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Defining the complexity of childhood obesity and related behaviours within the family environment using structural equation modelling

Gilly A Hendrie[1,2,]*, John Coveney[1] and David N Cox[2]
[1]Discipline of Public Health, School of Medicine, Flinders University, Adelaide, South Australia, Australia: [2]CSIRO Food and Nutritional Sciences, PO Box 10041, Adelaide BC, Adelaide, South Australia 5000, Australia

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Abstract

Objective: The present study aimed to define the complexity of the relationships between the family environment, health behaviours and obesity. A conceptual model that quantifies the relationships and interactions between parent factors, family environment, and certain aspects of children's behaviour and weight status is presented.
Design: Exploratory structural equation modelling was used to quantitatively model the relationships between parent, child and family environmental factors.
Setting: Adelaide, South Australia.
Subjects: Families (*n* 157) with children aged 5–10 years completed self-reported questionnaires, providing data on parents' knowledge, diet quality and activity habits; child feeding and general parenting styles; and the food and physical activity environments. Outcome variables included children's fruit and vegetable intake, activity and sedentary habits and weight status.
Results: The proposed model was an acceptable fit (normed fit index = 0·457; comparative fit index = 0·746; root-mean-squared error associated = 0·044). Parents' BMI ($\beta = 0\cdot32$) and nutrition and physical activity knowledge ($\beta = 0\cdot17$) had the strongest direct associations with children's BMI *Z*-score. Parents' dietary intake and energy expenditure behaviours were indirectly associated with children's behaviour through the creation of the home environment. The physical activity and food environments were associated with children's sedentary ($\beta = -0\cdot44$) and activity habits ($\beta = 0\cdot29$), and fruit and vegetable intake ($\beta = 0\cdot47$), respectively.
Conclusions: A conceptual model that quantifies the complex network of family environment factors influencing children's behaviour and weight status is presented. The model provides a basis for future research on larger representative samples with a view to guiding obesity prevention interventions.

Keywords
Family environment
Obesity
Children
Structural equation modelling

Childhood obesity is becoming increasingly common[1,2] and is of concern because childhood obesity has been shown to track into adulthood[3], with health consequences[4]. A range of personal, familial, cultural, community and environmental factors have been identified as contributing to the development of obesity in children[4]. The influence of socio-economic status as an independent determinant or mediator of behaviour adds further complexity to our understanding of obesity and its related behaviours[5,6].

The shared home environment is one of these factors likely to play an important role in the development of children's behaviours relevant to obesity. Aspects of the home environment have been associated with children's behaviour. Strong correlations between parents' and children's dietary habits have been reported, particularly for fruit and vegetable consumption[7–10]. Parental behaviours such as restriction and monitoring[11–13], food availability[9,10,14–16] and role modelling of eating behaviours[7–9,14,17] have also been shown to influence children's dietary behaviours. Similarly with respect to children's energy expenditure behaviours, positive associations between parents' and children's activity[18] and sedentary habits[18–20] have been reported. Family rules about television viewing have been linked to children's actual viewing time[21], and families with more televisions report greater viewing times and an increased risk of obesity[22]. Access to more sports equipment has been shown to be

*Corresponding author: Email gilly.hendrie@csiro.au

protective against obesity[22] and parental involvement in children's activity[23,24], such as providing transport or equipment, also has positive outcomes.

Parents, as the 'gatekeepers' of the home[25], are central to creating the environment in which their children develop. The notion of the family home environment is complex; because of this complexity, many studies choose to focus on one aspect of the environment or one side of the energy balance equation. It is unclear whether focusing on a single behaviour or using a multifaceted approach is most effective. However, few intervention studies have been able to show effectiveness capable of reversing population-level increases in obesity[26]. Some reviews are critical of approaches that test a single intervention component; yet uninformed 'kitchen sink' approaches[26] also lack efficacy.

