Prospective associations between diet quality and body mass index in disadvantaged women: the Resilience for Eating and Activity Despite Inequality (READI) study

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Title: Prospective associations between diet quality and body mass index in disadvantaged women: The Resilience for Eating and Activity Despite Inequality (READI) study

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ABSTRACT

Background: Dietary patterns that align with recommended guidelines appear to minimize long-term weight gain in the general population, however prospective associations between diet quality and weight change in disadvantaged adults have not been examined. This study examined associations between concurrent change in diet quality and body mass index (BMI) over 5 years amongst women living in socioeconomically disadvantaged neighbourhoods.

Methods: Dietary intake and BMI were self-reported amongst 1242 women living in disadvantaged neighbourhoods in Victoria, Australia at three time points from 2007/08 - 2012/13. Diet quality was evaluated using the Australian Dietary Guideline Index (DGI). Associations between concurrent change in diet quality and BMI were assessed over the three time points using fixed effects and mixed models. Models were adjusted for age, smoking, menopausal status, education, marital status, number of births, urban/rural location, and physical activity.

Results: Average BMI increased by 0.14 kg/m² per year increase in age in the fixed effects model, and by 0.13 kg/m² in the mixed model (p<0.0001). BMI decreased by 0.014 kg/m² for a woman of average age with each unit increase in DGI score in the fixed effects model (p<0.0001), and by 0.012 kg/m² in the mixed model (p=0.001). The rate of change in BMI with age was greater for those with a lower DGI score than for those with a higher score (p<0.10).

Conclusions: Positive change in diet quality was associated with reduced BMI gain among disadvantaged women. Supporting disadvantaged women to adhere to population-level dietary recommendations may assist them with long-term weight management.

Key words: Diet quality, body mass index, women, disadvantage, prospective cohort, fixed effects models, mixed models, multiple imputation
Key messages:

• Higher diet quality has been shown to minimize long-term weight gain in the general population. This study examined prospective associations between change in diet quality and change in BMI over 5 years amongst women living in disadvantaged neighbourhoods.

• Average BMI increased by 0.14 kg/m² per year increase in age in the fixed effects model, and by 0.13 kg/m² in the mixed model.

• BMI decreased by 0.014 kg/m² for a woman of average age with each unit increase in DGI score in the fixed effects model, and by 0.012 kg/m² in the mixed model. The rate of change in BMI with age was greater for those with a lower DGI score than for those with a higher DGI score.

• A 10 point increase in diet quality through, for example, moving from eating 0 to 2 servings of fruit daily, predicts a BMI reduction of 0.14 kg/m² for a 37 year-old Australian woman (0.37 kg for a woman of average height).

• Supporting disadvantaged women to adhere to population-level dietary recommendations may assist them with long-term weight management.
INTRODUCTION

Progressive weight gain among adults is common in high-income countries\textsuperscript{1–5} which is concerning given strong associations between obesity and chronic disease.\textsuperscript{6} Positive energy balance is a major contributor to weight gain among adults.\textsuperscript{7} However, foods and diets with equivalent caloric and macronutrient profiles may not have identical biological effects on satiety, consumption, body weight and body composition.\textsuperscript{8} Analysing dietary patterns permits assessment of how the quality of whole foods, and the interactions among them, influence weight and health outcomes over and above their individual constituents.

Dietary patterns that align with recommended guidelines appear to minimize long-term weight gain, as the majority of prospective studies have found inverse associations between measures of diet quality at baseline and weight change over periods of up to 16 years amongst the general population.\textsuperscript{9} As dietary behaviours\textsuperscript{10–17} and weight gain\textsuperscript{18–22} are socioeconomically patterned, it is also important to understand relationships between diet quality and weight change in disadvantaged groups. To our knowledge, however, these associations have not been examined in longitudinal studies of adults. This information can enhance understanding of the factors that contribute to disadvantaged individuals’ greater vulnerability to weight gain.

