasticity using the same data (BCS70) of the current paper.

[8] See Cawley (2000, 2004); Brunello and d'Hombres (2005); Sabia, (2007); Averett and Stiefel (2007).

In addition, parents' BMI must be uncorrelated with unobservable determinants of cognitive skills, that is with the error term ε. As suggested by Sabia (2007), this assumption may be problematic if parental obesity is correlated with unobserved family-level environmental characteristics that influence children's cognitive ability. However, as highlighted by Cawley (2004), there is medical evidence from studies using samples of adoptees[9] suggesting that genetics rather than household environment is the most important determinant of body weight. This result supports the use of biologically related individuals' BMI as a credible IV. Moreover, as we will see in the next section, all of the tests we performed in order to assess the validity of our instruments give satisfactory results.

We addressed the concerns about their potential correlation with household attitudes toward education including in our regressions several covariates measuring the "family-level school sentiment" and parents' general propensity to "intellectual" activities, such as reading newspapers or books (see Appendix 1). Moreover, we control for the mothers' psychological condition in 1980: obese mothers are more likely to suffer from depression (Faith, Matz and Jorge, 2002) and this may have a negative impact on their children, which might grow-up in a family environment where they receive less incentives and motivation. This, of course, may have serious consequences on the development of their cognitive ability.

Since in model (2) the endogenous regressor is a dummy variable, we can estimate the model parameters applying different estimation strategies.

We start with a standard IV approach, where, following the previous reasoning, the instruments are two dummy variables indicating whether parents are overweight/obese or not. Then, in order to check the robustness of our results, we move in the setting of endogenous treatment models, considering the condition of being overweight as the treatment.

In our first specification we assume homogeneous treatment effects (Dummy Endogenous Model) and we estimate the effect of obesity applying the Heckmann correction (or Heckmann two-steps) procedure.

Later, we allow for heterogeneous effects, using as a framework an Endogenous Switching Model (or Roy Model) and applying again the Heckmann two-steps technique.

It is worth to notice that the two Heckit models we are considering rely on different assumptions. In the Dummy Endogenous Model the treatment effect is assumed to be homogeneous in the population, that is, the idiosyncratic gain is zero for every individual. In other words, the impact of the treatment does not vary with individuals' observable characteristics and the unobservable determinants of the outcome are the same with or

[9] See Stunkar et al. (1986), Grilo and Pogue-Geile (1991) and Vogler et al. (1995).

without treatment. In the Endogenous Switching Model we relax the strong homogeneous effect assumption allowing for heterogeneous treatment, that is, for individual-specific effects: the average treatment effect is allowed to vary across individuals with different observable characteristics and to affect the probability of individuals to "choose" the treatment.

5. Results

5.1 OLS Estimates using the BMI as measure of weight

We start by analyzing the link between BMI (both current and lagged) and the basic skills test score, first in the entire sample and then for males and females separately.

The results of the OLS estimates are reported in Table 3. The coefficients in column (1) are those from the regression of the test score on individuals' BMI only (univariate regression), while the specification in column (2) includes our set of control variables (the vector X).

Looking at the whole sample, the OLS estimates are negative and statistically significant: in the baseline regression one unit increase in individuals' BMI is associated to a test score reduction of 0.086 points, while after controlling for individual- and family-level observable characteristics the drop is of 0.035 points for each additional unit of BMI.

However, when we distinguish between males and females, we can notice that the association between BMI and the test score is negative and highly significant for women only, which suffer a test score reduction of about 0.07 points for each additional unit of BMI.

One possible explanation for this difference between genders is that OLS estimates reflect both a (negative) causal and a (positive) spurious effect, the latter given by the effort and behaviors that obese individuals put to use during the work activity in order to offset the negative consequences of their weight condition. Since women are likely to spend less time in the labor market, because of pregnancies and their greater involvement in children education, this may harm their skills learning. Conversely, men may have more opportunities to build their human capital during the work activity, counterbalancing the potentially negative effect of obesity with superior experience and "learning-by-doing".

On the contrary, lagged BMI levels are not significantly correlated with the result of the test, neither for males nor for females.

