Do health inequalities equalise in South African adolescents?: A test of West's hypothesis using body composition outcomes among South African adolescents

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ABSTRACT

Objective To examine associations between household/school/neighbourhood SES measures in infancy/16 years and body composition outcomes at 16 years to test West's (1997) hypothesis of whether there is evidence of an equalizing of inequalities in health in adolescence.

Participants A sub-sample of the Birth to Twenty (Bt20) cohort (n=458, 75% Black) with measurements taken at birth and 16 years of age were included.

Methods Linear regression analyses of household/neighbourhood/school SES, biological and demographic predictors of fat mass (FM), lean mass (LM), and body mass index (BMI)outcomes were undertaken using a stepped approach to parameter inclusion, which allowed for the independent effects of infancy and age 16 year variables to be estimated.

Results Consistent predictors of higher FM/LM and BMI in fully adjusted models were gender (females had significantly higher FM/BMI and lower LM), being born post term, and having a mother with a higher BMI. Poor infancy household water facilities were associated with higher BMI/FM. Post school maternal education was associated with higher BMI/FM, before controlling for maternal BMI.

Conclusions SES was only weakly associated with body composition in these South African 16 year olds, which is in contrast to earlier findings with Bt20 9/10 year olds where SES was associated with body composition. This supports West's hypothesis of an equalising of health inequalities in adolescence in this South African setting. However, in addition to the social mechanisms proposed by West (1997) for this equalisation there is a need to also consider the context of the biological changes occurring in adolescence.

INTRODUCTION

Socio-economic status (SES) has been broadly associated with a variety of diseases as well as adverse birth outcomes, malnutrition, stunting, and impaired child growth (Adler and Ostrove, 1999; Barker et al., 2001; Bentley and Griffiths, 2003; Fuhrer et al., 2002; Griffiths and Bentley, 2001; Popkin, 2001; Sobal and Stunkard, 1989; Teranishi et al., 2001; Yen and Moss, 1999). Inequalities in many health and disease outcomes have been established globally, however the extreme income inequalities in some middle income countries such as South Africa provide a greater potential for exacerbation of health inequalities than those observed in many other regions of the world (Sanders and Chopra, 2006).

Despite the fact that health inequalities exist, researchers are still striving to understand their evolution across the life-course. Research has linked childhood SES measured by father's occupation, birth order, number of siblings, or occupation on entry to the workforce, with adult mortality, (Beebe-Dimmer et al., 2004; Davey Smith et al., 2006; Power et al., 2005; Wamala et al., 2001) cardiovascular disease (Blane et al., 1996), and adult BMI (Hardy et al., 2000). In these studies adverse childhood social conditions are associated with higher mortality or morbidity in adulthood, even after accounting for adult SES.

It is important to understand the potential mechanisms through which SES might work to increase risk of premature mortality and cardiovascular disease. One potential mechanism through which SES could influence risk of these adverse outcomes is to alter body composition earlier in life. In earlier work we investigated the association between household SES in infancy and household SES in later childhood (ages 9/10 years) with body composition outcomes in late childhood in a South African cohort known as Birth to Twenty (Bt20) whose participants were born in Johannesburg-Soweto in 1990 (Griffiths et al., 2008). We showed that the infancy SES environment was more strongly associated with lean mass than fat mass, with higher household SES in infancy being associated with higher lean mass. In contrast, the contemporary (age 9/10 years) household SES measures were more strongly associated with fat mass than lean mass in contrast to the pattern found during infancy, when the higher SES households had infants with higher fat mass. At ages 9/10 years, there was low prevalence of overweight and obesity in this cohort, with a higher prevalence of malnutrition, thus indicating at this age that the high SES children were advantaged. In order to prioritise intervention targeting it is important to know when SES inequalities have the most potential to influence risk factors for chronic disease.

The Bt20 cohort offers an opportunity to take this earlier research a stage further into the life-course to understand the relationship between SES and body composition during adolescence. This is important because despite the strongly established link between SES and many health outcomes across most stages of the life-course, the evidence for a social gradient in adolescent health outcomes is less consistent, certainly within developed countries (West, 1997). West (West, 1997) suggests that adolescence may be a period in which health inequalities equalise. This hypothesis is built based upon evidence relating to mortality, chronic illness, specific conditions, self-rated health, symptoms of acute illness, accidents and injury, and mental health. With the exception of severe chronic illness, West shows that evidence for equalisation of health inequalities exists in adolescents. Critics of West's arguments suggest that the equalisation in health inequalities may be an artefact of the data used to show such equalising, for instance because of poor measures of adolescent SES through adult occupation measures(Judge and Benzeval, 1993) or poor health indicators such as self report assessments of health outcomes, which may themselves be influenced by an individual's SES(Davey Smith et al., 1994).

If adolescent health equalisation exists there has to be a potential mechanism through which such equalisation might occur. West suggests a potential sociological explanation, whereby peer/youth culture and school influences become more important during the secondary school years of adolescent life relative to social class or household SES (West, 1997). This suggests that potentially the SES environment external to the household may become more important than the household SES environment as adolescents spend less time in the home and more time with peers in the school or neighbourhood environment. Adolescence marks the onset of increasing independence from the family and more time being spent in the community (Allison et al., 1999). West (1997) argues that the school and peer environment could be more important than even the neighbourhood SES environment because adolescents tend to identify more with their peer group culture than with other external forces like the household and aspects of the neighbourhood not relevant to that culture. At the time of West's writing the measures used to assess neighbourhood SES environment in studies of adolescent health inequalities had not attempted to assess the relevance of these measured components of neighbourhood SES to this adolescent age group.

Subsequent to the publication of West's hypothesis a number of review studies explored further the relationship between SES and adolescent health outcomes and found mixed evidence for a relationship, although the balance of the evidence was more strongly towards inequalities existing rather than not existing(Holstein et al., 2009; Starfield et al., 2002). More specifically focussing on the relationship between SES and obesity/adiposity, a review by Shrewsbury et al. (2008) of 45 child and adolescent (9 adolescent only) studies from developed countries between 1990 and 2005 found an inverse association in 6 out of 9 adolescent studies for boys and 1 out of 9 studies for girls(Shrewsbury and Wardle, 2008). Thus, again providing mixed evidence for a link between SES and this specific health outcome. Despite a number of review studies examining the link between household SES and adolescent health outcomes, there is less evidence considering the relationship between components of the neighbourhood/school SES environment and health outcomes in adolescents. One review paper did consider this topic in the context of overweight and obesity and its association with factors in the physical environment by reviewing 15 studies (7 adolescent) that met the inclusion criteria, of which most were cross sectional and published after 2005(Holstein et al., 2009). Whilst this review found evidence of a neighbourhood SES gradient in overweight and obesity for children, no such relationship was observed for adolescents. There is much less evidence examining inequalities in adolescent obesity within developing country contexts. The limited existing evidence relating SES to body composition outcomes in adolescents in South Africa suggests no association or a weak link in boys at the household level(Kruger et al., 2006) and no evidence exists to test the association at the neighbourhood level. Previous researchers studying the link between SES and health outcomes in adolescents have called for a need to use more longitudinal approaches to understand associations between SES and adolescent health outcomes in order for researchers to establish how inequalities might develop or equalise over the early life-course (Starfield et al., 2002). This study is the first to attempt use such an approach to study adolescent inequalities in body composition outcomes in the South African context.

