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ORIGINAL CONTRIBUTION

The dual-pathway and cognitive-behavioural models of binge eating: prospective evaluation and comparison

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Abstract To evaluate and compare the dual-pathway, original cognitive-behavioural, and enhanced "transdiagnostic" cognitive-behavioural models of binge eating, using prospective data from a pre-adolescent sample. Models were tested using multilevel longitudinal structural equation modelling. Participants were 236 children (48% male) aged between 8 and 13 years at baseline, who were interviewed annually over a 2-year period. Binge eating was assessed using the Child Eating Disorder Examination. The dual-pathway and enhanced cognitive-behavioural models provided an acceptable fit to the data, whereas the original cognitive-behavioural model did not. Partial support is provided for the prospective validity of the dual-pathway and enhanced cognitive-behavioural models of binge eating in childhood. Results suggest that body dissatisfaction and weight and shape over-evaluation may both contribute to dieting behaviour in youth, and that dieting and affect-related difficulties both require consideration in theories of binge eating development.

Keywords Binge eating · Eating disorders · Dual-pathway model · Cognitive-behavioural model

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Introduction

Eating disorders, including anorexia nervosa, bulimia nervosa, and eating disorders not otherwise specified, are estimated to affect up to 10% of adolescents [1–3]. Subclinical eating disorder symptoms, including binge eating and purging, affect a greater proportion [3] and may develop from middle childhood onwards [3, 4]. Thus, pre- to early-adolescence provides an important developmental period for investigating the onset and course of eating pathology [5, 6].

Stice and colleagues' dual-pathway (DP) model [7, 8] and Fairburn and colleagues' original [9, 10] and enhanced [11] cognitive-behavioural (CB) models have emerged as key frameworks for explaining the development and maintenance of binge eating and associated eating disorder symptoms. Both perspectives (DP and CB) have been evaluated empirically, and available data provide support for the central predictions of each. To date, however, the two frameworks have not been evaluated simultaneously in a single sample, nor have they been comprehensively evaluated with pre-adolescent participants.

The DP model proposes that elevated body mass and internalisation of societal ideals regarding body size (in the form of internalisation of the thin ideal and perceived pressure to be thin) are instrumental in predicting body dissatisfaction [7, 8]. Subsequently, body dissatisfaction is thought to predict binge eating via its prediction of dietary restraint (restraint pathway), or of negative affect/depressive symptoms (negative affect pathway). Restraint may trigger binge eating when breaking strict dietary rules results in disinhibited eating, and this effect is thought to apply irrespective of the success of dieting efforts (i.e., efforts at dietary restriction, rather than restriction per se, are important). The negative affect pathway draws on research linking depressive symptoms to binge eating, and proposes that binge eating may serve an affect regulation function for some individuals. The DP model has been extensively evaluated using cross-sectional [12–14] and prospective [8, 15, 16] data and clear support has been provided for its central predictions. However, most of this research has been conducted using female adolescent participants. Only preliminary support has been provided for the validity of the model's core predictions with younger individuals and males [14, 17–19].

The original CB model [10] proposes that low self-esteem is instrumental in predicting the over-evaluation of eating, weight and shape and their control (defined as the tendency to evaluate one's self-worth primarily or entirely in terms of eating, weight and shape and their control), which, in turn, is proposed to predict strict dietary restraint. Subsequently, dietary restraint is thought to predict binge eating, and binge eating is thought to predict purging. This original model has been evaluated in three studies [20–22], all of which provided cross-sectional support for an association between low self-esteem and weight- and shape-related concerns, and between weight and shape-related concerns and dietary restraint. Decaluwe and Braet [21] also provided support for an association between restraint and binge eating in their sample of obese children and adolescents ($N = 196$, aged 10–16 years), and Byrne and McLean [20] provided support for an association between binge eating and purging in their sample of adolescents and young adults ($N = 526$, aged 15–36 years). Notably, however, none of these studies distinguished between the over-evaluation of weight and shape and more general concerns about weight and shape. The specific role of over-evaluation, one of the defining features of the CB theory and a key different relative to the DP model, is thus untested.

The enhanced CB framework [11] aims to extend the original CB model in two main ways: (1) seeking to explain all forms of eating disorders, through the inclusion of an under-eating and low weight pathway, in addition to a binge eating/purging pathway; and (2) expanding the explanatory power of the model by including additional maintaining mechanisms that may contribute to persistent eating disorder symptoms in some individuals [11]. These maintaining mechanisms include clinical perfectionism, mood intolerance, and interpersonal difficulties. Low self-esteem is included in the original and enhanced accounts. There have been few direct tests of the enhanced CB model, but Wade and Lowes [22] provided cross-sectional support for significant associations between (1) low self-esteem, perfectionism and interpersonal difficulties, (2) weight and shape concern, and (3) disordered eating, in their female adolescent sample ($N = 323$, aged 11–16 years). Similar results were obtained in a recent study of adults receiving treatment for an eating disorder ($N = 1{,}451$, 94% female, aged 17 years and older) [23]. This latter study also provided support for significant cross-sectional associations between mood intolerance, interpersonal difficulties, and low self-esteem, although not, contrary to model predictions, for significant associations between mood intolerance or interpersonal difficulties and eating disorder symptoms. As both of these studies used global eating disorder symptom scores as the outcome variable of interest, the hypothesised associations between over-evaluation, dietary restraint, and binge eating were not tested. In contrast, a cross-sectional study of overweight children and adolescents ($N = 350$, aged 8–18 years) found significant associations between eating, weight and shape concerns, dietary restraint, and binge eating [24], and between depressive symptoms (assessed in lieu of mood intolerance) and binge eating. However, this study did not consider self-esteem, interpersonal difficulties or perfectionism, or specifically assess over-evaluation of weight and shape. The focus on depressive symptoms also means that support is provided for the DP as well as CB model.