Table 3 – Correlation between BMI and the Basic Skills Test score

	Basic Skills Test Score 2004					
	FULL SAMPLE		MALES		FEMALES	
	(1)	(2)	(1)	(2)	(1)	(2)
BMI 2004	-0.086***	-0.035*	-0.051*	0.022	-0.150***	-0.073***
	(4.63)	(1.95)	(1.75)	(0.74)	(6.20)	(3.18)
X_i	No	Yes	No	Yes	No	Yes
Cons	52.67***	34.45***	52.56***	31.03***	53.54***	35.80***
	(108.38)	(8.65)	(67.23)	(7.35)	(86.27)	(20.67)
BMI 1980	-0.014	0.032	0.075	0.091	-0.035	-0.001
	(0.32)	(0.78)	(1.12)	(1.37)	(0.62)	(0.00)
X_i	No	Yes	No	Yes	No	Yes
Cons	50.70***	32.90***	49.95***	30.28***	50.36***	33.75***
	(69.26)	(8.24)	(44.23)	(7.11)	(52.46)	(18.28)
N	6667	5985	3208	2873	3459	3112

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

Moving the attention to the outcome of the B.A.S. test, our results suggest that in the whole sample there is no significant association between BMI and cognitive abilities. However, quite surprisingly, performing separate analysis for males and female we find that BMI is positively associated with the boys' test score (Table 4).

Summing up, our OLS estimates show no evidence of a negative correlation between BMI and cognitive skills during childhood, while deficiencies in literacy and numeracy skills are associated with increased BMI in adult women but aren't influenced by past BMI levels.

This last result could appear surprising: we might expect that having a high BMI in childhood is more detrimental for future cognitive abilities, since it affects individuals during the educational process, which is the most important period for the human capital accumulation.

However, this finding can be justified noting that the variance of the BMI distribution is much lower in childhood than in adulthood. Therefore, the variance of the OLS estimator will be higher when using 1980 BMI values, implying less precise estimates.

Another possible explanation for the different relationship found between skills and BMI at different ages is that, as highlighted by the summary statistics presented in Table 1, a large number of individuals (about 47% of men and 29% of women) become overweight only *after* 1980.

Finally, it is plausible that also the existence of non-linear effects of weight may affect our results.

Table 4 - Correlation between the BMI in 1980 and the B.A.S score

	B.A.S. Test Score 1980					
	FULL SAMPLE		MALES		FEMALES	
	(1)	(2)	(1)	(2)	(1)	(2)
BMI 1980	0.071	0.087	0.299**	0.292**	-0.068	-0.034
	(0.91)	(1.18)	(2.36)	(2.42)	(0.69)	(0.37)
X_i	No	Yes	No	Yes	No	Yes
Cons	61.99***	39.43***	58.47***	36.88***	64.09***	38.87***
	(46.65)	(17.93)	(27.46)	(11.17)	(37.79)	(13.78)
N	5321	5053	2533	2399	2788	2654

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

5.2 OLS Estimates using the overweight dummy

Given the non-linearity concerns, we decide to move our attention from the continuous BMI variable to a dummy indicating whether individuals suffer from weight excess.

However, when using the overweight dummies instead of BMI values our results don't change. As it can be seen from Table 5, being overweight in 2004 is strongly associated with a decrease in basic skills for females but not for males, while no statistically significant association is found when using the probability of suffering from weight excess in 1980.

Concerning the B.A.S., our estimates do not show any significant link between the test score and cohort members' weight status (Table 6): not even boys' weight is now correlated with their cognitive ability.

Given that the results obtained using indicators for being overweight are in line with those previously found employing the continuous variable BMI, the non-linearity concerns seem to be a limited issue in our analysis.

Since our estimates show a negative association between obesity and basic skills at age 34 (at least for women) but not at age 10, it is interesting to study how individuals' weight evolution over time is associated with their test scores. Looking at the summary statistics presented in Table 1 we can notice that overweight rates are much higher in adulthood than in childhood (about 50% vs. 15%). Data about weight transition over time confirm that a large share of cohort members who were normal-weight at age 10 has become overweight in 2004.

To this aim, we create dummy variables that identify the individuals who become overweight, those who slim down and those who suffer from weight excess both in 1980 and 2004[10].

[10] The reference category is provided by the individuals who are normal-weight both in 1980 and 2004.