A lack of data on neighbourhood/ school SES, especially within developing country contexts, has made it difficult to specifically fully test West's hypothesis for equalisation of inequalities in adolescence. For the first 15 years of the Bt20 cohort study, data were collected on the household SES environment. At age 16 years these data were expanded for a sub-sample to include measures of the neighbourhood/school SES environment.Given that it has already been established that inequalities in body composition exist within the Bt20 cohort at the end of childhood, these data present an ideal opportunity to test West's hypothesis within a developing country context to see whether such inequalities continue to exist or whether equalisation occurs in adolescence (age 16) using a comprehensive set of both household and neighbourhood/school SES measures. This comprehensive set of SES measures addresses some of the earlier concerns of critics of West's argument for equalisation about the lack of robust measures of SES in adolescent studies by using a range of self assessed and caregiver assessed measures of SES taken at the household and neighbourhood/school level. This range of measures also presents the opportunity to test West's idea that aspects of the school SES environment might more strongly measure inequalities at this age than more traditional SES measures. Using objectively measured outcomes of body mass, lean mass, and fat mass also overcomes some of the earlier problems of adolescent studies using self report health outcomes. This paper examines the association between household/neighbourhood/school SES measures in infancy/ at age 16 years and body composition outcomes at age 16 years controlling for a range of potentially confounding factors.

MATERIALS AND METHODS

Participants

Birth to Twenty (Bt20) is a longitudinal cohort study of 3273 singleton births occurring in 1990 to permanently resident mothers in Johannesburg-Soweto, South Africa (Richter et al., 2007; Richter et al., 2004). At ages 9/10 years, a sub-sample from the cohort (n=429) was enrolled into a longitudinal study assessing factors influencing bone health. The bone health study also recruited additional White children at ages 9/10 years to allow for an over representation of this minority group within the sub-sample. Enrolment took place by sending letters to parents of predominantly White children attending the same schools as the Bt20 children, which increased the Bone Health sample to 589 children. Bone health participants had more detailed health and SES assessments than the Bt20 cohort. Those with data on household/neighbourhood/school SES and anthropometric and dual-energy X-ray absorptiometry (DXA) data at 16 years were included in current analyses (n = 458, 52% male, 75% Black).

Ethical approval was granted by the ethics committees of the University of the Witwatersrand, South Africa and Loughborough University, UK. The primary caregiver gave written informed consent for their adolescent to participate and the adolescent provided written ascent to participate at 16 years.

Socio-economic status measures

During infancy and at 16 years household SES measures were caregiver assessed using a questionnaire that was based on standard measures used by the Demographic and Health Surveys (www.measuredhs.com). The Bt20 SES questionnaire was piloted with 30 non-cohort caregivers to test for appropriate translation of concepts. Measures included caregiver's education and occupation, home ownership and type, water/toilet facilities, marital status, and household consumer durable ownership. At 16 years of age neighbourhood/school SES was assessed using a culturally relevant questionnaire, which was developed by consulting community leaders and Bt20 adolescents/caregivers using focus group discussions and in-depth interviews in 2005/2006 (Sheppard et al., 2010). Neighbourhood was defined for all participants as an area approximately 20 minutes walk or 2 kilometres from home in any direction.

The neighbourhood SES questionnaire included questions relating to; 1) economic aspects of neighbourhoods including neighbourhood wealth, perceived inequalities in wealth, type, condition, and spacing of housing, infrastructure and service provision type and condition of roads, and neighbourhood problems (e.g. traffic congestion, illegal dumping), 2) social aspects of neighbourhoods including safety, crime, activities for young people, neighbourhood friends/peer pressure, noise, and religious involvement, 3) school environment with questions on school type, facilities, class sizes, out of school activities, and problems (e.g. poor academic standards, alcohol/drug consumption, weapons).

To enable a more parsimonious analysis of SES measures and to avoid problems of multicollinearity, principal components analysis (PCA) was used to construct neighbourhood SES indices. A theory based approach was used to develop nine indices and PCA confirmed the appropriateness of grouping these variables together. In each case the first component scores were extracted and the statistical assumption that all Eigenvalues be greater than 1 was met. Three indices measured neighbourhood economics; 1) Neighbourhood economic index, 2) Neighbourhood need for more services/facilities index, and 3) Neighbourhood problem index. Two indices measured neighbourhood social aspects; 1) Neighbourhood crime prevention index and 2) Neighbourhood social support/happiness index. Two variables (How safe do you feel in the neighbourhood and How much crime is there in the neighbourhood?) did not load well onto any index and were thus retained as individual variables. There were also two school neighbourhood indices identified; 1) School environment index and 2) School problems index. In addition to the seven neighbourhood SES indices, household questionnaire data were used to construct two indices that measured ownership of consumer durables, the first during infancy and the second at 16 years. Regression factor scores were extracted for each index and tertiles for each index, based only on the Black sample, were created. A variable was created to identify Black adolescents who transitioned from one consumer durables tertile to another between infancy and 16 years. Due to the small n and a reasonable level of homogeneity of SES within the White sample, regression factor scores for White adolescents for each index were dichotomized about the median rather than using tertiles.

Anthropometric and DXA-derived body composition measures

Birthweight and weight and height at 16 years were assessed using standard techniques (Lohman et al., 1991). Weight was measured using digital scales and height using a stadiometer (Holtain, UK). Low birthweight was defined as a birthweight less than 2.5kg. Body mass index was calculated as weight (Kg)/height $(m)^2$ and adolescents were classified as normal weight, overweight, or obese using Cole et al.'s (Cole et al., 2000) international age specific cut-off points.

At 16 years of age a fan-beam densitometer (model QDR 4500A; Hologic Inc, Bedford, Massachusetts) was used to obtain DXA readings of body composition. Total body fat mass (FM) and lean mass (LM) were assessed using the adult software version 8.21 (Hologic Inc) to enable longitudinal follow up with comparable software into adulthood. DXA scans used recommended standardised patient positioning and scan analysis.

Other variables used in the analysis

Caregivers reported the ethnicity of the adolescent as recorded on the official birth notification. Individuals born before 37 weeks gestation were classified as preterm and after 41 weeks as post term. Adolescent's parity and mother's marital status and age were self reported during infancy. Adolescents reported smoking status (current, previous smoker, or never smoked) at age 16 years and assessed their own pubertal development with the use of picture cards detailing the different stages of the Tanner scales for breasts and genitalia or pubic hair development (Tanner, 1962). Maternal weight and height were available and maternal BMI was calculated in the same way as for adolescents, but overweight and obesity were defined using internationally accepted cut-offs of >25kg/m^2 and >30kg/m^2, respectively.