To extend research in this area, the current study aimed to compare the DP and CB models directly, using prospective data and a specific measure of weight and shape over-evaluation. The original and enhanced CB models were both tested and compared to the DP account. For simplicity, and to facilitate comparison between the theoretical approaches, the primary eating disorder outcome variable was binge eating. Objective binge eating (OBE; loss of control over eating with the consumption of an objectively large amount of food) and subjective binge eating (SBE; loss of control over eating without the consumption of an objectively large amount of food) were both considered. These two forms of loss of control eating have been established as equally important when considering disordered eating, particularly in childhood [4, 18], and both forms of eating behaviour are associated with psychological distress and other eating disorder symptoms [4, 18].

Analyses were conducted using structural equation modelling, and it was hypothesised that:

1. All models (DP, original CB, enhanced CB) would provide a good fit to the observed data.
2. The DP and enhanced CB models would account for a greater proportion of the variance in binge eating than the original CB model, due to the incorporation of an affect-related pathway to binge eating.

Method

Design

This research involved data from the Childhood Growth and Development (GAD) Study. The GAD Study is a prospective cohort study based in Perth, Western Australia, with a central focus on weight and eating behaviour in childhood. Children were recruited from Perth primary schools and interviewed at baseline (Time 1), 1-year follow-up (Time 2), and 2-year follow-up (Time 3). Additional details of the GAD Study methodology, including detailed recruitment information, have been reported previously [25–27].

Participants

Participants were community-recruited GAD Study children, aged between 8 and 13 years at baseline, who completed baseline, 1-year follow-up, and 2-year follow-up assessments between January 2004 and August 2008. This equated to 236 children, 48% of whom were male. This meets minimum criteria for analysis with structural equation modelling (i.e., $N > 150$–200) [28]. At baseline, the mean age of the sample was 10.05 years (SD = 1.41) and 60% of children ($n = 142$) were a healthy weight, 30% ($n = 70$) were overweight, and 10% ($n = 23$) were obese.

Multiple children (siblings) were recruited from some families, meaning that 87 children were sibling pairs or triplets (number of families = 149). This family clustering was controlled for in the analyses (see "Data analysis"). No children were twins.

Participant attrition over the 2-year period was 15%. Eighteen children withdrew from the study or were lost to follow-up between Time 1 ($N = 277$) and Time 2 ($n = 259$), and 23 children withdrew from the study or were lost to follow-up between Time 2 ($n = 259$) and Time 3 ($n = 236$). There were no significant differences between the 236 children who remained in the study and the 41 who were lost to follow-up, on baseline or 1-year follow-up variables.

As the mean age of the sample exceeded 12 years at Time 3, pubertal stage was considered as a possible confounder of the results. This was assessed via self-report Tanner stages [29], which have been found to converge well with physical examination in pre-adolescent samples [30, 31]. All boys were pre-pubertal at baseline and 93% ($n = 105/113$) remained pre-pubertal at 2-year follow-up. There were no significant differences between pre- and post-pubertal boys at 2-year follow-up, for any of the assessed variables. Most girls (94%; $n = 116/123$) were pre-pubertal at baseline and 72% ($n = 89/123$) were pre-pubertal at 2-year follow-up. Girls who were post-pubertal were significantly older than girls who were not at both time points, but there were no significant effects of pubertal status on any of the outcome variables of interest. Thus, pubertal status was not included as a covariate in any of analyses.

Procedure

Children and their parent(s) attended an assessment session at Princess Margaret Hospital for Children, the Telethon Institute for Child Health Research, or in their own home. Height and weight were measured prior to interview and children were interviewed separately from their parents. All measures were administered verbally. All participants provided informed consent.

Data analysis

Multilevel, longitudinal structural equation modelling was used to test the alternate models of binge eating (dual pathway, original CB, enhanced CB). Structural equation modelling involves estimating a measurement model, which specifies relationships between a set of theoretical or latent constructs and a set of measured or observed variables, and a structural model, which specifies relationships between the latent constructs under investigation. The overall model consists of both the measurement and structural components, and can be further divided into exogenous (predictor) and endogenous (dependent) variables. Feedback loops within the models were not specified, due to the use of prospective data.

Prospective associations were specified between (1) Time 1 psychosocial variables and weight and (2) Time 2 weight- and shape-related concerns, and between (3) Time 2 weight- and shape-related concerns and (4) Time 3 depressive symptoms and dietary restraint. Cross-sectional associations were specified between Time 3 depressive symptoms and dietary restraint and Time 3 binge eating. Prior levels of the dependent variables were controlled for in each instance. These relationships are summarised in Figs. 1, 2 and 3.

For BMI *z*-score, perfectionism, weight and shape over-evaluation, and binge eating, measurement models consisted of one (BMI *z*-score, perfectionism) or two (over-evaluation, binge eating) indicator variables. Error terms for those variables were fixed to pre-specified levels. For BMI *z*-score and weight and shape over-evaluation, error terms were fixed to the standard error of the item mean [28], which equated to 0.05 for BMI *z*-score, 0.08 for over-evaluation of weight, and 0.10 for over-evaluation of shape. For categorical, interviewer-rated variables (perfectionism and binge eating), error terms were set somewhat higher (=0.20), in recognition of the possibility of inter-rater differences in how perfectionism and binge eating episodes were coded.

