Title: Three-year change in diet quality and associated changes in BMI among schoolchildren living in socioeconomically disadvantaged neighbourhoods.

Authors: Sandrine Lioret[1], Sarah A McNaughton[1], Adrian J Cameron[1], David Crawford[1], Karen J Campbell[1], Verity J Cleland[2], Kylie Ball[1]

Affiliations:

[1]Centre for Physical Activity and Nutrition Research, School of Exercise and Nutrition Sciences, Deakin University, Victoria, Australia.

[2]Menzies Research Institute, Hobart, Tasmania, Australia.

Corresponding Author (and requests for reprints): Dr Sandrine Lioret

Centre for Physical Activity and Nutrition Research, School of Exercise and Nutrition Sciences; Deakin University; 221 Burwood Hwy, Burwood Victoria 3125, Australia

Phone: +61 3 9251 7236 Fax: +61 3 9244 6017

Email: sandrine.lioretsuteau@deakin.edu.au; sandrine.lioret@inserm.fr (from 01.01.14).

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ABSTRACT

Findings from research assessing the influence of dietary factors on child obesity have been equivocal. We aimed to test the hypothesis that a positive change in diet quality is associated with favourable changes in BMI z-scores in schoolchildren from low socio-economic backgrounds; and to examine whether this effect is modified by BMI category at baseline. This study utilized data from a subsample (n=216) of the Resilience for Eating and Activity Despite Inequality (READI) study, a longitudinal cohort with data collected in 2007-08 (T1) and 2010-11 (T2) in socio-economically disadvantaged women and children (5-12 years at T1). Dietary data was collected using a food frequency questionnaire, and diet quality index (DQI) scores derived at both times. Objective measures of weight, height and physical activity (accelerometers) were included. The other variables were reported in questionnaires. We examined the association between change in DQI and change in zBMI, with linear regression analysis adjusted for physical activity, screen sedentary behaviour and maternal education, both in the whole sample, and stratified by overweight status at baseline. After accounting for potential covariates, change in diet quality was inversely associated with change in zBMI only in children who were overweight at baseline (P=0.035), thus supporting the hypothesis that improvement in diet quality is associated with a concurrent improvement in zBMI among already overweight children, but not those of normal BMI status. The identification of modifiable behaviours such as diet quality that affect zBMI longitudinally is valuable to inform future weight gain prevention interventions in vulnerable groups.

INTRODUCTION

In many developed countries a large proportion of children and adolescents are overweight or obese (in the USA, more than one third[1]), with a higher prevalence frequently observed amongst those from more disadvantaged socio-economic backgrounds[2,3]. Beyond any genetic predisposition with regard to weight gain, the rapid increase in obesity prevalence over the past three decades underscores the negative impact of unhealthy eating, low physical activity, and increased sedentariness. Each of these factors is strongly influenced by socio-cultural[4] and environmental factors[5]. In particular, children's diet -the focus of the current study- has been shown to be of lower quality in population groups experiencing disadvantage, with higher intakes of energy-dense and nutrient-poor foods and beverages[6,7].

Research assessing the influence of dietary factors on child obesity has been equivocal[8,9]. Differences in study methods may partly explain these inconsistencies. For instance, a large variety of measures have been used to define dietary intakes, with studies focusing on specific nutrients or specific foods, and others addressing the diet as a whole, through dietary patterns or eating behaviours[8,9]. Differential misreporting of dietary intakes by overweight (OW) status may attenuate or even reverse the associations observed[10], and residual confounding may be important where analyses have not accounted for major covariates such as physical activity and sedentary behaviour[8,9]. It is also likely that the influence of diet on the development of adiposity is influenced by BMI category[8,11,12]. Most existing studies linking dietary intakes and child obesity are limited by their cross-sectional designs[8,9], while even in prospective studies, a true longitudinal perspective has frequently been lacking with one or other of diet and obesity measured only at a single time point[13-17]. Studies which have examined the dynamic relationship between changing dietary intakes and adiposity in children are scarce[18-21]. Their importance is obvious from the substantial dietary changes that occur across childhood with both physiological development and the growing independence from parents[10,22].