Although research has uncovered a number of significant determinants of children's health-related behaviour and obesity risk, a coherent model studying these factors is lacking. Such conceptual models need to include both dietary and activity/sedentary habits[27], and are necessary to 'disentangle the relative importance and effects of targeted antecedent behaviours in pediatric obesity [prevention and] treatment'[28].

Structural equation modelling approaches are likely to improve our understanding of the determinants of health behaviour and obesity risk in children and provide insight into this complex network of factors. The present study was limited to known determinants of behaviour from within the family environment, and was inclusive of those factors identified in previous research as significant, with a preference towards those measured using well-constructed, reliable and/or validated scales. Few studies have applied structural equation modelling to obesity. Guided by previous research, the current study aimed to explore whether parents' behaviours are directly and/or indirectly related to children's behaviours through the creation of the home environment. Furthermore, the aim was to explore all the direct and indirect relationships between factors within the family environment and children's dietary and activity behaviours and weight status.

Methods

The present study was approved by Flinders University Social and Behavioural Research Ethics Committee and the Department of Education and Children's Services (DECS). Under the existing guidelines parental consent was required for participation in the study; therefore no information about non-respondents was available.

Recruitment strategy

In late 2006, all Local Government Areas (LGA) within the Adelaide metropolitan area were ranked, using the Australian Bureau of Statistics' Socio-Economic Index for Areas (SEIFA), and classified into quartiles. One LGA from each quartile was randomly selected. The DECS website was used to list all government schools within the selected LGA, and ten schools were randomly selected from each selected LGA. An information letter was sent to principals of the forty selected schools, followed by a telephone call. Of the forty schools, eleven agreed to participate (two from the lowest quartile, three from each of the other quartiles).

All families of children in Reception to Year 5 were invited to participate via an information letter sent home with children. Approximately 3000 letters were provided to the schools and principals arranged for the letters to be distributed through the class teachers. Families volunteered to participate in the study by returning a response slip to the class teacher. There was no direct contact with families prior to them attending the first study assessment session. All assessment sessions were conducted during school terms 1 and 2, 2007 (March–July).

Procedure

The study assessment session was attended by at least one parent and child. In families where more than one child attended, parents were encouraged (but not required) to choose the oldest child to be the focus of the study. The session was conducted after school hours, in a classroom. At the first session, parents completed Questionnaire 1 (see below for details) and anthropometric measurements were taken for parents and children. A second questionnaire asking about parent's dietary intake was mailed out two weeks following the first session. A third questionnaire, addressing the family environment, was mailed out two weeks following the return of the second questionnaire. One reminder letter and one duplicate questionnaire were sent out when a questionnaire was not returned. No incentives were provided for the completion of questionnaires.

Measures

Questionnaire 1

Family demographics. Questions sought details of the attending parent's gender, age, marital status, self-identified culture, highest level of education and employment status, as well as the estimated annual income of the household.

Parent's knowledge. General nutrition knowledge was assessed using a version of the General Nutrition Knowledge Questionnaire developed by Parmenter and Wardle[29], recently validated for use in an Australian setting[30]. Knowledge of exercise and physical activity guidelines were measured using an adaptation of the validated American knowledge questionnaire[31]. This questionnaire showed moderate internal reliability (Kuder–Richardson value = 0·59)[31]. Three questions were added asking knowledge of the Australian physical activity guidelines for children[32] and the five key evaluation questions from the Active Australia campaign[33]. The three questions about the Australian physical activity guidelines were: 'It is recommended children participate in vigorous activity', 'How many hours per day should children spend using electronic equipment (this includes television, computer games, and the like)?' and 'It is recommended children are active for at least … hours'. Questions were answered as true or false or with multiple-choice options. Nutrition and physical activity knowledge was combined for an overall knowledge score (from now on referred to as knowledge).