For the other variables under investigation, measurement models were constructed by taking the highest loading items, as identified through principal components analysis, from the measure used to assess each construct. This approach to identifying indicator variables is

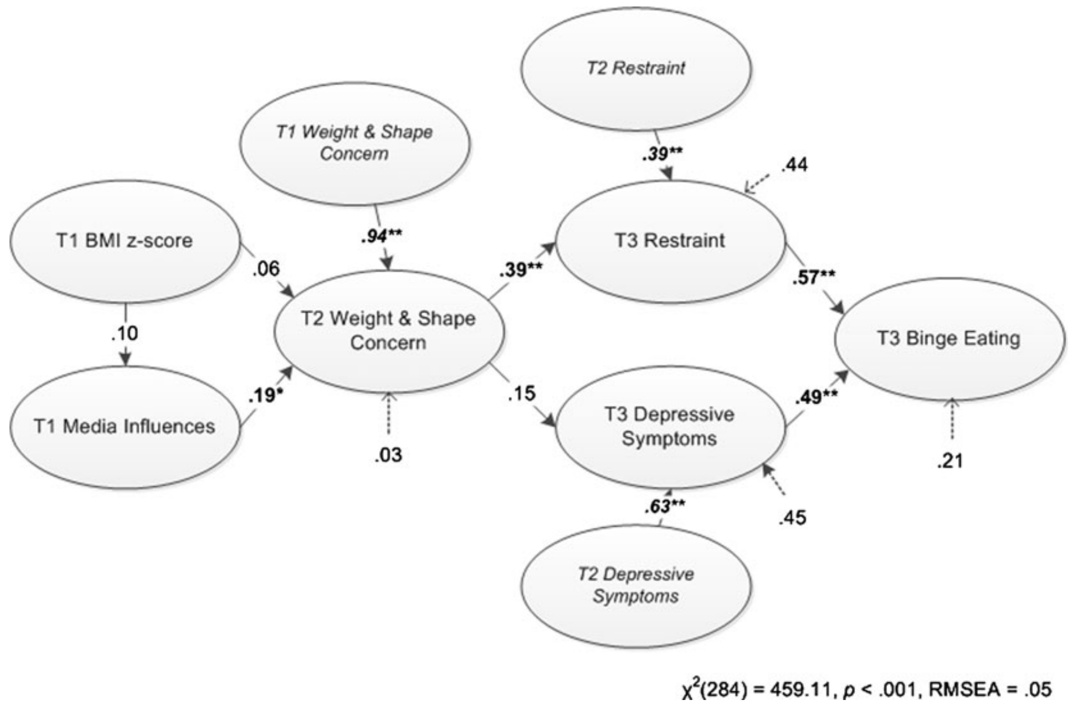

Fig. 1 Structural model (with standardised coefficients) for Stice and colleagues' dual-pathway model of binge eating. *Dotted lines* indicate standard error terms, and constructs in *italics* are included to control for previous levels of the Time 2 and 3 variables under investigation. *$P < 0.05$; **$P < 0.01$

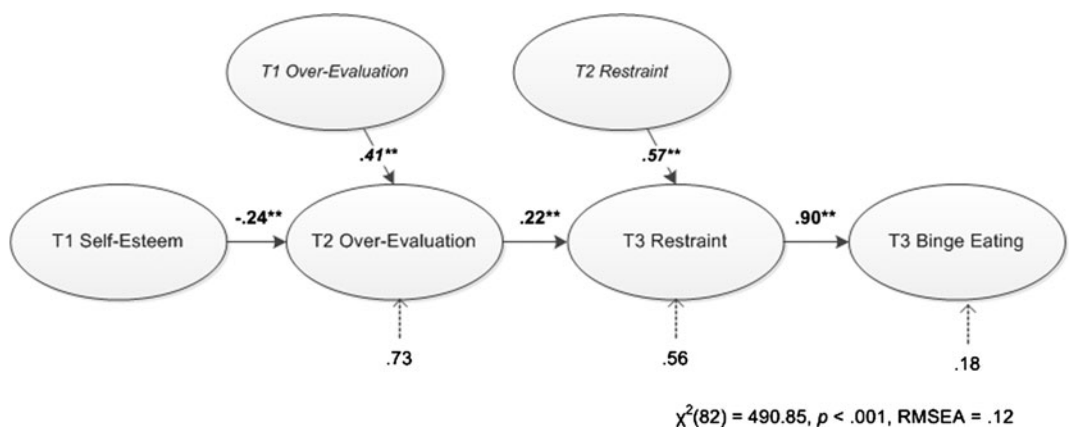

Fig. 2 Structural model (with standardised coefficients) for Fairburn and colleagues' original cognitive-behavioural model of binge eating. *Dotted lines* indicate standard error terms, and constructs in italics are included to control for previous levels of the Time 2 and 3 variables under investigation. *$P < 0.05$; **$P < 0.01$

beneficial when a large number of potential indicator variables is available, and is consistent with recommendations and with previous research in this area [21, 32].

Measures

Body mass index z-score

Body mass index *z*-score was included as a single-indicator predictor variable in the DP model. Unadjusted BMI scores (kg/m^2) were calculated using measured height and weight, and age- and sex-specific BMI *z*-scores were calculated using the CDC 2000 reference data [33].

