Investigation into longitudinal dietary behaviours and household socio-economic indicators and their association with BMI z-score and fat mass in South African adolescents: the Birth to Twenty cohort.

Abstract

Objective: The objective was to assess the relationship between dietary habits, change in socioeconomic status (SES) and BMI z-score and fat mass in a cohort of adolescents living in Soweto-Johannesburg.

Design: In this longitudinal study, data were collected at ages 13, 15 and 17 years on the Birth to Twenty birth cohort who have been followed since 1990. Black participants with complete dietary habits data (breakfast consumption during the week and at weekends, snacking while watching TV, eating main meal with family, lunch box use, number of tuck shop purchases, fast food consumption, confectionery consumption and sweetened beverage consumption) at all three ages and body composition data at aged 17 were included in the analyses. Generalized estimating equations (GEEs) were used to test the associations between individual longitudinal dietary habits, and obesity (denoted by BMI z-score and fat mass) with adjustments for change in SES between birth and aged 12.

Setting: Birth to Twenty (Bt20) study, Soweto-Johannesburg.

Subjects: 1298 subjects, (49.7% male).

Results: In males, the multiple variable analyses showed that soft drink consumption was positively associated with BMI z-score and fat mass respectively ($p<0.05$). Furthermore after adjustment for SE indicators, these relationships remained the same ($p<0.05$). No associations were found in females.

Conclusions: Longitudinal soft drink consumption was associated with increased BMI z-score and fat mass in males only. Furthermore fridge ownership at birth (a proxy for higher SES in this cohort) was shown to be associated with BMI z-score and fat mass respectively.

Introduction

Since the end of segregationist and discriminatory practices of Apartheid in1994, South Africa has undergone profound political, social and economic transitions. Parallel to these transformations have been lifestyle changes driven by rapid rates of urbanisation, from 10% in 1990 to 56% in 2005, especially among black South Africans [(1)]. In addition to infectious diseases and a rise in non-communicable diseases, the South African population also has the added burden of a high prevalence of HIV/AIDs and violence-related trauma [(2)], often this collection of health challenges has been referred to as the quadruple burden of disease.

Urbanization in low- or middle income countries (LMICs) drives changes in food habits and body composition and it is associated with both health gains and risks. In South Africa, Bourne et al. showed that between 1940 – 1992 diets among the black population shifted from a prudent pattern (>50% carbohydrate, <30% total fat, ~15% protein) to one that showed a progressive increase in fat (from 16.4% to 26.2%) with a concurrent decrease in carbohydrates (from 69.3% to 61.7%) [(3)].

The worldwide prevalence of obesity has reached alarming levels (475 million) affecting both high-income countries (HICs) and LMICs. Furthermore over 1 billion adults are overweight [(4)]. Latest figures from South Africa show that among those aged 15 years and older the prevalence of combined overweight and obesity is 30% among males and 55% among females [(5)]. Of note, black women experience the greatest burden of obesity (29%) followed by women of mixed ancestry (27%), white (14%) and Indian (25%). Among men, whites experience the highest levels (23%), followed by mixed ancestry (15%), Indian (11%) and then black men (7%). Overweight and obesity are also on the increase among younger generations and overweight has been shown to track from childhood into adulthood [(6)]. In a South African nationally representative study (aged between 1 – 9 years of age) showed that the national prevalence of combined overweight and obesity (denoted by a BMI (>25 kg/m^2) is 17.1% [(7)]. It is suggested that dietary patterns that are developed in childhood are maintained into adulthood, and poor dietary habits predispose individuals to obesity and related metabolic diseases later in life [8].

Among the lifestyle determinants of obesity, socioeconomic status (SES) has also been given attention [9, 10]. Briefly, SES and obesity relate to each other differently depending on the gross national product (GNP) of a country. Among women in HICs a higher likelihood of obesity is found in those of lower socioeconomic strata [9], while in LMICs the burden of obesity shifts towards lower SES groups as a country's GNP increases. The shift of obesity towards women within low SES groups seems to occur at an earlier stage of economic development than it does among men. The switch to higher rates of obesity in women of lower socioeconomic strata has been shown to occur when the GNP per capita is about $2500 [10].

There is little longitudinal data and none in South Africa assessing the association between dietary behaviours developed in childhood and adolescence and overweight and obesity. Thus, using longitudinal data from urban South African adolescents at ages 13, 15, and 17 years part of the Birth to Twenty cohort, we investigated dietary habits and household SES indicators and their associations with BMI z-score and fat mass.

Subjects and Methods

Study population, design and sample size

Data for this study were obtained from a longitudinal birth cohort study; The Birth to Twenty (Bt20) cohort which started in 1989 [11]. Singleton children (n=3 273, 78% black participants) born between April and June 1990 and resident for at least 6 months in the Soweto-Johannesburg municipality were enrolled into the birth cohort and have been followed up almost annually between birth and 20 years of age. Attrition over the two decades has been comparatively low (30%), mostly occurring during the children's infancy and early childhood; approximately 2 300 participants remain in contact with the study [12]. Assessments across multiple domains have been made of children, families, households, schools and communities during the course of the study. The assessments included growth, development, psychological adjustment, physiological functioning, genetics, school performance, and sexual and reproductive health [13].

Data for this current study were collected at ages 13 (n=1564), 15 (n=1586) and 17 years (n=1621). Only black participants with complete data at all three ages were included in the analysis, (N=1298; 49.7% male). Dietary habits data for all three ages were assessed against body composition outcomes at aged 17 years (see figure 1).