Statistical analyses

Linear regression was used with outcomes of BMI, FM, and LM, as well as logistic regression models that dichotomised adolescents into those who were overweight and obese compared to those who were not. Initial univariable regression analyses explored relationships between each SES measure and each of the outcomes. Subsequently multivariable regression analyses adjusted for all variables that had shown a relationship ($p<0.1$) with BMI, FM, or LM. Height was included as a covariate in all FM and LM models to correct for body size. This approach does not have the same flaws as percentage body fat/lean tissue or fat/lean mass indices, which include the fat/lean mass component in both the numerator and denominator and therefore overadjust for weight (Cole et al., 2008). In addition, sex was included as a covariate in all adjusted models. Regression models were built in steps; 1) significant infancy variables from the initial analysis, 2) significant year 16 household/ neighbourhood/school SES variables, 3) significant infancy and year 16 variables, and 4) added significant other variables. This approach allowed for the effects of the infancy variables and the year 16 variables to be interpreted separately, and subsequently for any mediating effect of the year 16 variables on the association between the infancy variables and the outcomes as well as any mediating effect of the other variables on the association between infancy/ year 16 SES variables and the outcomes to be investigated. Where both maternal BMI and weight status (i.e. normal, overweight, obese) were significantly associated with an outcome only weight status was taken forward to the multivariable analysis.

There was a relatively small number of White adolescents in the sample (n=112), the majority of whom were missing infancy household SES data because of the later recruitment strategy of the White group into the bone health sub-sample. Analyses were, therefore, conducted for Black adolescents (n=346) separately and these results are presented. Analyses for White adolescents were conducted but were limited to only include year 16 SES and other variables because of the large amount of missing infancy SES data for these adolescents. Separate results tables from these models are not presented, although differences between ethnic groups are highlighted in the text . All analyses were conducted using SPSS 16.0 (Chicago, Illinois).

RESULTS

Descriptive statistics revealed an overweight/obesity prevalence at 16 years of approximately 20% (Table 1). The highest prevalence of overweight/obesity was observed in Black girls (30.4%) and the lowest in Black boys (8.4%) and this difference was statistically significant ($\chi^2 = 26.8$, df = 1, $p<0.001$). BMI was also significantly greater for Black girls compared to Black boys ($t = -6.328$, df = 344, $p<0.001$). FM was greatest for girls and in both ethnic groups this difference between sexes was statistically significant (Blacks $t = -12.361$, df = 344, $p<0.001$ and Whites $t = -5.665$, df = 110, $p<0.001$). There were no statistically significant differences between ethnic groups in either BMI, FM, or prevalence rates of overweight and/or obesity, although LM was significantly greater for White adolescents compared to Blacks ($t = 6.096$, $df = 456$, $p<0.001$). Relative SES position, as measured by indices of consumer durables, was dynamic between birth and 16 years. Of those born into the lowest infancy consumer durables tertile at birth, 59% had transitioned into a higher tertile by 16 years of age (Figure 1).

Body mass index

For Black adolescents, initial linear regression models of BMI at 16 years showed that infancy variables resulting in significantly higher BMI were being female, being born post term, having a mother with post school education, and having sole and shared use of water and toilet facilities (Table 2). Being in the lowest infancy household consumer durables index was associated with significantly lower BMI. At 16 years, indoor sole use of running cold water, living in a safe neighbourhood and living in a neighbourhood with some crime, and being in the middle or lowest tertiles of the index of school environment were associated with significantly lower BMI (Table 3). Maternal BMI and obesity were associated with significantly higher adolescent BMI. In step one of the BMI multivariable regression model all infancy variables apart from the index of infancy consumer durables remained significant (Table 4). None of the year 16 variables in step two were significantly associated with BMI. When both infancy and year 16 variables were adjusted for in step three, all significant variables in the previous steps retained significance and direction of association, and indoor sole use of running cold water at 16 years became significant. When the model was also adjusted for maternal weight status, maternal post school education became insignificant and 22.5% of the variance in BMI was explained. Regression models for White adolescents revealed no significant factors.

Fat mass

Initial linear regression models of FM at 16 years for Black adolescents identified a similar list of significant predictor variables to that found for BMI. Being female, post term, having a mother with post school education, and having sole and shared use of water and toilet facilities were associated with significantly higher FM. Unlike the findings for BMI living in accommodation provided by an employer and not the index of infancy consumer durables was associated with significantly lower FM (Table 2). Year 16 variables that resulted in significantly lower FM were living in a safe or very safe neighbourhood and being in the middle or lowest tertiles of the index of school environment (Table 3). Significantly higher FM was observed in those with shared use of an indoor flush toilet and, unlike the findings for BMI, in those who reported that they never smoked at year 16. In addition, having a Tanner score of three of less for either pubic hair or breast/ genitalia development was associated with significantly lower FM . Maternal BMI and obesity were also associated with significantly higher FM at 16 years of age.

In step one of the adjusted FM regression model, all infancy variables apart from home ownership type remained significant (Table 4). All of the significant variables in step one were associated with significantly higher FM in all subsequent steps, apart from maternal education which retained significance and direction of association when year 16 variables were adjusted for in step three but not when maternal weight status was also adjusted for in step four. Of the year 16 variables, only being in the lowest tertile of the index of school environment was significant and only in step two where there was no adjustment for infancy and other variables. The final model explained 42.5% of the variance in FM at age 16 years. Regression models for White adolescents revealed three significant year 16 and other predictor variables with one associated with lower FM; living in a neighbourhood with relatively low crime, and two variables associated with higher FM; being in the lower group of the index of school environment dichotomy, and having previously smoked. When entered into a multivariable analysis, also adjusting for height and gender, only living in a neighbourhood with average crime was significantly associated with lower FM.

Lean mass

Initial linear regression models of LM showed that infancy variables resulting in significantly higher LM were being female, higher birthweight, and being born post term (Table 2). At 16 years, living in a neighbourhood with average safety and being in the lowest tertile of the index of crime prevention were associated with significantly higher LM, whereas having never smoked was associated with significantly lower LM (Table 3). Maternal BMI and obesity were associated with significantly higher LM at 16 years. All infancy variables remained significant in all steps of the model building, although none of the year 16 variables were significant in any step (Table 4). In the final model maternal obesity was associated with significantly higher LM and 65.8% of the variance in LM at 16 years was explained. Regression models for White adolescents revealed three significant year 16 and other predictor variables; indoor shared use of running hot and cold water, being in the lower group of the index of neighbourhood problems dichotomy, and having a score of four for either pubic hair or breast/genitalia development. None of these variables retained significance when adjusted for in a multivariable regression model including height and gender.

DISCUSSION

Our findings show that overweight and obesity are emerging as a health problem in the Bt20 cohort at 16 years with 20% of the sample overweight or obese, and 30% of Black females in this category. The finding of a higher prevalence of overweight and obesity in female adolescents, confirms the results of other studies of adolescents in South Africa that have also revealed a higher female prevalence of overweight and obesity when compared to males (Kruger et al., 2006; Reddy et al., 2009). At ages 9/10 years in this cohort the prevalence of childhood overweight and obesity in Black females was lower at 10% (Griffiths et al., 2008). Thus with emerging prevalence of overweight and obesity, it becomes increasingly important to understand the potential determinants of body composition outcomes to reduce risk for later chronic diseases and target interventions appropriately.

