Twin Research and Human Genetics (2021), **24**, 123–129
doi:10.1017/thg.2021.14

CAMBRIDGE
UNIVERSITY PRESS

Article

Association of Adult Socioeconomic Status with Body Mass Index: A Within- and Between-Twin Study

Samuel J. C. Crofts[1], Janine Lam[4,5], Katrina J. Scurrah[1,3] and Gillian S. Dite[2,3]

[1]Twins Research Australia, Centre for Epidemiology and Biostatistics, Melbourne School of Population and Global Health, The University of Melbourne, Melbourne, Victoria, Australia, [2]Genetic Technologies Ltd., Melbourne, Victoria, Australia, [3]Centre for Epidemiology and Biostatistics, The University of Melbourne, Melbourne, Victoria, Australia, [4]Neuroscience Research Australia, Sydney, New South Wales, Australia and [5]School of Psychology, University of New South Wales, Sydney, New South Wales, Australia

Abstract

Adult socioeconomic status (SES) has been consistently associated with body mass index (BMI), but it is unclear whether it is linked to BMI independently of childhood SES or other potentially confounding factors. Twin studies can address this issue by implicitly controlling for childhood SES and unmeasured confounders. This co-twin control study used cross-sectional data from Twins Research Australia's Health and Lifestyle Questionnaire ($N = 1918$ twin pairs). We investigated whether adult SES, as measured by both the Index of Relative Socioeconomic Disadvantage (IRSD) and the Australian Socioeconomic Index 2006 (AUSEI06), was associated with BMI after controlling for factors shared by twins within a pair. The primary analysis was a linear mixed-effects model that estimated effects both within and between pairs. Between pairs, a 10-unit increase in AUSEI06 was associated with a 0.29 kg/m^2 decrease in BMI (95% CI [−.42, −.17], $p < .001$), and a 1-decile increase in IRSD was associated with a 0.26 kg/m^2 decrease in BMI (95% CI [−.35, −.17], $p < .001$). No association was observed within pairs. In conclusion, higher adult SES was associated with lower BMI between pairs, but no association was observed within pairs. Thus, the link between adult SES and BMI may be due to confounding factors common to twins within a pair.

Keywords: Socioeconomic status; overweight; obesity; body mass index; twin; within-pair

(Received 26 October 2020; accepted 4 March 2021; First Published online 14 April 2021)

Overweight and obesity are widespread conditions that are commonly measured by thresholds on the body mass index (BMI) (World Health Organization [WHO], 2000). They are major risk factors for cardiovascular disease, diabetes, musculoskeletal disorders and various cancers (WHO, 2010). As such, understanding the causes of overweight and obesity is critical to improving population health, especially given their rapidly increasing prevalence in many countries (Hruby & Hu, 2015).

It is well documented that socioeconomic status (SES) is associated with overweight and obesity (Ball & Crawford, 2005; Galobardes et al., 2006; Herzog et al., 2016; Monteiro et al., 2004; Tiikkaja et al., 2012; Wu et al., 2015). Measures of SES commonly reflect a combination of income, education and occupation (Winkleby et al., 1992). As a country's gross national product increases, overweight and obesity move from diseases associated with people of higher SES to diseases associated with people of lower SES (Monteiro et al., 2004). In high-income countries, low SES has been consistently associated with an increased risk of childhood overweight and obesity (Wu et al., 2015). Systematic reviews have also shown that adults of lower SES generally experience greater weight gain over time than adults of higher SES (Ball & Crawford, 2005; Herzog et al., 2016). Finally, there is strong evidence that gender may modify the relationship between SES and BMI (McLaren, 2007; Sobal & Stunkard, 1989). For example, the association between higher SES and lower BMI in high-income countries has generally been more consistent for women than for men (McLaren, 2007; Sobal & Stunkard, 1989). This finding has been attributed to different social pressures and desires between men and women regarding body size (McLaren, 2007; Sobal & Stunkard, 1989).

There are many potential pathways by which SES may be influencing BMI, although there is debate as to which are most valid (Claassen et al., 2018). The higher cost of healthier diets in some countries and the lack of availability of healthy food choices in low-income areas (along with an abundance of unhealthy food choices) are two prominent theories (Aggarwal et al., 2011; Story et al., 2008). However, other factors associated with lower SES may also help explain the relationship with BMI. For example, higher stress levels (Moore & Cunningham, 2012; Spinosa et al., 2019) and other psychological factors (Cheon & Hong, 2017) have been associated with both unhealthy eating patterns and low SES.

Although SES has been consistently associated with BMI in general, the results are less clear when childhood and adult SES are considered separately. In particular, it is not clear whether adult SES is linked to BMI independently of childhood SES. Childhood SES is a predictor of adult SES (d'Addio, 2007), and disentangling their separate effects is challenging. Additionally, there may be confounding factors, such as genetics, which are responsible for the observed associations between adult SES and BMI (Dinescu et al., 2016).

Author for correspondence: Samuel Crofts, Email: sam.crofts@unimelb.edu.au

Cite this article: Crofts SJC, Lam J, Scurrah KJ, and Dite GS. (2021) Association of Adult Socioeconomic Status with Body Mass Index: A Within- and Between-Twin Study. *Twin Research and Human Genetics* **24**: 123–129, https://doi.org/10.1017/thg.2021.14

Studies of families and twins are one way of addressing these difficulties. Siblings generally grow up together in the same household and have the same parental figures. Therefore, siblings will usually have the same SES as each other throughout their childhoods. If they leave home and pursue different careers or live in different areas, their SES may change. By comparing siblings with each other, it is possible to isolate the effect of adult SES on BMI while holding childhood SES constant. Importantly, these study designs also allow for the control of other unmeasured factors that are similar between siblings, such as genetics and family environment.