Dietary assessment and exposure variables

Participants completed interviewer assisted questionnaires on dietary behaviours around food choices and eating practices occurring in the home, school and community, and which have been shown to be associated with poor nutritional outcomes[14-22]. The questions determined if participants engaged in a particular eating behaviour. If they did, and when appropriate, we enquired about which foods they ate (from a predetermined list) and how often they ate them in the previous week. This is similar to an unquantified food frequency questionnaire approach where the frequency of certain food items consumed over the recall period is recorded. Further information on the tool's development and piloting can be found [23]. We asked participants about eating behaviours in 3 environments of risk: In the home environment we enquired about how regularly breakfast was eaten during the week and at the weekend, how many snacks were consumed while watching TV in the previous week, and what snacks were eaten (e.g. crisps, bread, fruit, sweet biscuits, chocolate, popcorn, cakes, fried chips). We enquired about how frequently participants ate their main meal with their family. In the community environment, we asked about the number (0,1,2,3,4 or >5/week) of fast food items (for example fried chips, vetkoek (fried dough balls), pies, fried fish, boerewors (a local sausage), hotdogs, hamburger, pizza, samoosa, chicken burger, filled pita), confectionery (sweets, chocolate, doughnuts, crisps, ice-cream and cake) and sweetened beverages (soft drinks, and squash/cordials) consumed per week. In the school environment, we asked about the foods purchased from the tuck shop[a] (foods we asked about included: white bread, brown bread, fruit, pap (mielie meal), fruit juice, milk, yoghurt, cheese, popcorn, peanuts, crisps, fried chips, pie, vetkoek, sweetened beverages, sweets, cake) and how many days during the previous week a lunchbox was used. Lunch box food items we asked about included: cheese, brown bread, white bread, fruit juice, fruit, sweets, crisps, sweetened beverages, yoghurt, meat, sweet biscuits, pies, milk, peanuts, pap (mielie meal). Over the period of data collection, meals were not provided by schools.

Dietary behaviours at each age (breakfast during the week, breakfast at the weekend, snacking while watching TV, eating main meal with family, lunch box use, number of tuck shop purchases, fast food consumption, confectionery consumption and sweetened beverage consumption) were categorized into binary variables, i.e. a poor eating habit (e.g. infrequent breakfast consumption or the purchase of a high number of items from the tuck shop etc) = 1 and a 'healthier' eating habit (e.g. frequent breakfast consumption or the purchase of a low number of items from the tuck shop or a low number of fast food or confectionery items) = 0. See appendix A for categorisation for each dietary habit variable.

Anthropometric measurements at birth and at 17 years of age and body composition

Birth weight was retrieved from maternity records. Birth weight z-scores were calculated using The World Health Organization (WHO) 2006 growth standards [24]. Weight (digital scale from Dismed, USA), to the nearest 100 g, and height (stadiometer from Holtaine, UK), to the nearest millimeter, were measured with subjects wearing light clothing and no shoes. Body composition of the total body less head (TBLH) was determined by dual energy X-ray absorptiometry (DXA; Hologic QDR Discovery W) according to standard

[a] Which may have been a food vendor selling foods within or outside the school grounds.

procedures of the International Society of Clinical Densitometry (software version 11.2:3) [25]. For the purposes of this study, only fat mass was used

Body mass index was calculated (kg/m^2) and internal gender specific z-scores were calculated as an alternative to using actual BMI values since BMI z-scores provide a relative measure of adiposity adjusted for sex and age-specific growth. Internal z-scores were used for intra-population comparability. BMI z-score was calculated as the difference between the participant's BMI and the mean BMI divided by the SD of the cohort BMI for each gender. Fat mass (kg) was adjusted for height [the power coefficient was obtained from the regression analysis of fat mass (kg) on height (m)] as described by Prentice et al [26]. This measure was log transformed to improve normality. As shown by others [27, 28], birth weight z-score was found to be associated with the outcome measures for both genders therefore the outcome measures were adjusted for birth weight z-score by deriving the coefficient from the regression analysis of outcome on birth weight z-score.

Socioeconomic indicators

SES indicators in the form of household durables data were collected from the mother at the time of the child's birth and again when the cohort child was 12 years old. The information collected included maternal education, household electricity, and ownership of a television, washing machine, landline telephone, car and fridge.

SE household durables were categorized into binary variables; having a particular household durable item = 1, not having this household durable item = 0. Maternal education was categorized into those mothers who achieved a grade 10[b] or above = 1 and those who achieved less than this educational level = 0. Gender differences were assessed with chi square tests.

[b] Equivalent to grade 11 in the US and the legal point of exiting the education system in South Africa

Confounding was assessed by regressing individual SE household durable variables (collected at birth) against the outcome variables and the individual dietary habits. If the SE household variable was significantly associated with the outcome and exposure variable then is was considered a confounder and adjusted for in the regression models. The use of individual SE indicators resulted from preliminary exploratory analyses whereby a composite score (factor scores) of SES was derived. The score became non-significant when tested as a confounder. Upon doing factor analysis we noted that fridge ownership contributed the greatest amount (factor loadings) to the composite score. The rotated orthogonal Kaiser-Verimax factor analysis showed that 23% of the variability was explained by the first factor which had an Eigen value of 1.39, with fridge ownership having the greatest loading of 0.97. Therefore it was decided to use individual SE household variables in the regression models.

For each SE variable a new variable was created to assess the change in SES status between birth and age 12 years; that is if the participant ‘acquired’ a particular household variable between the two time points or if they ‘never’ had that particular durable item over the two time points. These two variables were compared to the reference variables ‘always’ having a particular durable item over the two time points. This variable was used in the multiple variable analyses.

Ethics

Ethics clearance was obtained from Witwatersrand University Committee for Research on Human Subjects, protocol number: M080320. Primary caregivers gave written informed consent for their child to participate in the research at each assessment visit and the child provided written assent. Confidentiality has been maintained by the allocation of an identification number for each participant which was used on all questionnaires

Statistical analysis

All statistical analyses were performed using STATA version 10.0 [29]. Demographic and SES variables at birth were compared between the analytic sample (n=1298) and the remaining Bt20 cohort (n=1975).

