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Resilience to obesity amongst socioeconomically disadvantaged women: The READI study

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Running header: Obesity resilience in disadvantaged women

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Abstract

Objective: This cross-sectional study aimed to identify sociodemographic and behavioural characteristics of ‘overweight-resilient’ women, i.e., women who were in a healthy body weight range, despite living in socioeconomically disadvantaged neighbourhoods that place them at increased risk of obesity. The study also aimed to test a comprehensive theoretically-derived model of the associations between intrapersonal, social and environmental factors and obesity amongst this target group.

Participants: 3 235 women aged 18-45 years from 80 urban and rural neighbourhoods throughout Victoria, Australia, participating in the Resilience for Eating and Activity Despite Inequality (READI) study.

Measurements: Women reported height, weight, sociodemographic characteristics, leisure-time physical activity, dietary behaviours, and a range of theoretically-derived cognitive, social and neighbourhood environmental characteristics hypothesized to influence obesity risk. A theoretical model predicting body mass index was tested using structural equation models.

Results: Women classified as ‘resilient’ to obesity tended to be younger, born overseas, more highly educated, unmarried, and to have higher or undisclosed household incomes. They engaged in more leisure-time physical activity, and consumed less fast foods and soft drinks than overweight/obese women. Neighbourhood characteristics, social characteristics and cognitive characteristics all contributed to explaining variation in BMI in the hypothesized directions.

Conclusions: These results demonstrate several characteristics of women appearing ‘resilient’ to obesity, despite their increased risk conferred by residing in socioeconomically disadvantaged neighbourhoods. Acknowledging the cross-sectional study design, the results advance theoretical frameworks aimed at investigating obesity risk by providing evidence in support of a comprehensive model of direct and indirect effects on obesity of neighbourhood as well as social, cognitive, and behavioural characteristics.

Keywords: obesity risk factors, socioeconomic disadvantage, structural equation models
Introduction

In developed countries, individuals experiencing socioeconomic disadvantage, including low education levels, low income, or living within socioeconomically disadvantaged neighbourhoods, are at increased risk of obesity\(^1,2\). This pattern is particularly pronounced amongst women\(^1,2\). Despite the well-established nature of these inequalities, little is understood about the underlying determinants of obesity amongst socioeconomically disadvantaged individuals. Hence we have an insufficient evidence base to inform preventive interventions targeting this high-risk population group.

Typically, epidemiological studies aiming to establish aetiological pathways to obesity have focused on identifying the correlates or predictors of excess weight\(^3,4\). An alternative approach involves elucidating the predictors of healthy weight maintenance in high-risk target groups. Although socioeconomic disadvantage appears to confer an increased risk of obesity, not all individuals experiencing socioeconomic disadvantage are obese. We have argued\(^5,6\) that individuals who are socioeconomically disadvantaged, yet manage to maintain a healthy weight despite the increased risk of obesity, may be considered as demonstrating ‘resilience’ (defined as a “dynamic process encompassing positive adaptation within the context of significant adversity”\(^7\)).

Identification of the modifiable characteristics of these ‘resilient’ individuals may comprise a useful avenue for innovative research capable of better informing obesity prevention initiatives amongst others experiencing socioeconomic disadvantage.

Historically, research on the correlates of obesity has focused primarily on individual-level risk factors, such as behaviours or individual-level socioeconomic factors\(^3,8\). Recently, however, the role of broader social and environmental determinants of the obesity epidemic has received increased attention\(^9\). Given the plethora and complexity of such potential aetiological drivers of obesity, research into the determinants of obesity (and obesity-resilience) should be informed by sound theoretical frameworks. Two reviews of the application of
theoretical models to predicting obesity\textsuperscript{10,11}, however, concluded that existing models do not perform well in explaining obesity risk. One concluded that social ecological models, which posit that behaviours are determined by a combination of factors from personal, social, and physical environmental domains, offer good potential for guiding exploration of obesity risk\textsuperscript{10}, but noted that social ecological models have generally not included specific cognitive variables. It was suggested that future research should focus on developing and testing overarching theoretical models which include both physical activity and eating behaviours and incorporate concepts from several of the more promising theoretical models and from the empirical literature.

We have previously examined sociodemographic, behavioural and familial correlates of resilience to obesity amongst a subsample of mothers from the READI cohort\textsuperscript{12,13}. However few other studies have examined either obesity resilience, or correlates of obesity, amongst socioeconomically disadvantaged women. Moreover, existing studies have tended to examine only a limited range of potential modifiable correlates, such as stress and diet\textsuperscript{14}, fear of crime\textsuperscript{15}, or built environmental factors\textsuperscript{16,17}. To our knowledge, no studies have attempted to test a comprehensive model of obesity correlates in socioeconomically disadvantaged women. In a recent review of neighbourhood determinants of obesity\textsuperscript{18}, the authors argued that analytic approaches such as structural equation modeling may be useful for untangling the ‘complex web’ of direct and indirect influences of neighbourhood and individual-level factors on obesity risk.