Twin and family studies on similar topics have so far been limited and have given somewhat mixed results. In an Australian study, Webbink et al. (2010) found that more years of education were linked to lower bodyweight within male twin pairs, but no association was observed within female twin pairs. In another Australian study, Scurrah et al. (2015) found that a change to lower SES in young adulthood was associated with an increase in BMI after controlling for childhood SES. In studies from other countries, Tiikkaja et al. (2012) found a similar result, in that moving from a higher to lower occupational class was associated with an increase in mortality from cardiovascular disease (for which BMI is a prominent risk factor). Krieger et al. (2005) also found that lower adult social class in twins was associated with higher cardiovascular disease risk and other measures of poor health, but not with BMI specifically. Interestingly, these relationships did not hold when years of education were used as a measure of adult SES, although others have found a weak association (Fujiwara & Kawachi, 2009). Dinescu et al. (2016) found that while adult SES was associated with BMI in their population as a whole, the effect disappeared when looking at the family level. Similarly, Osler et al. (2007) found no significant differences in adult BMI in twins discordant for adult SES.

Our study aims to clarify these varied results by using a twin study design that controls for measured and unmeasured confounders to examine the association between adult SES and BMI. We use a statistical approach in which we include both within- and between-pair effects in the same model. To the best of our knowledge, this method has not been used before in this context and it allows inferences to be made about the potential impact of confounding on the association, which has not been a focus of other published articles on this topic. Additionally, we use both individual and area-level measures of SES, which to the best of our knowledge has only been done once before on a similar topic with a twin design (Dinescu et al., 2016). Overweight and obesity are generally preventable and reversible conditions (WHO, 2010), and by further understanding their main drivers, there is significant potential to dramatically reduce their impact.

Materials and Methods

Study Design, Setting and Participants

Cross-sectional data were obtained from Twins Research Australia (TRA), which maintains a registry of twins who are willing to consider participation in ethically approved research (Murphy et al., 2019). Eligible twins were those who had completed the adult version of the TRA Health and Lifestyle Questionnaire, which was emailed to all Australian twin pairs on the registry who were aged 18 years and over and had provided an email address (Cutler, 2015). The questionnaire covered a variety of topics such as health, education, employment and zygosity (Cutler, 2015). All data were self-reported.

Table 1. Australian Socioeconomic Index 2006 (AUSEI06) scores for Australian and New Zealand Standard Classification of Occupations (ANZSCO) major groups

ANZSCO major group	Weighted AUSEI06 score*	Range of AUSEI06 scores within group
Professionals	81.6	66.2–100.0
Managers	58.1	34.0–81.5
Clerical and administrative workers	45.6	32.9–67.4
Community and personal services workers	41.7	29.4–82.3
Technicians and trades workers	35.9	17.7–63.6
Sales workers	34.8	27.8–56.3
Machinery operators and drivers	21.0	3.4–35.7
Laborers	18.5	0.0–28.1

Note: *Calculated as the mean score of component units, and it is weighted according to the number of workers in each unit.
Data are sourced from McMillan et al. (2009).

Exposure Measures

This study used two indicators of SES: the Australian Socioeconomic Index 2006 (AUSEI06; McMillan, Beavis et al., 2009) and the Index of Relative Socioeconomic Disadvantage (IRSD; Pink, 2011).

The AUSEI06 is a socioeconomic index based on occupation data (McMillan, Beavis et al., 2009; Mcmillan, Jones et al., 2009), and it (and its previous iterations) have been widely used as a measure of SES (e.g. Byrne et al. (2018); Lam et al. (2019); Nabipour et al., 2011). It uses occupation data coded according to the Australian and New Zealand Standard Classification of Occupations (ANZSCO) to create scores on a status scale from 0 (low-status occupations) to 100 (high-status occupations) (McMillan, Beavis et al., 2009); see Table 1. We coded responses from the Health and Lifestyle Questionnaire into these categories (Lam et al., 2019). In all regression analyses, AUSEI06 was used in steps of 10 units for an appropriate effect size.

The IRSD is a more composite, but less specific measure of SES based on area-level variables relating to education, occupation and economic resources (Pink, 2011). The IRSD ranks areas from most disadvantaged to least disadvantaged (Pink, 2011). IRSD scores have been validated as generally reflecting the SES of regions as determined by the Australian Bureau of Statistics (Pink, 2011) and have been associated with BMI in a similar family study (Scurrah et al., 2015). Investigating both individual and area-based measures is important because they reflect different aspects of SES and may have different associations with BMI (Chen & Paterson, 2006). As recommended by the Australian Bureau of Statistics, our analysis used IRSD scores in deciles for ease of interpretation (Pink, 2011).

Statistical Analysis

Methods to account for clustering are necessary in twin analyses because outcomes within a pair tend to be correlated. We used a regression model outlined by Carlin et al. (2005) that accounts for clustering and includes estimates of the association between SES and BMI both within and between twin pairs. This model is known as a co-twin control within-between analysis and can be described as follows:

https://doi.org/10.1017/thg.2021.14 Published online by Cambridge University Press

$$Y_{ij} = \beta_0 + \beta_w(X_{ij} - \overline{X}_i) + \beta_b\overline{X}_i,$$

where Y_{ij} is the expected value of the outcome for a certain individual in the i^{th} twin pair, in which j equals either 1 or 2 and represents the arbitrary ordering of twins in the pair. β_b is the between-pair coefficient, representing the expected change in Y for a unit change in the mean value of variable X in the i^{th} twin pair ($\overline{X}_i$). β_w is the within-pair coefficient, representing the expected change in Y for a unit change in the difference between a twin's individual value of the exposure variable X (X_{ij}) and the mean value of variable X in their twin pair ($\overline{X}_i$). β_0 is the intercept.