The majority of prospective studies assessing associations between diet quality and weight gain have used a single change score (i.e. the difference in body weight between baseline and follow-up) as the outcome in linear regression analyses, rather than model the full trajectory of weight change over multiple time points.\textsuperscript{23–27} Moreover, most have only considered the impact of diet quality assessed at baseline, which assumes that diet quality remains stable over multiple years, and have excluded participants with missing data. Marginal models can overcome these limitations, although their use in this field has been more limited.\textsuperscript{28–30} Unlike simple linear regression, marginal models can model change across multiple time points, address correlations in repeated measures data, and can include
participants with missing values. They assume associations between exposures and outcomes are the same for all participants, and estimate a population-averaged effect. However, as evidence indicates substantial inter-individual variability in weight change in response to dietary interventions, subject-specific modelling techniques that allow the relationship between diet quality and weight change to differ between participants may be better suited to these types of analyses.

The purpose of this study was to examine prospective associations between change in diet quality and change in body mass index (BMI) over 5 years amongst women living in disadvantaged neighbourhoods. Given limitations of past analytical approaches, we conducted these analyses using participant-specific statistical models that modelled the full trajectory of change in diet quality and BMI over time.

**METHODS**

**Study population**

Data were provided by women who participated in the Resilience for Eating and Activity Despite Inequality (READI) study; detailed methods are provided elsewhere. READI is a cohort study of women living in socioeconomically disadvantaged areas within Victoria, Australia, and was designed to investigate pathways by which socioeconomic disadvantage influences behaviours associated with obesity risk. The study was approved by the Deakin University Human Research Ethics Committee. Women provided written, informed consent to participate.

The Index of Relative Socio-economic Disadvantage was used to classify all neighbourhoods (suburbs) in Victoria, Australia within urban/rural strata into tertiles of disadvantage. Within the most disadvantaged tertile, 40 urban and 40 rural neighbourhoods were randomly selected. The electoral roll (voting is compulsory in Australia) was then used to randomly identify 150 women aged
18–46 years from each of these neighbourhoods (n=11,940, as some included areas had fewer than 150 eligible women; n=11,079 surveys were able to be delivered), who were invited to complete a mailed questionnaire on sociodemographic, anthropometric, and lifestyle-related variables.

A total of 4938 women (45% response rate) completed a survey at baseline, of whom 4349 were eligible to participate (39% of those delivered a survey) (2007/08; Figure 1). At baseline, non-respondents were more likely to reside in an urban than a rural area, and resided in areas with greater area-level disadvantage compared with respondents (p<0.01). Compared with the general population of women living in the 80 sampled neighbourhoods, a greater proportion of READI women at baseline were Australian born (89% vs 73%) and were married or living as married (65% vs 49%), while a lower proportion were in full-time employment (37% vs 58%). In 2010/11, 1913 women completed surveys, with 1560 (36% of initial cohort) completing surveys in 2012/13. Bias may be introduced when individuals lost to follow-up differ in both exposure status and outcome compared to those who remain. In this cohort, while those who were lost to follow-up had a lower mean DGI score at baseline (78.8 vs 82.2, p<0.0001), mean BMI did not differ among women who were and were not lost to follow-up. The final analytical sample (n=1242) represented 80% of eligible women who completed a survey at all three time points. As described in Figure 1, primary reasons for exclusion included pregnancy, poor self-rated health, and missing ≥ 50% of BMI values or questionnaire responses.

**Questionnaire**

**Dietary intake**

Dietary intake (Table 1 lists foods/beverages) was assessed at all time points using a semi-quantitative short food frequency questionnaire (FFQ). Questions were based on previously published and validated Australian surveys. 

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Diet quality was evaluated using the Australian Dietary Guideline Index (DGI), which reflects adherence to the Dietary Guidelines for Australian Adults. The DGI has been shown to be a valid measure of diet quality in the Australian population that is associated with a variety of socioeconomic factors, intakes of key nutrients, and indicators of health status. The Australian DGI reflects age- and sex-specific recommendations for the consumption of foods in five core food groups (vegetables, fruits, cereals, meats and alternatives, and dairy) and extra foods (foods not essential to meet nutrient requirements and that contain excess fat, sugar and/or salt) found in the Australian Guide to Healthy Eating. The DGI includes 15 indicators, however the current analyses are based on 12 indicators as it was not possible to derive scores for salt intake, variety, and lean protein sources from the questions included in the FFQ. Each indicator could receive a score from 0-10, where 10 indicates full compliance with recommendations, thus total scores could range from 0-120. Cut-offs for minimum and maximum scores are provided in Table 1, and participants who consumed intermediate amounts were scored proportionately.