In the present study, we developed a model drawing on elements of social ecological theories and extending this to incorporate specific cognitive variables. This model also draws on a theoretical framework proposed to explain socioeconomic variations in physical activity and diet\textsuperscript{19}. Key elements of the hypothesized model are:

- Intrapersonal variables, including motivational variables such as outcome expectancies; cognitive resource variables such as self-efficacy and nutrition knowledge; and behaviour change strategies such as self-control and behavioural skills (e.g., setting goals, planning);
Social environmental variables, including perceived social support for healthy eating and physical activity;

Physical environmental variables, including perceptions of the food and physical activity environments of the local neighbourhood.

Hypothesised associations are shown in Figure 1.

The aims of the present cross-sectional study were to identify those women who were in a healthy weight range despite living in socioeconomically disadvantaged neighbourhoods, and to describe the sociodemographic and behavioural characteristics of these ‘resilient’ women. Finally, the study aimed to test a comprehensive theoretically-derived model of links between intrapersonal, social, and environmental factors and obesity amongst this target group.

Materials and methods

This paper examined data collected in 2007-08 as part of the baseline cohort data collection within the Resilience for Eating and Activity Despite Inequality (READI) study13,20, approved by the Deakin University Human Research Ethics Committee. All participants gave written consent to participate. The READI cohort will be followed up again during 2011; however, given the lack of evidence on correlates of body weight in socioeconomically disadvantaged groups, this study presents initial cross-sectional data on theoretically-derived hypothetical associations amongst a comprehensive range of variables.

Participants

The Socio-Economic Index for Areas (SEIFA Index of Disadvantage)21, a widely-used indicator based on 2001 population census factors such as neighbourhood income and proportion of the neighbourhood employed, was used to classify all neighbourhoods (suburbs) of Victoria, Australia, into thirds. Areas in the bottom SEIFA third
were considered ‘disadvantaged’. Forty urban and 40 rural areas were randomly selected from this sampling frame. The electoral roll was used to randomly identify 150 women aged 18-45 years from the 80 areas (n=11 940; some included areas had <150 eligible women). Participants (n= 4 934; 41%) replied to a postal invitation to complete a questionnaire. Respondents who moved from the sampled neighbourhood prior to completing the survey (n=571), were not the intended participant (n=3), withdrew their data after completing the survey (n=2), or were <18 or >46 years old (n=9), were excluded, leaving 4 349 eligible participants.

Women who were pregnant (n=210), menopausal (n=133), or underweight (BMI<18.5; n=145) were excluded from analyses (underweight was an exclusion criteria since the focus of this study was on comparing characteristics of ‘resilient’ – i.e., healthy weight – women with those who were overweight or obese). Women were also excluded if they were missing data on any study variable (n=780). Some women met more than one exclusion criteria, leaving 3 297 women. Women whose data represented multivariate outliers (n=62), deviant on a combination of the dependent variables, were excluded, leaving a final sample of 3 235 women.

Compared with women whose data were excluded from analyses, women whose data were included were significantly older, had higher BMI, spent more time in leisure-time physical activity, and consumed more vegetables and water, and less fast food and soft drink; but showed no differences in fruit or energy-dense snack intakes.

**Outcome Measure**

Body mass index (BMI) (kg/m²) was calculated by dividing self-reported weight (in kilograms) by self-reported height (in metres) squared, and categorised as healthy weight (18.5–24.9 kg/m²), overweight ( 25.0–29.9 kg/m²), or obese (BMI 30.0 or more).
Correlates

Behavioural factors

Leisure-time physical activity: Participants completed the International Physical Activity Questionnaire (IPAQ-L). The IPAQ-L has excellent test-retest reliability, and its criterion validity has been demonstrated through comparisons to accelerometer-measured physical activity. Participants reported time (minutes/week) spent in walking, moderate- and vigorous-intensity physical activity in their leisure time during the past seven days, which was summed to estimate total minutes/week in leisure-time physical activity.

Dietary intake: Food intake was measured via a food frequency questionnaire created by drawing on several well-validated measures, including the 2001 National Food and Nutrition Monitoring and Surveillance Project instrument, the 1995 National Nutrition Survey, the Romp and Chomp Eating and Activity Survey and the Cancer Council of Victoria Food Frequency Questionnaire. Participants reported how often in the past month they had consumed six types of foods/drinks, previously implicated in the aetiology of weight gain/obesity: fruit, vegetables, fast food, energy-dense snacks, water and soft drink. Categorical frequency responses for all intake items were converted into weekly equivalent scores (e.g., ‘once a day’ was coded 7 times/week). A fast food weekly intake score was calculated by summing weekly equivalent scores for fast food, pizza, and pies/pasties/sausage rolls. An energy-dense snacks weekly intake score was calculated by summing weekly equivalent scores for chocolates/lollies, potato crisps/salty snack foods and cakes/doughnuts/sweet biscuits.

Self-reported smoking status (included as a potential confounder given its relationship with body weight) was categorized as never smoked, previously smoked, or current smoker.
Intrapersonal, social and physical environmental factors

A variety of intrapersonal, social environmental, and physical environmental measures, selected on the basis of theoretical models and prior evidence of their importance as predictors of obesity or its determinant behaviours, were assessed. These measures are described in detail in Table 1. The intrapersonal variables included outcome expectancies for physical activity (perceived benefits; enjoyment), and for healthy eating (perceived benefits of eating fruit and vegetables); nutrition knowledge; self-efficacy for physical activity and for healthy eating; and behavioural skills/strategies/control for physical activity and for healthy eating. Social environmental variables included perceived social support for both physical activity (encouragement, co-participation) and healthy eating (encouragement for healthy eating, discouragement from unhealthy eating, and co-participation in healthy eating). Perceived neighbourhood physical environmental variables comprised a measure of the neighbourhood walking environment and two measures (availability and affordability) of the neighbourhood food environment.