In relation to West's hypothesis of equalisation of health inequalities among adolescents, we show that there does appear to be equalisation for body composition outcomes which are risk factors for later chronic diseases in these 16 year old urban South Africans. We have tested the association between an extensive range of household, school and neighbourhood SES measures and body composition outcomes. Findings show little evidence of a strong relationship with SES measures taken at age 16 years. There is some weak evidence of an association between SES measures that are more reflective of the infant SES environment and body composition outcomes. Poor household water facilities in infancy are associated with increased FM and BMI, whereas maternal education shows that those with mothers with post school education had higher values of FM/BMI before controlling for maternal BMI. Adolescent reported neighbourhood/school SES variables at age 16 years show some association with BMI/FM in unadjusted models whereas caregiver assessed household measures do not. This supports West's idea that there is a need to measure relevant aspects of an adolescent's SES environment, which includes their relevant wider social environment. Our school/neighbourhood SES questionnaire should encompass aspects of the SES environment that adolescents consider to be important as it was developed using input from information gained from Bt20 participants at age 15 years in focus group discussions about relevant aspects of their neighbourhood and school environment (Sheppard et al., 2010). However, even these adolescent assessed neighbourhood/school measures were not significantly associated with body composition in adjusted models. Our findings therefore show a mixed pattern of association between measures of SES and body composition and no clear pattern of a unidirectional inequality in body composition outcomes at this age. This is in contrast to our earlier findings in children of 9/10 years where an SES gradient in body composition was observed using traditional household measures (Griffiths et al., 2008). West's hypothesis was built upon evidence relating to adolescent health inequalities in high income countries and as far as we are aware this is the first formal test of the hypothesis within a low/middle income country setting using longitudinal data.

The findings of this paper are important because they suggest that for body composition outcomes, SES is not driving differences within the adolescent period. Despite the lack of inequalities observed in adolescence in this study, this should be framed within the context of earlier observed inequalities both in infancy (Willey et al., 2009) and late childhood (Griffiths et al., 2008) in body composition and growth, where the low SES groups were most disadvantaged. We do not yet know whether those inequalities will again emerge in early adulthood in this cohort. It is possible that besides the original social reasons proposed by West (West, 1997) for an equalisation of youth inequalities, that biological factors also complicate the assessment of inequalities in health outcomes like body composition at this age. Such biological factors combined with the rapid social change that has been taking place in South Africa in the post-Apartheid period during which this cohort has grown up could influence the findings observed at age 16 in the cohort. Body composition is very heavily influenced by pubertal status. During puberty both boys and girls experience the adolescent growth spurt but sexually dimorphic increases in fat mass in girls and lean mass in boys under the influence of the sex hormones oestrogen and testosterone respectively (Roemmich J.N. and Rogol A.D., 1999; Tanner, 1989). Pubertal status is itself associated with SES, with low SES being associated with later entry into puberty(Adair, 2001) .In a transitioning society like South Africa, lower SES adolescents enter puberty later (Adair, 2001), thus likely reducing the amount of fat mass acquired by age 16 compared to those who enter puberty earlier. At the same time, for low SES adolescents the transitioning environment could have resulted in a greater gain in fat mass (compared to high SES) from environmental factors such as high fat diets and less physical activity during the period from late childhood to adolescence when we observe a significant increase in overweight in the cohort. Low SES groups tend to be more vulnerable to such environmental factors during nutrition transition in middle income countries (Monteiro et al., 2001; Popkin, 2001). In contrast higher SES adolescents would have been more likely to enter puberty early and acquire pubertal fat mass by age 16 years, although their high SES could have provided them with more protection from becoming overweight from factors driven by the rapidly changing environment. Thus these two factors may act to equalise any effects of SES observed at age 16 years because environmental factors would have the potential for more influence on the low SES group to increase their FM, whilst biological factors would have had the potential for greater influence in the high SES group because of earlier entry into puberty, suggested by their larger size in late childhood (Griffiths et al., 2008). There is a need for researchers to also consider this biological context as well as the social context when studying inequalities in adolescent health.

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Limitations

The sub-sample used for this analysis represents a small proportion of the original Bt20 cohort, which is not completely socio-economically representative of Bt20. The sub-sample has a significantly higher SES on some measures compared to the original Bt20 children, thus under-representing the poor. Nevertheless the same bone health sub-sample was used to perform the analysis on the 9/10 year old children thus making the findings of the two papers comparable. This study also lacks environmental SES measures during infancy outside of the household, which means that we are only able to study the effect of environmental measures of SES in adolescence. Finally the study has a smaller number of White than Black participants, which means that it is difficult to detect ethnic specific SES effects, especially in the White sample. We have not also been able to fully test West's idea that peers may be a stronger influence on health outcomes in adolescence compared to the SES environment because our school measures did not encompass measures of the social status of peers.

Conclusion

We have provided evidence of a lack of strong association between SES and body composition outcomes in this South African cohort of 16 year olds that supports West's hypothesis of equalisation of inequalities in adolescence. There are both biological and wider societal level social factors that were occurring in South Africa at this time that could go some way to explaining equalisation in inequalities in body composition at this age in this context. These factors in addition to the original social reasons for equalisation proposed by West (1997) show that adolescence is a complex period to study in relation to health inequalities because of the challenge of adequately measuring the social and biological context in which health outcomes occur at this stage in the life course. There is a need to assess whether inequalities evolve again in early adulthood in this cohort to more fully understand the equalisation process. With the range of variables tested within this study at both the household, school, and the neighbourhood level, our findings suggest that targeting obesity interventions at Black females in households with a mother who already has a high BMI and especially to those of lower educational status would likely target the most at risk for obesity in adolescence within this urban South African context.

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CONFLICT OF INTEREST

None

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TABLES

Table 1 Mean (SD) birthweight, weight, height, body mass index (BMI), fat mass (FM), lean mass (LM); and percent low birth weight, overweight, and obese by ethnicity and sex for South African children aged 16 years

	Black (n=346)		**White (n=112)**		**Total**
Sex (n)	Male (185)	Female (161)	Male (54)	Female (58)	Total (458)
Mean (SD) birthweight (g)[1]	3162.8 (515.7)	3008.5 (493.2)[a]	3273.8 (434.6)	3057.5 (497.7)[a]	3107.2 (503.6)
Percent (n) LBW (birthweight <2500g)[1,b]	8.6 (16)	13.7 (22)	3.7 (2)	12.1 (7)	10.3 (47)
Age 16 mean (SD) weight (kg)[b]	58.25 (10.62)	57.88 (11.63)	68.33 (11.37)	59.89 (12.115)[a]	59.52 (11.70)
Age 16 mean (SD) height (cm)[b]	168.9 (7.5)	158.2 (5.8)[a]	176.8 (8.3)	165.0 (6.6)[a]	165.6 (9.3)
Age 16 mean (SD) BMI (kg/m^2)	20.4 (3.6)	23.1 (4.3)[a]	21.8 (3.0)	22.0 (4.1)	21.7 (4.0)
Age 16 mean (SD) FM (kg)	9.65 (6.68)	19.17 (7.64)[a]	10.50 (4.86)	17.72 (8.11)[a]	14.12 (8.34)
Age 16 mean (SD) LM (kg)[b]	46.99 (6.10)	37.32 (4.85)[a]	55.66 (7.94)	40.64 (5.75)[a]	43.81 (8.45)
Age 16 percent (n) overweight[2]	5.4 (10)	22.4 (36)[a]	16.7 (9)	20.7 (12)	14.6 (67)
Age 16 percent (n) obese[2]	3.2 (6)	8.1 (13)[a]	3.7 (2)	3.4 (2)	5.0 (23)
Age 16 percent (n) overweight or obese	8.6 (16)	30.4 (49) [a]	20.4 (11)	24.1 (14)	19.7 (90)

[1]10 cases did not have birthweight, and therefore LBW, recorded.
[2]Overweight and obesity are defined using Cole et al.'s (Cole et al., 2000) age appropriate international cut-offs for children and adolescents .
[a]Indicates a significant ($P<0.05$) sex difference in this variable within the ethnic group indicated in the column of the table. Continuous variables were tested using an independent samples t-test and categorical variables using a multidimensional Chi-square test.
[b]Indicates a significant ($P<0.05$) ethnic difference in this variable. Continuous variables were tested using an independent samples t-test and categorical variables using a multidimensional Chi-square test.