Children's dietary intake and physical activity. Children's dietary intake was estimated using two 24 h recalls, completed primarily by the parent, with assistance from the child. The second recall formed part of Questionnaire 3. Parents were asked to recall all foods and beverages consumed by their child on the previous day. Amounts were estimated in household measures and brand names reported where possible. Data were analysed using the software FoodWorks Professional version 2007 (Xyris Software, Brisbane, Australia). The dietary outcome reported is total fruit and vegetable (F&V) intake (average of two days' intake, not including potatoes or fruit juice). F&V intake was chosen as the dietary outcome because it is commonly used as a marker of diet quality, the health benefits of F&V have been well documented and due attention given to their consumption in national guidelines[34]. F&V intake has been associated with higher micronutrient and lower fat intakes, a healthier overall dietary pattern[8] and weight status[35].

Children's activity levels were measured using the Children's Leisure Activity Study Survey (CLASS)[36], which details usual activity taking into account moderate- and vigorous-intensity activities, and weekday and weekend participation. The parent-reported questionnaire has been validated against accelerometry[36] and reported to be a consistent measure of habitual activity in young children[37]. Questions on usual screen time, including television and all electronic gaming, were also asked. The average times spent per day in active (moderate and vigorous) and screen (television and gaming) behaviours were calculated and are reported in minutes per day.

BMI and weight status. Height and weight were measured by one trained researcher using digital scales and a portable stadiometer. Children wore light clothing and no shoes. Children were measured in private, but within visible sight of their parents. BMI was calculated (weight in kilograms divided by the square of height in metres) and converted to a *Z*-score using the US Centers for Disease Control and Prevention 2000 reference data, calculated using a computer program (User's Guide to ImsGrowth; Medical Research Council, London, UK, 2002–2007). Children were classified by weight status according to age- and gender-specific cut-offs using the International Obesity Taskforce definitions[38], as recommended for use in Australia[39].

Parents were also measured in light clothing without shoes. BMI was calculated and the WHO international classification cut-offs[40] were used to classify parents as healthy weight or less, overweight and obese.

Questionnaire 2

Parent's diet quality. Usual dietary intake was measured using a self-reported, self-administered, quantified FFQ containing more than 180 food and beverage items, with qualitative and quantitative questions relating to food preparation practices and dietary habits[41]. Diet quality was calculated using the US Department of Agriculture's Healthy Eating Index[42], with food group criteria adjusted to be consistent with the Australian dietary guidelines[43] and Nutrient Reference Values[44].

Questionnaire 3

Parent's activity. The International Physical Activity Questionnaire (IPAQ), short version, was used to measure parents' usual activity levels. This version of the IPAQ shows good reliability, fair to moderate agreement with accelerometry, and is well accepted by participants[45] compared with the longer format.

Parenting style. General parenting style was assessed using the self-reported General Parenting Practices Questionnaire (GPPQ)[46] characterising parenting style (not practices per se) consistent with Baumrind's authoritative, authoritarian and permissive typologies[47]. It encompasses parents' attitudes and values about parenting[46]. Following a formal ethical review by the DECS, seven items were removed from the original questions (because they implied anger or physical violence), leaving a fifty-five-item scale. Parents reported on their own parenting style and received a score for each of the three parenting typologies or subscales. The internal reliability, Cronbach's α values, ranged from 0·74 to 0·86 for the three subscales within the GPPQ, which was comparable to the reliability values reported for the original questionnaire. In the obesity resistance model the subscales were represented by the latent variable 'parenting style'.

Child feeding practices. Specific parenting feeding practices were measured using the Child Feeding Questionnaire (CFQ)[11]. This self-reported questionnaire assesses parental beliefs, attitudes and practices regarding child feeding specifically[11]. Seven factors were included in the present study: (i) perceived feeding responsibility; (ii) perceived parent weight; (iii) perceived child weight; (iv) concerns about child weight; (v) restriction; (vi) pressure to eat; and (vii) monitoring. Reliability of the questionnaire in this study population was generally above the accepted value (Cronbach's α values: 0·65–0·88 for subscales within the CFQ). In the obesity resistance model the CFQ factors were represented by the latent variable 'child feeding practices'.