For the analytic sample, descriptive statistics were performed for each variable, which for continuous variables was the mean and standard deviation. For categorical variables frequencies are presented and associations were assessed using Pearson's Chi square tests. Gender differences were assessed with Student's t-test for Gaussian continuous variables.

Univariate and multiple variable analyses

We used a Generalized estimating equation (GEE) approach to fit our univariate and multiple variable models, details are given in appendix B. For the Gaussian family based outcomes BMI z-score and adjusted fat mass, we used the identity and log link functions respectively with independent covariance structure. The Binomial family was used for the socio-economic variables with independent covariance structures and a logit link function [30]. First, individual dietary habit variables were inserted individually into the statistical model, then if significantly associated ($p<0.05$), multiple variable analysis was carried out with the inclusion of the confounding SE household durable variables (previously assessed by univariate analysis).

Results

Basic characteristics and outcome variables

The analytic sample was better off at birth than the remaining Bt20 cohort in terms of having electricity (96% vs 90%, $p<0.001$), however the Bt20 cohort not included was better off in terms of car (32% vs 25%, $p<0.001$) and washing machine (20% vs 8%, $p<0.001$) ownership. No differences were found in the ownership of TV, fridge or phone or in maternal education. However for marital status, 50% of the Bt20 parents were either married or cohabiting compared with only 32% of the parents of the analytic sample (p<0.001).

Descriptive characteristics of the two gender groups are described in table 1. Females had a lower mean birthweight than males (p<0.001). At 17 years of age, females were shorter than males (p<0.001) with a similar weight thus their mean BMI was greater than males (p<0.001). Furthermore mean fat mass (less head) was 2.4 times higher in females than their male counterparts (p<0.001). Combined overweight and obesity in this cohort was 8% in males and 27% in females (p<0.001), this was a decrease in boys and an increase in girls respectively from when they were 13 years old (p=0.038).

Table 2 shows dietary habits and eating practices stratified by gender, at all ages, 13, 15 and 17 respectively. With age both boys and girls irregular breakfast (both weekday and weekend) consumption increased, with girls consistently skipping breakfast more often than boys (p<0.05). Between 30 – 40% of the cohort ate their main meal with their family infrequently (never/some days), throughout the follow-up period. Over two-thirds consumed fast food and sweetened beverages on 3 or more occasions per week. Over two-thirds consumed confectionery on 7 or more occasions per week, with girls consuming them more than boys at ages 15 and 17 respectively (p<0.05). Generally lunchbox usage was low (5 – 20%) with girls using them more regularly than boys, at all ages (p<0.05). Between 50 – 70% participants purchased 10 or more tuck shop items per week.

There were no gender differences in socioeconomic household indicators or maternal education at the birth of the cohort participants. At that time, most of the cohort families had electricity in the home (96%), and a television (80%), and fridge (76%). A smaller proportion owned a landline phone (<58%), car (<26%) or a washing machine (8%). Nearly half the mothers (45%) had schooling to grade 10 or above, with only 7% of this group having had post-school education.

Univariate analysis

Dietary habits and practices

Univariate GEE analyses between the body composition outcome measures at aged 17 years and each longitudinal dietary habit and practice variable were assessed. All GEEs were stratified by gender since gender differences were shown for the outcome and exposure variables.

The univariate analyses showed that among males longitudinal sweetened beverage consumption was positively associated with both BMI z-score [β=0.050 (95% CI 0.014 - 0.085); p=0.007] and fat mass [β=0.035 (95% CI 0.007 - 0.063); p=0.015], while infrequent consumption of the main family meal was negatively associated with fat mass [β= -0.06 (95% CI -0.052 - -0.001); p=0.038].

Among females positive associations were found between irregular weekend breakfast consumption and BMI z-score [β=0.044 (95% CI 0.0135 - 0.075); p=0.005] and fat mass [β=0.030 (95% CI 0.000 - 0.060); p=0.047]. As with boys, infrequent consumption of the main family meal was negatively associated with fat mass [β= -0.026 (95% CI -0.052 - -0.001); p=0.038].

Confounders

Socioeconomic household durable variables were regressed against the exposure and outcome variables separately (table 3). Among males only, fridge ownership was positively associated with both BMI z-score and fat mass and with one exposure variable, soft drink consumption ($p<0.05$). No other SES variables were associated with either exposure or outcome variables, for either gender.

Birth weight z-score

Linear regression showed that birth weight z-score was positively associated with BMI z-score and fat mass at 17 years of age ($p<0.001$) for both genders (table 4). Therefore in the multiple variable analyses each outcome variable was adjusted for birth weight z-score.

Multiple variable models

Multiple variable GEEs were conducted separately for both outcome measures (BMI z-score and fat mass) and all exposures and confounders.

For BMI z-score in the unadjusted model, only sweetened beverage consumption was positively and significantly associated with BMI z-score. Furthermore, after adjustment for confounders (SE household assets, in this case fridge ownership) the association between sweetened beverage consumption and BMI z-score remained ($p<0.05$), see table 5. For fat mass, in the unadjusted model, sweetened beverage consumption was also positively and significantly associated, and after adjusting for confounding the relationship remained the same ($p<0.001$), see table 5.

Discussion

The aim of this study was to investigate adolescent dietary behaviours and their association with BMI z-score and fat mass. Among males only, in both the unadjusted and adjusted models we found that sweetened beverage consumption was positively associated with both BMI z-score and fat mass respectively ($p<0.001$). These findings reflect the importance of sweetened beverage consumption in terms of the quantity and range consumed (in terms of their energy content) and their relationship with obesity. In this cohort, 76% of participants owned a fridge which differentiates them from poorer households. Other studies have shown the use of multiple individual measures of SES when assessing children's nutritional status [(31)]. Furthermore in a sub-study of the Bt20 cohort, individual household durable variables were shown to act as a proxies for higher SE strata [(32)]. Among males, those from higher socioeconomic strata at birth in this environment were more predisposed to overweight (denoted by BMI z-score and fat mass) than those from lower income groups.