(Table 1 here)

BMI

Women self-reported their height at baseline, and their body weight at each time point. BMI was calculated as kg/m². Extreme values for weight (weight gain/loss ≥ 20% between waves) were audited, and unless errors in data entry were found, these values were retained in the analyses.

Potential confounders

Individual-level confounders included: age (continuous), smoking status (current, former, never), menopausal status (yes, no/don’t know), highest education level completed (high: tertiary, medium: trade/diploma/high school, low: less than high school), marital status (living with partner, not living
with partner), and number of births (0, 1-3, 4-8). Total physical activity was measured as a continuous variable, and represented the weekly sum of the number of minutes spent in any intensity of domestic, leisure, transport or occupational activity (each domain was assigned a subscore), as assessed in the long version of the International Physical Activity Questionnaire (IPAQ). The IPAQ has been shown to have acceptable reliability and validity. Urban/rural location of residence at baseline was included as a potential neighbourhood-level confounder.

Multiple imputation

Of the 1242 eligible women, 887 (71.4%) had complete data for all variables. Among the variables considered in the analysis, the proportion of missing values across all time points was 2.3% for BMI, 2.1% for IPAQ subscores, and < 1% for DGI subscores and for smoking status, educational level, marital status, and number of births. There were no missing values for age, menopausal status, or urban/rural residence. To reduce bias due to item non-response, missing data were imputed using chained equations multiple imputation with the user-written ice command in Stata (version 12.0; Stata Corp, TX, USA) under a missing at random assumption. Imputation models included BMI, age, smoking status, menopausal status, educational level, marital status, and number of births at each of the three time points, and urban/rural residence at baseline. In addition, the 12 DGI subscores and the four IPAQ subscores were used in the imputation models, rather than the total scores, to retain as much complete information as possible. Thirty imputations were performed to correspond to the proportion of participants with missing data. Imputed BMI values (n=86) were deleted, as removing imputed outcomes provides more precise estimates and can minimize bias introduced by a misspecified model.

Statistical analyses

Associations between concurrent change in diet quality (DGI score, mean centred, continuous) and BMI (continuous) were assessed over the three time points in Stata (version 12.0; Stata Corp, TX,
Concurrent changes were considered as they yield more robust, consistent and biologically plausible results compared to analyses based on prevalent or lagged-change in diet.\textsuperscript{49}

Fixed effects and mixed models allow estimation of subject-specific associations in longitudinal studies. As each approach has distinct capabilities, both models were fitted in order to understand how their effect estimates might differ. The first model was a fixed effects model with robust standard errors. This model examined within-individual change accounting for any time-invariant confounding (measured and unmeasured), since each woman acts as her own control. Importantly, only observations where the exposure changes contribute to their estimates.\textsuperscript{50} In this model, the coefficient of DGI represents the average change in BMI for a 1 unit within-individual change in DGI score.

The second model was a mixed model with level-1 (measurement occasion) and level-2 (individuals) random effects, and clustered standard errors at the neighbourhood level. The intercept and slope for age were allowed to vary randomly, meaning each woman had her own trajectory of change in BMI. Models were fitted using maximum likelihood estimation with an unstructured correlation matrix. Although their effect estimates may be biased by unmeasured time-invariant confounders, mixed models provide more precise estimates, permit explicit modelling and partitioning of variance structures both within and between individuals, and can estimate effects for time-invariant factors.\textsuperscript{50-52} The coefficients for time-varying predictors in mixed models are a combination of between-(i.e. the average difference in BMI associated with a 1 unit increase in DGI score between women) and within-individual effects (i.e. the average change in BMI associated with a 1 unit increase in DGI score within a woman).