The within-pair coefficient (β_w) will not be affected by any potentially confounding factors that are common to twins within a pair (Carlin et al., 2005). The between-pair coefficient (β_b) may be affected by these potentially confounding factors, and so a comparison of these two coefficients yields important information on the impact of confounding when not accounting for these factors (Carlin et al., 2005).

This model was fitted using a mixed-effects regression approach, accounting for clustering by incorporating a pair-specific random effect term that allows the intercept to vary between pairs (not shown in equation for simplicity). Age and gender both affect BMI and were adjusted for in all analyses. Parents' post-school education was also included in the model because it has been commonly used as a proxy measure of childhood SES (Wu et al., 2015) and was the best measure of this available from the Health and Lifestyle Questionnaire data. Childhood SES is correlated with adult SES and BMI, and hence is a potential confounder in the between-pair analyses (it is controlled for implicitly in the within-pair analyses).

Gender was tested as an effect modifier via likelihood ratio tests. These compared the models with and without an interaction between SES and gender, for both within- and between-pair effects and for both measures of SES.

A sensitivity analysis was conducted to determine the effect of outlying data. Standardized residuals were calculated after fitting the model and any observation with an absolute value greater than 3 was deemed a likely outlier and removed from the analysis (Field, 2013). The model was then fitted again.

Results

Figure 1 shows the participant flowchart; 1918 twin pairs completed the Health and Lifestyle Questionnaire from approximately 35,000 adult pairs on the registry. After removal of those with incorrect or missing data, 1431 pairs remained for the AUSEI06 analysis and 1558 remained for the IRSD analysis.

Table 2 shows the characteristics of the study participants. As the continuous variables were somewhat skewed, their distributions are displayed as median (interquartile range) rather than mean (standard deviation). Participants were predominantly female (76.6%) and monozygotic (74.1%). Ages ranged from 18 to 85, with a median of 48 (interquartile range 35–60). The median BMI was 24.5 kg/m^2, with just under half of all participants classified as overweight or obese by the WHO thresholds (WHO, 2000). This is slightly below the national average of 63% (Australian Institute of Health and Welfare, 2018). Average SES was higher than in the general population, with a median IRSD decile of 8 and median AUSEI06 score of 67 — a score that lies between the two highest ANZSCO groups of managers (58.1) and professionals (81.6) (McMillan, Beavis et al., 2009); see Table 1.

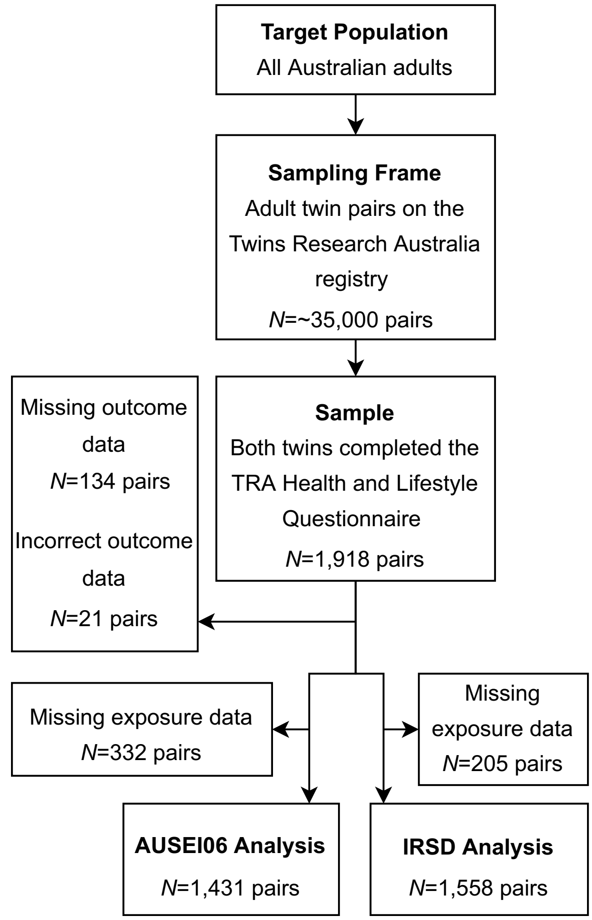

Fig. 1. Participant flowchart.

There was little correlation between age and SES in the sample ($r = .05$ between age and AUSEI06 and $r = -.05$ between age and IRSD decile). There was some difference in mean SES between genders: mean (*SD*) AUSEI06 score 62.4 (21.8) for females and 64.1 (22.4) for males, and mean (*SD*) IRSD decile 6.7 (2.7) for females and 7.1 (2.6) for males. Similarly, mean SES varied depending on whether participants' parents had undertaken post-school education: mean (*SD*) AUSEI06 score 60.9 (21.7) for neither parent having undertaken post-school education and 66.5 (21.6) for at least one parent, mean (*SD*) IRSD decile 6.4 (2.8) for neither parent and 7.1 (2.6) for at least one parent.

Approximately 65% of twin pairs were discordant for IRSD deciles and the median within-pair absolute difference in the AUSEI06 score was 11.9 (interquartile range 3.0–28.7). The median within-pair difference in BMI was 2.0 kg/m^2 (interquartile range 0.8–4.1).