Family food environment. The family food environment was measured using Campbell *et al.*'s Family Food Environment scale[14], and included thirty-nine items asking about usual food availability, parental perception of the adequacy of their child's diet, opportunities for parental modelling of eating behaviours, opportunities for parent modelling of food-related behaviours, parental views on meal preparation, meal preparation practices and television interruptions. Parents' general involvement in food was also measured using the Food Involvement Scale[48].

Family activity environment. Questions on the family activity environment were based on Campbell *et al.*'s scale about the food environment[14] and the Food Involvement Scale[48]. The modification of these scales to assess the parents' activity-related attitudes and beliefs is described elsewhere[49]. Briefly, three factors describe the family activity environment: (i) parental involvement (factor loading = 0·784); (ii) opportunity for role modelling (factor loading = 0·438); and (iii) parental support (factor loading = 0·422)[49]. The three factors were combined to measure the family activity environment, and included as a latent variable in the obesity resistance model presented. The three factors explained 37·6 % of the total variance and Cronbach's α values ranged from 0·790 to 0·877.

Statistical analyses

Confirmatory factor analysis (CFA) is a technique used to verify a priori knowledge of the relationships between variables and their underlying latent constructs[50]. CFA was conducted using the structural equation modelling program AMOS™ version 7·0 (Amos Development Corporation, Crawfordville, FL, USA) to test that the construct of parental food involvement fit with Campbell *et al.*'s established factors of the food environment[14]. Maximum likelihood estimation was used to determine standardised regression weights for the factors.

Structural equation modelling integrates factor analysis and multiple regression analysis and takes into account multiple independent variables and modelling of interactions between variables[51]. A proposed obesity resistance conceptual model is shown in Fig. 1, where rectangles denote variables measured and circles denote latent variables. A latent variable is not directly measured but rather inferred from other variables that are measured. Each hypothesised path relationship (solid lines plus dotted lines) was explored using structural equation modelling in AMOS, and the final