Dietary pattern analysis has been increasingly used over the past decade to describe the total diet, accounting for the interactions between dietary components[23,24]. The methods most often used include empirical *a posterior* statistical approaches such as cluster and factor analyses, and the *a priori* dietary index approach. The latter ranks various dietary items reflecting current nutrition guidelines, and provides a score of overall diet quality. This construct is useful to assess longitudinal changes in diet quality as it is based upon external criteria. Diet quality indexes (DQI) have been rarely used to assess relationships between diet and obesity in children, with all studies having been cross-sectional, and all showing null or weak inverse associations[25].

This study addressed diet as a whole and aimed to test the hypothesis that a positive change in diet quality is associated with favourable changes in BMI z-scores in schoolchildren from low socio-economic backgrounds. We also assessed the hypothesis that this effect would be modified by BMI category at baseline. These objectives were investigated using longitudinal data and accounting for child physical activity, sedentary behaviour and socio-economic status (with maternal education level used as a proxy), the latter being potential covariates as previously described.

MATERIALS AND METHODS

Subjects

This study utilized data from the Resilience for Eating and Activity Despite Inequality (READI) study, a three-year longitudinal cohort study with data collected at two time points (T1, 2007-08 / T2, 2010-11) examining resilience to obesity in 4,349 socio-economically disadvantaged women (18-45 years at baseline) and 684 children (5-12 years at baseline). Methods -including sample selection- have been described in details elsewhere[26]. Briefly, 40 urban and 40 rural areas (suburbs) from the bottom third of the Australian Bureau of Statistics' 2001 Socioeconomic Indexes for Areas[27] were randomly selected in Victoria. Within each of these 80 areas, the Australian electoral roll was used to randomly select 150 women aged 18-45. Of the 11,940 women selected, 4,938 (41%) responded to a postal invitation to complete written questionnaires. Data were excluded for 589 respondents (571 who had moved from the sampled suburb before survey completion, three who completed the survey but were not the intended participants, two who withdrew their data after completing the survey, and 13 who were aged under 17 or over 46 years). Of the 4,349 eligible respondents, those with a child aged 5-12 years (n=1,457) were invited to complete a questionnaire about their child, with 771 (53%) agreeing to child participating and 684 (89%) de facto completing questionnaires regarding their child in this age group. We excluded 317 (46%) children lost to follow-up and 151 who presented missing data for any of the variables included in the main analysis (BMI, diet, physical activity, sedentary behaviour, and maternal education level), yielding a final sample of 216 children. This flow chart is illustrated in Figure 1. This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects were approved by the Deakin University Human Research Ethics Committee (EC 91-2006). Written informed consent was obtained from all subjects.

Measures

Women completed two questionnaires at both baseline (T1) and follow-up (T2), one concerning the mother; the other concerning their child. These included questions on children's diet and sedentary behaviour; maternal weight and height; and a range of socio-demographic and socio-economic factors.

BMI status

Children's height (to the nearest 0.1 cm) and weight (to the nearest 0.1 kg) were measured by trained research assistants at both T1 and T2, without shoes and in light clothing, using a portable stadiometer and digital scales. Both BMI (kg/m^2) and age- and sex-adjusted BMI z-scores (zBMI) were calculated, the latter based on the Centers for Disease Control reference population[28]. Additionally, child BMI category (underweight, healthy weight, overweight or obese) was defined using cut-off points established by Cole *et al*.[29]. Mothers' self-reported height and weight were also used to calculate BMI (kg/m^2).

A priori derived dietary quality index (DQI)

Children's food intake was measured both at T1 and T2 using a questionnaire based on several validated short questions[30-35]. Mothers reported how often in the past month their child had consumed 17 types of foods/drinks along with 9 answer alternatives, i.e.: "Never or less than once/month", "1-3 times/month", "Once/week", "2-4 times/week", "5-6 times/week", "Once a day", "2-3 times a day", "4-5 times a day" and "6 or more times a day"). The questionnaire also included 13 additional questions relating to the type and amount of milk usually consumed (number of serves per day); the type and amount of bread usually consumed (number of slices per day); and the usual frequency of consumption for other items, i.e. vegetables (excluding potatoes, hot chips and fried potatoes), hot chips, potatoes, fruit, trimmed fat, flavoured milk, water, and fruit juice. These data were then converted into daily equivalent frequencies. When <10% of these questions had missing values (22 children concerned), missing values for consumption frequency were set to zero and missing food type was set to 'unknown', as is standard practice[36].