Table 5 - Correlation between the probability of being overweight/obese and Basic Skills

	Basic Skills Test Score 2004					
	FULL SAMPLE		MALES		FEMALES	
	(1)	(2)	(1)	(2)	(1)	(2)
Overweight/obese 2004	-0.814***	-0.419**	-0.617**	0.061	-1.654***	-0.851***
	(4.55)	(2.39)	(2.36)	(0.23)	(6.57)	(3.55)
X_i	No	Yes	No	Yes	No	Yes
Cons	50.87***	33.95***	51.59***	31.58***	50.43***	34.25***
	(402.75)	(8.60)	(253.86)	(7.60)	(316.10)	(21.30)
Overweight/obese 1980			-0.156	0.132	-0.429	0.038
			(0.44)	(0.38)	(1.26)	(0.12)
X_i			No	Yes	No	Yes
Cons			51.24***	31.64***	49.83***	33.74***
			(368.04)	(7.64)	(368.20)	(21.00)
N	6667	5985	3208	2873	3459	3112

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

Table 6 - Correlation between the probability of being overweight/obese and the B.A.S score

	B.A.S. Test Score 1980			
	MALES		FEMALES	
	(1)	(2)	(1)	(2)
Overweight/obese 1980	0.738	0.958	-1.271**	-0.788
	(1.12)	(1.54)	(2.10)	(1.40)
X_i	No	Yes	No	Yes
Cons	63.36***	41.51***	63.13***	38.12***
	(243.61)	(15.63)	(268.29)	(16.21)
N	2533	2399	2788	2654

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

As it can be seen from Table 7, weight gain is strongly associated with a lower basic skill level at age 34 for females, but not for males, at least when we include our controls in the regression.

In the univariate regression, becoming overweight is correlated with a test score reduction of about 0.6 points for males and 1.7 for females, while in the more complete specification the reduction is of about 0.9 points for females and there is no statistically significant association for males.

Also the probability of remaining overweight is negatively correlated with females' basic skills, even if the statistical significance is weak (t=1.67), while moving from the over- to the normal-weight category is not significantly associated with an increase of the test score.

Table 7 – Weight evolution and the Basic Skills Test score

	Basic Skills Test Score 2004			
	MALES		FEMALES	
	(1)	(2)	(1)	(2)
Get overweight	-0.589**	0.060	-1.672***	-0.866***
	(2.10)	(0.22)	(5.89)	(3.20)
Stay overweight	-0.624	0.142	-1.522***	-0.638*
	(1.54)	(0.35)	(3.78)	(1.67)
Slim down	0.338	0.314	0.318	0.649
	(0.39)	(0.36)	(0.52)	(1.16)
X	No	Yes	No	Yes
Cons	51.57***	31.59***	50.41***	34.19***
	(246.27)	(7.60)	(303.83)	(21.25)
N	3208	2873	3459	3112

*t-statistics in parenthesis; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*

5.3 IV Estimates using the BMI as measure of weight

Following the previous literature, we instrument individuals' BMI with that of biological family members. Since we have information about the BMI of both the parents of cohort members, we can rely on two instruments and perform the Sargan over-identification test.

Again, we start by focusing on the Basic Skill Test taken in 2004. Using the current BMI as a regressor (Table 8), IV coefficients are negative and highly significant for both genders and not just for females, as it was in OLS estimates. In our best specification (Colum 2) one unit increase in 2004 average BMI causes a reduction of about 0.35 points out of 60 in the males' average score and of 0.21 points in the females' one.

Therefore, we can notice that males' coefficient has switched its sign, while females' one is now three times larger in size than the corresponding OLS value. Overall, in the full sample, the BMI coefficient rises by about seven times.

Increases of comparable size, as well as switches in coefficients' sign, are found also by some of the previous studies using relatives' BMI as an IV for individual BMI in order to study the effect of weight on economic and educational/cognitive outcomes[11].

[11] See Sabia (2007), Brunello and d'Hombres (2005), Averett Averett and Stiefel (2007) and Cawley (2000, 2004).