Figures 2 and 3 give a visual representation of the range of within-pair differences in the exposures and the outcome, and the unadjusted relationship between them. As shown by the flat overlaid Lowess lines, no association was observed between within-pair differences in either measure of SES and BMI.

Table 3 shows the results of the co-twin control within-between analysis, which adjusted for age, gender and parents' post-school education. Consistent with Figures 2 and 3, the within-pair estimates (β_w) for both SES measures were approximately zero and had confidence intervals roughly centered around the null, showing that no association between SES and BMI was observed within-pairs. Conversely, the between-pair estimates (β_b) showed strong

https://doi.org/10.1017/thg.2021.14 Published online by Cambridge University Press

Table 2. Characteristics of participants in the sample after removal of those with missing or incorrect outcome data (*N* = 3526 individuals)

Characteristic	Number (%)
Individual gender	
Female	2701 (76.6)
Male	825 (23.4)
Twin gender combinations (pairs)	
Female–female	1265 (71.8)
Male–female	171 (9.7)
Male–male	326 (18.5)
Zygosity	
Identical (monozygotic)	2614 (74.1)
Nonidentical (dizygotic)	912 (25.9)
Participant has undertaken post-school education	
Yes	2761 (80.3)
No	678 (19.7)
Any parent of participant has undertaken post-school education	
Yes	1779 (60.7)
No	1150 (39.3)
	Median [Q1–Q3]
Age	48 [35–60]
Australian Socioeconomic Index 2006 score	67 [42.6–82]
Index of Relative Socioeconomic Disadvantage score	1033 [984–1071]
Index of Relative Socioeconomic Disadvantage Decile	8 [5–9]
Body mass index (kg/m²)	24.5 [21.8–27.9]

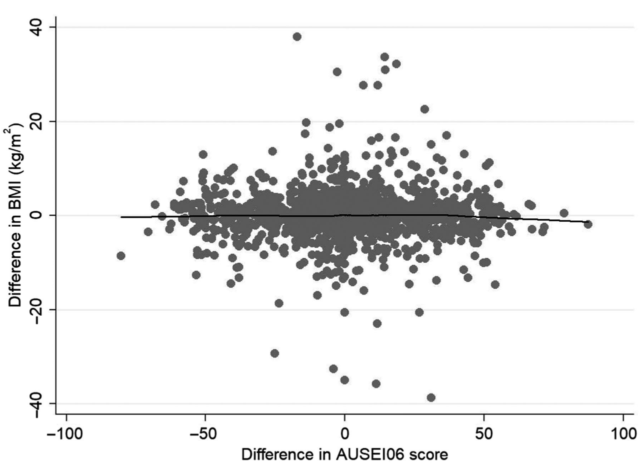

Fig. 2. Scatter plot of within-pair differences in body mass index versus within-pair differences in Australian Socioeconomic Index 2006 score with Lowess line overlaid.

inverse associations between SES and BMI. A 10-unit increase AUSEI06 was associated with an estimated population mean BMI decrease of 0.29 kg/m^2 (95% CI [−.42, −.17], $p < .001$) and a 1-decile increase in IRSD score was associated with a population mean BMI decrease of 0.26 kg/m^2 (95% CI [−.35, −.17], $p < .001$).

The likelihood ratio tests comparing the models with and without a gender interaction provided no evidence against the null hypothesis

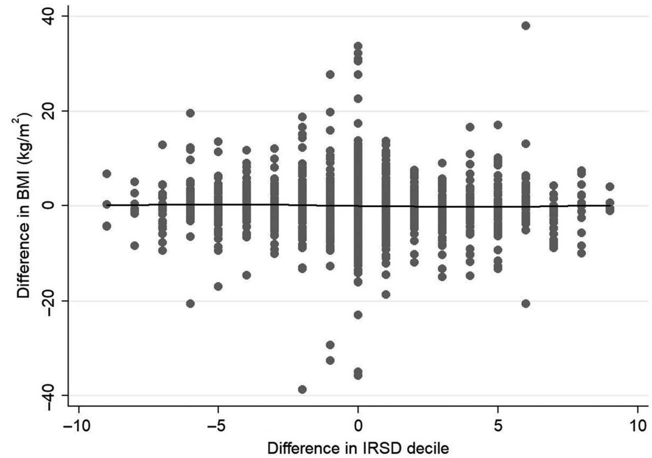

Fig. 3. Scatter plot of within-pair differences in body mass index versus within-pair differences in Index of Relative Socioeconomic Disadvantage decile with Lowess line overlaid.

of no modification of the relationship between SES and BMI by gender ($p = .81$ for the AUSEI06 model, $p = .30$ for the IRSD model).

No meaningful differences were observed in the results after removing potential outliers in the sensitivity analysis (data are not shown). Additionally, as there was such an extreme imbalance in the zygosity and gender of pairs, all analyses were repeated with just monozygotic pairs and separately with just female–female pairs. No meaningful differences were observed in either case. For example, upon restriction to just female–female pairs, the within-pair and between-pair coefficients for the AUSEI06 regression changed from .01 (95% CI [−.10, .13]) and −.29 (95% CI [−.42, −.17]), respectively, to −.02 (95% CI [−.16, .11]) and −.30 (95% CI [−.45, −.15]). Upon restriction to just monozygotic pairs, these coefficients changed to .06 (95% CI [−.07, .19]) and −.34 (95% CI [−.48, −.19]). As such, we did not restrict our sample to these categories in the main analyses.