Children's diet quality was assessed both at baseline (DQI_{T1}) and follow-up (DQI_{T2}) using a diet quality index[37-39] reflecting adherence to the 2003 Australian Dietary Guidelines for Children and Adolescents[40] based on an index validated in Australian children and adolescents[37-39]. The diet quality index was slightly modified, as a measure relating to dietary variety could not be assessed with the FFQ used in this study. The impact on the validity is however likely to be minor given the small absolute differences in this component of the score compared to other indicators that was seen in our previous work[39]. The index included 10 components (**Table 1**) with age and sex-specific cut-offs based on the Australian Guide to Healthy Eating[41]. Points were awarded (0-10) for each component met, with 10 indicating the participant was meeting the recommendation or had an optimal intake. Participants with intakes between the minimum and maximum amount were assigned scores proportionately. Points were summed to give an overall dietary score ranging from 0-100, with a higher score indicating higher compliance with the dietary guidelines.

Change in diet quality between baseline and follow-up was calculated as $DQI_{T2-T1}=DQI_{T2}-DQI_{T1}$, and this continuous variable was then categorized in three groups. Those participants with a negative change in diet quality were split into two categories based on the median, i.e. larger negative change (≤ - 7.7) and smaller negative change (- 7.7 to 0). Those participants with a positive change in diet quality formed the third group. The categories defined in this variable corresponded approximately to tertiles, with 34.5% of children showing a large negative change in DQI_{T2-T1}, 34.5% a smaller negative change; and 31.0% a positive change.

Moderate and vigorous physical activity (MVPA) time

Children's physical activity was objectively measured at T1 using uniaxial accelerometers (Actigraph Model AM7164-2.2C, Pensacola, Florida, USA). They were set to record movement counts in 1-minute epochs. Children were instructed in the use of the accelerometer at school by trained data collectors; and asked to wear the accelerometer for an eight-day period during waking hours, except during bathing and aquatic activities. This method has been shown to be a valid objective measure of children's physical activity[42,43]. Non-wearing periods (where 20-minutes or more of consecutive zeros were recorded) were removed from the total possible wear time. For children with valid data, i.e. at least eight hours[44] and no more than 18 hours (to exclude children who wore the device to bed) of wear time for at least three weekdays and one weekend day, average time (min/day) spent in physical activity and sedentary pursuits was calculated. Using an established age-adjusted regression equation[45], MVPA was calculated as the time during which >4 metabolic equivalent units was achieved between 6 am and 9 pm. This continuous variable was categorized in tertiles. Therefore three levels were defined (min/day), i.e. 'low' (9.3 to 59.7), 'intermediate' (59.7 to 95.6), and 'high' (95.6 to 255.6).

Screen time

In the T1 questionnaire, mothers reported the usual time their child spent watching television/videos/DVD's; Playstation©/Nintendo©/computer games; and computer/Internet (excluding games) on both weekdays and weekend days. Total screen time (a proxy for sedentary behaviour) was calculated for both weekdays and weekend days and truncated at 40 hrs (5 days X 8 hrs per day) and 32hrs (2 days X 16hrs per day), respectively. Average screen time per day was then calculated and categorized in tertiles. Three levels were therefore defined (h/day), i.e. 'low' (0 to 1.6), 'intermediate' (1.6 to 2.6), and 'high' (2.6 to 9.3).

Socio-demographic and socio-economic factors

Socio-demographic variables included children's age and sex; and mothers' age, marital status, country of birth, employment status and education level. Maternal education level was defined in three categories: low (no formal qualifications/Year 10 or equivalent), intermediate (Year 12 or equivalent, trade, apprenticeship, certificate or diploma) or high (university undergraduate or postgraduate degree), and used as a proxy of socio-economic status.