Table 2 Infancy predictors of body mass index (BMI), fat mass (FM (kg)), and lean mass (LM (kg)) from initial regression analyses and unadjusted odds ratios for overweight or obesity

Total n=346	Percent or mean (SD)	Linear regression coefficient (se) BMI	Linear regression coefficient (se) FM[1]	Linear regression coefficient (se) LM[1]	Unadjusted Odds (95% CI) of overweight or obesity
Female (ref[2] male)	46.5	2.693 (0.425)****	10.011 (0.984)****	-4.669 (0.631)****	4.621 (2.504, 8.529)****
Birthweight (g)	3107.2 (503.6)	0.001 (0.000)	0.001 (0.001)	0.002 (0.001)****	1.000 (1.000, 1.001)*
Low birthweight (ref normal)	11.0	0.154 (0.721)	-1.215 (1.442)	-0.373 (0.871)	0.779 (0.311, 1.948)
Preterm (ref term)	13.6	-0.576 (0.634)	-1.758 (1.238)	-0.448 (0.758)	0.515 (0.195, 1.362)
Post term	1.2	5.971 (2.031)***	10.476 (3.950)***	7.027 (2.417)***	12.982 (1.325, 127.185)*
Term missing	0.6	11.427 (2.862)****	24.916 (5.580)****	12.233 (3.414)****	No cases of at risk
Parity 2 (ref 1)	28.9	-0.286 (0.538)	0.473 (1.051)	-0.545 (0.644)	0.850 (0.429, 1.683)
Parity 3	16.5	0.090 (0.647)	0.452 (1.258)	0.346 (0.771)	1.318 (0.622, 2.793)
Parity 4 plus	12.7	-0.328 (0.711)	0.339 (1.385)	-0.369 (0.849)	0.991 (0.413, 2.381)
Parity missing	0.9	7.627 (2.406)***	18.189 (4.681)****	6.238 (2.869)**	8.923 (0.779, 102.154)*
Maternal age 15-19 years (ref 35 plus)	19.7	-0.093 (0.989)	-2.218 (1.916)	1.220 (1.175)	0.621 (0.188, 2.054)
Maternal age 20-24 years	29.8	0.311 (0.945)	-0.563 (1.831)	0.937 (1.123)	0.867 (0.287, 2.618)
Maternal age 25-29 years	25.7	-0.119 (0.959)	-1.864 (1.857)	1.122 (1.139)	0.672 (0.214, 2.108)
Maternal age 30-34 years	17.6	0.191 (1.003)	-0.559 (1.943)	0.710 (1.191)	1.072 (0.337, 3.409)
Maternal age missing	0.6	11.514 (3.022)****	23.779 (5.863)****	13.113 (3.595)****	No cases of at risk
Widowed/ divorced/ separated (ref married/ living together)	0.6	-2.394 (2.924)	-3.679 (5.684)	-3.251 (3.473)	No cases of at risk
Single	74.3	-0.088 (0.511)	-0.541 (0.997)	-0.409 (0.609)	0.718 (0.392, 1.314)
Missing birth marital data	0.6	11.357 (2.924)****	24.548 (5.695)****	11.872 (3.479)***	No cases of at risk
Maternal education grades 11-12 (ref up to grade 10)	35.3	0.006 (0.473)	0.433 (0.929)	-0.119 (0.567)	1.093 (0.601, 1.987)
Maternal education post school	8.1	2.137 (0.826)**	3.837 (1.623)**	1.222 (0.990)	1.987 (0.805, 4.906)
Maternal education missing	1.4	6.147 (1.848)***	11.483 (3.626)***	6.066 (2.213)***	7.453 (1.197, 46.418)***
Private hospital (ref public hospital)	3.8	-0.069 (1.163)	-2.786 (2.258)	1.979 (1.386)	0.802 (0.173, 3.710)
Missing data for birth hospital	0.9	7.735 (2.386)***	17.830 (4.628)****	6.461 (2.840)**	8.820 (0.787, 98.838)*

Rented private (ref owns property)	17.1	-0.135 (0.682)	0.263 (1.326)	-0.274 (0.812)	1.143 (0.477, 2.740)
Rented local authority	49.4	-0.256 (0.523)	-0.706 (1.018)	0.130 (0.623)	1.441 (0.742, 2.797)
Provided by employer	2.0	-2.090 (1.621)	-6.656 (3.155)**	-0.433 (1.933)	0.933 (0.105, 8.316)
Missing data for home ownership	2.9	2.996 (1.375)**	5.865 (2.674)**	2.596 (1.638)	3.733 (0.940, 14.829)*
Mixture of inside/ outside water and toilet facilities (ref all indoor facilities)	24.3	0.431 (0.656)	1.657 (1.283)	0.059 (0.777)	1.353 (0.599, 3.056)
Outside only water and toilet facilities	48.3	0.105 (0.573)	0.596 (1.121)	0.119 (0.679)	1.168 (0.562, 2.429)
Missing data on birth water and toilet facilities	5.5	2.619 (1.062)**	5.450 (2.079)***	3.296 (1.259)***	2.462 (0.782, 7.752)
Both sole and shared use of toilet and water facilities (ref Sole use of water and toilet facilities)	3.8	1.963 (1.172)*	5.030 (2.287)**	0.476 (1.390)	1.398 (0.370, 5.275)
Shared use of toilet and water facilities	13.9	0.488 (0.647)	0.701 (1.262)	0.533 (0.767)	1.075 (0.488, 2.370)
Missing birth water/ toilet source information	5.5	2.605 (0.980)***	5.022 (1.913)***	3.317 (1.163)***	2.151 (0.778, 5.948)
Middle tertile for the index of infancy consumer durables (ref highest)	39.6	-0.801 (0.574)	-0.664 (1.133)	-0.695 (0.685)	0.949 (0.473, 1.903)
Lowest tertile for index of infancy consumer durables	30.9	-1.003 (0.604)*	-0.796 (1.197)	-0.712 (0.724)	0.860 (0.409, 1.808)
Missing data for the index of infancy consumer durables	5.2	1.215 (1.076)	2.829 (2.115)	1.424 (1.280)	2.125 (0.693, 6.520)

*p<0.1, **p<0.05, ***p<0.01, ****p<0.001 (two tailed)
[1]Adjusted for height
[2]Ref = reference category.