The primary analyses examined findings in the imputed data set (n=1242 participants). All models adjusted for the following time-variant confounders: age (mean centred), smoking status,
menopausal status, educational level, marital status, number of births, and physical activity.

Urban/rural location of residence at baseline was included as a time-invariant confounder in the mixed model only. The interaction between age and DGI score was included to determine if the change in BMI with age differed depending on DGI score.

Sensitivity analyses

In sensitivity analyses, a complete case analysis (n=887) was conducted under the assumption that the data were missing completely at random.

RESULTS

Characteristics of study cohort

At baseline, women were on average 36.9 (SD=7.5) years of age. The majority were living with a partner (71.9%), had children (66.9%), and had completed secondary school and/or a trade/diploma (46.6%) (Table 2). Mean BMI increased from 25.8 kg/m² (SD=5.7) at baseline, to 26.5 kg/m² (SD=6.1) at wave 3, while the mean DGI score increased from 83.1 (SD=18.3) at baseline to 85.4 (SD=16.9) at wave 3.

Associations between change in DGI score and change in BMI

Table 3 shows the estimates from the two different modelling approaches, with and without the interaction between age and DGI score included in the model. Results from the fixed effects model indicated that the average BMI for a given woman increased by 0.14 kg/m² (95% CI: 0.11, 0.17, p<0.0001) with each year increase in age. Similar results were obtained from the mixed model (increase of 0.13 kg/m², 95% CI: 0.10, 0.16, p<0.0001). From the fixed effects model that included the interaction term, average BMI decreased by 0.014 kg/m² (95% CI: -0.021, -0.007, p<0.0001) for a
woman of average age (37 years) with each unit increase in DGI score, while the mixed model coefficient, representing a combination of within- and between-individual effects, was estimated to be \(-0.012 \text{ kg/m}^2\) (95% CI: -0.019, -0.005, \(p=0.001\)). The negative coefficient for the interaction between age and DGI score suggests that the rate of change in BMI with age was greater for those with a lower DGI score than for those with a higher DGI score (fixed effects model \(p=0.09\), mixed model \(p=0.07\); Figure 2).

**Sensitivity analyses**

The descriptive baseline characteristics of the complete cases were similar to those of the imputed sample, and overall findings were unchanged in the complete case analysis (Supplemental File). However, although the effect estimates for the interaction between age and DGI score were similar in analyses based on complete cases and those with imputed data, the \(p\)-values and confidence intervals were larger in the complete case analysis (fixed effects model \(p=0.22\), mixed model \(p=0.16\), potentially due to the smaller sample size.

**DISCUSSION**

This study is among the first to have used an entirely food-based measure of diet quality to assess prospective associations between diet quality and BMI, and the first to do so in a sample of disadvantaged women. Moreover, we examined how change in diet quality relates to change in BMI, advancing prior analyses that have primarily assessed diet quality at a single point in time.\(^{23-27}\) Findings showed that greater compliance with the food-based recommendations in the Dietary Guidelines for Australians can assist disadvantaged women to minimize long-term weight gain. The similarity in the effect estimates provided by fixed effects and mixed models allows for a more robust conclusion in this respect, and suggests little confounding by time-invariant variables.
According to the fixed effects model, a 1 point change in diet quality was associated with a change in BMI of 0.014 kg/m² for a 37 year-old Australian woman, or 0.04 kg for a woman of average height (162 cm). Estimates from the mixed model were similar, but cannot be interpreted solely as within-individual change, therefore we use the fixed effects estimates here. A larger increase in diet quality on the order of 10 points may be achieved by, for example, changing from 0 to 2 servings of fruit daily, from white to whole grain bread, or from 0 to 1 serving of lean meat daily. The DGI score for half of the women in our cohort changed by ≥ 10 points between one or more waves (~2.5 years between waves), while the DGI score for nearly one-quarter changed by ≥ 20 points, suggesting that changes of this magnitude are feasible for this population. According to our models, any one of these changes, or smaller combinations thereof, is associated with a change in BMI on the order of 0.14 kg/m² (0.37 kg), although in reality some changes may be more/less potent than others. A 10 unit increase in DGI score has furthermore been associated with improvements in cardiometabolic risk factors.40