Statistical analyses

Two-sided Chi square and Fisher's exact tests (categorical variables), and linear regression analyses (continuous variables) were used to compare children's characteristics at T1 according to their BMI category, i.e. non-overweight (non-OW, including underweight) *vs.* overweight (OW, including obese). Multivariable regression analysis was performed to investigate the longitudinal relationships between change in diet quality (DQI_{T2-T1}) and change in zBMI, adjusting for child's age, gender and DQI_{T1} (Model 1). Change scores for zBMI were not calculated, but rather change in zBMI was assessed in models where $zBMI_{t2}$ was the outcome and $zBMI_{t1}$ was included as a covariate[46]. In Model 2, we also controlled for child's MVPA, accelerometer wearing time, screen time and maternal education (all measured at T1). To assess moderation by zBMI at baseline, an additional multivariable model contained terms for $zBMI_{T1}$, DQI_{T2-T1} and a term for the interaction between these two variables. For the purpose of hypothesis generation, stratified analyses by OW status (i.e. non-OW_{T1} and OW_{T1}) were conducted regardless of whether interaction tests were significant as such tests are highly sensitive to both sample size and sample distribution[47]. Adjusted parameter estimates and 95% confidence intervals were calculated. Clustering by suburb was accounted for in all models. The significance level was set at 0.05. Analyses were computed on Stata software (release 10; StataCorpLP, College Station, TX, USA).

RESULTS

Sample characteristics

At baseline, none of the children were underweight, 77.3% (72.5; 82.1) were in the healthy BMI category, 16.2% (11.9; 20.5) were overweight (but not obese) and 6.5% (3.3; 9.7) were obese. Further characteristics of the sample are shown in **Table 2**. Mothers of children OW at baseline had higher BMIs and were more likely to be obese than mothers of children with healthy BMI. The other maternal socio-demographic characteristics did not differ significantly between these two groups. Overweight children at T1 were slightly older; spent more time on screen sedentary behaviours (30 min on average); and devoted less time to MVPA than their non-OW counterparts. Eighty percent of the OW children at T1 were still OW at T2. Mean DQI scores were low at baseline and change in DQI between T1 and T2 was overall negative, without significant differences between OW and non-OW children.

Previously, study participants at baseline have been found to be more likely to be Australian born (89 vs. 73%), to be married or living as married (65 vs. 49%), and less likely to be in a full-time employment (37 vs. 58%), as compared with the general population of women living in the 80 neighbourhoods (2006 census)[26]. In addition, compared to the children included in the analytic sample, children excluded due to loss to follow-up (n=317) or missing data (n=151) came from families where on average mothers were significantly slightly younger (38.1 years [SD 5.3] compared with 39.2 years [SD 4.9]); and less likely to be married/or in a de-facto relationship (76.5% compared with 87.4%). Children excluded from the analyses were significantly slightly older (9.5 years [SD 2.2] compared with 9.1 years [SD 2.1]); had higher zBMIs at T1 (0.62 [SD 0.92] compared with 0.35 [SD 0.92]); and higher rates of OW at T1 (33.0% compared with 24.1%).

Relationships between change in z-BMI and change in diet quality

In the whole sample (n=216), neither diet quality at baseline (DQI_{T1}) nor change in diet quality (DQI_{T2-T1}) was significantly associated with change in zBMI after accounting for potential confounders (**Table 3**). In stratified analyses, an inverse relationship between improvement in diet quality and zBMI at T2 was observed in the group identified as being OW at baseline after accounting for $zBMI_{T1}$(Model 1, P-trend=0.078), while this longitudinal association was not observed in non-OW children. This association was stronger after further adjustment for MVPA, screen sedentary behaviour and maternal education (Model 2, P-trend=0.035).

DISCUSSION

This study supports the hypothesis of an association between improvement in diet quality and corresponding decrease in zBMI over three years, but only in schoolchildren overweight at baseline. To our knowledge, no previous study in children has considered the effect of change in total diet quality on zBMI change, accounting for physical activity, sedentary behaviour and maternal education.