Sociodemographic factors

Women reported their age and country of birth (categorized as ‘Australian’ or ‘other’), highest education level (categorized as low [did not complete year 12], medium [completed year 12 or equivalent], or high [tertiary qualification]), marital status (married/de facto, previously married, or never married), number of children (none, one, two, or three or more), employment status (working full-time, working part-time, or not currently in paid employment), personal income (low [$0-299/week], medium [$300-699/week], high [$700+/week], or undisclosed) and household income (low [$0-699/week], medium [$700-1499/week], high [$1500+/week], or undisclosed).

Statistical Analyses

Differences in sociodemographic and behavioural characteristics between healthy weight (BMI 18.5-24.99) and overweight/obese (BMI ≥ 25) women were examined using chi-square tests for categorical variables, and t-tests
for continuous variables. Four variables – soft drink intake, fast food intake, energy-dense snacks intake, and leisure-time physical activity – were non-normally distributed so were log-transformed prior to inclusion in group and SEM analyses.

While structural equation modelling (SEM) is a technique commonly used to analyse cross-sectional data, its use in this regard precludes conclusions regarding causal relations among variables. Rather SEM was used here to test the theoretical model elucidating potential obesity-related associations. SEM allows for the assessment of latent variables free of measurement error, and can enable evaluation of hypothesized associations between a range of variables in the model simultaneously30. SPSS Statistics 17.0 was used for descriptive analyses, and AMOS 17.0 was used to perform SEM.

Two latent variables were used to represent dietary intake, low-energy consumption and energy-dense consumption. Initially, for conceptual reasons, fruit, vegetable and water intake were loaded onto low-energy consumption, while fast food, energy-dense snack and soft drink intake were loaded onto energy-dense consumption. However, water and energy-dense snack intake showed poor fit in their respective measurement models and were subsequently removed, leaving fruit and vegetable intake and fast food and soft drink intake as the indicators for low-energy consumption and energy-dense consumption, respectively.

The structural model was developed as shown in Figure 1. Eating and physical activity behaviours and their hypothesized determinants were incorporated into a single model with weight (BMI) as the outcome. For these analyses, continuous BMI score was used in order to best capitalize on the abilities of SEM. Social and physical environmental factors (social support and neighbourhood environment measures) were treated as the initial “predictor” variables, with paths from these to the cognitive intrapersonal factors (outcome expectancies, self-efficacy, and behavioural skills for each of eating and physical activity, and nutrition knowledge). As self-efficacy
has been previously suggested to influence other cognitive factors\textsuperscript{31}, paths were also added from self-efficacy to
behavioural skills and outcome expectancies. Behavioural factors (energy-dense intake and low energy intake,
and leisure-time physical activity) were then added with paths drawn to each of these from the relevant
cognitive factors. A path was added from low energy intake to energy-dense intake, and finally paths were
drawn from energy-dense intake and leisure-time physical activity to BMI.

Associations between all sociodemographic measures and BMI were examined using multiple regression, with
those significantly associated with BMI (age, education, and country of birth) used as covariates in the SEM.
Sociodemographic characteristics might impact on weight both indirectly via the behaviours tested in this model,
but also via other behavioural factors not assessed here (e.g., via occupational or domestic physical activity; or
via dietary components such as portion size), and so paths were added from each of the sociodemographic
covariates to energy-dense consumption, low-energy consumption, and leisure-time physical activity, as well as
directly to BMI.

Given that social support for both healthy eating and physical activity are likely to be strongly related (e.g., due
to having a generally supportive network of friends and family), these two factors were allowed to correlate
within the model. Likewise, the pairs of neighbourhood environment factors (healthy food environment and
walking environment) and pairs of self-efficacy factors (eating and physical activity) were allowed to correlate.
The latent variables neighbourhood walking environment, self-efficacy for healthy eating, self-efficacy for
physical activity, behavioural skills for healthy eating, leisure-time physical activity, and BMI each had only one
indicator variable. In such cases it is recommended that the error variance for a single indicator is set to the
variance multiplied by one minus the reliability coefficient for the indicator variable, e.g. \( [\text{sd}^2 \times (1-\alpha)] \)\textsuperscript{32}. This
equation was used to set error variances for the scale variables using the scale reliability (\( \alpha \)). For BMI, the test-
retest reliability (ICC=0.99) was substituted instead. Since no reliability data were available for leisure-time physical activity, the error variance was not manually defined.

Prior to testing the structural equation model, two measurement models were assessed for fit: one for eating behaviours, with the energy-dense and low energy intake factors correlated; and one for social support, with the social support for healthy eating and physical activity factors correlated. Finally, the fit of the structural model was evaluated using four indices: the goodness-of-fit index (GFI ≥ 0.90 indicates good fit\textsuperscript{30}), the adjusted goodness-of-fit index (AGFI ≥ 0.90 indicates good fit\textsuperscript{30}), the comparative fit index (CFI ≥ 0.90 indicates good fit\textsuperscript{30}) and the root mean square error approximation with 90% confidence interval (RMSEA; values < 0.07 indicate good fit\textsuperscript{33}).