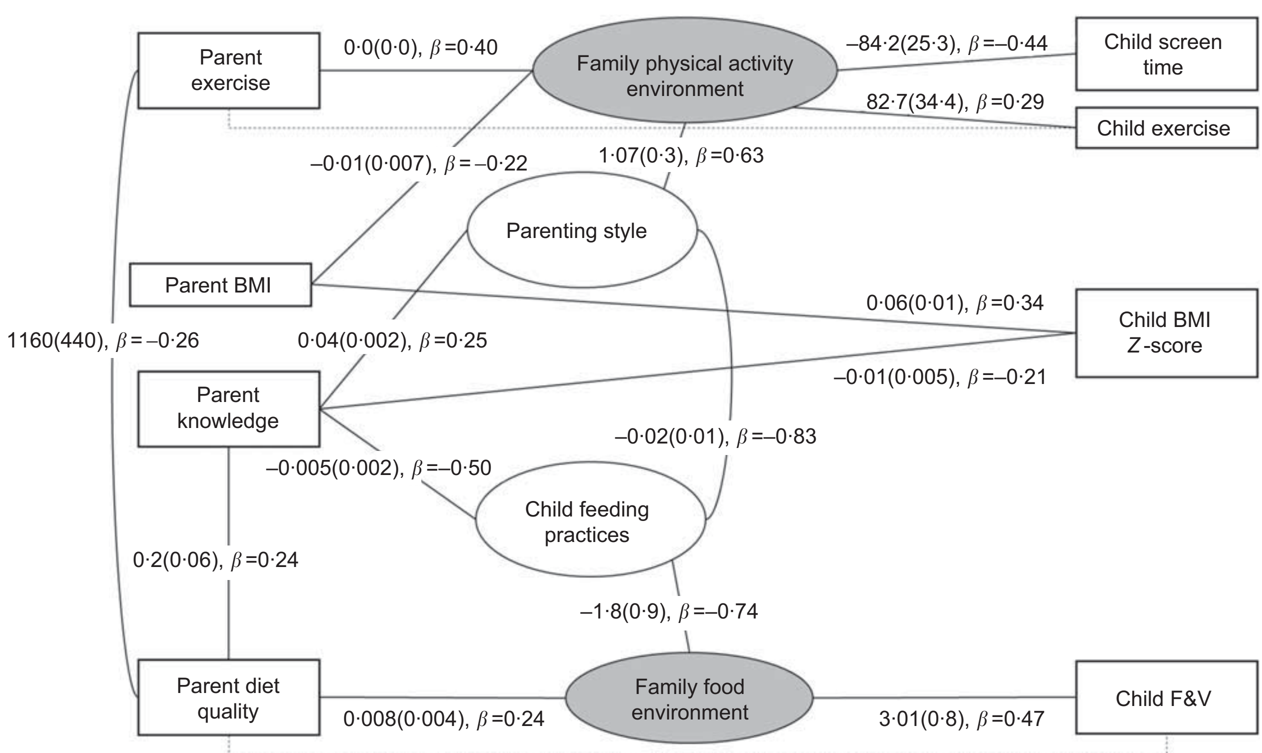

Fig. 1 Obesity resistance model: a summary of the interactions of family environmental factors influencing children's weight status and behaviours. Path coefficients are presented as: unstandardised regression weight (SE), standardised regression weight (β); dashed lines represent relationships that were included in the exploratory analysis, but were non-significant. Model fit: CMIN = 383·614; df = 291; P < 0·001; CMIN/df = 1·381; NFI = 0·458; CFI = 0·741; RMSEA = 0·045 (F&V, fruit and vegetable; CMIN, χ^2; CMIN/df, relative χ^2; NFI, normed fit index; CFI; comparative fit index; RMSEA; root-mean-squared error associated)

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model (solid lines) represents the model of best fit. The path relationships can be interpreted as standardised regression weights and correspond to effect size estimates. Standardised coefficients reflect the degree of change in the outcome variable associated with a standard deviation change in the predictor. Standardised regression coefficients permit comparisons of predictor–outcome relationships across studies in which the variables have been measured using different units of measure[52]. All relationships of the final model presented are significant ($P < 0·05$).

Fifteen cases per predictor is a reasonable sample estimation for the use of structural equation modelling, although larger samples are always preferred. Consequences of smaller samples would be evident in the parameter estimates, convergence failure or improper solutions[53]. Based on this, it is estimated that this model could include approximately ten or eleven predictors. Structural equation modelling relies on several statistical tests to determine the adequate of model fit to the data. It is recommended that multiple fit indices are reported; therefore the predictive ability of the obesity resistance model was determined using four measures of fit: χ^2 (CMIN), relative χ^2 (CMIN/df), normed fit index (NFI), comparative fit index (CFI) and root-mean-squared error associated (RMSEA). Smaller CMIN values indicate better fit and an insignificant CMIN is desirable. CMIN is sensitive to sample size and therefore may not have sufficient power in small samples[54]. CMIN/df is thought to be less dependent on sample size, and values greater than 1 and below 2 are considered good fit[51,55,56]. NFI and CFI range from 0 to 1, with values closer to 1 representing very good fit. RMSEA is an index of the degree to which a confirmatory structure approximates the data being modelled, and a value less than 0·06 reflects good model fit[51,56].

Results

Sample characteristics

Active consent was received by 157 families, 154 completed the baseline questionnaire, 126 completed Questionnaire 2, and 106 completed Questionnaire 3. Most parents were mothers (92·4 %), aged between 35 and 44 years (63·7 %), and were married or living as married (80·9 %). Parents' education level varied – 42 % had tertiary qualifications. Most were employed; 51 % part-time and almost 17 % on a full-time basis. About half of the parents were of a healthy weight (57·3 %), 27·4 % were overweight and 15·3 % obese (Table 1). Children (51·6 % girls) were aged between 5 and 11 years (mean 8·29 (SD 1·55) years). The mean BMI *Z*-score was 0·28 (range: −0·0024, 0·89). The majority of children were of a healthy weight (77·1 %), and 16·6 % were overweight or obese (Table 1).