Other studies have found an association between adolescent soft drink consumption and obesity in both LMICs and HICs. Cross-sectional associations have been found for soft drink consumption and obesity in Saudi boys [(33)] and then both Jamaican males and females respectively [(34)]. Unlike cross-sectional studies, longitudinal studies are able to account for the temporal criteria of causality in that repeated observations are possible. However some US longitudinal studies have found an association between soft drink consumption and obesity [(35)] but others have not [(36)]. Perhaps the equivocal findings relate to the concept that soft drinks may be a marker for other dietary factors or other lifestyle factors which are associated with obesity, or due to study design and questionnaire nuances, including the definition of a soft drink.

Research into specific dietary habits associated with poor diet quality and obesity risk among adolescents has focused on breakfast skipping, snack behaviours (including the influence of TV viewing on snacking), food intake at school, eating the main meal with the family, fast food and sweetened beverage consumption [(37-39)]. While a number of cross-sectional analyses have shown positive associations between eating behaviours (breakfast skipping, fast food intake, soft drink consumption and eating the main meal with the family) and obesity these relationships have been attenuated and become statistically non-significant in some longitudinal analyses [(40, 41)]. However other longitudinal studies have shown positive relationships with obesity, namely with fast food intake and soft drink consumption and breakfast skipping, among adult populations [42] and adolescent populations [43, 44].

The longitudinal dietary patterns of this cohort show that with age both boys and girls have increasingly irregular breakfast (weekday and weekend) consumption, with girls consistently skipping breakfast more often than boys, findings corroborated by other studies in developing countries [45]. Eating the main meal with the family decreased slightly when participants were 17 years old. In the US however, older adolescents eat with their families less frequently than younger adolescents, furthermore advancing age has been associated with irregular family meal consumption and poorer diet quality [46]. Although cross-sectional analyses have shown that the family meal had a protective effect against obesity, longitudinal analyses have not confirmed this [38].

Increased TV viewing has been shown to be associated with reduced fruit and vegetable consumption, and more snacking [37]. One study found that every additional hour of TV viewed equated to an additional intake of 653 kJ/d [47]. In our study, the number of snacks eaten while watching TV increased with age and girls consistently consumed them more frequently than boys ($p<0.01$).

US ecological data have shown that snacking (including confectionery) in adolescents has increased between 1977 and 2006 with around 3 snacks eaten per day which account for up to 27% of total energy intake [48]. In our cohort a higher proportion of girls consumed confectionery >7 times per week than boys at all ages.

It is thought that bringing food from home to school is healthier than purchasing items available at the school tuck shop but in this cohort lunch box usage was low (5 – 20%) across all ages with boys using them less regularly than girls ($p<0.05$). However we did show that of those who took lunch boxes to school, the five most popular items were relatively healthy (brown and white bread, cheese, fruit and fruit juice) [23].

SES can influence dietary intake and eating behaviours through purchasing of foods. In a developing environment such as Soweto those in higher income strata have a greater disposable income to purchase relatively expensive fast foods and snacks. However what is unique about this environment is the access to informal food vendors which makes such energy dense foods also available to those in poorer income strata. We have observed the sale of cheap snacks and fast foods both in poorer rural and more affluent urban environments [49, 50].

The prevalence of combined overweight and obesity was significantly higher in females than in males, which is consistent with other South African research [51]. However the data show that dietary patterns are not mediated by SES among this female group which is contrary to other research undertaken in HIC and LIMCs [9, 10]. Perhaps the lack of evidence of a relationship between SES and obesity among females might reflect the choice of indicators used in this research, for example it has been demonstrated that in men at least, the SES/obesity relationship depended on the indicator under assessment [9]. Another possible reason why no associations were found among females in this cohort is because we are witnessing a change in social patterning of overweight/obesity, as suggested by Monteiro [10]. For example, in some countries, for certain SE indicators the association with obesity was more often negative than positive suggesting that the social patterning of overweight is possibly undergoing transition in middle-income-countries [10] and reflecting those of developed countries. Another possibility is that the cohort did not reflect a very wide distribution of SES since most can be defined as poor as compared to HICs.

An alternative hypothesis suggests that the greater prevalence of obesity among females (both in this population and others in South Africa [5, 52]) relates to nutritional programming in utero whereby a relationship exists between the environment during critical windows of development and the progression of disease in adult life [53]. Studies have shown that perinatal nutritional deficits predispose adult offspring to increased fat accumulation and other metabolic outcomes. Another explanation for our lack of a finding in girls might relate to physical activity. Other South African research has reported declines in physical activity with girls exercising less often than boys [(54)].

Further limitations; the findings from this study cannot be extrapolated to other sub-groups in South Africa since we only assessed black South African adolescents in Soweto reflecting a particular social stratum. This study did not investigate total energy intake or energy expenditure.

To conclude, we showed that among males longitudinal sweetened beverage consumption was positively and significantly associated with both BMI z-score and fat mass at age 17 years. Furthermore fridge ownership at birth (a proxy for higher SES in this cohort) was shown to be associated with BMI z-score and fat mass respectively.