**Results**

Sociodemographic characteristics of healthy-weight and overweight/obese women are presented in Table 2. Compared with women who were overweight/obese, healthy weight women tended to be younger, born overseas, more highly educated, unmarried, and had higher or undisclosed household incomes.

Behavioural characteristics of healthy weight and overweight/obese women are presented in Table 3. Healthy-weight women reported greater leisure-time physical activity duration, and lower consumption of fast foods and soft drink, compared with overweight/obese women.

**Structural equation model**

The measurement model for eating (GFI=1.00, AGFI=1.00, CFI=1.00, RMSEA=0.00) indicated good fit. The measurement model for social support (GFI=0.97 , AGFI=0.92, CFI= 0.96, RMSEA=0.11[0.10-0.13]) indicated generally good fit, but modification indices suggested that covarying the error terms for the indicators 'Co-
participation in healthy eating’ and ‘Co-participation in physical activity’ would substantially improve the model fit. As this modification was conceptually justifiable, the indicators were covaried, resulting in a superior fit for the measurement model (GFI=1.00, AGFI=0.99, CFI= 0.99, RMSEA=0.04[0.03-0.06]).

Overall model fit for the structural model was reasonable, with two indicators (GFI=0.91, RMSEA=0.06[0.06-0.07]) indicating acceptable fit, although the AGFI (0.88) and CFI (0.82) were slightly lower than ideal. Indicator variables generally loaded strongly on latent factors, with regression coefficients all above 0.50, with the exceptions of neighbourhood affordability of healthy foods (neighbourhood healthy food environment) and benefits of physical activity (outcome expectancies for physical activity); nonetheless these two indicators still had over 20% of their variance explained by their latent factors (see Figure 1). AMOS does not account for the clustering arising from sampling via neighbourhoods. However, the neighbourhood intraclass correlation coefficients for BMI and behavioural variables in the model were extremely low (0.01-0.03), and thus unlikely to substantially affect the reported estimates.

Associations

Due to the large number of associations tested, statistical significance for assessing associations (paths) was conservatively set at p < .005. Even so, a majority of the associations within the model were significant (Figure 2). Of particular note (commencing with the most distal eating-related variables predicting BMI), the neighbourhood food environment was positively associated with self-efficacy for healthy eating, behavioural skills (perceived behavioural control) for healthy eating, nutrition knowledge, and healthy eating outcome expectancies. Perceived social support for healthy eating was positively associated with self-efficacy for healthy eating. Amongst the cognitive variables, self-efficacy for healthy eating was positively associated with perceived behavioural control for healthy eating and with healthy eating outcome expectancies. Nutrition knowledge, perceived behavioural control for healthy eating, and healthy eating outcome expectancies were all positively associated with low-energy consumption (i.e., women with higher scores on these measures ate low-energy
foods more frequently), and nutrition knowledge and self-efficacy were inversely associated with energy-dense consumption (i.e. women with higher nutrition knowledge and self-efficacy scores ate energy-dense foods less frequently). Energy-dense consumption was positively associated with BMI.

On the physical activity side of the model, the perceived neighbourhood walking environment was positively associated with physical activity self-efficacy and outcome expectancies. Perceived social support for physical activity was positively associated with physical activity self-efficacy, behavioural skills, and outcome expectancies. Amongst cognitive variables, physical activity self-efficacy was positively associated with physical activity outcome expectancies and behavioural skills, and both of these were associated with leisure-time physical activity. Leisure-time physical activity was negatively associated with BMI.

Unexpectedly, associations for self-efficacy for healthy eating and self-efficacy for physical activity and their respective behavioural outcomes were not statistically significant. However, as shown in Figure 2, in both cases these associations were mediated almost entirely by the relevant behavioural skills and outcome expectancies variables, which were strongly correlated with self-efficacy.

**Variance explained**

The physical activity-related environmental, social and cognitive factors explained 77% of the variance in leisure-time physical activity (82% was explained once covariates were considered). The eating-related environmental, social and cognitive factors explained 91% and 38% of the variance in low-energy and energy-dense consumption, respectively (93% and 42% with covariates included). Finally, 5% (11% with covariates) of the variance in BMI was explained by the combined environmental, social, cognitive, and behavioural factors.

**Discussion**
This study examined sociodemographic and behavioural characteristics of women who appear ‘resilient’ to obesity – that is, those who are in a healthy weight range despite living in socioeconomically disadvantaged neighbourhoods – and to test a theoretically-derived model of the links between intrapersonal, social and environmental factors and obesity amongst this high-risk target group. While past studies have utilized the capabilities of SEM to investigate inter-relations amongst correlates of obesity, including some in disadvantaged populations, they have been based on small samples, and have not tested comprehensive theoretically-derived models incorporating intrapersonal, social, and environmental determinants of physical activity and eating behaviours simultaneously.