While we did not observe an overall relation between change in diet quality and change in zBMI, our findings suggest that this longitudinal association may differ according to the child's BMI category at baseline. Despite the test for moderation failing to reach statistical significance -which may be due to a relatively low sample size for this type of test[(47)], stratified analysis according to OW status did suggest that among children overweight at baseline, a relationship between improvement in diet quality and reduced zBMI was evident. Similar conclusions were drawn from two other studies, one performed in women[(48)]; the other in children[(20)]. Both of those studies also investigated the relation between change in diet (assessed using *a posterior* factor analysis) and change in BMI prospectively. Newby *et al*.[(48)] observed a stronger association between an improvement in diet (i.e. positive changes in the "Healthy pattern" scores) and a reduction in adiposity amongst OW and obese women in comparison with their non-OW counterparts. Likewise, the study by Oellingrath*et al*.[(20)] suggested that Norwegian schoolchildren scoring high in a "varied Norwegian" eating pattern over time had lower risk of remaining overweight than did children with declining adherence to this pattern. The latter was characterised by food items typical of a traditional Norwegian diet (such as fish and meat for dinner, brown bread, regular white or brown cheese, lean meat, fish spread, and fruit and vegetables), close to what is recommended by the health authorities. The moderation of the relationship between diet and zBMI by baseline OW status observed here may be due to metabolic differences. Excessive adiposity is often associated with greater insulin resistance and greater vulnerability to weight gain upon exposure to a diet of low quality (e.g. rich in sugars and fats)[11,12]. In the group of overweight children in particular, it may be that maintaining or improving diet quality may help to prevent or reduce zBMI.

While over the past decade several indices measuring compliance with dietary guidelines have been developed for adults[49,50], fewer have been developed for children[25]. Few studies, all of which were cross-sectional, examined diet quality and child obesity, showing null or weak inverse associations[25]. Assessing diet quality according to established guidelines is useful for measuring changes over time, and is a technique that leads to greater comparability between studies. In fact, contrary to *a posteriori* statistical approaches that are data driven, such as cluster and factor analyses, the dietary index approach is an *a priori* technique based upon external nutritional criteria. Provided that variables are available in a given study, the construction of this DQI score is thus transposable to any other dataset. Our prospective findings confirmed that diet quality decreases with age, as suggested in previous cross-sectional studies spanning a range of age groups[25,39].The DQI used in the current study has the advantage of having been based on Australian dietary guidelines and based on an index previously validated in a national sample of Australian children[39]. Higher scores in this index were shown to reflect diets of higher nutrient density and both lower energy intake and energy density. This DQI is therefore easily translatable into public health messages relating to the whole diet.

It is important to recognize the limitations of this study. The modest participation rate means that the final sample should not be considered representative of children living in the sampled areas, reflecting the difficulty of both reaching and following-up socio-economically disadvantaged groups. We also acknowledge that parents might not be aware of what children eat outside the home and that differential misreporting of dietary intake by OW status is possible[10], both leading to potential over-reporting of healthy products and underreporting of unhealthy foods or beverages due to social desirability. Given that the reported diets are still poor this potential bias is however likely to be limited. In addition, any bias would be expected to affect the same children at both points in time[51], and therefore have little influence on our prospective findings. Longitudinal assessment of screen time and physical activity was not undertaken due to the additional missing values that would have resulted. Although screen time has been shown to track throughout childhood[52,53], residual confounding involving changes in MVPA and changes in screen time cannot be excluded.

Objective measurement of anthropometric variables and physical activity is an important strength of our study. From an analytical point of view, showing that change in diet quality is associated with change in zBMI provides stronger evidence for a causal relationship than models involving measurement at only a single point in time. Adjusting for patterns of sedentariness and physical activity is a further analytical strength.

A novel aspect of the current study is also the recruitment of women and children living in socio-economically disadvantaged areas and, as such, more likely to be at high risk of poor diet and obesity. While our findings suggest that a relationship exists between change in diet quality and change in BMI in OW and obese children, further studies among a larger sample of children and incorporating more sensitive measurements of fat mass and body composition would be valuable to address our hypothesis more comprehensively.

CONCLUSION

Investigation of the dynamic relationship between diet and zBMI throughout childhood provides a valuable perspective on the way that diet and zBMI change together over time. Our findings support the hypothesis that improvement in diet quality is associated with a concurrent improvement in zBMI, however only among already OW children. The identification of modifiable behaviours such as diet quality that affect zBMI longitudinally is valuable to inform future weight gain prevention interventions in vulnerable groups.

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S. L. led the study, conducted the statistical analysis, drafted the manuscript, and had primary responsibility for final content. S.A. M., A.J. C., D. C., K.J. C., V.J. C., and K. B. contributed to the analytical approach, interpretation of results, and revised each draft. D. C., V.J. C. and K. B. designed and led the READI study. All authors have read and approved the final manuscript.