Figures and Tables

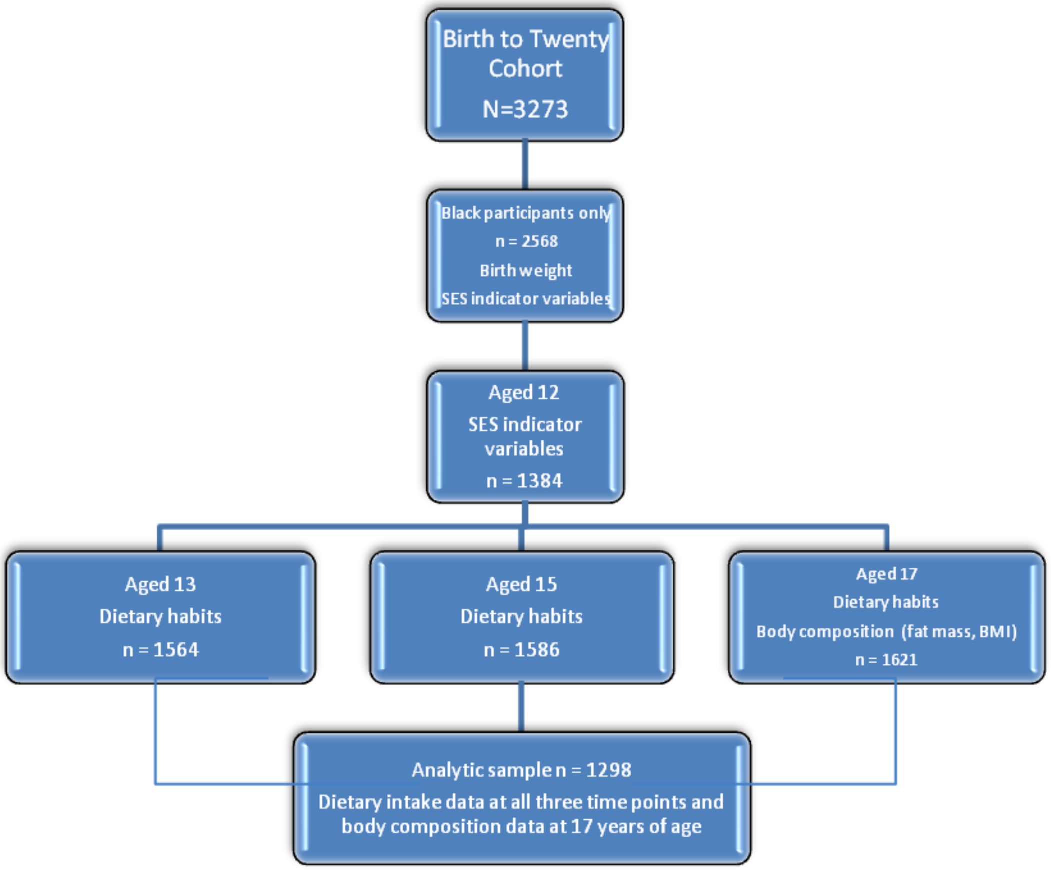

Figure 1. Flow diagram to show measurements at the different time points.

Table 1. Descriptive characteristics of the cohort stratified by gender

Variable	Males (n=607)		Females (n=616)		p-value
	Mean	SD	Mean	SD	
Birth weight (g)	3128.7	504.8	3012.8	491.6	<0.001
Birth weight z-score[a]	-0.52	1.1	-0.54	1.1	0.639
Age (years)	17.7	0.3	17.7	0.3	1.000
Height (cm)	170.6	7.9	159.7	6.0	<0.001
Weight (kg)	59.3	9.7	58.5	12.2	0.253
BMI (kg/m^2)	20.4	3.2	22.9	4.4	<0.001
Total Fat mass (kg) less head	7.7	4.8[b]	18.5	7.6[c]	<0.001
Overweight/obese[d] (n,%)	43	8.1	152	27	<0.001
Age (years)	13.7	0.2	13.7	0.2	1.000
Height (cm)	154.3	8.5[f]	155.7	6.2[g]	<0.001
Weight (kg)	44.5	9.8	50.0	11.6	<0.001
BMI (kg/m^2)	18.6	3.2	20.6	4.3	<0.001
Overweight/obese[e] (n,%)	52	9.8	115	20.5	0.038

[a] WHO 2006
[b] (n=592)
[c] (n=594)
[d] Using International Obesity Task Force (IOTF) cutoffs for 17.5 year olds [55]
[e] Using International Obesity Task Force (IOTF) cutoffs for 13.5 year olds
[f] (n=529)
[g] (n=561)

Table 2. Dietary habits variables stratified by gender, by age.

Age	13		15		17	
Exposure	Males (n=645)	Females (n=653)	Males (n=645)	Females (n=653)	Males (n=645)	Females (n=653)
Home	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Irregular breakfast weekday (<2/wk)	136 (21.1)	188 (28.8)[c]	176 (27.3)	304 (46.6)[c]	193 (29.9)	268 (41.0)[c]
Irregular breakfast weekend (1 day)	79 (12.3)	91 (13.9)	107 (16.6)	148 (22.7)[b]	220 (34.1)	180 (27.6)
Irregular eat with family (never/some d/wk)	220 (34.2)	244 (37.4)	222 (34.6)	254 (38.9)	269 (41.7)	257 (39.4)
TV snacks (>3/wk)	353 (54.7)	400 (61.2)[b]	329 (51.0)	395 (60.5)[c]	380 (58.9)	450 (68.9)[c]
Community						
Fast foods (>3/wk)	438 (67.9)	454 (69.5)	440 (68.2)	422 (64.6)	415 (64.3)	395 (60.5)
Confectionery (>7/week)	386 (59.8)	422 (64.6)	415 (64.3)	495 (75.8)[c]	380 (58.9)	435 (66.6)[b]
Sweetened beverages (>2/week)	431 (66.8)	451 (69.1)	452 (70.1)	466 (71.4)	431 (66.8)	450 (68.9)
Schools						
Lunch boxes (</=2/wk)	539 (84.3)	519 (79.7)[a]	581 (92.1)	531 (85.5)[c]	618 (95.8)	563 (86.2)[c]
Tuck shop purchases (>10/week)	461 (64.5)	452 (69.2)	438 (49.9)	445 (68.2)	434 (67.3)	427 (65.4)

[a] Gender difference p<0.05
[b] Gender difference p<0.01
[c] Gender difference p<0.001

Table 3. The significant associations (β, 95% CI) estimated by the GEE 'univariate' analyses regarding the SES household durable measures (stratified by gender) in relation to the individual dietary habits and eating practices and outcome variables (BMI z-score and fat mass).