Women in the sample gained an average of 0.7 kg/m² over the 5 year study time frame. The contribution of diet quality to this weight gain was small relative to the impact of age. Thus, while a higher quality diet can modify weight gain in disadvantaged women, it is not sufficient to avert it, as many other factors contribute to weight gain.4 The interaction between age and DGI score suggests that those with lower quality diets may derive slightly greater weight-related benefits from further improvements relative to those with higher quality diets. However, given that the average DGI score was low, ranging from just 83-85 out of a total possible score of 120, the impact of high adherence may not be fully captured by our findings.

It is difficult to directly compare our results with those from other studies due to differences in sample characteristics, methods of dietary assessment, diet quality scores, follow-up times, and
statistical techniques, however, the direction of associations has been remarkably consistent. For instance, greater adherence to Mediterranean-style dietary patterns diminished annual weight gains amongst the highest adherents in several studies, although no impact was found in another. Similarly, greater adherence to recommended Western dietary patterns was associated with more favourable anthropometric changes, including in waist circumference, waist-to-hip ratio, weight gain, and BMI in several studies, although in some instances these associations were race- or sex-specific. A recent study in an Australian cohort that also used the DGI score found that men in the highest quartile of diet quality had the lowest gain in BMI over 15 years, yet no associations were observed among women. Factors such as the longer (15 vs 5 years), and different time frames (1992-2007 vs 2007/08-2012/13) during which our analyses were conducted, the distinct characteristics of the groups of women that were examined (e.g. mixed population vs disadvantaged women), and/or differences in analytical techniques (e.g. categorical vs continuous exposures) may explain why our findings differ.

This is the first prospective study to examine how change in diet quality relates to change in BMI amongst disadvantaged adults. Previous cross-sectional analyses have demonstrated that diet quality is associated with both individual- and neighbourhood-level indicators of disadvantage, with more advantaged Australian men and women achieving higher DGI scores. In light of these findings, it is encouraging that mean diet quality improved over time amongst disadvantaged women in our cohort, from 83.1 to 85.4 (out of 120) over 5 years, compared to a change in DGI score of 80.6 to 83.8 (out of 130) from 1992-2007 amongst a general sample of Australian women. It is possible that although women in our study resided in disadvantaged neighbourhoods, they may have leveraged their individual-level resources (i.e. 77% had a medium or high educational level at baseline) to overcome environmental barriers to healthy eating. Future studies should attempt to ascertain the specific axes of differentiation that may constrain the diet quality of some disadvantaged women more than others.
Strengths and limitations

This study was strengthened by use of a validated food-based diet quality score which helps to minimize confounding due to biological and metabolic interactions among nutrients and foods. Moreover, we compared estimates from two powerful participant-specific modelling techniques, assessed diet quality, potential confounders and BMI at three time points, and used multiple imputation to reduce bias associated with item non-response.

The primary limitation of this study is that measures of BMI and food intake were self-reported, and both tend to be underreported among women. However, the FFQ was adapted from validated measures, and self-reported BMI corresponds closely with measured BMI in Australian women. Moreover, underreporting would tend to attenuate associations, and if women underreported similarly at all time points there would be little to no bias in the change value. Data were adjusted for physical activity level, which was also assessed on the basis of self-reported data. Although the IPAQ has been shown to have acceptable reliability and validity, residual confounding may nevertheless exist due to misreporting. As the current study used a brief FFQ we were unable to adjust for total energy intake, although we did adjust for age and physical activity level, which are major determinants of energy intake. In addition, many similar studies have shown that adjustment for energy intakes has little to no impact on estimates, while others contend that energy adjustment is not required as energy intake may mediate the effects of diet quality on weight gain.