Family food environment latent variable

The standard regression weights and significance values for the CFA of the family food environment factors including the food involvement factor are presented in Table 2. Food involvement loaded well with other food environment factors. The model fit was of acceptable fit (NFI = 0·779, CFI = 0·890, RMSEA = 0·060).

Obesity resistance model testing

This model describes the interactions between parent behaviours and family home environment factors, and their relationship with children's weight, dietary and activity behaviours (Fig. 1). The model fit values (CMIN/df = 1·381, NFI = 0·458, CFI = 0·741, RMSEA = 0·045), except for the significance of CMIN, suggest the model has an acceptable predictive ability or fit. CMIN can be influenced by sample size[54], and it has been suggested that the ratio of CMIN to degrees of freedom (CMIN/df) actually provides a better index than CMIN alone[57]. In this model, the CMIN/df of 1·381 met the model fit criterion that CMIN should have a degree of freedom between 1 and 2[58]. Other goodness-of-fit indices (CFI and RMSEA) also support model fit. The RMSEA, which is less sensitive to sample size, indicated a good model fit in relation to degrees of freedom.

The relationships between parent and child behaviours were found to be indirect through the creation of the family environment. The paths presented in Fig. 1 can be interpreted as standardised regression weights, and all path coefficients (solid lines) in the conceptual model were significant ($P < 0·05$). Parents' weight ($\beta = 0·34$) and knowledge ($\beta = -0·21$) were found to have a direct relationship with children's BMI *Z*-score. Lower knowledge of nutrition and physical activity and higher BMI in parents were associated with a higher BMI *Z*-score in children. Parents' knowledge was directly associated with their general parenting style ($\beta = 0·25$) and child feeding practices ($\beta = -0·50$), which in turn was related to the family physical activity ($\beta = 0·63$) and food environment ($\beta = -0·74$), respectively. Other factors found to be associated with the physical activity environment were parents' BMI ($\beta = -0·22$) and exercise habits ($\beta = 0·40$). A lower parent BMI and higher activity level were associated with a more positive or supportive activity environment at home. Parents' knowledge was directly related to their own diet quality ($\beta = 0·24$), which in turn had a positive relationship with the food environment ($\beta = 0·24$). The relationships between parent and child behaviours were not direct, instead indirect through the creation of the family environment. The latent environment variables had direct relationships with children's F&V intake ($\beta = 0·47$), screen time ($\beta = -0·44$) and exercise time ($\beta = 0·29$), in the expected directions (Fig. 1).

In summary, all significant relationships in the obesity resistance model were in the expected direction. Parents' BMI and knowledge were associated with children's

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Table 1 Characteristics of parents and children sampled, Adelaide, South Australia

Characteristics	*n*	%
Parent gender		
Female	145	92·4
Male	12	7·6
Parent age (years)		
25–34	28	17·8
35–44	100	63·7
45+	26	16·6
Missing	3	1·9
Marital status		
Single	14	8·9
Married/living as married	127	80·9
Other (separated, divorced, widowed, did not respond)	16	10·2
Self-identified culture		
Australian	118	75·2
Other	39	24·8
Parent education level		
Some high school or less	17	10·8
Completed high school	35	22·3
Tech or trade qualification	35	22·3
Tertiary degree	66	42·0
Did not respond	4	2·5
Parent employment status		
Full-time	26	16·6
Part-time	80	51·0
Home duties	34	21·7
Other (student, unemployed, retired/disabled, too ill to work)	17	10·8
Estimated annual household income ($AU)		
<20 800	15	9·6
20 800–36 399	25	15·9
36 400–51 999	18	11·5
52 000–77 999	28	17·8
78 000+	63	40·1
Prefer not to answer	8	5·1
Parent weight status		
Healthy weight or less (BMI < 25 kg/m^2)	90	57·3
Overweight (BMI ≥25 and <30 kg/m^2)	43	27·4
Obese (BMI ≥ 30 kg/m^2)	24	15·3
Child gender		
Girl	81	51·6
Boy	76	48·4
Child age (years)		
5	10	6·4
6	16	10·2
7	18	11·5
8	29	18·5
9	50	31·8
10	25	15·9
11	9	5·7
Child weight classification		
Healthy weight or less	131	77·1
Overweight	18	11·5
Obese	8	5·1