Discussion

Main Findings

The between-pair coefficients give estimates that do not account for unmeasured potential confounders that are common to twins within a pair. As shown in Table 3, these values indicate moderately sized, but strong inverse associations between both measures of adult SES and BMI between twin pairs.

In contrast, the within-pair coefficients account for any unmeasured confounders that are common to twins within a pair. As shown in Table 3, the magnitudes of these estimates were all approximately zero and provided no evidence against the null hypotheses of no association. This result shows that there was no association between adult SES and BMI once we implicitly controlled for these unmeasured confounders.

Together, the results from the within- and between-pair analyses suggest that substantial confounding is present in the association between adult SES and BMI when not controlling for factors common to twins within a pair.

Finally, despite previous findings that gender may be an effect modifier of the relationship between SES and BMI (McLaren, 2007; Sobal & Stunkard, 1989), our study does not support this conclusion.

https://doi.org/10.1017/thg.2021.14 Published online by Cambridge University Press

Table 3. Results of the co-twin control within-between analysis of the effect of two measures of socioeconomic status on body mass index (kg/m^2)

		Estimate	95% CI	*p* value
Australian Socioeconomic Index 2006 (10 units)	β_w	0.01	[−0.10, 0.13]	.84
	β_b	−0.29	[−0.42, −0.17]	<.001
Index of Relative Socioeconomic Disadvantage Decile	β_w	−0.05	[−0.14, 0.04]	.27
	β_b	−0.26	[−0.35, −0.17]	<.001

β_w = within-pair coefficient; β_b = between-pair coefficient.
Note: Model fit using a mixed-effects approach and is adjusted for age, gender and parents' post-school education.

Interpretations

Our finding of no association between adult SES and BMI after accounting for factors shared between twins is one that is consistent with much of the previous research. Of the prominent twin and family studies looking into SES and BMI, Osler et al. (2007) and Dinescu et al. (2016) also found no association. Krieger et al. (2005) did not find an association between adult SES and BMI either, although they did find an association with cardiovascular disease risk, as did Tiikkaja et al. (2012). One explanation for this finding may be that adult SES is associated with cardiovascular disease via pathways that do not involve BMI. Somewhat consistent with our findings, Webbink et al. (2010) found similar null results when looking at years of education and adult BMI within female twin pairs, although they did find an association within male twin pairs. However, our study used more direct measures of SES than years of education, which may explain this difference. Finally, Scurrah et al. (2015) found that a change in SES in young adulthood is inversely associated with BMI while controlling for childhood SES. Despite their study also being conducted on an Australian population, their results are not consistent with our findings. However, some significant differences may help explain this discrepancy, such as the fact that the study occurred approximately 20 years before the release of the Health and Lifestyle Questionnaire (1990−1996 compared to 2014 onwards) and involved a much younger sample (18−30 years compared to 18 years and over).

Our findings suggest that there are factors common to twins within a pair that are confounding associations between adult SES and BMI seen in the general population (i.e. between unrelated individuals). It is unclear from the literature exactly what these factors are, but there are many potential candidates. Early life environment is one possibility and is known to be a strong influence on both adult SES (Branigan et al., 2013) and adult BMI (Campbell, 2016). If any aspects of early life environment affect both variables, then confounding will occur. For example, an authoritative parenting style, characterized by rational, warm and responsive direction (Baumrind, 1967), has been associated with lower BMI (Sokol et al., 2017). It has also been associated with greater academic success (Spera, 2005; Steinberg et al., 1992), which is linked to measures of adult SES such as educational attainment. Combined, these two associations would potentially result in the creation of a noncausal association between adult SES and BMI.

Similarly, genes may play a confounding role in the association between adult SES and BMI (Dinescu et al., 2016). It is well established that there is a heritable component to BMI (Goodarzi, 2018; Locke et al., 2015) and to certain measures of adult SES, such as educational attainment (Branigan et al., 2013; Lee et al., 2018; Marks, 2017; von Stumm et al., 2020). As such, confounding will occur if there is a common genetic component between the two variables. This may work through many possible pathways, including psychological factors. For example, a recent meta-analysis concluded that there is a genetic basis to self-discipline (Willems et al., 2019). This is a trait that may affect dietary choices and consequently BMI (Koike et al., 2016; Tsukayama et al., 2010). Additionally, self-discipline may affect academic success (Duckworth & Seligman, 2005; Mischel et al., 1989) and educational attainment (Moffitt et al., 2011), and consequently adult SES. Again, such a scenario would create an association between adult SES and BMI in the absence of any causal relationship.

Although our study does not support a causal association between SES and BMI in adulthood, other literature does suggest that one may exist in childhood and adolescence. As mentioned previously, a recent systematic review concluded that children of lower SES backgrounds in high-income countries had significantly higher risks of overweight and obesity (Wu et al., 2015). Other systematic reviews have found similar associations between childhood SES and adult cardiovascular disease (Galobardes et al., 2006; Pollitt et al., 2005), a relationship in which BMI may be on the causal pathway (Pollitt et al., 2005).

In explaining the association between childhood SES and adult cardiovascular disease in their systematic review, Pollitt et al. (2005) found most support for the theory that the psychosocial and physiological impacts associated with low SES can accumulate throughout a person's life and result in negative health outcomes. Additionally, many of the links between early life SES and BMI may exist through learned behaviors, such as diet and exercise practices (Pollitt et al., 2005), which may persist in later life despite a change in SES. Unsurprisingly, childhood obesity is also a very strong risk factor for adulthood obesity (WHO, 2000). Taken together, these findings lead to the conclusion that any change in SES in adulthood will be operating on strong foundations laid in early life and that these may be difficult to change. These early life foundations are perhaps why we did not find an association between adult SES and BMI, but one does seem to exist between childhood SES and BMI.