Amongst our sample, sociodemographic and behavioural factors that might contribute to ‘resilience’ to obesity were identified. These included a younger age, a country of birth outside of Australia, being unmarried, and having a higher socioeconomic position (education and household income). Behaviourally, obesity-resilient women were more physically active during leisure-time, and less frequently consumed fast foods and soft drink. Such characteristics have been identified (although sometimes tentatively) as potentially protective against obesity in previous research, here we extended this to a sample of women at increased risk of obesity due to their residence in socioeconomically disadvantaged neighbourhoods. Interestingly, amongst this sample, who were relatively homogeneous in terms of neighbourhood-level socioeconomic disadvantage, there emerged a gradient in obesity resilience according to individual-level education and household income, attesting to the importance of favourable individual socioeconomic circumstances for obesity resilience, even in the context of neighbourhood disadvantage. Consumption of fruits, vegetables, water, and energy-dense snacks were not associated with obesity-resilience. This is not entirely inconsistent with previous research, which has produced mixed evidence regarding the impact of specific dietary components such as these on obesity risk. Possibly the influence of low-energy dense consumption on obesity risk may be outweighed by the impact of
consumption of high-energy foods, which plausibly would impact energy balance more directly, and which was strongly associated with BMI in our model.

There have been calls for a focus on socio-environmental as well as individual determinants to provide a picture of how and why obesity occurs. The importance of studying both sides of the energy-balance equation has also been highlighted. The present study aimed to address these gaps, and to empirically test a comprehensive model of relationships amongst interpersonal, social and physical environmental factors and obesity. Our hypothesized model showed reasonable fit to the data and key links were significant and in the expected directions. In brief, neighbourhood physical activity and eating variables were associated with respective selected cognitive variables that they were hypothesized to influence, as did social support for these behaviours. In turn, cognitive variables were associated directly or indirectly with their respective behavioural outcomes, which generally predicted BMI in the anticipated directions. Some unexpected results were observed; for instance, self-efficacy for healthy eating and physical activity were not directly associated with their respective behavioural outcomes. However, these associations were strongly mediated by behavioural skills and outcome expectancies, suggesting that self-efficacy was indirectly linked with behaviour via these cognitive and behavioural characteristics.

While there are few studies testing comprehensive models of obesity against which to compare our results, Pouliou & Elliott recently found associations of obesity with a number of built environmental factors, including neighbourhood walkability, even after adjustment for individual-level sociodemographic and behavioural characteristics. However, the correlates assessed in that study were not specific to the relevant behavioural outcomes. For example, social variables included membership of a voluntary organization, and a sense of belonging to the community, neither of which was found to be associated with obesity risk. In addition, no
theoretically-derived cognitive variables were investigated, and the use of multivariate regression analyses in that study did not allow for the examination of inter-relationships amongst predictor variables, as undertaken here.

In the present study, we recruited a large sample of women from socioeconomically disadvantaged neighbourhoods, a group at high risk in terms of obesity and its determinant behaviours; and used a novel conceptual approach to investigating ‘resilience’ and its correlates. Further strengths included the testing of a comprehensive model derived from theory and previous findings, and the use of the capabilities of SEM to assess complex multiple direct and indirect linkages amongst variables simultaneously. Limitations include the response rate of less than 50%, cross-sectional design, and the use of self-reported measures, including height and weight, although recent evidence suggests substantial agreement between self-report and measured height and weight amongst Australian women. Sizeable proportions of women who had moved from the targeted neighbourhoods (i.e., whose location may have been less stable), or with incomplete data, were omitted, and this may have excluded some of the most socioeconomically vulnerable women. Correspondence between associational variables and specific behavioural variables varied; for instance, some asked about ‘eating healthy low-fat foods’, others about fruit and vegetable intake specifically. Overall model fit was not ideal on some indices, but good on others, and plausible paths showed significance in the expected directions. Our model explained only 11% of the variance in BMI (with covariates included), but this is not inconsistent with other studies; nor was it surprising given the range of other potential determinants of BMI not assessed. Moreover, the variance explained in physical activity and dietary behaviours was high.

In conclusion, the present study identified sociodemographic and behavioural characteristics associated with ‘resilience’ to obesity amongst women at risk due to their residence in socioeconomically disadvantaged neighbourhoods. Further, the study provides initial support for the development of a comprehensive,
theoretically-derived model of BMI on the basis of key environmental, social, cognitive and behavioural
characteristics. The results help to advance theoretical bases underpinning the investigation of obesity risk by
providing insights not only into the range of obesity correlates from multiple domains, but also their
interrelationships. The next important step in this line of research is to systematically test these relationships
using prospective data, which will eventually be possible with the READI cohort. Through such investigations, key
potential leverage points for intervention can be implicated. Based on the current results, possibilities might
include strategies not only targeting traditional behavioural and cognitive characteristics, but also those aimed at
fostering supportive physical activity and food environments in disadvantaged neighbourhoods.