Media influences

Thin-ideal internalisation and perceived pressure to be thin are included as separate predictor variables in the DP model. In this study, these constructs were assessed using the Internalisation and Pressure subscales of the Multidimensional Media Influence Scale (MMIS) [34]. These subscales aim to assess the degree to which participants

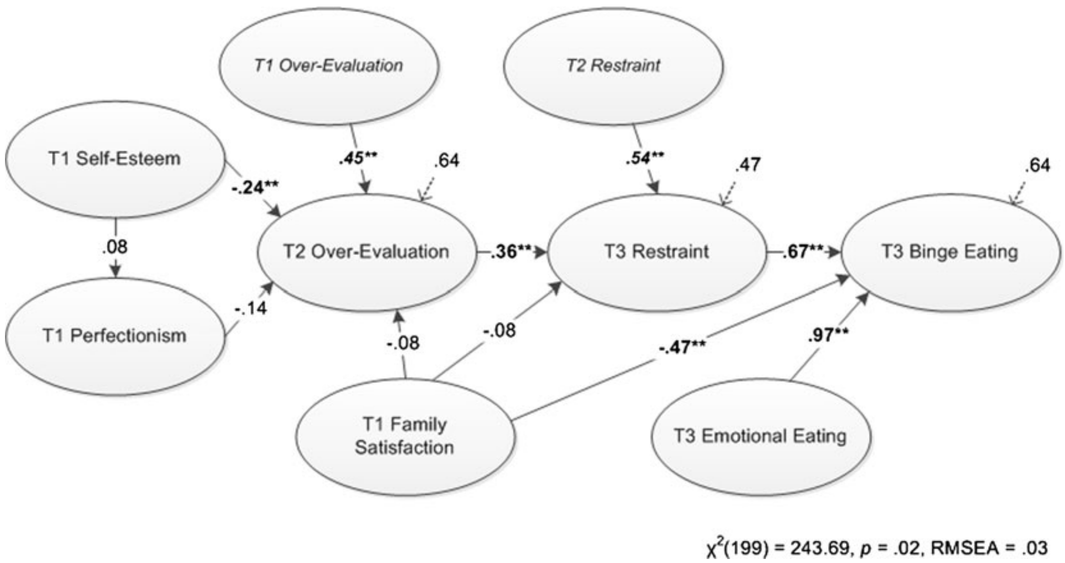

Fig. 3 Structural model (with standardised coefficients) for Fairburn and colleagues' enhanced cognitive-behavioural model of binge eating. *Dotted lines* indicate standard error terms, and constructs in italics are included to control for previous levels of the Time 2 and 3 variables under investigation. *$P < 0.05$; **$P < 0.01$

internalise the thin-ideal as a personal standard of attractiveness (Internalisation) and feel pressured by the media to achieve this ideal (Pressure). The MMIS has been validated for children aged 8 years and older [34], but in this sample the internal consistency of the Pressure subscale was unacceptably low ($\alpha = 0.58$). Furthermore, factor analysis did not provide support for separate Internalisation and Pressure factors. A combined "media influences" construct was thus created by taking the three highest loading items from the Internalisation and Pressure subscales combined ($\alpha = 0.72$). This construct was used in place of separate Internalisation and Pressure variables in the DP model (see Fig. 1).

Self-esteem

Self-esteem was included as a predictor variable in the original and enhanced versions of the CB model. This construct was assessed using the three highest loading items from the Global Self-Worth subscale of the Self-Perception Profile for Children (SPPC) [35], which has been established as having excellent psychometric properties [35, 36]. The subscale alpha coefficient in this sample was 0.70 and the coefficient for the three items used as indicator variables was 0.73.

Perfectionism

Perfectionism was included as a dependent and predictor variable in the enhanced CB model. This construct was assessed through parent report, as no validated measures for child perfectionism were available at the commencement of the study. The Perfectionism section of the Oxford Risk Factor Interview [37] was used, which has been established as having satisfactory inter-rater reliability (e.g., $\kappa = 0.66$) [37, 38]. Questions were adapted for parent-report: "does your child set very high standards in work and other respects, more so than other children their age?" and "does your child get very upset if they do not reach these standards?". If answering in the affirmative, parents were asked to describe the nature of the standards in question and the domains to which they applied. Interviewers subsequently classified children as having "no problematic perfectionism" ($n = 156$; 66%), "possible perfectionism" ($n = 22$; 9%), or "probable perfectionism" ($n = 59$; 25%). These scores served as a single indicator for the perfectionism construct.

Family satisfaction

Interpersonal difficulties were included as a predictor variable in the enhanced CB model. Given the age of the sample, family-based difficulties were assessed as an index of the broader interpersonal difficulties construct. Children completed the Family Satisfaction subscale of the Students' Life Satisfaction Scale (SLSS) [39], which includes seven items designed to assess satisfaction with family, parents, and the nature of family interactions ($\alpha = 0.77$ in this sample). The three highest loading items were taken as indicator variables ($\alpha = 0.78$).

Body dissatisfaction and weight and shape over-evaluation

Body dissatisfaction was included as a predictor and dependent variable in the DP model. Weight and shape over-evaluation was included as a predictor and dependent variable in the original and enhanced CB models.

These constructs were assessed using items from the weight concern and shape concern subscales of the Child Eating Disorder Examination (ChEDE) [41]. The ChEDE is a modified version of the adult Eating Disorder Examination (EDE) [11], a semi-structured interview that is considered the "gold standard" for assessing eating disordered cognitions and behaviours [42]. It has been used with overweight and healthy weight children, and with participants recruited from community and clinical settings [4, 25, 43]. The ChEDE yields four subscale scores (Restraint, Eating Concern, Weight Concern, Shape Concern), a Global score, and estimates of the frequency of core eating disordered behaviours, including binge eating.