It is possible that women who volunteered to participate in the study were more health conscious than those who chose not to participate, or that participation caused them to become more health conscious. However, mean BMI and DGI scores were poor at all three waves, and were similar to
values reported in large national surveys.\textsuperscript{57, 64} We also updated DGI scores and BMI at each wave, and adjusted for other time-variant behaviours that could impact diet quality and BMI such as smoking and physical activity. Provided that lifestyle behaviours and BMI were accurately reported, or reported with a similar degree of error over time, and that important confounders were not omitted, our estimates of change should be unbiased. A further limitation is that we were unable to consider neighbourhood of residence as a potential time-varying confounder.

Factors that might relate to missingness were included in imputation and analytical models to make the missing at random assumption more plausible. Scale scores were used during imputation as it was computationally infeasible to include all of the individual dietary and physical activity items, and because imputing only the total DGI and IPAQ scores would have discarded real values from subscores with complete data. Imputing scale subscores has been shown to be superior to complete case analyses and to imputing total scale scores.\textsuperscript{65, 66} Because we imputed DGI subscores rather than the total score, our imputation models did not contain the total DGI score, nor the interaction between age and DGI score. However, DGI subscores should be highly correlated with the total score, and the interaction between age and DGI score was very small.

**Implications for policy and research**

Nutrient- and energy-focussed metrics are increasingly being challenged by evidence indicating their inadequacy in explaining patterns of chronic disease and weight gain, and have therefore been superseded by a focus on consumption of whole foods and overall dietary patterns.\textsuperscript{67, 68} Acknowledging the self-reported nature of the data, the current study supports this paradigm shift, and demonstrates that adherence to food-based recommendations can assist women living in disadvantaged neighbourhoods to avoid weight gain. Such recommendations are likely to be more readily understood and acted upon than nutrient-based recommendations.\textsuperscript{69} As research proceeds to identify particular foods and combinations thereof that can help to support maintenance of a
healthy body weight, researchers should be careful to apply robust modelling strategies that maximize the power of their analyses in order to generate more robust evidence from which to formulate dietary recommendations.

CONCLUSIONS

Positive change in diet quality consistent with the recommendations in the Dietary Guidelines for Australians is associated with reduced BMI gain amongst women living in disadvantaged neighbourhoods. Although small, these changes are important at a population-level. Thus, supporting disadvantaged women to adhere to population-level dietary recommendations is likely to assist them with long-term weight management.