Strengths and Limitations

Our study had several significant strengths. Most importantly, the twin study design provides the ability to account for confounding from unmeasured variables that are common to twins within a pair. Our statistical approach, in which we included both within- and between-pair effects in the same model, to our knowledge had not been used before in this context and allowed us to make inferences about the potential impact of confounding on the association between adult SES and BMI. Additionally, our use of two separate indicators of SES is valuable given that one indicator may not show the whole picture, and that the relationship with BMI can vary with different measures (Basto-Abreu et al., 2018; Galobardes et al., 2006; Krieger et al., 2005; McLaren, 2007). Our conclusions are consistent across both an individual and an area-level measure of SES, which increases their generalizability to SES as a whole. The sample size was also large — especially for a twin study — which gives weight to the results. Finally, the sensitivity analysis conducted also showed that the results are robust and not significantly affected by the presence of any outliers.

The main limitation of this study was that the sample was quite homogenous. Of particular note, there were few people from the lowest SES backgrounds, which may make conclusions

https://doi.org/10.1017/thg.2021.14 Published online by Cambridge University Press

regarding them less strong. That said, the sample size was large enough that most underrepresented groups still had a reasonable number of people in them. Similarly, as is often the case with twin studies in general, the differences in exposures within twin pairs tended to be relatively small, which may have increased the chance of a null finding regarding the within-pair estimates. However, the confidence intervals for the within-pair estimates were quite narrow, with the largest magnitude limits being an increase in BMI of 0.13 kg/m^2 for every 10 units increase in AUSEI06 and a 0.14 kg/m^2 decrease for every decile increase in IRSD. Hence, large true effects appear implausible from these results, despite the relatively small differences in exposures within twin pairs.

Additionally, there may be some selection bias occurring within this sample due to the nature of the questionnaire. As is the case with optional participation, people who respond may be systematically different from those who do not. In this case, it is reasonable to suspect that those who responded may be more likely to have an interest in health research, and by extension, their own health.

Finally, we were somewhat limited by the availability of variables in our dataset. The proxy measure of childhood SES we used (parents' post-school education) is by no means perfect, and so there may be some residual confounding in the between-twin estimates. Unfortunately, more accurate measures of childhood SES such as parental income were not available. Similarly, a measure of household income, which could have been used in addition to the AUSEI06 as a measure of individual SES, was also unavailable. The fact that the AUSEI06 only applies to part- and full-time workers and reflects only an individual's status (as opposed to the highest status in the household) are drawbacks of this measure.

Conclusions

This study found that associations observed between adult SES and BMI may be explained by factors that are common to twins within a pair. This has significant implications for research into adult SES and BMI that does not account for potential confounding factors. Future research should determine what these confounding factors are so they can potentially be targeted in health interventions.

Acknowledgments. I would like to extend my thanks to Twins Research Australia for the opportunity to conduct this research, along with all the generous participants of the Health and Lifestyle Questionnaire who made it possible.

Financial Support. This research was facilitated through access to Twins Research Australia, a national resource supported by a Centre of Research Excellence Grant (ID: 1079102), from the National Health and Medical Research Council.

Conflicts of Interest. None.

Ethical Standards. This study received formal approval from TRA and ethics approval from the Melbourne School of Population and Global Health's Human Ethics Advisory Group (Ethics ID: 1853456.1).

References

Aggarwal, A., Monsivais, P., Cook, A. J., & Drewnowski, A. (2011). Does diet cost mediate the relation between socioeconomic position and diet quality? *European Journal of Clinical Nutrition*, *65*, 1059–1066.

Australian Institute of Health and Welfare. (2018). Australia's Health 2018. https://www.aihw.gov.au/reports/australias-health/australias-health-2018/contents/table-of-contents

Ball, K., & Crawford, D. (2005). Socioeconomic status and weight change in adults: A review. *Social Science & Medicine*, *60*, 1987–2010.

Basto-Abreu, A., Barrientos-Gutiérrez, T., Zepeda-Tello, R., Camacho, V., Gimeno Ruiz de Porras, D., & Hernández-Ávila, M. (2018). The relationship of socioeconomic status with body mass index depends on the socioeconomic measure used. *Obesity*, *26*, 176–184.

Baumrind, D. (1967). Child care practices anteceding three patterns of preschool behavior. *Genetic Psychology Monographs*, *75*, 43–88.

Branigan, A. R., McCallum, K. J., & Freese, J. (2013). Variation in the heritability of educational attainment: An international meta-analysis. *Social Forces*, *92*, 109–140.

Byrne, M. L., Schwartz, O. S., Simmons, J. G., Sheeber, L., Whittle, S., & Allen, N. B. (2018). Duration of breastfeeding and subsequent adolescent obesity: Effects of maternal behavior and socioeconomic status. *Journal of Adolescent Health*, *62*, 471–479.

Campbell, M. K. (2016). Biological, environmental, and social influences on childhood obesity. *Pediatric Research*, *79*, 205–211.

Carlin, J. B., Gurrin, L. C., Sterne, J. A., Morley, R., & Dwyer, T. (2005). Regression models for twin studies: A critical review. *International Journal of Epidemiology*, *34*, 1089–1099.

Chen, E., & Paterson, L. Q. (2006). Neighborhood, family, and subjective socioeconomic status: How do they relate to adolescent health? *Health Psychology*, *25*, 704.