Table 2 Confirmatory factor analysis: standardised regression weights for measures of the family food environment

	Factor loading		
Latent variable/factor	β	Estimate	*P* value
Family food environment*			
Perceived adequacy of child's diet	0·366	1·00	
Opportunities for role modelling – meal preparation views	0·639	1·421	0·004
Perceived food availability	0·552	1·133	0·005
Opportunities for role modelling – eating behaviours	0·519	1·225	0·006
Family food preferences	0·497	1·174	0·007
Food involvement	0·421	13·039	0·012
Television interruptions to meals	0·304	1·432	0·037

β, standardised regression weight; CMIN, χ^2; NFI, normed fit index; CFI; comparative fit ndex; RMSEA; root-mean-squared error associated.
*CMIN = 21·737, df = 14, P = 0·084; CFI = 0·890, NFI = 0·779, RMSEA = 0·060.

BMI *Z*-score. Other parent characteristics such as their exercise, diet quality, parenting and feeding practices were significantly associated with the family environments. More supportive family physical activity and food environments were related to positive exercise and screen time habits and F&V intakes in children.

Discussion

Structural equation modelling allowed the present study to examine the complexity of the family environment as an influence on children's health behaviours and obesity risk. By including an unprecedented number of factors into one conceptual model, the study was able to describe the network of interactions between factors and examine their influence on children's behaviours. The standardised coefficients within the model represent the strength of the relationships and potentially reflect their relative importance. The model supports the need for multi-component interventions for obesity prevention in children[4,59]. It may also assist in prioritising intervention components to predict the likelihood of success or to direct resources to maximise the effectiveness of future interventions.

While parent's knowledge and BMI were the only two direct influences on children's obesity risk, there were many indirect pathways observed between parent's behaviours, parenting practices and styles, the home environment and children's behaviour. Higher knowledge in parents was associated with a healthier weight status in children. Maternal knowledge has been associated with healthier diets in children[60] but to the researchers' knowledge an association between parent knowledge and child weight has not been reported previously. Knowledge was also found to be related to parent's own behaviour, such as their parenting styles, feeding practices and diet quality; which in turn was indirectly related to children's behaviour through the creation of the family environment. Knowledge is considered a relatively malleable individual characteristic, and these findings provide support for knowledge as a determinant of behaviour – the crux of the nutrition education framework. At a population level knowledge of individuals is most amenable to policy intervention[60] and therefore such findings support population-level health education campaigns.

Studies have shown a strong familial trend in weight status[12]; however, this conceptual model proposes that the implications of overweight and obesity in parents go beyond the genetic predisposition for overweight in their children. Overweight parents were less likely to provide an environment supportive of physical activity in children. This extends the philosophy of parents as role models, and suggests it may be important for parents to have insight into the significant role they play in establishing a healthy lifestyle for their children early in life.

Aspects of the food environment have been associated with dietary patterns in children such as consumption of vegetables, snack foods and high-energy drinks[14]; however fewer studies have measured the activity environment in as much detail. In the present study a family home environment supportive of physical activity was associated with higher activity and lower screen times in children. These results support previous Australian research which examined the influence of the home and neighbourhood environments on children's activity and BMI[61,62]. That research, conducted over a 5-year period, found the establishment of rules regarding activity, co-participation in activity with the child and direct support were positively associated with children's physical activity level[61,62]. The home environment variables measured in the cited research appeared to have a greater influence on children's physical activity and BMI than their neighbourhood environment[61].