Table 3 Year 16 predictors of body mass index (BMI), fat mass (FM (kg)), and lean mass (LM (kg)) from initial regression analyses and unadjusted odds ratios for overweight or obesity

Total n=346	Percent or mean (SD)	Linear regression coefficient (se) BMI	Linear regression coefficient (se) FM[1]	Linear regression coefficient (se) LM[1]	Unadjusted Odds (95% CI) of overweight or obesity
Indoor shared use running hot and cold water (ref[2] indoor sole use running hot and cold water)	9.8	-0.477 (0.831)	1.134 (1.648)	-0.197 (0.999)	0.629 (0.216, 1.835)
Indoor sole use running cold water	26.9	-1.122 (0.608)*	-1.467 (1.193)	-1.186 (0.723)	0.541 (0.247, 1.183)
Indoor shared use running cold water	8.4	0.530 (0.882)	1.255 (1.731	-0.350 (1.049)	1.390 (0.536, 3.605)
Other water source sole or shared outside the home	25.7	-0.309 (0.615)	-0.177 (1.206)	-0.445 (0.731)	1.058 (0.524, 2.134)
Missing data for water	2.3	-2.980 (1.527)*	-3.831 (2.999)	-2.997 (1.818)	No cases of at risk
Shared use indoor flush toilet (ref sole use of indoor toilet)	10.1	1.020 (0.795)	2.842 (1.558)*	0.598 (0.942)	1.347 (0.540, 3.359)
Sole use outdoor flush toilet	37.6	-0.119 (0.523)	0.269 (1.024)	-0.513 (0.619)	0.826 (0.426, 1.604)
Shared use outdoor flush toilet	12.1	0.901 (0.742)	1.367 (1.453)	0.797 (0.879)	2.038 (0.915, 4.538)*
Other toilet type/ missing toilet	4.9	-1.738 (1.074)	-2.123 (2.102)	-2.323 (1.271)*	0.606 (0.129, 2.844)
Neighbourhood has average safety (ref very unsafe/ unsafe)	23.7	-0.461 (0.808)	-2.630 (1.581)*	1.866 (0.957)*	0.938 (0.377, 2.329)
Neighbourhood is safe	48.3	-1.190 (0.739)	-2.988 (1.454)**	0.917 (0.880)	0.671 (0.287, 1.568)
Neighbourhood is very safe	16.8	-1.476 (0.860)*	-3.172 (1.695)*	0.674 (1.026)	0.694 (0.253, 1.906)
Neighbourhood has some crime (ref a lot of crime)	29.8	-1.172 (0.639)*	-1.597 (1.256	-0.756 (0.764)	0.537 (0.232, 1.243)
Neighbourhood has average crime	23.4	0.310 (0.674)	0.987 (1.323)	0.603 (0.804)	1.248 (0.573, 2.717)
Neighbourhood has not much crime	23.1	-0.044 (0.676)	0.726 (1.326)	-0.281 (0.806)	1.182 (0.539, 2.593)
Neighbourhood has no crime	3.2	-1.267 (1.343)	-1.778 (2.636)	-0.601 (1.602)	0.905 (0.176, 4.664)
Middle tertile for the neighbourhood economic index (ref highest)	35.3	0.348 (0.552)	0.278 (1.080)	0.029 (0.654)	0.902 (0.480, 1.697)
Lowest tertile for the neighbourhood economic index	33.5	0.159 (0.558)	-0.518 (1.096)	0.013 (0.664)	0.560 (0.279, 1.123)
Middle tertile for the neighbourhood	32.4	0.528 (0.558)	1.501 (1.089)	-0.483 (0.661)	1.189 (0.611, 2.315)

index of need for more services/ facilities (ref highest)					
Lowest tertile for the neighbourhood index of need for more services/ facilities	34.2	0.381 (0.551)	1.207 (1.074)	-0.142 (0.653)	0.996 (0.507, 1.957)
Missing for neighbourhood index of need for more services/ facilities	1.2	1.833 (2.124)	4.892 (4.149)	-0.747 (2.521)	1.533 (0.152, 15.513)
Middle tertile for the neighbourhood index of problems (ref highest)	33.2	0.265 (0.556)	0.561 (1.087)	0.065 (0.659)	0.810 (0.421, 1.558)
Lowest tertile for the neighbourhood index of problems	32.9	-0.100 (0.557)	-0.422 (1.089)	0.469 (0.660)	0.680 (0.346, 1.337)
Missing for neighbourhood problems index	1.7	1.193 (1.751)	2.566 (3.420)	0.862 (2.073)	1.812 (0.313, 10.498)
Middle tertile for the neighbourhood index of crime prevention (ref highest)	33.8	-0.251 (0.550)	-0.798 (1.074)	0.164 (0.647)	0.862 (0.441, 1.684)
Lowest tertile for the neighbourhood index of crime prevention	33.2	-0.037 (0.552)	-0.623 (1.081)	1.150 (0.652)*	1.045 (0.545, 2.007)
Middle tertile for the neighbourhood index of social support and happiness (ref highest)	32.9	0.677 (0.547)	0.393 (1.082)	0.305 (0.654)	1.481 (0.755, 2.907)
Lowest tertile for the neighbourhood index of social support and happiness	32.9	0.411 (0.547)	0.723 (1.078)	-0.514 (0.652)	1.404 (0.712, 2.769)
Middle tertile for the index of school environment (ref highest)	33.5	-1.030 (0.551)*	-2.124 (1.083)*	0.215 (0.662)	0.814 (0.428, 1.549)
Lowest tertile for the index of school environment	32.7	-1.018 (0.554)*	-2.890 (1.081)***	0.435 (0.661)	0.616 (0.312, 1.218)
Missing school environment index	1.4	-0.707 (1.899)	-1.529 (3.702)	-1.143 (2.264)	0.870 (0.093, 8.139)
Middle tertile for the index of school problems (ref highest)	31.5	0.242 (0.567)	0.345 (1.111)	1.005 (0.672)	0.931 (0.472, 1.838)
Lowest tertile for the index of school problems	31.5	-0.319 (0.567)	-1.025 (1.107)	0.349 (0.670)	1.048 (0.537, 2.043)
Missing for school problems index	5.8	-0.382 (1.017)	-0.610 (1.986)	0.066 (1.201)	0.460 (0.099, 2.140)
Middle tertile for the index of year 16	31.8	-0.427 (0.546)	-0.452 (1.071)	-0.386 (0.648)	0.684 (0.359, 1.305)