FUNDING

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.
<table>
<thead>
<tr>
<th>Dietary Guidelines for Australian Adults</th>
<th>Indicators in the READI sample</th>
<th>Criteria for minimum score (0)&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Criteria for maximum score (10)&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eat plenty of vegetables, legumes, and fruits</td>
<td>Fruit: servings of fruit (excluding juice) per day</td>
<td>0</td>
<td>≥ 2</td>
</tr>
<tr>
<td></td>
<td>Vegetables: servings of vegetables (including unfried potatoes) per day</td>
<td>0</td>
<td>≥ 5</td>
</tr>
<tr>
<td>Eat plenty of cereals (including breads, rice, pasta, and noodles), preferably whole-grain</td>
<td>Cereals: frequency of consumption of breads, cereals, pasta, rice and noodles per day</td>
<td>0</td>
<td>≥ 4</td>
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<tr>
<td></td>
<td>Whole-grain cereals: proportion of whole-meal/whole-grain bread consumed relative to total bread</td>
<td>0%</td>
<td>100%</td>
</tr>
<tr>
<td>Include lean meat, fish, poultry, and/or alternatives</td>
<td>Meat and meat alternatives: frequency of consumption of lean meats and alternatives per day</td>
<td>0</td>
<td>≥ 1</td>
</tr>
<tr>
<td>Include milks, yoghurts, cheeses, and/or alternatives; Reduced-fat varieties should be chosen where possible</td>
<td>Dairy foods: frequency of consumption of white milk, cheese and yoghurt per day</td>
<td>0</td>
<td>≥ 2</td>
</tr>
<tr>
<td>Low-fat/reduced-fat dairy: type of milk usually consumed</td>
<td>Whole milk</td>
<td>Low-fat milk</td>
<td></td>
</tr>
<tr>
<td>Drink plenty of water</td>
<td>Fluids: frequency of consumption of beverages (not including regular soft drinks and alcohol) and proportion of water consumed relative to total beverages (not including regular soft drinks and alcohol) per day</td>
<td>0 with 0% water</td>
<td>≥ 8 with ≥ 50% water</td>
</tr>
<tr>
<td>Limit saturated fat and moderate total fat intake</td>
<td>Saturated fat intake: type of milk usually consumed and trimming of fat from meat</td>
<td>Whole milk; Never trim fat</td>
<td>Low-fat milk; Always trim fat</td>
</tr>
<tr>
<td>Limit your alcohol intake if you choose to drink</td>
<td>Alcohol: frequency of consumption of all alcoholic beverages per day</td>
<td>≥ 2</td>
<td>≤ 1</td>
</tr>
<tr>
<td>Consume only moderate amounts of sugars and foods containing added sugars</td>
<td>Added sugars: frequency of consumption of chocolate/lollies, flavoured milk, and soft drinks per day</td>
<td>&gt; 1.25</td>
<td>≤ 1.25</td>
</tr>
<tr>
<td>Prevent weight gain: be physically active and eat according to your energy needs</td>
<td>Extra foods: frequency of consumption of crisps/salty snacks, chocolate/lollies, cakes, biscuits, pies, fast foods, pizza, processed meat, flavoured milk, soft drinks, alcohol, and hot chips per day</td>
<td>&gt; 2.5</td>
<td>≤ 2.5</td>
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</table>
*Values represent servings unless otherwise indicated. Participants with intakes between the maximum and minimum amounts were assigned scores proportionately.
Table 2. Descriptive characteristics of participants in the Resilience for Eating and Activity Despite Inequality (READI) cohort (n=1242 participants)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>BMI, mean (SD)</td>
<td>25.8 (5.7)</td>
<td>26.3 (6.0)</td>
<td>26.5 (6.1)</td>
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<tr>
<td>BMI categories, % (n)</td>
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<tr>
<td>Under/normal weight (&lt; 25kg/m²)</td>
<td>55.2 (685)</td>
<td>49.9 (620)</td>
<td>48.9 (607)</td>
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<tr>
<td>Overweight (25kg/m² - 30kg/m²)</td>
<td>25.6 (318)</td>
<td>28.0 (348)</td>
<td>27.6 (343)</td>
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<tr>
<td>Obese (≥ 30kg/m²)</td>
<td>19.2 (239)</td>
<td>22.1 (274)</td>
<td>23.5 (292)</td>
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<tr>
<td>DGI score*, mean (SD)</td>
<td>83.1 (18.3)</td>
<td>84.3 (17.4)</td>
<td>85.4 (16.9)</td>
</tr>
<tr>
<td>Area of residence, % (n)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Rural</td>
<td>59.7 (741)</td>
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</tr>
<tr>
<td>Urban</td>
<td>40.3 (501)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Highest education level, % (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low (no high school)</td>
<td>23.2 (289)</td>
<td>20.4 (254)</td>
<td>17.4 (216)</td>
</tr>
<tr>
<td>Medium (high school/trade/diploma)</td>
<td>46.6 (579)</td>
<td>45.9 (570)</td>
<td>46.5 (578)</td>
</tr>
<tr>
<td>High (tertiary)</td>
<td>30.1 (374)</td>
<td>3.7 (418)</td>
<td>36.1 (448)</td>
</tr>
<tr>
<td>Marital status, % (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living with partner</td>
<td>71.9 (893)</td>
<td>72.4 (899)</td>
<td>73.5 (912)</td>
</tr>
<tr>
<td>Not living with partner</td>
<td>28.1 (349)</td>
<td>27.6 (343)</td>
<td>26.5 (330)</td>
</tr>
<tr>
<td>Number of births, % (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>33.2 (412)</td>
<td>29.3 (363)</td>
<td>27.8 (345)</td>
</tr>
<tr>
<td>1-3</td>
<td>60.3 (749)</td>
<td>63.2 (785)</td>
<td>64.2 (797)</td>
</tr>
<tr>
<td>4-8</td>
<td>6.6 (81)</td>
<td>7.5 (94)</td>
<td>8.1 (100)</td>
</tr>
<tr>
<td>Smoking status, % (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never smoked</td>
<td>52.5 (652)</td>
<td>50.4 (626)</td>
<td>49.6 (616)</td>
</tr>
<tr>
<td>Former smoker</td>
<td>27.2 (338)</td>
<td>32.3 (401)</td>
<td>34.6 (430)</td>
</tr>
<tr>
<td>Current smoker</td>
<td>20.3 (252)</td>
<td>17.3 (215)</td>
<td>15.8 (196)</td>
</tr>
<tr>
<td>Menopausal status, % (n)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reached menopause</td>
<td>2.7 (33)</td>
<td>6.5 (81)</td>
<td>13.7 (170)</td>
</tr>
<tr>
<td>Not reached menopause or unsure</td>
<td>97.3 (1209)</td>
<td>93.5 (1161)</td>
<td>86.3 (1072)</td>
</tr>
<tr>
<td>Mean age (yrs), mean (SD)</td>
<td>36.9 (7.5)</td>
<td>39.9 (7.5)</td>
<td>41.9 (7.5)</td>
</tr>
<tr>
<td>Physical activity (hrs/wk)², mean (SD)</td>
<td>24.9 (21.8)</td>
<td>23.3 (20.5)</td>
<td>23.2 (20.9)</td>
</tr>
</tbody>
</table>