Table 8 – The effect of current BMI on the Basic Skills Test score

	Basic Skills Test Score 2004					
	FULL SAMPLE		MALES		FEMALES	
	(1)	(2)	(1)	(2)	(1)	(2)
BMI 2004	-0.655***	-0.258***	-0.718***	-0.347***	-0.592***	-0.210***
	(9.86)	(4.21)	(5.65)	(2.84)	(8.16)	(3.08)
X_1	No	Yes	No	Yes	No	Yes
Cons	67.35***	41.32***	70.24***	41.65***	64.64***	39.53***
	(39.27)	(9.37)	(20.82)	(7.56)	(35.39)	(15.52)
Sargan Test p-value	0.473	0.446	0.556	0.974	0.668	0.213
Cragg-Donald Wald F-stat	324.77	289.94	103.91	88.88	240.36	202.12
N	6667	5985	3208	2873	3459	3112
First-stage:			BMI 2004			
BMI mother	0.290***	0.305***	0.213***	0.224***	0.360***	0.373***
	(18.74)	(18.40)	(10.03)	(9.68)	(16.53)	(15.73)
BMI father	0.268***	0.257***	0.224***	0.211***	0.311***	0.297
	(13.83)	(12.64)	(8.71)	(7.75)	(11.09)	(9.87)
R^2	0.09	0.13	0.06	0.08	0.12	0.14

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

One possible explanation for the rise of coefficients' size is that OLS estimates are biased upwards by the positive correlation between unobservables, like motivation and perseverance, and the BMI: overweight and obese individuals compensate the potentially negative effect of weight with unobservable behaviours (such as the effort put in their work activity and in the skill learning process) that improve their abilities.

However, it is also worth remembering that IV coefficients should be given a *local average treatment effect* (L.A.T.E.) interpretation. Indeed, the parental BMI instrument is informative about the effect of individuals' weight excess on the test score only for the sub-population of offspring who are obese only when their parents are (but would not be obese otherwise), but it is not for the offspring whose BMI is unaffected by their parents weight status. In other words, our IV captures the effect of being overweight (the *treatment*) only on individuals whose treatment status is influenced by the instrument itself, that is the *compliers* (Angrist, Imbens and Rubin, 1996). Therefore, the IV estimates in Tables 8-13 capture the average treatment effect for the sub-population of compliers only, which are a subset of the treated. This may provide an additional justification to explain the difference in size from OLS estimates.

When looking at the effect of lagged BMI (Table 9), we observe again a change in coefficients' sign and significance with respect to OLS estimates: the effect of 1980 BMI becomes negative and highly significant. The increase in size is in absolute value much greater than the one found using current BMI values. According to our IV estimates, a unitary increase in average BMI in 1980 leads to an average test score reduction of about 0.78 points for males and 0.55 for females.

Therefore, contrary to OLS results, it seems that high BMI levels are more penalizing when recorded during childhood, that is when education is taking place. This is a reasonable finding, since it is likely that obesity influences more seriously the literacy and numeracy skills acquisition in the first part of the human capital accumulation process.

Similar results hold when we investigate the impact of BMI on the B.A.S. score: IV coefficients are negative and larger in size than OLS ones (Table 10). In the specification of the model where we include our covariates, a unitary increase in BMI leads to a test score reduction of about 1 point in the full sample, 0.8 and 1.1 points in the males and females sub-population respectively. However, the effect on the males' test score is weakly statistically significant.

Table 9 – The effect of past BMI on the Basic Skills Test score

	Basic Skills Test Score 2004					
	FULL SAMPLE		MALES		FEMALES	
	(1)	(2)	(1)	(2)	(1)	(2)
BMI 1980	-1.70***	-0.633***	-1.73***	-0.775***	-1.65***	-0.546***
	(9.42)	(4.10)	(5.48)	(2.83)	(7.57)	(2.95)
X_1	No	Yes	No	Yes	No	Yes
Cons	79.22***	42.66***	80.13***	43.33***	77.92***	43.08***
	(25.94)	(9.25)	(15.18)	(7.33)	(20.93)	(11.83)
Sargan Test p-value	0.197	0.290	0.452	0.895	0.299	0.152
Cragg-Donald Wald F-stat	249.66	239.51	93.94	94.28	152.90	140.13
N	6667	5985	3208	2873	3459	3112
	BMI 1980					
First-stage:						
BMI mother	0.104***	0.115***	0.085***	0.095***	0.118***	0.131***
	(15.43)	(15.64)	(9.21)	(9.41)	(12.17)	(12.36)
BMI father	0.112***	0.115***	0.097***	0.102***	0.126***	0.123***
	(13.29)	(12.83)	(8.63)	(8.61)	(10.08)	(9.19)
R^2	0.07	0.10	0.06	0.09	0.08	0.10