Cheon, B. K., & Hong, Y.-Y. (2017). Mere experience of low subjective socioeconomic status stimulates appetite and food intake. *Proceedings of the National Academy of Sciences,* 114, 72–77.

Claassen, M. A., Klein, O., Bratanova, B., Claes, N., & Corneille, O. (2018). A systematic review of psychosocial explanations for the relationship between socioeconomic status and body mass index. *Appetite*, *132*, 208–221.

Cutler, T. (2015). *The Australian Twin Registry Health and Lifestyle Questionnaire*. Australian Twin Registry. http://twins.org.au/images/general/publications/HLQ_abstract.pdf

d'Addio, A. C. (2007). *Intergenerational transmission of disadvantage: Mobility or immobility across Generations? A review of the evidence for OECD countries*. OECD. https://www.oecd-ilibrary.org/social-issues-migration-health/intergenerational-transmission-of-disadvantage_217730505550

Dinescu, D., Horn, E. E., Duncan, G., & Turkheimer, E. (2016). Socioeconomic modifiers of genetic and environmental influences on body mass index in adult twins. *Health Psychology*, *35*, 157.

Duckworth, A. L., & Seligman, M. E. (2005). Self-discipline outdoes IQ in predicting academic performance of adolescents. *Psychological Science*, *16*, 939–944.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. SAGE Publications.

Fujiwara, T., & Kawachi, I. (2009). Is education causally related to better health? A twin fixed-effect study in the USA. *International Journal of Epidemiology*, *38*, 1310–1322.

Galobardes, B., Smith, G. D., & Lynch, J. W. (2006). Systematic review of the influence of childhood socioeconomic circumstances on risk for cardiovascular disease in adulthood. *Annals of Epidemiology*, *16*, 91–104.

Goodarzi, M. O. (2018). Genetics of obesity: What genetic association studies have taught us about the biology of obesity and its complications. *Lancet Diabetes Endocrinology*, *6*, 223–236.

Herzog, B., Lacruz, M. E., Haerting, J., Hartwig, S., Tiller, D., Medenwald, D., Vogt, S., Thorand, B., Holle, R., Bachlechner, U., Boeing, H., Merz, B., Nöthlings, U., Schlesinger, S., Schipf, S., Ittermann, T., Aumann, N., Schienkiewitz, A., Haftenberger, M., & Kluttig, A. (2016). Socioeconomic status and anthropometric changes — A meta-analytic approach from seven German cohorts. *Obesity*, *24*, 710–718.

Hruby, A., & Hu, F. B. (2015). The epidemiology of obesity: A big picture. *PharmacoEconomics*, *33*, 673–689.

Koike, S., Hardy, R., & Richards, M. (2016). Adolescent self-control behavior predicts body weight through the life course: A prospective birth cohort study. *International Journal of Obesity*, *40*, 71–76.

Krieger, N., Chen, J. T., Coull, B. A., & Selby, J. V. (2005). Lifetime socioeconomic position and twins' health: An analysis of 308 pairs of United States women twins. *PLoS Medicine*, *2*, e162.

Lam, J. R., Tyler, J., Scurrah, K. J., Reavley, N. J., & Dite, G. S. (2019). The association between socioeconomic status and psychological distress: A within and between twin study. *Twin Research and Human Genetics*, *22*, 312–320.

Lee, J. J., Wedow, R., Okbay, A., Kong, E., Maghzian, O., Zacher, M., Nguyen-Viet, T. A., Bowers, P., Sidorenko, J., Karlsson Linnér, R., Fontana, M. A., Kundu, T., Lee, C., Li, H., Li, R., Royer, R., Timshel, P. N., Walters, R. K., Willoughby, E. A., & Cesarini, D. (2018). Gene discovery and polygenic prediction from a genome-wide association study of educational attainment in 1.1 million individuals. *Nature Genetics*, *50*, 1112–1121.

Locke, A. E., Kahali, B., Berndt, S. I., Justice, A. E., Pers, T. H., Day, F. R., Powell, C., Vedantam, S., Buchkovich, M. L., Yang, J., Croteau-Chonka, D. C., Esko, T., Fall, T., Ferreira, T., Gustafsson, S., Kutalik, Z., Luan, J., Mägi, R., Randall, J. C., & Speliotes, E. K. (2015). Genetic studies of body mass index yield new insights for obesity biology. *Nature*, *518*, 197–206.

Marks, G. N. (2017). The contribution of genes and the environment to educational and socioeconomic attainments in Australia. *Twin Research and Human Genetics*, *20*, 281–289.

McLaren, L. (2007). Socioeconomic status and obesity. *Epidemiologic Reviews*, *29*, 29–48.

McMillan, J., Beavis, A., & Jones, F. L. (2009). The AUSEI06: A new socioeconomic index for Australia. *Journal of Sociology*, *45*, 123–149.

McMillan, J., Jones, F. L., & Beavis, A. (2009). A new scale for measuring socioeconomic status in educational research: Development and validation of the Australian Socioeconomic Index 2006 (AUSEI06). Paper presented at the AARE International Education Research Conference, Canberra.

Mischel, W., Shoda, Y., & Rodriguez, M. I. (1989). Delay of gratification in children. *Science*, *244*, 933–938.

Moffitt, T. E., Arseneault, L., Belsky, D., Dickson, N., Hancox, R. J., Harrington, H., Houts, R., Poulton, R., Roberts, B. W., Ross, S., Sears, M. R., Thomson, W. M., & Caspi, A. (2011). A gradient of childhood self-control predicts health, wealth, and public safety. *Proceedings of the National Academy of Sciences*, *108*, 2693–2698.