consumer durables (ref highest)					
Lowest tertile for the index of year 16 consumer durables	28.0	-0.496 (0.565)	-0.877 (1.107)	-0.307 (0.670)	0.647 (0.328, 1.275)
Missing data for the index of year 16 consumer durables	4.3	-1.547 (1.140)	-1.283 (2.248)	-0.889 (1.361)	0.234 (0.029, 1.856)
Stayed in the same consumer durables tertiles at birth and year 16 (ref moved up tertiles)[3]	37.6	-0.026 (0.630)	0.688 (1.241)	-1.042 (0.748)	0.963 (0.442, 2.097)
Moved down consumer durables tertiles between birth and year 16	31.2	0.497 (0.726)	1.097 (1.426)	-0.049 (0.860)	1.519 (0.627, 3.682)
Missing transitioning consumer durables tertiles data	9.0	-0.629 (1.259)	0.697 (2.486)	-0.570 (1.498)	0.414 (0.049, 3.487)
Previously smoked (ref currently smoke)	50.0	0.539 (0.637)	1.939 (1.240)	-0.950 (0.751)	0.974 (0.447, 2.125)
Never smoked	8.7	0.679 (0.595)	2.736 (1.162)**	-1.432 (0.704)**	0.984 (0.475, 2.036)
Missing smoking data	19.1	2.748 (1.214)**	5.567 (2.365)**	1.534 (1.433)	2.479 (0.712, 8.632)
Score of 4 on Tanner scale for either pubic hair or breast/genitalia development (ref score of 5 for either)	30.6	-0.758 (0.572)	-1.229 (1.116)	-0.490 (0.677)	0.740 (0.380, 1.443)
Score of 3 or less on Tanner scale for either pubic hair or breast/genitalia development	44.8	-0.592 (0.898)	-3.025 (1.757)*	0.837 (1.065)	1.283 (0.486, 3.392)
Missing pubic hair and breast/genitalia development data	4.0	-0.629 (0.700)	-0.724 (1.366)	-0.259 (0.829)	0.630 (0.266, 1.492)
Maternal BMI (kg/m^2)	28.8 (5.9)	0.205 (0.041)****	0.349 (0.080)****	0.168 (0.048)***	1.090 (1.038, 1.145)***
Maternal overweight (ref normal weight)[4]	30.6	0.345 (0.591)	1.041 (1.173)	0.557 (0.719)	1.080 (0.453, 2.575)
Maternal obese	28.3	2.974 (0.601)****	5.110 (1.189)****	2.517 0.729)***	3.285 (1.495, 7.217)***
Missing maternal overweight/obese	17.6	1.210 (0.679)*	3.078 (1.345)**	0.886 (0.824)	1.392 (0.540, 3.591)

*p<0.1, **p<0.05, ***p<0.01, ****p<0.001 (two tailed)

[1]Adjusted for height

[2]Ref = reference category.

[3]Adjusted for starting position (i.e. infancy consumer durables tertile at birth)

[4]Maternal overweight and obesity defined using internationally accepted cut-offs of >25kg/m^2 and >30kg/m^2, respectively

Table 4 Adjusted parameter estimates for body mass index (BMI) at 16 years for variables that had a previous significant bivariate association with BMI

	n	Step 1[1] Adjusted parameter estimate (SE)	Step 2 Adjusted parameter estimate (SE)	Step 3 Adjusted parameter estimate (SE)	Step 4 Adjusted parameter estimate (SE)
Constant	346	17.524 (0.804)	19.295 (1.184)	18.988 (1.209)	17.709 (1.235)
Gender (ref[2] male)	185				
Female	161	2.824 (0.412)***	2.520 (0.440)***	2.682 (0.427)***	2.671 (0.413)***
INFANCY VARIABLES					
Term birth (ref[2] term)	293				
Preterm	47	-0.828 (0.613)		-0.731 (0.635)	-0.481 (0.617)
Post term	4	5.881 (1.932)**		6.353 (1.973)**	5.359 (1.919)**
Missing	2	10.005 (3.461)**		9.177 (3.505)**	9.052 (3.397)**
Maternal education at birth (ref up to grade 10)	191				
Grades 11-12	122	0.123 (0.447)		0.175 (0.478)	0.254 (0.467)
Post school	28	1.795 (0.769)*		1.739 (0.776)*	1.110 (0.762)
Missing	5	0.525 (2.499)		0.359 (2.571)	0.887 (2.490)
Water and toilet facilities (ref sole use)	266				
Both sole and shared use	13	2.224 (1.078)*		2.425 (1.098)*	3.006 (1.073)**
Shared use	48	0.377 (0.604)		0.439 (0.631)	0.291 (0.612)
Missing	19	1.760 (1.290)		1.782 (1.320)	1.909 (1.293)
Index of infancy consumer durables (ref highest tertile)	84				
Middle tertile	137	-0.532 (0.523)		-0.490 (0.532)	-0.115 (0.523)
Lowest tertile	107	-0.539 (0.565)		-0.371 (0.588)	-0.151 (0.575)
Missing	18	-1.005 (1.375)		-0.891 (1.426)	-1.014 (1.385)
YEAR 16 VARIABLES					
Water facilities (ref indoor sole use running hot and cold water)	93				
Indoor shared use running hot and cold water	34		-0.231 (0.802)	-0.588 (0.786)	-0.453 (0.763)
Indoor sole use running cold water	93		-1.081 (0.600)	-1.173 (0.589)*	-1.154 (0.572)*
Indoor shared use running cold water	29		0.258 (0.850)	0.201 (0.828)	0.006 (0.804)
Other water source sole or shared outside the home	89		-0.435 (0.607)	-0.541 (0.605)	-0.546 (0.587)
Missing	8		-2.854 (1.477)	-2.911 (1.437)*	-2.779 (1.391)
Neighbourhood safety (ref very unsafe/unsafe)	39				

Average safety	82		-0.062 (0.805)	-0.187 (0.777)	-0.062 (0.752)
Safe	167		-0.573 (0.753)	-0.553 (0.733)	-0.432 (0.711)
Very safe	58		-0.812 (0.866)	-0.946 (0.835)	-0.680 (0.809)
Neighbourhood crime (ref a lot)	71				
Some crime	103		-0.995 (0.639)	-1.001 (0.625)	-0.831 (0.607)
Average crime	81		0.534 (0.673)	0.346 (0.655)	0.576 (0.637)
Not much crime	80		0.013 (0.678)	-0.165 (0.667)	-0.157 (0.653)
No crime	11		-0.725 (1.316)	-0.564 (1.285)	-0.500 (1.247)
Index of school environment (ref highest tertile)	112				
Middle tertile	116		-0.380 (0.533)	-0.148 (0.516)	-0.039 (0.501)
Lowest tertile	113		-0.242 (0.557)	-0.008 (0.551)	0.062 (0.534)
Missing	5		-1.247 (1.845)	-0.980 (1.803)	-0.388 (1.766)
OTHER VARIABLES					
Maternal weight status (ref normal weight) [3]	81				
Overweight	106				0.015 (0.555)
Obese	98				2.396 (0.573)***
Missing	61				0.411 (0.658)
Adjusted R^2		0.185	0.110	0.190	0.243

*p<0.05, **p<0.01, ***p<0.001 (two tailed)
[1]Multivariable regression models were adjusted for gender and built in four steps: 1- significant infancy variables from initial analysis, 2- significant year 16 variables from initial analysis, 3- significant infancy and year 16 variables from initial analysis, 4- added significant other variables from initial analysis.
[2]Ref = reference category.
[3]Maternal overweight and obesity defined using internationally accepted cut-offs of >25kg/m^2 and >30kg/m^2, respectively.