The Weight Concern and Shape Concern subscales have been established as internally consistent [4, 21, 43, 44] and collectively include 12 items, two of which specifically assess the over-evaluation of weight and shape. In the current sample, alpha coefficients were 0.75 and 0.84 for the Weight Concern and Shape Concern subscales, respectively.

The two items pertaining to the over-evaluation of weight and shape were used as dual indicators of the over-evaluation construct, in the CB models ($\alpha = 0.95$).

Four of the remaining Weight Concern and Shape Concern items were taken as indicators of body dissatisfaction. Although body dissatisfaction can be conceptualised in different ways [26, 40], affective body dissatisfaction, in the form of concern and distress about weight and shape, has most commonly been considered in the DP model. The two highest loading items from each of the Weight Concern and Shape Concern subscales provided an estimate of this construct. These four items were internally consistent ($\alpha = 0.89$).

Dietary restraint

Dietary restraint was included as a dependent and predictor variable in all models. It was assessed using the ChEDE Restraint subscale, which includes five items designed to assess strict and rigid attempts at dieting. Previous studies have provided support for the reliability and validity of the subscale [4, 21, 43, 44]. Again, the three highest loading items were taken as indicator variables for these analyses. Although the internal consistency of the full subscale was sub-optimal in this sample ($\alpha = 0.67$), the alpha coefficient for the three items used as indicator variables was acceptable ($\alpha = 0.70$). Consistent with the focus of the DP and CB models, these items assessed efforts at dietary restriction (restraint), rather than actual dietary restriction.

Depressive symptoms

Time 3 depressive symptoms were included as a dependent and predictor variable in the DP model. These were assessed using the short form of the Child Depression Inventory (CDI) [45], which has been established as having good psychometric properties [45, 46]. The three highest loading items were used as indicator variables.

Affect regulation difficulties

Mood intolerance is hypothesised to predict binge eating in the enhanced CB model. Currently, there are no direct measures of mood intolerance available for use with children, and very few measures available for use with adults. The Child Affect Regulation Scale (CARES) [47] was thus utilised as an indirect measure of mood intolerance. The CARES includes ten items that assess the tendency to eat as a means of affect regulation ("emotional eating"). The three highest loading items were taken as proxy indicators of mood intolerance.

Binge eating

Binge eating was assessed using the ChEDE and was conceptualised as a categorical variable—that is, as present (developing between Time 2 and Time 3) or absent. As noted, OBE and SBE were both assessed, and these two forms of loss of control eating behaviour served as dual indicators of the binge eating construct. Fifteen children (6%) began binge eating between Time 2 and Time 3, with seven developing OBE and eight developing SBE. Children who reported binge eating at baseline ($n = 20$) or who developed binge eating between Time 1 and Time 2 ($n = 8$) were excluded from analyses.

Measurement models

After identifying indicator variables for each latent construct, confirmatory factor analysis was conducted in LISREL 8.72 for the exogenous and endogenous measurement models within each overall model. Error terms for each set of indicator variables were allowed to co-vary. Analyses were conducted using polychoric correlations and covariance matrices, using the maximum likelihood technique. Due to the hierarchical nature of the data (children clustered within families), covariance matrices were obtained using the multilevel feature of PRELIS. Specifically, analyses were run using family as the Level 3 grouping variable and children as the Level 2 grouping variable. The

Level 2 covariance matrix was then used for all analyses. This matrix can be considered to represent relationships between variables at the child level, relatively independent of any family effects [48].

Measurement models were evaluated in terms of (1) the overall χ^2 value and (2) the Goodness of Fit Index (GFI), Adjusted Goodness of Fit Index (AGFI), Normed Fit Index (NFI), Comparative Fit Index (CFI), Parsimonious Goodness of Fit Index (PGFI), Critical N (CN), and Root Mean Square Error of Approximation (RMSEA). The χ^2 statistic should be small relative to the degrees of freedom and non-significant, if a model does not differ significantly from the observed data. The GFI, AGFI, NFI, and CFI should also exceed 0.90, with values closer to 1.00 being preferable and values above 0.85 being acceptable in small samples [28, 49, 50]. For the PFI, values should be in the vicinity of 0.50, and for the RMSEA, values should be below 0.05, with values below 0.10 being considered acceptable. The CN should exceed 200 in most cases, with values below 150 indicating that the sample size may be insufficient for an adequate model fit to be estimated [28, 49, 50].

Structural models

After measurement models had been estimated, the exogenous and endogenous components of each model were combined and the structural pathways specified. For these analyses, pathways between the latent constructs and their respective indicator variables were fixed to the values identified during measurement model analyses. Thus, only pathways between the latent constructs needed to be estimated at this stage. This approach reduces the number of pathways being estimated at any one time, which is advantageous when many paths are being investigated and sample size is modest.

The structural models were evaluated using the χ^2 statistic and goodness-of-fit indices described above. As the models were not nested (i.e., no one model was a subset of another), it was not possible to utilise χ^2 difference tests to statistically compare model fit. However, the predictive utility of each model was compared by examining the percentage of variance accounted for in binge eating by each model.

Preliminary analyses

Most indicator variables were significantly skewed. Accordingly, all indicator variables were normalised prior to analysis using Blom's method. This reduced skewness values to a range that spanned from normal to moderately non-normal (i.e., skewness values <3) [51], and kurtosis values to a range that may be considered normal (i.e., kurtosis values <7) [41]. Maximum likelihood estimation is considered robust to moderate violations of normality [28, 51], and the normalised data were therefore considered suitable for analysis with this method.