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Conflict of interest

The authors declare no conflict of interest.
References


Figure 1 Measurement model for full SEM showing factor loadings for multiple indicator latent variables

Figure 2 Structural model showing standardized regressions weights and latent variable variance explained (in bold). For simplicity, factor loadings have been omitted.
Table 1  Summary of intrapersonal, social, and physical environmental measures

<table>
<thead>
<tr>
<th>Variable</th>
<th>How Measured</th>
<th>Scale</th>
<th>Internal Reliability (α)</th>
<th>Retest Reliability²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intrapersonal variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Outcome expectancy</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Perceived benefits of physical activity (sum of 6 items)</td>
<td>How important do you think these reasons are for being physically active? 'Health', 'Appearance', 'Weight', 'Feeling fit', 'Relaxation', 'Stress relief'⁴⁴</td>
<td>4 point: 1=no reason at all, 4=a very important reason</td>
<td>0.79</td>
<td>0.45-0.61</td>
</tr>
<tr>
<td>Enjoyment of physical activity (sum of 6 items)</td>
<td>Feelings about physical activity: 'I love it/I hate it', 'I feel interested/I feel bored', 'I find it pleasurable/I find it unpleasurable', 'I find it energising/I find it tiring', 'It makes me happy/It makes me depressed', 'I feel good physically while doing it/I feel bad physically while doing it'² (adapted)</td>
<td>7 point: 1=least enjoyable, 7=most enjoyable</td>
<td>0.95</td>
<td>51-74% agreement</td>
</tr>
<tr>
<td>Perceived benefits of eating fruit (sum of 6 items)</td>
<td>I like to eat fruit because: 'they are good for your health', 'I like to eat them', 'of the vitamins and minerals they have', 'they taste good', 'I grew up eating them', 'they are easy to prepare'³⁴ (adapted)</td>
<td>5 point: 1=strongly disagree, 5=strongly agree</td>
<td>0.83</td>
<td>ICC=0.62³⁴</td>
</tr>
<tr>
<td>Perceived benefits of eating vegetables (sum of 7 items)</td>
<td>I like to eat vegetables because: 'they are good for your health', 'I like to eat them', 'of the vitamins and minerals they have', 'they taste good', 'I grew up eating them', 'they are easy to prepare', 'I need them for what I am preparing'³⁴ (adapted)</td>
<td>5 point: 1=strongly disagree, 5=strongly agree</td>
<td>0.82</td>
<td>ICC=0.71³⁴</td>
</tr>
<tr>
<td>Nutritional knowledge (sum of 8 items)</td>
<td>Example item: 'In your view, which one of the following would be the best choice for a low fat, high fibre snack?' Response options: 'diet strawberry yoghurt / sultanas / a muesli bar / wholemeal biscuits with cheddar cheese / I don’t know'⁴⁵ (adapted)</td>
<td>2 point (correct/incorrect): 0=incorrect choice, 1=correct choice</td>
<td>0.52</td>
<td>0.41-0.71</td>
</tr>
<tr>
<td><strong>Self efficacy</strong></td>
<td></td>
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</tr>
<tr>
<td>Self-efficacy for physical activity (sum of 5 items)</td>
<td>How confident are you that you could do physical activity: 'even when I am tired?', 'even when I am in a bad mood?', 'even when I feel I don’t have time', 'even when I am on holiday?', 'even when it is raining'?³⁵</td>
<td>5 point: 1=not at all confident, 5=extremely confident</td>
<td>0.82</td>
<td>0.33-0.49</td>
</tr>
<tr>
<td>Self-efficacy for healthy eating (sum of 15 items)</td>
<td>How confident are you that you could: 'Shop regularly for healthy nutritious foods over the next year', 'Prepare/cook healthy nutritious foods over the next year', 'Eat enough fruit for good health over the next year', 'Eat enough vegetables for good health over the next year', 'Limit your fast food consumption to once a week or less over the next year', 'Eat a low-fat diet over the next year', 'Stick to low-fat healthy foods even when you feel depressed, bored or tense', 'Stick to low-fat healthy foods when you are eating out', 'Stick to low-fat healthy foods when you are eating at work/place of study', 'Stick to low-fat healthy foods even when there are high-fat foods available', 'Stick to low-fat healthy foods even when eating with friends or co-workers', 'Stick to low-fat healthy foods even when you are alone and there is no one to watch you', 'Stick to low-fat healthy foods even when you feel too tired or lazy to prepare something healthy', 'Stick to low-fat healthy foods even when watching TV', 'Not eat meals while watching TV', 'Not eat snacks while watching TV'⁴⁶ (adapted)</td>
<td>5 point: 1=strongly agree, 5=strongly disagree</td>
<td>0.95</td>
<td>0.30-0.66</td>
</tr>
<tr>
<td><strong>Behavioural skills/strategies</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Goal setting for physical activity (sum of 2 items)</td>
<td>How many times in the past month did you: 'Set a goal for how much physical activity you would like to do?', 'Plan particular days on which you would do physical activity'?⁴⁷</td>
<td>4 point: 1=never, 2=once or twice, 3=weekly, 4= more than once/week</td>
<td>0.83</td>
<td>0.37-0.48</td>
</tr>
<tr>
<td>Goal oriented behaviour for physical activity (1 item)</td>
<td>How many times in the past month did you meet someone to do physical activity with?⁴⁷</td>
<td>4 point: 1=never, 2=once or twice, 3=weekly, 4= more than once/week</td>
<td>NA</td>
<td>0.66</td>
</tr>
</tbody>
</table>
### Social environmental variables