	Fridge				Television				Car				Electricity				Washing machine				Phone				Maternal Education			
	Males		Females		Males		Females		Males		Females		Males		Females		Males		Females		Males		Females		Male		Females	
	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI	β	95% CI
Irregular Breakfast weekday	x		x		x		x		x		x		x		0.122	0.005 – 0.239[a]	X		-0.010	-0.182 - -0.023[b]	x		-0.061	-0.107 - -0.016[b]	x		x	
Irregular Breakfast weekend	x		x		x		x		x		x		x		0.104	0.004 – 0.203[c]	x		x		x		x		x		x	
TV snacking	0.108	0.055-0.160[c]	0.067	0.017 – 0.118[b]	0.056	0.001 – 0.112[c]	x		x		x		0.127	0.012 – 0.242[c]	x		x		x		x		0.058	0.014 – 0.103[b]	x		0.062	0.019 – 0.104[c]
Irregular Eat Family	x		0.055	0.003 – 0.106[c]	x		x		x		0.064	0.015 – 0.114[b]	x		x		x		x		x		x		x		x	
Fast food	x		x		0.055	0.002 – 0.108[a]	-0.056	-0.110 - -0.002[a]	0.077	0.027 – 0.128[b]	x		x		x		0.086	0.009 – 0.167	x		x		x		x		0.052	0.010 – 0.095[b]
Confectionery	x		x		x		x		x		x		0.164	0.052 – 0.276[b]	x		x		x		-0.050	-0.096 - -0.004[c]	x		x		X	
Sweetened beverages	0.088	0.039 – 0.137[c]	0.057	0.009 – 0.106[b]	x		x		0.059	0.010 – 0.109[b]	x		0.138	0.031 – 0.246[b]	x		0.120	0.042 – 0.195[b]	x		x		x		x		0.103	0.063 – 0.144[c]
Lunch boxes	x		x		x		x		x		x		x		x		-0.078	-0.126 - -0.031[c]	x		x		-0.042	-0.078 - -0.006[b]	-0.035	-0.061 – 0.009[c]	x	
Tuck shop	x		x		x		x		x		x		0.167	0.058 – 0.276[b]	x		x		x		x		x		x		x	
BMI z-score	0.079	0.044-0.113[c]	x		x		x		x		x		x		x		x		0.069	0.196 – 0.119[b]	x		x		x		-0.031	-0.058 - -0.004[a]
Fat mass	0.064	0.34 – 0.094[c]	x		x		x		x		x		x		x		x		0.095	0.045 – 0.145[c]	0.062	0.036 – 0.089[c]	x		x		x	

[a]p<0.05
[b]p<0.01
[c]p<0.001

Table 4 Association of birth weight z-score with BMI z-score and fat mass (unadjusted and adjusted for height) at 17 years old.

BMI z-score	ß[a]	95%CI	ß	95%CI
Males	0.150	0.084 – 0.216[b]		-
Females	0.128	0.063 – 0.193[b]		-
Fat mass	Unadjusted for height		Adjusted for height	
Males	0.702	0.354 – 1.049[b]	0.268	0.119 – 0.417[b]
Females	1.092	0.577 – 1.607[b]	0.772	0.382 – 1.161[b]

[a] Regression coefficient

[b]p<0.001

Table 5 BMI z-score (males), SD then each adjusted model, and the final multiple variable model

	Unadjusted model		Adjusted models	
BMI z-score	ß[a]	95%CI	adj. ß	95%CI
Sweetened beverages	0.022	0.006 – 0.037[c]	0.044	0.022 – 0.067[d]
Fridge, never			-0.095	-0.152 – -0.039[d]
Fridge, acquired			-0.026	-0.056 - 0.004
Fat mass				
Sweetened beverages	0.016	0.005 – 0.030[c]	0.018	0.002 – 0.036[b]
Fridge, never			-0.040	-0.083 – 0.002
Fridge, acquired			-0.034	-0.057 - -0.011[c]

[a] Regression coefficient
[b] $p<0.05$
[c] $p<0.01$
[d] $p<0.001$

REFERENCES

1 Steyn K, Fourie J, Temple N. Chronic Diseases of Lifestyle in South Africa: 1995 - 2005. Technical Report. Cape Town: Medical Research Council, 2006.

2 Mayosi BM, Flisher AJ, Lalloo UG*, et al.* The burden of non-communicable diseases in South Africa. *Lancet*. 2009 **374**: 934-47.

3 Bourne LT, Lambert EV, Steyn K. Where does the black population of South Africa stand on the nutrition transition? *Public Health Nutr*. 2002 **5**: 157-62.

4 IASO. International Association for the Study of Obesity. About Obesity. London: IASOed, 2010.

5 Department of Health, Medical Research Council, OrcMacro. The South African Demographic and Health Survey (SADHS) 2003. Pretoria: Department of Healthed, 2007.

6 Gordon-Larsen P, Adair LS, Nelson MC*, et al.* Five-year obesity incidence in the transition period between adolescence and adulthood: the National Longitudinal Study of Adolescent Health. *Am J Clin Nutr*. 2004 **80**: 569-75.

7 Steyn NP, Labadarios D, Maunder E*, et al.* Secondary anthropometric data analysis of the National Food Consumption Survey in South Africa: the double burden. *Nutrition*. 2005 **21**: 4-13.

8 St-Onge MP, Keller KL, Heymsfield SB. Changes in childhood food consumption patterns: a cause for concern in light of increasing body weights. *Am J Clin Nutr*. 2003 **78**: 1068-73.

9 McLaren L. Socioeconomic status and obesity. *Epidemiol Rev*. 2007 **29**: 29-48.

10 Monteiro CA, Moura EC, Conde WL*, et al.* Socioeconomic status and obesity in adult populations of developing countries: a review. *Bull World Health Organ*. 2004 **82**: 940-6.