Results

Measurement models

Dual-pathway model

Standardised item loadings, standard error terms, and *t* values for the indicator variables within the DP model are shown in Table 1. When confirmatory factor analysis was conducted for the exogenous measurement model, the χ^2 statistic was significant, $\chi^2(15) = 37.70$, $P = 0.001$, but fit statistics were good (e.g., GFI = 0.97). Similar results were obtained for the endogenous measurement model, $\chi^2(33) = 53.88$, $P = 0.004$, GFI = 0.97 (see Table 4).

Original cognitive-behavioural mode

Standardised item loadings, standard error terms, and *t* values for the indicator variables within the original CB model are shown in Table 2. When confirmatory factor analysis was conducted for the exogenous measurement model, the χ^2 statistic was significant, $\chi^2(9) = 17.32$, $P = 0.04$, but fit statistics were good (e.g., GFI = 0.98; see Table 4). The endogenous measurement model also provided a good fit to the observed data (e.g., GFI = 0.99; see Table 4), and in this instance the χ^2 value was not significant, $\chi^2(6) = 12.48$, $P = 0.05$.

Enhanced cognitive-behavioural model

Standardised item loadings, standard error terms, and *t* values for the indicator variables within the enhanced CB model are shown in Table 3. When confirmatory factor analysis was conducted for the exogenous measurement model, the χ^2 statistic was significant, $\chi^2(35) = 76.46$, $P = 0.006$, but fit statistics were good (e.g., GFI = 0.96; see Table 4). The endogenous measurement model was equivalent to that for the original CB model, as above.

Structural models

Dual-pathway model

When the structural component of the DP model was specified, three key pathways within the model failed to reach significance: Time 1 BMI *z*-score to Time 1 Media Influences; Time 1 BMI *z*-score to Time 2 Weight and Shape Concern; and Time 2 Weight and Shape Concern to Time 3 Depressive Symptoms (see Fig. 1). The model

Table 1 Indicator variables in Stice et al.'s dual-pathway model

Item		Standardised coefficient	SE	*t* value
Exogenous model				
Time 1 BMI *z*-score				
bmiz	BMI *z*-score	0.95	0.09	19.71
Time 1 Weight and shape concern				
ws35	Dissatisfaction with weight	0.88	0.23	–
ws38	Dissatisfaction with shape	0.89	0.21	18.60
ws43	Discomfort seeing body	0.86	0.25	18.09
ws44	Avoidance of exposure	0.74	0.45	13.76
Time 2 Restraint				
r2	Restraint over eating	0.79	0.37	–
r5	Food avoidance	0.73	0.46	13.04
r6	Dietary rules	0.93	0.14	11.80
Time 2 Depressive symptoms				
d1	I feel sad	0.57	0.67	–
d4	I hate myself	1.06[a]	0.12	6.36
d8	I feel alone	0.41	0.63	4.99
Endogenous model				
Time 1 Media influences				
m6	I try to look like the models in magazines	0.81	0.34	7.54
m9	I would like my body to look like the models in magazines	1.01[a]	0.02	–
m11	I try to look like the actors/actresses in movies	0.62	0.62	6.14
Time 2 Weight and shape concern				
ws35	Dissatisfaction with weight	1.09[a]	0.29	–
ws38	Dissatisfaction with shape	0.78	0.30	12.19
ws43	Discomfort seeing body	0.82	0.33	12.34
ws44	Avoidance of exposure	0.79	0.37	10.29
Time 3 Restraint				
r2	Restraint over eating	0.90	0.19	–
r5	Food avoidance	0.48	0.55	8.47
r6	Dietary rules	0.68	0.53	10.85
Time 3 Depression				
d1	I feel sad	0.92	0.15	–
d4	I hate myself	1.40[a]	0.09	11.19
d8	I feel alone	0.85	0.25	12.20
Time 3 Binge eating				
obe	Objective binge eating	0.91	0.20	–
sbe	Subjective binge eating	0.91	0.20	13.78

t values were not tested for the highest loading item in each set. The error term for BMI *z*-score was set to 0.05, and the error terms for objective and subjective binge eating were set to 0.20

SE standard error

[a] In contrast to other statistical techniques, standardised coefficients can exceed 1 in structural equation modelling

Table 2 Indicator variables within Fairburn et al.'s original cognitive-behavioural model

Item		Standardised coefficient	SE	*t* value
Exogenous model				
Time 1 Self-esteem				
se18	Happy with self as a person	0.67	0.55	9.90
se24	Like the kind of person you are	0.78	0.38	10.93
se30	Happy being the way you are	0.86	0.26	–
Time 1 Weight and shape over-evaluation				
ov1	Over-evaluation of shape	0.92	0.15	16.90
ov2	Over-evaluation of weight	1.02[a]	0.04	–
Time 2 Restraint				
r2	Restraint over eating	0.91	0.17	–
r5	Food avoidance	0.96	0.08	22.84
r6	Dietary rules	0.79	0.38	16.77
Endogenous model				
Time 2 Weight and shape over-evaluation				
ov1	Over-evaluation of shape	0.95	0.10	20.15
ov2	Over-evaluation of weight	0.99	0.02	–
Time 3 Restraint				
r2	Restraint over eating	0.81	0.34	–
r5	Food avoidance	0.94	0.11	11.28
r6	Dietary rules	0.77	0.41	15.65
Time 3 Binge eating				
obe	Objective binge eating	0.89	0.20	–
sbe	Subjective binge eating	0.89	0.20	13.29

t values were not tested for the highest loading item in each set. The error terms for over-evaluation of shape and over-evaluation of weight were set to .10 and .08, respectively, and the error terms for objective and subjective binge eating were set to 0.20

SE standard error

[a] In contrast to other statistical techniques, standardised coefficients can exceed 1 in structural equation modelling

provided a sub-optimal fit to the data, with a significant χ^2 value, $\chi^2(284) = 459.11$, $P < 0.001$, but acceptable fit indices (e.g., GFI = 0.87; see Table 5). The model accounted for 52% of the variance in binge eating, 95% of the variance in Time 2 Weight and Shape Concern, 54% of the variance in Time 3 Restraint, and 54% of the variance in Time 3 Depressive Symptoms. Standardised coefficients for the structural model are shown in Fig. 1.