<table>
<thead>
<tr>
<th><strong>Perceived behavioural self-control for physical activity (1 item)</strong></th>
<th>Assuming that you tried to do physical activity over the next two weeks, how likely or unlikely is it that you would actually stick to this?(^1)</th>
<th>7 point: 1=very unlikely, 7=very likely</th>
<th>NA</th>
<th>(k=0.50)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Perceived behavioural self-control for healthy eating (sum of 2 items)</strong></td>
<td>Assuming that you tried to eat two serves of fruit (five serves of vegetables) or more per day in the next two weeks, how likely or unlikely is it that you would actually stick to your routine?(^2) (adapted)</td>
<td>7 point: 1=very unlikely, 7=very likely</td>
<td>0.63</td>
<td>(k=0.36-0.51)</td>
</tr>
<tr>
<td><strong>Social support</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Encouragement of physical activity (sum of 2 items)</td>
<td>During the past year, how often did friends/work colleagues (members of your family) encourage you to be physically active?</td>
<td>5 point: 1=never, 5=very often</td>
<td>NA</td>
<td>(k=0.56-0.74)</td>
</tr>
<tr>
<td>Co-participation in physical activity (sum of 2 items)</td>
<td>During the past year, how often did friends/work colleagues (members of your family) do physical activity with you?</td>
<td>5 point: 1=never, 5=very often</td>
<td>NA</td>
<td>(k=0.55-0.63)</td>
</tr>
<tr>
<td>Encouragement of healthy eating (sum of 2 items)</td>
<td>During the past year, how often did friends/work colleagues (members of your family) encourage you to eat healthy low-fat foods?</td>
<td>5 point: 1=never, 5=very often</td>
<td>NA</td>
<td>(k=0.30-0.48)</td>
</tr>
<tr>
<td>Discouragement of unhealthy eating (sum of 2 items)</td>
<td>During the past year, how often did friends/work colleagues (members of your family) discourage you from eating unhealthy foods?</td>
<td>5 point: 1=never, 5=very often</td>
<td>NA</td>
<td>(k=0.22-0.24)</td>
</tr>
<tr>
<td>Co-participation in healthy eating (sum of 2 items)</td>
<td>During the past year, how often did friends/work colleagues (members of your family) eat healthy low-fat foods with you?</td>
<td>5 point: 1=never, 5=very often</td>
<td>NA</td>
<td>(k=0.40-0.44)</td>
</tr>
<tr>
<td><strong>Physical environmental variables</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neighbourhood walking environment (sum of 7 items)</td>
<td><em>My neighbourhood offers many opportunities to be physically active</em>, <em>Local sports clubs and other facilities in my neighbourhood offer many opportunities to get exercise</em>, <em>It is pleasant to walk in my neighbourhood</em>, <em>The trees in my neighbourhood provide enough shade</em>, <em>In my neighbourhood it is easy to walk places</em>, <em>I often see other people walking in my neighbourhood</em>, <em>I often see other people exercising (e.g. jogging, bicycling, playing sports) in my neighbourhood</em>(^3)</td>
<td>5 point: 1= strongly agree, 5= strongly disagree</td>
<td>0.80</td>
<td>(k=0.37-0.66)</td>
</tr>
<tr>
<td>Neighbourhood affordability of healthy foods (sum of 2 items)</td>
<td><em>I do not buy many fruits because they cost too much</em>, <em>I do not buy many vegetables because they cost too much</em>(^4) (adapted)</td>
<td>5 point: 1= strongly agree, 5= strongly disagree (reverse coded)</td>
<td>0.90</td>
<td>(k=0.25-0.55)</td>
</tr>
<tr>
<td>Neighbourhood availability of healthy foods (sum of 2 items)</td>
<td><em>A large selection of fruit and vegetables are available in my neighbourhood</em>, <em>A large selection of low-fat products are available in my neighbourhood</em>(^5) (adapted)</td>
<td>5 point: 1= strongly agree, 5= strongly disagree (reverse coded)</td>
<td>0.77</td>
<td>(k=0.49-0.53)</td>
</tr>
</tbody>
</table>

\(\alpha\): Cronbach’s alpha

\(\kappa\): Cohen’s kappa coefficient, assessed in an independent sample of 75 women administered the survey measures twice, a week apart.
Table 2 Sociodemographic characteristics of healthy and overweight/obese women