11 Yach D, Cameron N, Padayachee N*, et al.* Birth to ten: child health in South Africa in the 1990s. Rationale and methods of a birth cohort study. *Paediatr Perinat Epidemiol*. 1991 **5**: 211-33.

12 Norris SA, Richter LM, Fleetwood SA. Panel studies in developing countries: case analysis of sample attrition over the past 16 years within the birth to twenty cohort in Johannesburg, South Africa. *J Intl Dev*. 2007 **19**: 1143-50.

13 Richter L, Norris S, Pettifor J*, et al.* Cohort Profile: Mandela's children: the 1990 Birth to Twenty study in South Africa. *Int J Epidemiol*. 2007 **36**: 504-11.

14 Birch LL, Fisher JO. Development of eating behaviors among children and adolescents. *Pediatrics*. 1998 **101**: 539-49.

15 Birch LL. Development of food preferences. *Annu Rev Nutr*. 1999 **19**: 41-62.

16 Guthrie JF, Lin BH, Frazao E. Role of food prepared away from home in the American diet, 1977-78 versus 1994-96: changes and consequences. *J Nutr Educ Behav*. 2002 **34**: 140-50.

17 Neumark-Sztainer D, Story M, Perry C*, et al.* Factors influencing food choices of adolescents: findings from focus-group discussions with adolescents. *J Am Diet Assoc*. 1999 **99**: 929-37.

18 Story M, Neumark-Sztainer D, French S. Individual and environmental influences on adolescent eating behaviors. *J Am Diet Assoc*. 2002 **102**: S40-51.

19 French SA, Story M, Neumark-Sztainer D*, et al.* Fast food restaurant use among adolescents: associations with nutrient intake, food choices and behavioral and psychosocial variables. *Int J Obes Relat Metab Disord*. 2001 **25**: 1823-33.

20 Gillman MW, Rifas-Shiman SL, Frazier AL*, et al.* Family dinner and diet quality among older children and adolescents. *Arch Fam Med*. 2000 **9**: 235-40.

21 Nicklas TA, Bao W, Webber LS*, et al.* Breakfast consumption affects adequacy of total daily intake in children. *J Am Diet Assoc*. 1993 **93**: 886-91.

22 Dwyer JT, Evans M, Stone EJ*, et al.* Adolescents' eating patterns influence their nutrient intakes. *J Am Diet Assoc*. 2001 **101**: 798-802.

23 Feeley A, Musenge E, Pettifor J*, et al.* Changes in dietary habits and eating practices in adolescents living in urban South Africa: the Birth to Twenty cohort. *Nutrition*. 2012 **(In press)**.

24 De Onis M, Garza C, Onyango AW*, et al.* WHO Multicentre Growth Reference Study Group. 2006. Comparison of the World Health Organization (WHO) child growth standards and the National Centre of Health Statistics/WHO international growth reference: Implication for child health programmes. *Public Health Nutr*. 2006 **9**: 942-7.

25 Gordon CM, Bachrach LK, Carpenter TO*, et al.* Dual energy X-ray absorptiometry interpretation and reporting in children and adolescents: the 2007 ISCD Pediatric Official Positions. *J Clin Densitom*. 2008 **11**: 43-58.

26 Prentice A, Parsons TJ, Cole TJ. Uncritical use of bone mineral density in absorptiometry may lead to size-related artifacts in the identification of bone mineral determinants. *Am J Clin Nutr*. 1994 **60**: 837-42.

27 Rogers I. The influence of birthweight and intrauterine environment on adiposity and fat distribution in later life. *Int J Obes Relat Metab Disord*. 2003 **27**: 755-77.

28 Labayen I, Moreno LA, Ruiz JR*, et al.* Small birth weight and later body composition and fat distribution in adolescents: the Avena study. *Obesity (Silver Spring)*. 2008 **16**: 1680-6.

29 StataCorp. *Stata Statistical Software Release 10*. *College Station*. Texus,USA: StataCorp LPed, 2007.

30 Horton NJ, Lipsitz SR. Review of software to fit generalized estimating equation regression models. *American Statistician*. 1999 **53**: 160-9.

31 King SE, Nicholas Mascie-Taylor CG. Nutritional status of children from Papua New Guinea: associations with socioeconomic factors. *Am J Hum Biol*. 2002 **14**: 659-68.

32 Sheppard ZA, Norris SA, Pettifor JM*, et al.* Approaches for assessing the role of household socioeconomic status on child anthropometric measures in urban South Africa. *Am J Hum Biol*. 2009 **21**: 48-54.

33 Collison KS, Zaidi MZ, Subhani SN*, et al.* Sugar-sweetened carbonated beverage consumption correlates with BMI, waist circumference, and poor dietary choices in school children. *BMC Public Health*. 2010 **10**: 234.

34 Francis DK, Van den Broeck J, Younger N*, et al.* Fast-food and sweetened beverage consumption: association with overweight and high waist circumference in adolescents. *Public Health Nutr*. 2009 **12**: 1106-14.

35 Ludwig DS, Peterson KE, Gortmaker SL. Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis. *Lancet*. 2001 **357**: 505-8.

36 Berkey CS, Rockett HR, Field AE*, et al.* Sugar-added beverages and adolescent weight change. *Obes Res*. 2004 **12**: 778-88.

37 Snoek HM, van Strien T, Janssens JM*, et al.* The effect of television viewing on adolescents' snacking: individual differences explained by external, restrained and emotional eating. *J Adolesc Health*. 2006 **39**: 448-51.

38 Fulkerson JA, Neumark-Sztainer D, Hannan PJ*, et al.* Family meal frequency and weight status among adolescents: cross-sectional and 5-year longitudinal associations. *Obesity (Silver Spring)*. 2008 **16**: 2529-34.

39 Piernas C, Popkin BM. Trends in snacking among U.S. children. *Health Aff (Millwood)*. **29**: 398-404.

40 Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. *Am J Clin Nutr*. 2006 **84**: 274-88.