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

Table 10 – The Effect of BMI on the B.A.S Test score

	B.A.S. Test Score 1980					
	FULL SAMPLE		MALES		FEMALES	
	(1)	(2)	(1)	(2)	(1)	(2)
BMI 1980	-2.56***	-0.998***	-2.36***	-0.86*	-2.69***	-1.11***
	(8.12)	(3.65)	(4.17)	(1.69)	(7.22)	(3.53)
X_1	No	Yes	No	Yes	No	Yes
Cons	106.41***	56.80***	102.92***	55.72***	134.43***	56.74***
	(19.98)	(11.90)	(10.88)	(6.37)	(17.13)	(9.87)
Sargan Test p-value	0.246	0.387	0.749	0.737	0.201	0.099
Cragg-Donald Wald F-stat	214.04	204.77	78.90	73.13	134.43	129.56
N	5321	5053	2533	2399	2788	2654
First-stage:						
	BMI 1980					
BMI mother	0.107***	0.113***	0.086***	0.088***	0.124***	0.133***
	(14.45)	(14.46)	(8.39)	(8.19)	(11.66)	(11.80)
BMI father	0.112***	0.113***	0.098***	0.098***	0.125***	0.127***
	(12.07)	(11.76)	(7.93)	(7.64)	(9.08)	(8.85)
R^2	0.07	0.09	0.06	0.08	0.09	0.10

*t-statistics in parenthesis; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$*

Again, one possible explanation for the rise in coefficients' absolute value when instrumenting is that OLS estimates are upward biased because of a positive correlation between the BMI and hidden characteristics. We suggest that these traits could be for example motivation and willpower: overweight children offset the negative consequences of weight excess with unobservable behaviours that improve their skills, like the effort put in the educational process and the time devoted to studying.

Note that the tests performed to check the goodness of our instruments are always satisfied[12]: the high p-value of the Sargan over-identification test supports their validity (i.e. no correlation with the error term), while the high Cragg-Donald Wald F-statistic suggests that excluded restrictions are relevant, that is strongly correlated with individual BMI. This is confirmed looking at instruments' coefficients in our first-stage regressions, which are always highly statistically significant.

However, even if our IVs are strong predictors of individuals' BMI and satisfy the Sargan over-identification test, the first-stage R^2 values, which are sometimes quite low, may raise some doubts about the presence of a weak instrument problem, resulting in size distortion.

[12] The only exception is given by the Sargan over-identification test for the female subsample taking the B.A.S. test in 1980. In this case the p-value of the Sargan test turns out to be 0.099, while its critical threshold is 0.100.

5.4 IV Estimates using the overweight dummy

When we investigate the effect of being overweight, using a dummy that takes value 1 if the individual suffers from weight excess and 0 otherwise, results are perfectly in line with those previously obtained using the BMI. The 2-SLS coefficients for the overweight dummy are summarized in Tables 11-13, while the full set of results, which includes the estimates obtained applying the Heckman control function approach are left in Appendix 3 (Tables A-D).

Looking at the basic skills test (Tables 11-12), the estimates accounting for endogeneity are always negative, highly significant and almost 9 times larger in size than OLS ones in the full sample. As it happened with current BMI, when we consider the current weight condition males' coefficient changes its sign, while females' one increases by about four times in the specification where control variables are included (column 2).

The overweight condition has an even stronger impact on adults' skills if recorded at age 10.

Again, possible explanations that can be provided to explain the substantial change in coefficients' size when instrumenting are the presence of unobservable characteristics and behaviours that allow overweight individuals to compensate the negative effect of weight, biasing downward the OLS estimates, and the *local average treatment effect* interpretation that should to be given to IV results.

The tests performed to check instruments' validity and relevance are once again satisfied.