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>All women (N=3235)</th>
<th>Healthy weight (n=1634)</th>
<th>Overweight/obese (n=1601)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>(n)</td>
<td>%</td>
</tr>
<tr>
<td>Age: Mean (SD)</td>
<td>34.6 (8.0)</td>
<td></td>
<td>33.6 (8.2)</td>
</tr>
<tr>
<td></td>
<td>***</td>
<td></td>
<td>35.6 (7.6)</td>
</tr>
<tr>
<td>Country of birth</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>90.8 (2938)</td>
<td>88.4 (1445)</td>
<td>93.3 (1493)</td>
</tr>
<tr>
<td>Other</td>
<td>9.2 (297)</td>
<td>11.6 (189)</td>
<td>6.7 (108)</td>
</tr>
<tr>
<td>Education</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>20.9 (676)</td>
<td>17.1 (279)</td>
<td>24.8 (397)</td>
</tr>
<tr>
<td>Medium</td>
<td>51.8 (1676)</td>
<td>52.6 (859)</td>
<td>51.0 (817)</td>
</tr>
<tr>
<td>High</td>
<td>27.3 (883)</td>
<td>30.4 (496)</td>
<td>24.2 (387)</td>
</tr>
<tr>
<td>Marital status</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married / de facto</td>
<td>68.2 (2206)</td>
<td>65.4 (1069)</td>
<td>71.0 (1137)</td>
</tr>
<tr>
<td>Previously married</td>
<td>7.5 (244)</td>
<td>7.1 (116)</td>
<td>8.0 (128)</td>
</tr>
<tr>
<td>Never married</td>
<td>24.3 (785)</td>
<td>27.5 (44)</td>
<td>21.0 (336)</td>
</tr>
<tr>
<td>Employment</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working full-time</td>
<td>38.2 (1237)</td>
<td>37.8 (618)</td>
<td>38.7 (619)</td>
</tr>
<tr>
<td>Working part-time</td>
<td>29.9 (967)</td>
<td>28.8 (471)</td>
<td>31.0 (496)</td>
</tr>
<tr>
<td>Not working</td>
<td>31.9 (1031)</td>
<td>33.4 (545)</td>
<td>30.4 (486)</td>
</tr>
<tr>
<td>Personal income</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>27.5 (891)</td>
<td>27.6 (451)</td>
<td>27.5 (440)</td>
</tr>
<tr>
<td>Medium</td>
<td>33.0 (1067)</td>
<td>32.1 (524)</td>
<td>33.9 (543)</td>
</tr>
<tr>
<td>High</td>
<td>24.7 (800)</td>
<td>24.9 (407)</td>
<td>24.5 (393)</td>
</tr>
<tr>
<td>Undisclosed</td>
<td>14.7 (477)</td>
<td>15.4 (252)</td>
<td>14.1 (225)</td>
</tr>
<tr>
<td>Household income</td>
<td>***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>24.4 (789)</td>
<td>22.1 (361)</td>
<td>26.7 (428)</td>
</tr>
<tr>
<td>Medium</td>
<td>36.9 (1193)</td>
<td>36.0 (588)</td>
<td>37.8 (605)</td>
</tr>
<tr>
<td>High</td>
<td>19.2 (620)</td>
<td>19.8 (323)</td>
<td>18.6 (297)</td>
</tr>
<tr>
<td>Undisclosed</td>
<td>19.6 (633)</td>
<td>22.2 (362)</td>
<td>16.9 (271)</td>
</tr>
<tr>
<td>Number of children</td>
<td>ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>38.7 (1252)</td>
<td>40.9 (669)</td>
<td>36.4 (583)</td>
</tr>
<tr>
<td>One</td>
<td>18.9 (610)</td>
<td>18.1 (296)</td>
<td>19.6 (314)</td>
</tr>
<tr>
<td>Two</td>
<td>25.4 (821)</td>
<td>24.4 (399)</td>
<td>26.4 (422)</td>
</tr>
<tr>
<td>Three or more</td>
<td>17.1 (552)</td>
<td>16.5 (270)</td>
<td>17.6 (282)</td>
</tr>
</tbody>
</table>

* p<.05, ** p<.01, *** p<.005, ns: non-significant

* Significance of difference between groups, assessed using chi-square tests (t-test for age)
### Table 3: Behavioural characteristics of healthy and overweight/obese women

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>All women (N=3235)</th>
<th>Healthy weight (n=1634)</th>
<th>Overweight/obese (n=1601)</th>
<th>Sig *</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td></td>
</tr>
<tr>
<td>Leisure time physical activity (mins/week)</td>
<td>201.1 (263.5)</td>
<td>221.6 (277.5)</td>
<td>180.2 (246.8)</td>
<td>***</td>
</tr>
<tr>
<td>Fruit (serves/week)</td>
<td>11.3 (7.4)</td>
<td>11.4 (7.4)</td>
<td>11.1 (7.4)</td>
<td>ns</td>
</tr>
<tr>
<td>Vegetables (serves/week)</td>
<td>16.2 (8.9)</td>
<td>16.0 (9.0)</td>
<td>16.5 (8.8)</td>
<td>ns</td>
</tr>
<tr>
<td>Water (serves/week)</td>
<td>40.9 (20.9)</td>
<td>40.8 (21.0)</td>
<td>41.1 (20.8)</td>
<td>ns</td>
</tr>
<tr>
<td>Fast food (serves/week)</td>
<td>1.3 (1.3)</td>
<td>1.2 (1.3)</td>
<td>1.3 (1.3)</td>
<td>***</td>
</tr>
<tr>
<td>Energy-dense snacks (serves/week)</td>
<td>5.4 (5.5)</td>
<td>5.4 (5.8)</td>
<td>5.4 (5.2)</td>
<td>ns</td>
</tr>
<tr>
<td>Soft drink (serves/week)</td>
<td>4.2 (8.1)</td>
<td>3.7 (7.7)</td>
<td>4.7 (8.5)</td>
<td>***</td>
</tr>
<tr>
<td>Smoker</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>50.6 (1637)</td>
<td>53.1 (867)</td>
<td>48.1 (770)</td>
<td></td>
</tr>
<tr>
<td>Previous</td>
<td>25.4 (822)</td>
<td>24.5 (400)</td>
<td>26.4 (422)</td>
<td></td>
</tr>
<tr>
<td>Current</td>
<td>24.0 (776)</td>
<td>22.5 (367)</td>
<td>25.5 (409)</td>
<td></td>
</tr>
</tbody>
</table>

*p<.05, ***p<.005, ns: non-significant

*Significance of difference between groups, assessed using t-tests