Table 5 Adjusted parameter estimates for fat mass (FM) at 16 years for variables that had a previous significant association with FM (adjusting for height only)

	n	Step 1[1] Adjusted parameter estimate (SE)	Step 2 Adjusted parameter estimate (SE)	Step 3 Adjusted parameter estimate (SE)	Step 4 Adjusted parameter estimate (SE)
Constant	346	-6.298 (9.911)	-6.237 (10.496)	-5.097 (10.093)	-7.006 (10.035)
Height (cm)	346	0.026 (0.055)	0.051 (0.058)	0.033 (0.055)	0.039 (0.055)
Gender (ref[2] male)	185				
Female	161	10.282 (0.941)***	9.659 (1.000)***	10.064 (0.959)***	9.899 (0.973)***
INFANCY VARIABLES					
Term birth (ref[2] term)	293	-1.753 (1.098)		-1.654 (1.122)	-1.204 (1.110)
Preterm	47	10.573 (3.434)**		10.973 (3.475)**	8.546 (3.449)*
Post term	4	22.495 (6.168)***		22.807 (6.185)***	21.062 (6.107)**
Missing	2				
Maternal education at birth (ref up to grade 10)	191				
Grades 11-12	122	0.689 (0.797)		0.630 (0.835)	0.802 (0.832)
Post school	28	4.242 (1.391)**		4.120 (1.411)**	2.669 (1.413)
Missing	5	0.462 (4.984)		-0.703 (5.041)	-1.121 (4.925)
Home ownership (ref owns property)	99				
Rented private	59	0.175 (1.135)		0.474 (1.151)	0.081 (1.131)
Rented local authority	171	0.234 (0.869)		0.380 (0.877)	0.054 (0.859)
Provided by employer	7	-2.377 (2.663)		-1.950 (2.711)	-3.042 (2.681)
Missing data for home ownership	10	-5.258 (3.867)		-4.946 (3.929)	-3.222 (3.916)
Water and toilet facilities (ref sole use)	266				
Both sole and shared use	13	5.899 (1.930)**		5.498 (1.951)**	6.401 (1.923)**
Shared use	48	0.301 (1.098)		0.099 (1.117)	-0.035 (1.099)
Missing	19	4.904 (2.333)*		5.032 (2.375)*	3.811 (2.337)
YEAR 16 VARIABLES					
Toilet facilities (ref sole use indoor flush toilet)	122				
Shared use indoor flush toilet	35		1.426 (1.390)	0.632 (1.329)	0.144 (1.306)
Sole use outdoor flush toilet	130		0.334 (0.931)	0.024 (0.901)	-0.016 (0.883)
Shared use outdoor flush toilet	42		2.058 (1.306)	1.702 (1.250)	2.332 (1.238)
Other toilet type/ missing toilet	17		-1.463 (1.874)	-2.191 (1.796)	-1.435 (1.760)

Neighbourhood safety (ref very unsafe/unsafe)	39				
Average safety	82		-1.538 (1.429)	-1.625 (1.366)	-1.384 (1.340)
Safe	167		-1.437 (1.314)	-1.318 (1.257)	-0.940 (1.231)
Very safe	58		-2.028 (1.527)	-2.155 (1.453)	-1.628 (1.435)
Index of school environment (ref highest tertile)	112				
Middle tertile	116		-1.419 (0.965)	-0.987 (0.921)	-0.936 (0.903)
Lowest tertile	113		-2.100 (1.002)*	-1.512 (0.979)	-1.639 (0.961)
Missing	5		-3.770 (3.338)	-3.770 (3.184)	-2.657 (3.152)
OTHER VARIABLES					
Smoking status (ref currently smokes)	275				
Previously smoked	106				-0.117 (1.041)
Never smoked	155				0.419 (0.999)
Missing	14				3.545 (2.058)
Puberty rating (ref 5 for either pubic hair or breast/genitalia)					
Score of 4 for either pubic hair or breast/genitalia	173				-1.036 (0.931)
Score of 3 or less for either pubic hair or breast/genitalia	30				-1.388 (1.474)
Missing	66				-1.921 (3.256)
Maternal weight status (ref normal weight) [3]	81				
Overweight	106				0.000 (1.013)
Obese	98				4.229 (1.043)***
Missing	61				2.783 (3.257)
Adjusted R^2		0.391	0.308	0.391	0.425

*p<0.05, **p<0.01, ***p<0.001 (two tailed)

[1]Multivariable regression models were adjusted for height and gender and were built in four steps: 1- significant infancy variables from initial analysis, 2- significant year 16 variables from initial analysis, 3- significant infancy and year 16 variables from initial analysis, 4- added significant other variables from initial analysis.

[2]Ref = reference category.

[3]Maternal overweight and obesity defined using internationally accepted cut-offs of >25kg/m^2 and >30kg/m^2, respectively.

Table 6 Adjusted parameter estimates for lean mass (LM) at 16 years for variables that had a previous significant bivariate association with LM (adjusting for height only)

	n	Step 1[1] Adjusted parameter estimate (SE)	Step 2 Adjusted parameter estimate (SE)	Step 3 Adjusted parameter estimate (SE)	Step 4 Adjusted parameter estimate (SE)
Constant	346	-25.734 (6.348)	-28.582 (6.697)	-28.046 (6.430)	-30.039 (6.428)
Height (cm)	346	0.420 (0.036)***	0.469 (0.037)***	0.425 (0.036)***	0.438 (0.036)***
Gender (ref[2] male)	185				
Female	161	-4.813 (0.602)***	-4.582 (0.637)***	-4.740 (0.607)***	-4.690 (0.624)***
INFANCY VARIABLES					
Birthweight (g)	342	0.002 (0.001)***		0.002 (0.001)***	0.002 (0.001)**
Term birth (ref[2] term)	293				
Preterm	47	0.590 (0.739)		0.804 (0.747)	0.888 (0.753)
Post term	4	5.746 (2.196)**		5.942 (2.205)**	5.007 (2.231)*
Missing	2	13.524 (3.100)***		13.204 (3.103)***	13.144 (3.185)***
YEAR 16 VARIABLES					
Neighbourhood safety (ref very unsafe/unsafe)	39				
Average safety	82		1.179 (0.899)	1.456 (0.864)	1.510 (0.863)
Safe	167		0.159 (0.828)	0.363 (0.792)	0.400 (0.791)
Very safe	58		0.072 (0.961)	0.203 (0.919)	0.307 (0.915)
Index of crime prevention (ref highest tertile)	114				
Middle tertile	117		0.404 (0.605)	0.663 (0.580)	0.762 (0.578)
Lowest tertile	115		1.018 (0.607)	0.857 (0.579)	0.762 (0.582)
OTHER VARIABLES					
Smoking status (ref currently smokes)	275				
Previously smoked	106				-0.091 (0.687)
Never smoked	155				-0.099 (0.654)
Missing	14				1.345 (1.351)
Maternal weight status (ref normal weight)[3]	81				
Overweight	106				0.696 (0.644)
Obese	98				2.025 (0.673)**
Missing	61				0.307 (0.756)
Adjusted R^2		0.650	0.613	0.652	0.658

*p<0.05, **p<0.01, ***p<0.001 (two tailed)

[1]Multivariable regression models were adjusted for height and gender and were built in four steps: 1- significant infancy variables from initial analysis, 2- significant year 16 variables from initial analysis, 3- significant infancy and year 16 variables from initial analysis, 4- added significant other variables from initial analysis.

[2]Ref = reference category.

[3]Maternal overweight and obesity defined using internationally accepted cut-offs of >25kg/m^2 and >30kg/m^2, respectively.

FIGURES

Figure 1 The transitioning socioeconomic profile of African Black participants (n=346) from birth to 16 years