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Conflicts of interest: None.

Figure 1. Flow chart of the current study

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Table 1. Components of the dietary guideline index

Dietary Guideline Index indicator and description	**Criteria for maximum score (10)**[1]			**Criteria for minimum score (0)***
	4-7yrs	8—11yrs	12-18yrs	
1. Fruit: Serves of fruit per day.	1	1	3	0
2. Vegetables: Serves of vegetables and legumes per day.	2	3	4	0
3. Total Cereals: Frequency of consumption of breads and cereals per day.	5	6	5	0
4. Wholegrain cereals: Type of bread consumed.	Wholegrain, wholemeal bread			All other bread types
5. Meat and meat alternatives: Frequency of consumption of lean meats and alternatives per day.	0.5	1	1	0
6. Total dairy foods: Frequency of consumption of dairy products per day.	2	2	4	0
7. Low fat dairy: Type of milk usually consumed.	Low fat milk			Whole milk
8. Fluids: Frequency of consumption of water. †	5	6	5.5	0
9. Saturated fat intake: Trimming of fat from meat.	Usually			Never or rarely
10. Extra Foods: Frequency of consumption of "extra foods" per day. ‡	<1	<1	<1	≥1

*Based on recommendations from the Australian Guide to Healthy Eating. Servings unless otherwise indicated. Participants with intakes between the maximum and minimum amount were assigned scores proportionately. The diet quality score was adapted to reflect obesity-risk behaviours and to account for the fact that an indicator of dietary variety could not calculated based on the FFQ used in this study.

†Age groups for recommendation for fluids are as follows: 4-8yrs, 9-13 years, >14 years.

‡Guidelines concerning "extra foods" are presented as an upper limit. Extra foods are defined as potatoes cooked in fat; crisps; confectioneries; cakes and sweet biscuits; savoury pastries; fast-foods; pizzas; meat products; flavoured milks; soft drinks; and fruit juices.

Table 2. Characteristics of the sample

Variables	All	Stratification by child OW status at T1		P-value*
		Non-OW	OW	
n	216	167	49	
MOTHERS (at T1)				
Age, mean (SD)	39.2 (4.9)	39.1 (4.7)	39.3 (5.4)	0.86
Country of birth, % (CI 95%)				
Australia	92.6 (88.6; 96.6)	92.2 (88.3; 96.2)	93.9 (86.9; 100.0)	
Other	7.4 (3.4; 11.4)	7.8 (3.8; 11.7)	6.1 (0; 13.1)	1.00
Education level, % (CI 95%)				
Low	24.5 (18.3; 30.7)	22.2 (15.8; 28.5)	32.7 (15.6; 49.7)	
Intermediate	44.9 (39.1; 50.7)	43.7 (36.2; 51.2)	49.0 (33.8; 64.1)	
High	30.6 (23.3; 37.9)	34.1 (26.2; 42.1)	18.4 (7.8; 28.9)	0.08
Employment status, % (CI 95%)				
Working full-time	21.0 (15.1; 27.0)	20.0 (13.5; 26.5)	24.5 (12.2; 36.7)	
Working part-time	44.9 (38.8; 50.9)	46.1 (39.1; 53.0)	40.8 (27.0; 54.6)	
Not currently employed	34.1 (28.5; 39.7)	33.9 (27.2; 40.7)	34.7 (22.1; 47.3)	0.74
Marital status, % (CI 95%)				
Married/de facto relationship	87.4 (83.0; 91.8)	89.2 (85.2; 93.1)	81.6 (70.7; 92.6)	
Separated/divorced/widowed	8.8 (5.1; 12.6)	7.8 (4.3; 11.4)	12.2 (3.7; 20.8)	
Never married	3.7 (1.0; 6.5)	3.0 (0.4; 5.6)	6.1 (0; 12.6)	0.32
Number of siblings, % (CI 95%)				
None	10.3 (5.9; 14.7)	9.1 (4.8; 13.4)	14.3 (4.8; 23.7)	
One	47.2 (41.1; 53.3)	50.3 (43.4; 57.2)	36.7 (23.5; 50.0)	
Two or more	42.5 (36.9; 48.2)	40.6 (34.1; 47.1)	49.0 (34.9; 63.0)	0.21
BMI (kg/m2), mean (SD)	26.3 (6.0)	25.1 (5.0)	30.3 (7.4)	<0.0001
Categorical BMI, % (CI 95%)				
Non-OW	52.4 (46.4; 58.3)	59.9 (53.2; 66.6)	27.1 (15.8; 38.4)	
OW	27.1 (20.1; 34.2)	27.2 (19.7; 34.6)	27.1 (14.2; 40.0)	
Obese	20.5 (14.3; 26.6)	13.0 (7.2; 18.7)	45.8 (31.6; 60.1)	<0.0001
CHILDREN				
Age at T1, mean (SD)	9.1 (2.1)	8.9 (2.2)	9.8 (1.8)	0.002
Sex, % (CI 95%)				
Boys	44.0 (37.3; 50.6)	44.9 (37.4; 52.4)	40.8 (26.5; 55.1)	
Girls	56.0 (49.4; 62.7)	55.1 (47.6; 62.6)	59.2 (44.9; 73.5)	0.61
Screen time (h/day) at T1, mean (SD)	2.3 (1.4)	2.2 (1.4)	2.7 (1.3)	0.049
Average time (min/d) devoted to MVPA at T1, mean (SD)	81.6 (39.7)	85.5 (41.7)	68.2 (28.4)	<0.0001
Accelerometer wearing time (min/d) at T1, mean (SD)	727.6 (74.3)	719.3 (70.2)	755.8 (81.5)	0.004
zBMI at T1, mean (SD)	0.35 (0.92)	-0.02 (0.69)	1.59 (0.34)	<0.0001