General parenting styles have previously been included in models of the family environment as part of child feeding[63] or left out all together. Excessive control has been associated with negative outcomes in children, such as lower F&V intake[64,65], whereas a more balanced approach or authoritative style has been shown to relate to higher F&V intake[65] and lower 'junk' food intake[66]. Parenting style has also been shown to influence children's physical activity levels[67]. A relationship exists between feeding practices and general parenting style[68], and while both were shown to be an integral part of the family dynamic influencing children's food and activity environments, they each appear to have a unique influence on different aspects of the family environment. It is possible that parenting style and feeding practices can be learnt and both should be considered in family-based obesity prevention interventions.

There have been a few Australian and international longitudinal studies that have examined the associations between the aspects of the family environment and children's weight status[61,69], activity[61,62] and screen time[21,70]. The larger-scale, multifaceted nature of these studies means they often have limited scope to capture the complexity of the family environment. To ensure that potentially important influences of behaviour are not missed, more complex models of obesity resistance should be developed, tested longitudinally and most importantly used to design interventions aimed at changing children's health-related behaviours and weight status.

The model proposed in the present paper highlights some relatively unexplored targets for obesity prevention interventions such as parent's knowledge, general parenting style and the family activity environment, and presents the beginnings of a framework from which to inform multidisciplinary obesity interventions. It has been widely advocated that obesity is a complex problem that requires multidisciplinary approaches and solutions[59] and while the conceptual model presented attempted to define this complexity, it is acknowledged the model may not be complex enough. There are numerous other factors that should also be considered in future models. For example, other household determinants such as socio-economic position and ethnicity, personal characteristics such as children's self-esteem and disinhibition, and other behaviours such as sleep, which may all influence children's propensity for obesity, deserve attention.

The exploratory model is of acceptable fit but this does not imply that other models may yield equivalent or better results. In the absence of other structural equation models of similar complexity, the CFI value for this model is considered acceptable. The few studies in this field to use structural equation modelling have reported better model fit(8,12) but included fewer variables. It is thought that models with fewer factors will have higher apparent fit than models with more factors(51). The path coefficients reported in the proposed model were of similar magnitude to those in previous studies(8,12). Structural equation modelling appears to be appropriate for the multifaceted problem of obesity and future research should progress this type of analysis to include even more factors in larger population studies, improve model goodness of fit and predictive ability to further our understanding of the complexity surrounding the development of obesity.

Validated measures of dietary intake can be cumbersome. Here, unassisted dietary recalls were used, and F&V intake was used as a marker of diet quality. In measuring a large number of factors including dietary intake, the balance between the detailed assessment of diet and participant burden needs to be considered. Future research should test this model using other foods groups, such as energy-dense snacks, or overall diet quality, estimated using rigorous dietary assessment methodology.

The findings of the present study need to be considered in the context of the study design. The obesity resistance model is based on the recruitment strategy of volunteers who were not provided with incentives to participate, resulting in a relatively low response rate. The small sample lacks the diversity of a larger representative sample, and the response bias potentially heightened as a result of the recruitment strategy. Socio-economic factors may mediate the relationships presented here, and the likely direction and magnitude of bias associated with this sample need to be considered and any generalisation of the findings to the wider population needs to be made with caution. Future research in a large and diverse sample should test the model for statistical fit in samples of differing socio-economic and ethnic backgrounds. It is important to understand obesity resistance at a population level; but it is feasible that different population groups have different associations between the model's factors, reflected in the resulting strengths of the path coefficients. This information may be useful to health professionals to tailor interventions to population groups.

Conclusions

The present study presents a conceptual model, quantifying and defining the complexity of the family environmental influences on children's behaviour and obesity risk. The model may provide an initial framework to broaden our understanding of the interactions between determinants of obesity. Future research should continue to develop such models and test them longitudinally as a model alone will not address the increasing problem of obesity and the tendency for children to adopt energy-dense diets and sedentary lifestyles.

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