BMI: body mass index; DGI: Dietary Guideline Index; SD: standard deviation

*Diet quality was evaluated using the Australian Dietary Guideline Index (DGI).¹⁷ The total possible score is 120.

²Physical activity was calculated as the weekly sum of the number of minutes spent in any intensity of domestic, leisure, transport or occupational activity as assessed in the long version of the International Physical Activity Questionnaire.⁴³
Table 3. Multivariable models of associations between Dietary Guideline Index score and BMI over 5 years (2007/08-2012/13) in the Resilience for Eating and Activity Despite Inequality (READI) cohort (n=1242 participants)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fixed effects models</th>
<th>Mixed models</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No interaction</td>
<td>With interaction</td>
</tr>
<tr>
<td></td>
<td>Coefficient (95% CI)</td>
<td>Coefficient (95% CI)</td>
</tr>
<tr>
<td>Age</td>
<td>0.142* (0.111, 0.173)</td>
<td>0.142* (0.111, 0.173)</td>
</tr>
<tr>
<td>DGI score</td>
<td>-0.015* (-0.022, -0.008)</td>
<td>-0.014* (-0.021, -0.007)</td>
</tr>
<tr>
<td>Age*DGI score</td>
<td>--</td>
<td>-0.0007 (-0.0015, 0.0001)</td>
</tr>
<tr>
<td>SD of random intercept</td>
<td>5.48</td>
<td>5.48</td>
</tr>
<tr>
<td>SD of random slope</td>
<td>1.55</td>
<td>1.55</td>
</tr>
<tr>
<td>Covariance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CI: confidence interval; DGI: Dietary Guideline Index; SD: standard deviation

*All models adjusted for the following time-varying confounders: age (mean centred), smoking status, menopausal status, educational level, marital status, number of births, and physical activity. Urban/rural location of residence at baseline was included as a time-invariant confounder in the mixed model only.

*p<0.0001

**p=0.001
FIGURE LEGENDS

Figure 1 Flow chart of participants in the Resilience for Eating and Activity Despite Inequality (READI) study

Figure 2 Interaction of Australian Dietary Guideline Index score and age
This figure depicts how associations between age (years) and BMI (kg/m²) differ according to Dietary Guideline Index score when the score is held constant. Analyses are based on the mixed model with a random intercept and slope.
DGI: Dietary Guideline Index score
p<0.0001 for all slopes for age
REFERENCES


65. Plumpton CO, Morris T, Hughes DA, White IR. Multiple imputation of multiple multi-item scales when a full imputation model is infeasible. BMC research notes 2016; 9: 45.