41 Rosenheck R. Fast food consumption and increased caloric intake: a systematic review of a trajectory towards weight gain and obesity risk. *Obes Rev*. 2008 **9**: 535-47.

42 Pereira MA, Kartashov AI, Ebbeling CB*, et al.* Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet*. 2005 **365**: 36-42.

43 Ma Y, Bertone ER, Stanek EJ, 3rd*, et al.* Association between eating patterns and obesity in a free-living US adult population. *Am J Epidemiol*. 2003 **158**: 85-92.

44 Thompson OM, Ballew C, Resnicow K*, et al.* Food purchased away from home as a predictor of change in BMI z-score among girls. *Int J Obes Relat Metab Disord*. 2004 **28**: 282-9.

45 Leal GV, Philippi ST, Matsudo SM*, et al.* Food intake and meal patterns of adolescents, Sao Paulo, Brazil. *Rev Bras Epidemiol*. 2010 **13**: 457-67.

46 Neumark-Sztainer D, Hannan PJ, Story M*, et al.* Family meal patterns: associations with sociodemographic characteristics and improved dietary intake among adolescents. *J Am Diet Assoc*. 2003 **103**: 317-22.

47 Van den Bulck J, Van Mierlo J. Energy intake associated with television viewing in adolescents, a cross sectional study. *Appetite*. 2004 **43**: 181-4.

48 Piernas C, Popkin BM. Trends in snacking among U.S. children. *Health Aff (Millwood)*. 2010 **29**: 398-404.

49 Feeley A, Pettifor J, Norris S. Fast-food consumption among 17-year-olds in the Birth to Twenty cohort. *South African Journal of Clinical Nutrition*. 2009 **22**: 118-23.

50 Feeley A, Twine R, Kahn K*, et al.* Exploratory survey of informal vendor-sold fast food in rural South Africa. *South African Journal of Clinical Nutrition*. 2011 **24**: 199-201.

51 Puoane T, Steyn K, Bradshaw D*, et al.* Obesity in South Africa: the South African Demographic and health survey. *Obes Res*. 2002 **10**: 1038-48.

52 Puoane T, Steyn K, Bradshaw D*, et al.* Obesity in South Africa: the South African demographic and health survey. *Obes Res*. 2002 **10**: 1038-48.

53 Barker DJ. Early growth and cardiovascular disease. *Arch Dis Child*. 1999 **80**: 305-7.

54 Reddy SP, Panday S, Swart D*, et al.* Uhlaba Usamila – The South African Youth Risk Behaviour Survey 2002. Cape Town: Medical Research Council, 2003.

55 Cole TJ, Bellizzi MC, Flegal K*, et al.* Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ*. 2000 **320**: 1240-3.

56 Zeger SL, Liang KY. Longitudinal data analysis for discrete and continuous outcomes. *Biometrics*. 1986 **42**: 121-30.

Appendix A: New Coding; SD excluding diet SD

Continuous exposure variables were categorised into binary variables

Exposure variable	Positive eating behaviour (0)	Negative eating behaviour (1)
TV snacks (TV)	<=3 (35.5%)	>3 (64.5%)
Fast food (FF)	<=3 (38.5%)	>3 (61.5)
Confectionery (conf)	<=7 (37%)	>7 (63%)
Sweetened beverages (SB)	<=1 (31.56%)	>2 (68.44%)
Tuck shop purchases (TS)	<=9 (36%)	>10 (64%)

Coding for categorical variables

	Positive eating behaviour (0)	Negative eating behaviour (1)
Breakfast weekday (brkd)	3+/wk	0-2/wk
Breakfast weekend (brkw)	2 during weekend	0-1/during the weekend
Eat main meal with family (EatF)	Most or everyday	Never or some days
Lunch box (LB)	3-5/wk	0-2/wk

Appendix B: The Generalized estimating equation (GEE) model structure

The data for our study were longitudinal since they were collected at times 13, 15 and 17 years. As such the observations are correlated on individual level. We thus employed the GEEs which are an extension the Generalized Linear Models (GLMs) that can handle the correlation in the data. Our model which follows from the exponential family of distributions, GLMs introduced has the link form:

$$g(\mu_i) = g(E[Y_i]) = x_i'\beta,$$

where x_i is a $p \times 1$ vector of covariates for the i^{th} subject, and β is a $p \times 1$ vector of regression coefficients, $g(.)$ is the link function which can take any form of the exponential family and Y_i is the outcome of i^{th} subject[30].

The GEE extension of this model for repeated measures we model the average response for observations sharing the same covariates (marginal expectation) as:

$$g(\mu_{ij}) = g(E[Y_{ij}]) = x_{ij}'\beta,$$

where x_{ij} is a $p \times 1$ vector of covariates for the $i^{th} = 1, 2, \ldots. n$ subject at the $j^{th} = 1, .., t$ outcome, and β is a $p \times 1$ vector of regression coefficients, $g(.)$ is the link function which can take any distributional form and Y_{ij} is the outcome of i^{th} subject at the j^{th} outcome whose mean and variance are characterized as the GLM [56].

The correlated observations have a certain working correlation matrix $R(\alpha)$ of the forms: independent, exchangeable, unstructured, time series auto-regressive orders, user defined and many others. Assuming no missing data, the $t \times t$ covariance structure for Y_i is with A_i a matrix of variance functions and ϕ the GLM dispersion parameter:

$$V_i = \phi A_i^{1/2} R(\alpha) A_i^{1/2}$$

In this paper we fit our models using three link functions, the identity ($g(E[Y_{ij}]a) = E[Y_{ij}]$) for the BMI-z score, the log link function ($g(E[Y_{ij}]) = \log(E[Y_{ij}])$) for the fat mass adjusted for height and the logit link ($g(E[Y_{ij}]) = \log(E[Y_{ij}]/(1 - E[Y_{ij}])$) for binary socio-economic variables. Our families of distributions were the Gaussian and the Binomial. The working correlation was the identity matrix for the independent covariance structure.