Table 3 Indicator variables within Fairburn et al.'s enhanced cognitive-behavioural model

Item		Standardised coefficient	SE	*t* value
Exogenous model				
Time 1 Self-esteem				
se18	Happy with self as a person	0.69	0.52	10.19
se24	Like the kind of person you are	0.81	0.34	11.33
se30	Happy being the way you are	0.81	0.34	–
Time 1 Perfectionism				
perf	Parent-reported perfectionism	0.99	0.01	–
Time 1 Family satisfaction				
fs2	My family gets along well together	0.92	0.15	–
fs6	Members of my family talk nicely to one another	0.82	0.33	14.34
fs7	My parents treat me fairly	0.66	0.57	11.17
Time 1 Weight and shape over-evaluation				
ov1	Over-evaluation of shape	0.94	0.09	16.51
v2	Over-evaluation of weight	1.00	0.02	–
Time 2 Restraint				
r2	Restraint over eating	0.90	0.17	–
r5	Food avoidance	0.97	0.08	15.12
r6	Dietary rules	0.73	0.38	7.52
Time 3 Emotional eating				
ee2	Eat when worried, anxious or tense	0.89	0.20	–
ee5	Eat when things have gone wrong	0.86	0.26	15.65
ee7	Eat to block out bad feelings	0.77	0.40	14.19
Endogenous model				
Time 2 Weight and shape over-evaluation				
ov1	Over-evaluation of shape	0.95	0.10	20.15
ov2	Over-evaluation of weight	0.99	0.02	–
Time 3 Restraint				
r2	Restraint over eating	0.81	0.34	–
r5	Food avoidance	0.94	0.11	11.28
r6	Dietary rules	0.77	0.41	15.65
Time 3 Binge eating				
obe	Objective binge eating	0.89	0.20	–
sbe	Subjective binge eating	0.89	0.20	13.29

T values were not tested for the highest loading item in each set. The error terms for over-evaluation of shape and over-evaluation of weight were set to 0.10 and 0.08, respectively, and the error terms for perfectionism, objective binge eating, and subjective binge eating were set to 0.20

SE standard error

Original cognitive-behavioural model

When the original CB model was specified, all key pathways within the model were significant. However, the model differed significantly from the observed data, $\chi^2(82) = 490.85$, $P < 0.001$, and fit statistics were poor (e.g., GFI = 0.78; see Table 5). The model accounted for 33% of the variance in Time 3 Binge Eating, 27% of the variance in Time 2 Over-Evaluation, and 41% of the variance in Time 3 Restraint. Standardised coefficients for the structural model are shown in Fig. 2.

Enhanced cognitive-behavioural model

When the enhanced CB model was specified, the Chi square statistic remained significant, but was reduced relative to the original model, $\chi^2(199) = 243.69$, $P = 0.02$. Fit statistics were good (e.g., GFI = 0.91; see Table 5), but four of the specified pathways were not significant: Time 1 Self-Esteem to Time 1 Perfectionism; Time 1 Perfectionism to Time 2 Over-Evaluation; Time 1 Family Satisfaction to Time 2 Over-Evaluation; and Time 1 Family Satisfaction to Time 3 Restraint (see Fig. 3). The model accounted for virtually all of the variance in Time 3 Binge Eating (99%), 60% of the variance in Time 2 Over-Evaluation, and 51% of the variance in Time 3 Restraint.

Summary of results

This study evaluated three models of binge eating development using multilevel longitudinal structural equation modelling. All measurement models provided an acceptable fit to the observed data. Structural model results revealed that the DP and enhanced CB models provided acceptable (although not optimal) fits to the data, whereas the original CB model did not.

Discussion

This study aimed to evaluate and compare the DP, original CB, and enhanced CB models of binge eating, using prospective data collected from pre- to early-adolescent boys and girls. The results extend and complement those from previous research on binge eating and other eating disorder symptoms in childhood [4, 5, 17], and provide insight into the relative importance of different psychosocial and weight-related variables in predicting binge eating onset.