Monteiro, C. A., Moura, E. C., Conde, W. L., & Popkin, B. M. (2004). Socioeconomic status and obesity in adult populations of developing countries: A review. *Bulletin of the World Health Organization*, *82*, 940–946.

Moore, C. J., & Cunningham, S. A. (2012). Social position, psychological stress, and obesity: A systematic review. *Journal of the Academy of Nutrition and Dietetics*, *112*, 518–526.

Murphy, K., Lam, J., Cutler, T., Tyler, J., Calais-Ferreira, L., Li, S., Little, C., Ferreira, P., Craig, J. M., Scurrah, K. J., & Hopper, J. L. (2019). Twins Research Australia: A new paradigm for driving twin research. *Twin Research and Human Genetics*, *22*, 438–445.

Nabipour, I., Cumming, R., Handelsman, D. J., Litchfield, M., Naganathan, V., Waite, L., Creasey, H., Janu, M., Le Couteur, D., Sambrook, P. N., & Seibel, M. J. (2011). Socioeconomic status and bone health in community-dwelling older men: The CHAMP study. *Osteoporosis International*, *22*, 1343–1353.

Osler, M., McGue, M., & Christensen, K. (2007). Socioeconomic position and twins' health: A life-course analysis of 1266 pairs of middle-aged Danish twins. *International Journal of Epidemiology*, *36*, 77–83.

Pink, B. (2011). *Socio-Economic Indexes for Areas (SEIFA)*. Australian Bureau of Statistics. https://www.ausstats.abs.gov.au/Ausstats/subscriber.nsf/0/22CEDA8038AF7A0DCA257B3B00116E34/$File/2033.0.55.001%20seifa%202011%20technical%20paper.pdf

Pollitt, R. A., Rose, K. M., & Kaufman, J. S. (2005). Evaluating the evidence for models of life course socioeconomic factors and cardiovascular outcomes: A systematic review. *BMC Public Health*, *5*, 7.

Scurrah, K. J., Kavanagh, A. M., Bentley, R. J., Thornton, L. E., & Harrap, S. B. (2015). Socioeconomic position in young adulthood is associated with BMI in Australian families. *Journal of Public Health*, *38*, e39–e46.

Sobal, J., & Stunkard, A. J. (1989). Socioeconomic status and obesity: A review of the literature. *Psychological Bulletin*, *105*, 260.

Sokol, R. L., Qin, B., & Poti, J. M. (2017). Parenting styles and body mass index: A systematic review of prospective studies among children. *Obesity Reviews*, *18*, 281–292.

Spera, C. (2005). A review of the relationship among parenting practices, parenting styles, and adolescent school achievement. *Educational Psychology Review*, *17*, 125–146.

Spinosa, J., Christiansen, P., Dickson, J. M., Lorenzetti, V., & Hardman, C. A. (2019). From socioeconomic disadvantage to obesity: The mediating role of psychological distress and emotional eating. *Obesity*, *27*, 559–564.

Steinberg, L., Lamborn, S. D., Dornbusch, S. M., & Darling, N. (1992). Impact of parenting practices on adolescent achievement: Authoritative parenting, school involvement, and encosuragement to succeed. *Child Development*, *63*, 1266–1281.

Story, M., Kaphingst, K. M., Robinson-O'Brien, R., & Glanz, K. (2008). Creating healthy food and eating environments: Policy and environmental approaches. *Annual Review of Public Health*, *29*, 253–272.

Tiikkaja, S., Olsson, M., Malki, N., Modin, B., & Sparén, P. (2012). Familial risk of premature cardiovascular mortality and the impact of intergenerational occupational class mobility. *Social Science & Medicine*, *75*, 1883–1890.

Tsukayama, E., Toomey, S. L., Faith, M. S., & Duckworth, A. L. (2010). Self-control as a protective factor against overweight status in the transition from childhood to adolescence. *Archives of Pediatrics & Adolescent Medicine*, *164*, 631–635.

von Stumm, S., Smith-Woolley, E., Ayorech, Z., McMillan, A., Rimfeld, K., Dale, P. S., & Plomin, R. (2020). Predicting educational achievement from genomic measures and socioeconomic status. *Developmental Science*, *23*, e12925.

Webbink, D., Martin, N. G., & Visscher, P. M. (2010). Does education reduce the probability of being overweight? *Journal of Health Economics*, *29*, 29–38.

Willems, Y., Boesen, N., Li, J., Finkenauer, C., & Bartels, M. (2019). The heritability of self-control: A meta-analysis. *Neuroscience & Biobehavioral Reviews*, *100*, 324–334.

Winkleby, M. A., Jatulis, D. E., Frank, E., & Fortmann, S. P. (1992). Socioeconomic status and health: How education, income, and occupation contribute to risk factors for cardiovascular disease. *American Journal of Public Health*, *82*, 816–820.

World Health Organization (WHO). (2000). Obesity: Preventing and managing the global epidemic. https://www.who.int/nutrition/publications/obesity/WHO_TRS_894/en/

World Health Organization (WHO). (2010). Global status report on noncommunicable diseases 2010. https://www.who.int/nmh/publications/ncd_report2010/en/

Wu, S., Ding, Y., Wu, F., Li, R., Hu, Y., Hou, J., & Mao, P. (2015). Socio-economic position as an intervention against overweight and obesity in children: A systematic review and meta-analysis. *Scientific Reports*, *5*, 11354.