Variables	All	Stratification by child OW status at T1 Non-OW	OW	P-value*
Categorical BMI at T1, % (CI 95%)				
Healthy weight (including underweight)	77.3 (72.5; 82.1)			
OW (including obesity)	22.7 (17.9; 27.5)			
Obese	6.5 (3.3; 9.7)			
zBMI at T2, mean (SD)	0.33 (0.94)	-0.001 (0.78)	1.46 (0.46)	<0.0001
Categorical BMI at T2, % (CI 95%)				
Healthy weight (including underweight)	75.9 (70.1; 81.7)	92.2 (87.6; 96.8)	20.4 (10.0; 30.8)	
OW (including obese)	24.1 (18.3; 29.9)	7.8 (3.2; 12.4)	79.6 (69.2; 90.0)	<0.0001
Obese	5.6 (2.6; 8.5)	0	24.5 (12.9; 36.0)	
Diet quality at T1 (DQI_{T1}), mean (SD) †	64.2 (10.3)	64.7 (10.6)	62.5 (9.0)	0.16
Diet quality at T2 (DQI_{T2}), mean (SD) ‡	59.7 (12.4)	59.8 (12.5)	59.4 (12.0)	0.84
Change in diet quality (DQI_{T2-T1}), mean (SD) §	-4.5 (9.2)	-4.9 (8.7)	-3.1 (10.9)	0.35

*Two-sided Chi square and Fisher's exact tests (categorical variables), and linear regression analyses (continuous variables) were used to compare children's characteristics at T1 and T2 according to their weight status, i.e. non-overweight (non-OW, including underweight) *vs.* overweight (OW, including obese).
†min=36.9, max=92.6.
‡min=31.0, max=94.0.
§ min=-33.1, max=25.6.
BMI, Body Mass Index; DQI, Diet Quality Index; MVPA, Moderate and Vigorous Physical Activity; OW, Overweight; T1, baseline; T2, follow-up; zBMI, BMI z-scores.

Table 3. Results from the multivariable linear regression analyses*, i.e. linear regression coefficients and 95% confidence intervals (CI), with $zBMI_{T2}$ as the outcome.