Moreover, it is important to notice that all of the estimation strategies we used gave very similar results (Tables A-B, Appendix 2) and support the finding that obesity has a strong negative impact on cognitive skills. The coefficient associated to the Heckman correction term (*lambda*) is significant at 1% and positive (Tables A-B, column 3), meaning that our endogeneity concerns were justified and positive self-selection into treatment takes place. In other words, there is a positive correlation between unobservable traits, included in the error term, and individuals' BMI: overweight and obese people seem to have on average better unobserved characteristics than non-obese peers.

The estimates we obtained for the B.A.S. test seem to suggest that weight excess has a significant negative impact for females only (Table 13). However, our results are likely to be problematic, since now, in the females' sub-sample, the instruments do not pass the over-identification test. Moreover, as it can be seen from Tables C-D in Appendix 2, the coefficients we get using the Heckit models are now much less homogeneous. For this reasons our estimates of the effect of childhood obesity on cognitive skills should be taken with caution.

Table 11 – The effect of being overweight in 2004 on the Basic Skills Test score

	Basic Skills Test Score 2004					
	FULL SAMPLE		MALES		FEMALES	
	(1)	(2)	(1)	(2)	(1)	(2)
Overweight/obesity in 2004	-8.645***	-3.738***	-8.151***	-4.299***	-8.535***	-3.420***
	(8.94)	(4.22)	(5.07)	(2.86)	(7.73)	(3.21)
X_1	No	Yes	No	Yes	No	Yes
Cons	54.78***	38.56***	56.14***	36.78***	53.19***	35.83***
	(111.06)	(9.11)	(57.09)	(7.86)	(114.82)	(19.84)
Sargan Test p-value	0.844	0.813	0.735	0.430	0.413	0.234
Cragg-Donald Wald F-stat	153.42	128.55	55.06	47.41	116.76	84.91
N	6667	5985	3208	2873	3459	3112
First-stage:						
	Pr(Overweight/Obesity 2004)					
Overweight/Obesity mother	0.185***	0.179***	0.149***	0.146***	0.221***	0.211***
	(12.83)	(11.77)	(7.23)	(6.58)	(11.45)	(10.07)
Overweight/Obesity father	0.129***	0.125***	0.122***	0.123***	0.142***	0.128***
	(10.21)	(9.56)	(6.79)	(6.47)	(8.37)	(7.08)
R^2	0.04	0.10	0.03	0.05	0.06	0.08

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

Table 12 – The effect of being overweight in 1980 on the Basic Skills Test score

	Basic Skills Test Score 2004			
	MALES		FEMALES	
	(1)	(2)	(1)	(2)
Overweight/Obesity in 1980	-12.52***	-6.15***	-14.47***	-5.03***
	(4.79)	(2.78)	(6.86)	(3.07)
X_1	No	Yes	No	Yes
Cons	53.18***	32.27***	52.05***	34.79
	(121.60)	(7.40)	(142.04)	(19.94)
Sargan Test p-value	0.502	0.327	0.193	0.184
Cragg-Donald Wald F-stat	41.13	39.42	69.76	65.55
N	3208	2873	3459	3112
First-stage:				
	Pr(Overweight/Obesity 1980)			
Overweight/Obesity mother	0.103***	0.107***	0.119***	0.134***
	(6.71)	(6.45)	(8.17)	(8.45)
Overweight/Obesity father	0.072***	0.077***	0.093***	0.092***
	(5.35)	(5.42)	(7.26)	(6.72)
R^2	0.03	0.04	0.04	0.06

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

Table 13 – The effect of being overweight in 1980 on the B.A.S. score

	B.A.S. Score 1980			
	MALES		FEMALES	
	(1)	(2)	(1)	(2)
Overweight/Obesity in 1980	-13.81***	-3.98	-23.14***	-12.66***
	(3.04)	(0.97)	(6.90)	(4.50)
X_1	No	Yes	No	Yes
Cons	65.62***	36.09***	66.44***	36.74***
	(87.30)	(14.24)	(116.06)	(15.26)
Sargan Test p-value	0.242	0.155	0.035	0.015
Cragg-Donald Wald F-stat	32.64	28.89	69.75	63.92
N	2533	2412	2788	2662
First-stage:				
	Pr(Overweight/Obesity in 1980)			
Overweight/Obesity mother	0.099***	0.099***	0.138***	0.143***
	(5.79)	(5.53)	(8.71)	(8.56)
Overweight/Obesity father	0.073***	0.070***	0.094***	0.093***
	(4.84)	(4.52)	(6.76)	(6.43)
R^2	0.03	0.04	0.05	0.06

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

6. Conclusions

In this paper we studied the effects of childhood and adulthood obesity on the cognitive abilities of a cohort of U.K. individuals, measured by the outcome of two standardized tests: the British Ability Scale, taken when cohort members are 10 years old, and a literacy and numeracy test sit at the age of 34.