It was hypothesised that all models would provide a good fit to the data. This prediction was not supported, as the original CB model could not be considered a "good fit" in this sample. This contrasts with results from previous studies, and may stem from differences in the sample used

Table 4 Fit statistics for the exogenous and endogenous measurement models for the three models of binge eating

	RMSEA	GFI	AGFI	NFI	CFI	PGFI	CN
Dual pathway							
Exogenous	0.05	0.97	0.90	0.98	0.99	0.30	222.75
Endogenous	0.08	0.97	0.86	0.99	0.99	0.19	176.33
Original cognitive-behavioural							
Exogenous	0.06	0.98	0.93	0.99	0.99	0.25	284.15
Endogenous[a]	0.07	0.99	0.93	0.99	0.99	0.21	292.46
Enhanced cognitive-behavioural							
Exogenous	0.07	0.96	0.86	0.97	0.98	0.28	165.20
Endogenous[a]	0.07	0.99	0.93	0.99	0.99	0.21	292.46

RMSEA root mean square error of approximation, *GFI* goodness of fit index, *AGFI* adjusted goodness of fit index, *NFI* normed fit index, *CFI* comparative fit index, *PGFI* parsimony goodness of fit index, *CN* critical *N*

[a] These models were identical

Table 5 Fit statistics for the overall dual pathway and cognitive behavioural models

	RMSEA	GFI	AGFI	NFI	CFI	PGFI	CN
Dual pathway	0.05	0.87	0.84	0.89	0.95	0.70	157.24
Cognitive behaviour							
Original	0.12	0.78	0.75	0.83	0.85	0.69	51.71
Enhanced	0.03	0.91	0.89	0.86	0.97	0.72	240.21

RMSEA root mean square error of approximation, *GFI* goodness of fit index, *AGFI* adjusted goodness of fit index, *NFI* normed fit index, *CFI* comparative fit index, *PGFI* parsimony goodness of fit index, *CN* critical *N*

(i.e., boys and girls of varying ages and weights vs. overweight/obese boys and girls [21, 24], female adolescents [20], or adult men and women [22, 23]), and/or from the use of prospective data. As noted in the Introduction, the CB framework was originally developed to account for the maintenance of binge eating. It is possible that the original model is able to explain binge eating maintenance but not its development.

Fit statistics were acceptable for the DP and enhanced CB models. This is consistent with the study's second hypothesis, and suggests that binge-eating theories may be improved by the inclusion of an affect-related pathway to binge eating. Notably, however, the DP and CB models do not account for affect-related effects in the absence of weight- and shape-related concerns or dieting behaviour. Studies have found that up to two-thirds of binge eaters may report binge-eating onset before dieting onset [52, 53]. Our finding that weight and shape concern did not significantly predict depressive symptoms in the DP model, even though depressive symptoms predicted binge eating, is consistent with these results. Similarly, although fit statistics were acceptable for the DP and enhanced CB models, they were not excellent (e.g., GFI < 0.95). This suggests that additional variables and/or alternative theories may deserve attention when considering binge eating in this age group. Personality factors (e.g., impulsivity) and dialectical behaviour therapy (DBT) perspectives [54] may, for example, be able to account for affect-driven binge eating that occurs in the absence of dietary restraint. Additional research on this topic is warranted.

Although the enhanced CB model provided the best fit to the data, four of the proposed pathways failed to reach statistical significance. Low self-esteem was not significantly associated with perfectionism, perfectionism was not significantly associated with the over-evaluation of weight and shape, and family satisfaction was not significantly associated with over-evaluation or dietary restraint (although it was a significant independent predictor of binge eating). Further evaluation of the enhanced model is thus necessary. Mood intolerance was also assessed using a proxy variable (affect-related eating), in response to the absence of specific mood intolerance measures available for children. This variable proved to be highly related to binge eating, and replication with a direct mood intolerance measure is thus important. Finally, as the current study had a specific focus on binge eating, it is important that the model's ability to account for other eating disorder symptoms be considered in future analyses, given the transdiagnostic focus of the enhanced account.

The DP and CB models emphasise the effects of dietary restraint (efforts to restrict dietary intake, as assessed here), rather than actual dietary restriction (caloric reduction). However, there is some evidence to suggest that dietary restriction is more powerful than restraint in predicting binge eating [55]. Thus, future studies may also benefit from distinguishing between different forms of dieting behaviour, so that the relative importance of restraint and restriction can be determined.

This study has a number of strengths. As noted, it is the first study to simultaneously evaluate the DP and CB models of binge eating, and to test the two CB models (original and enhanced) using prospective data. The age of the sample was also suited to investigating changes in eating disorder symptoms over time [5, 6], and serves to extend findings with older samples to a pre- to early-adolescent group. The use of interview-based measures provides support for the validity of the assessed constructs. Finally, we considered all forms of loss of control eating, which is beneficial when considering that loss of control, rather than the amount of food consumed, is the defining feature of binge eating and the feature that has been linked to psychological distress [4, 18, 24].

The relatively modest sample size, 15% attrition over time, and small number of binge-eating cases represent limitations of this research. Others include the relatively short follow-up period and use of three assessment points (rather than four), which precluded all pathways being specified prospectively. Further to this, some participants in this study may go on to develop binge eating later in adolescence. Following children from pre- to late-adolescence would be optimal for addressing this issue, and would allow age differences in risk factors for binge eating to be considered. The assessment of complex emotional and behavioural constructs in childhood also raises difficulties, and in this instance, perfectionism was assessed through parent report whilst other constructs were child reported. Development and validation of child-report measures for perfectionism and mood intolerance will facilitate future evaluations of the models tested here. Comparison of results when using child- and parent-report data may also prove beneficial.

In summary, this study has evaluated the DP, original CB, and enhanced CB accounts of binge eating using prospective data. Results suggest that the DP and enhanced CB models may be more successful in accounting for binge eating onset than the original CB version, and that dietary restraint and affect-related difficulties both require consideration in theories of binge eating in this age group. The results also suggest that body dissatisfaction (weight and shape concerns) and weight and shape over-evaluation may be able to mediate links between psychosocial factors and dietary restraint in children. It would be useful for future studies to consider sex differences in binge eating development, as sample size was not sufficient to evaluate possible sex effects in this research.

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Conflict of interest None.

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