	Model 1			**Model 2**		
		Stratification by OW status at T1			**Stratification by OW status at T1**	
	All (n=216)	Non-OW (n=167)	OW (n=49)	All (n=216)	Non-OW (n=167)	OW (n=49)
Change in diet quality (DQI_{T2-T1})						
Larger Negative change ≤ - 7.7	0	0	0	0	0	0
Smaller Negative change]- 7.7; 0]	-0.09 (-0.24; 0.07)	-0.07 (-0.27; 0.13)	-0.15 (-0.33; 0.03)	-0.09 (-0.24; 0.07)	-0.03 (-0.23; 0.16)	-0.25 (-0.47; -0.03)
Positive change	-0.09 (-0.27; 0.08)	-0.08 (-0.32; 0.15)	-0.14 (-0.30; 0.02)	-0.10 (-0.27; 0.07)	-0.07 (-0.29; 0.15)	-0.22 (-0.44; -0.01)
P-trend	0.31	0.49	0.078	0.26	0.52	**0.035**
Diet quality at T1 (DQI_{T1})	-0.0004 (-0.007; 0.006)	-0.0009 (-0.01; 0.007)	0.002 (-0.01; 0.01)	0.004 (-0.003; 0.01)	0.005 (-0.003; 0.01)	0.006 (-0.006; 0.02)
P-value	0.90	0.82	0.78	0.28	0.22	0.31
zBMI at T1 ($zBMI_{T1}$)	0.91 (0.83; 0.98)	0.93 (0.82; 1.04)	1.05 (0.82; 1.28)	0.88 (0.82; 0.95)	0.90 (0.80; 1.01)	1.10 (0.86; 1.33)
P-value	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Gender						
Male	0	0	0	0	0	0
Female	0.10 (-0.03; 0.24)	0.10 (-0.07; 0.27)	0.11 (-0.03; 0.25)	0.14 (-0.03; 0.31)	0.14 (-0.07; 0.35)	0.21 (-0.004; 0.41)
P-value	0.12	0.24	0.11	0.11	0.19	0.054
Age at T1	0.02 (-0.02; 0.05)	0.04 (-0.001; 0.07)	-0.04 (-0.10; 0.01)	0.02 (-0.02; 0.05)	0.04 (-0.01; 0.08)	-0.04 (-0.12; 0.03)
P-value	0.28	0.059	0.10	0.42	0.11	0.22
MVPA at T1						
Low				0	0	0
Intermediate				0.13 (-0.01; 0.28)	0.12 (-0.05; 0.29)	0.23 (-0.01; 0.48)
High				0.11 (-0.11; 0.34)	0.11 (-0.14; 0.36)	0.24 (-0.08; 0.56)
P-trend				0.28	0.36	0.10

	Model 1			Model 2		
		Stratification by OW status at T1			Stratification by OW status at T1	
	All (n=216)	Non-OW (n=167)	OW (n=49)	All (n=216)	Non-OW (n=167)	OW (n=49)
Accelerometer wearing time at T1				0.0002 (-0.0006; 0.001)	0.0002 (-0.0008; 0.001)	0.00001 (-0.001; 0.001)
P-value				0.56	0.67	0.91
Screen sedentary behaviour at T1						
Low				0	0	0
Intermediate				0.13 (-0.04; 0.29)	0.13 (-0.05; 0.32)	0.15 (-0.06; 0.35)
High				0.22 (0.04; 0.40)	0.28 (0.06; 0.49)	0.20 (-0.0002; 0.40)
P-trend				**0.017**	**0.012**	0.091
Maternal education level						
Low				0	0	0
Intermediate				0.01 (-0.16; 0.18)	0.04 (-0.15; 0.24)	-0.13 (-0.31; 0.04)
High				-0.11 (-0.29; 0.07)	-0.09 (-0.32; 0.13)	-0.33 (-0.62; -0.04)
P-trend				0.19	0.36	**0.030**

[*] Multivariable regression analyses were performed to investigate the longitudinal relationships between $zBMI_{T2}$ (as the outcome) and change in diet quality between T1 and T2 (DQI_{T2-T1}, categorical variable), adjusting for $zBMI_{T1}$, DQI_{T1}, child's age and gender (Model 1). In Model 2, we also controlled for child's MVPA, accelerometer wearing time, screen time and maternal education (all measured at T1). Both models accounted for clustering by suburb.
DQI, Diet Quality Index; MVPA, Moderate and Vigorous Physical Activity; OW, Overweight; T1, baseline; T2, follow-up; zBMI, BMI z-scores.