The topic is of great relevance since cognitive skills are important determinants of individuals' productivity and wage. Economists have indeed studied the link between obesity and economic outcomes like employment probability, work absenteeism and wages, finding that weight excess has a negative effect on them. However, the potential mechanisms that can explain this relationship have not yet been clarified: a decline of cognitive ability stemming from the negative consequences of obesity can explain part of the wage and employment gap between obese and non-obese workers.

We performed the analysis using data from the British Cohort Study of 1970, which provides us with the information about individuals' BMI in both the years when the two tests are taken. Therefore, for the test sit at age 34 we can study both the current and lagged effects of weight excess.

We started our research by analyzing the association between BMI and the tests' outcome. Then, we focused on the existence of a causal link between the two, following an instrumental variable approach.

According to our OLS estimates, current BMI is negatively and significantly correlated with cognitive skills in adulthood (age 34). However, when splitting the sample between males and females, such relationship turned out to be statistically significant only for the latters. In our preferred specification, one unit increase in females average BMI was associated to a test score reduction of about 0.07 points out of 60.

On the contrary, we didn't find for both genders any significant relationship neither between the test score of 2004 and lagged BMI values, nor between the B.A.S. score and the BMI levels of 1980.

The subsequent OLS analysis carried out using an indicator for weight excess in place of the continuous BMI variable confirmed our results. Being overweight when taking the basic skills test in 2004 is associated to a decrease of about 0.85 points in the females' average test score, while no statistically significant relationship is found for males. Surprisingly, childhood obesity is not correlated with the outcome of the two tests.

However, OLS estimates are likely to suffer from endogeneity problems because of the potential existence of unobservable individual characteristics that simultaneously affect both weight and cognitive ability. Therefore, in order to understand whether obesity has a causal effect on cognitive skills, following Cawley (2000, 2004), Brunello and d'Hombres (2005), Sabia (2007) and Averett and Stifel (2007) we instrumented individuals' BMI with relatives' BMI. Contrary to previous studies, our dataset contains information on both parents' BMI allowing us to perform an over-identification test to check instruments' validity.

Our IV estimates revealed the existence of a negative and statistically significant causal effect of BMI on cognitive skills, both in childhood and in adulthood. The effect is significant also for males (even if only at 10% in the B.A.S. test) and larger in absolute value with respect to OLS estimates. These results are confirmed by the regressions carried out using a dummy that identifies overweight individuals in place of the BMI.

A raise in coefficients' size was found, when instrumenting, by most of the above mentioned studies, at least for some the population subgroups considered. This increase can be explained by the presence of a positive correlation between unobservables (like motivation, perseverance and the effort choice) and the BMI, that makes OLS coefficients downward biased. Intuitively, overweight and obese individuals may compensate the negative effect of weight with characteristics, attitudes and behaviours that can improve their skills but are unobservable to us. For example, they might put more effort in their school and work activities or devote more time to studying, maybe because they are less involved in social and sport activities.

Moreover, it is worth remembering that IV estimates should be given a local average treatment effect (L.A.T.E.) interpretation. In other words, they capture the effect of obesity on cognitive skills only for the compliers, that is the individuals whose weight status is influenced by those of their parents.

Despite the validity and the relevance of our instruments are confirmed by the Sargan over-identification test and by the Stock-Yogo weak identification test, the R^2 values of the first-stage regressions, which are sometimes quite low, cannot rule out size distortions.

Therefore, even if we are confident about the sign of our IV estimates, their difference in size with respect to OLS coefficients should be interpreted with caution.

Finally, exploiting the availability of BMI data at different ages, we studied the effect of weight gain over time, finding that moving from a normal-weight condition in childhood to obesity in adulthood is associated with lower basic skills levels.

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Appendix 1 – List of Control Variables

The observables included in the vector X_{1i} are:

- Birth country of the cohort member (CM)
- Living country of the CM
- Years of schooling of the CM's mother
- Years of schooling of the CM's father
- Years of schooling of the CM *(only in the basic skills test regression, age 34)*
- Family income when the CM was 10 years old
- Number of household members when the CM was 10 years old
- Birth-weight of the CM
- Whether the CM was breast-fed
- Psychological condition (depression) of the CM's mother in 1980

Variables describing the cultural environment and parental attitudes towards education:

- newspapers and magazines are usually available at home
- parents reads books or magazines
- parents expect children to do homework
- parents expect children to go to school
- parents visit children's school
- parents help children in doing homework
- parents impose curfew in schooldays

Appendix 2 – Results from alternative estimation strategies

Table A – The effect of being overweight in 2004 on the Basic Skill Test score (Full Sample)

	Basic Skills Test score 2004			
			Heckit Models	
	(1) OLS	(2) IV	(3) DEM	(4) Roy Model
Overweight/Obesity in 2004	-0.42**	-3.74***	-3.76***	-3.57***
	(2.39)	(4.22)	(4.14)	
X_i	Yes	Yes	Yes	Yes
Λ			2.15***	
			(3.75)	
Cons	33.95***	38.56***	37.93***	
	(8.60)	(9.11)	(17.85)	
N	5985	5985	5985	5985

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

Table B – The effect of being overweight in 2004 on the Basic Skill Test score (Males vs Females)

	Basic Skills Test score 2004							
	MALES				FEMALES			
			Heckit Models				Heckit Models	
	(1) OLS	(2) IV	(3) DEM	(4) Roy Model	(1) OLS	(2) IV	(3) DEM	(4) Roy Model
Overweight/Obesity 2004	0.061	-4.30***	-4.09***	-3.95***	-0.85***	-3.42***	-3.43***	-4.86***
	(0.23)	(2.86)	(2.79)		(3.55)	(3.21)	(2.80)	
X_i	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Λ			2.62***				1.68**	
			(2.87)					
Cons	31.58***	36.78***	35.91***		34.25***	35.83***	36.69***	
	(7.60)	(7.86)	(12.52)		(21.30)	(19.84)	(10.51)	
N	2873	2873	2873	2873	3112	3112	3112	3112

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

Table C – The Effect of being overweight in 1980 on the Basic Skill Test score (Males vs Females)

	Basic Skills Test score 2004							
	MALES				FEMALES			
			Heckit Models				Heckit Models	
	(1) OLS	(2) IV	(3) DEM	(4) Roy Model	(1) OLS	(2) IV	(3) DEM	(4) Roy Model
Overweight/Obesity 1980	0.132	-6.15**	-4.58**	-4.27**	0.038	-5.03***	-4.05***	-5.04***
	(0.38)	(2.78)	(2.35)		(0.12)	(3.07)	(2.74)	
X_i	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Λ			2.68**				2.38***	
			(2.46)				(2.89)	
Cons	31.64***	32.27***	33.51***		33.74***	34.79***	35.40***	
	(7.64)	(7.40)	(12.88)		(21.00)	(19.94)	(10.31)	
N	2873	2873	2873	2873	3112	3112	3112	3112

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*

Table D - Effect of being overweight in 1980 on the B.A.S. score

	B.A.S. Score 1980							
	MALES				FEMALES			
			Heckit Models				Heckit Models	
	(1) OLS	(2) IV	(3) DEM	(4) Roy Model	(1) OLS	(2) IV	(3) DEM	(4) Roy Model
Overweight/Obesity 1980	0.958	-3.98	-2.25	-1.72	-0.788	-12.66***	-10.85***	-6.68***
	(1.54)	(0.97)	(0.63)		(1.40)	(4.50)	(4.40)	
X_1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Λ			1.80				5.83***	
			(0.90)				(4.22)	
Cons	41.51***	36.09***	39.33***		38.12***	36.74***	44.73***	
	(15.63)	(14.24)	(8.75)		(16.21)	(15.26)	(8.12)	
N	2399	2412	2412	2412	2654	2662	2662	2662

*t-statistics in parenthesis; * p < 0.10, ** p < 0.05, *** p < 0.01*