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The association between overweight and internalizing and externalizing behavior in early childhood

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ABSTRACT

Objective: The aim of this study was to examine bidirectional associations between overweight and behavior problems during early childhood taking into account the adiposity rebound, which is the turning point in the nonlinear development of Body Mass Index in early childhood.
Methods: Longitudinal data from 6624 Dutch children in the Generation R Study were used to analyze the association between measured overweight and scores on the internalizing and externalizing scale of the Child Behavior Checklist between one-and-a-half, three and six years. The adiposity rebound was determined for each child by estimating the lowest point in their growth curve. Cross-lagged modeling was used to test (bi)directional associations.
Results: Both body mass and behavior problems were modest to highly stable from age one-and-a-half to six years. Externalizing and internalizing behavior were both associated with later overweight, although effect sizes were small (βs ranged between 0.06 and 0.07, *ps* < 0.05). No significant associations in the other direction were found. Controlling for adiposity rebound did not change the pattern of associations. There was a moderating effect of gender, and ethnicity, and timing of adiposity rebound.
Conclusion: Behavior problems in early childhood may put children at risk for overweight at a later age. This implies that young children with behavior problems may benefit from careful monitoring of eating behavior and weight development. Future studies should take the adiposity rebound into account.

The prevalence of childhood overweight and obesity has increased significantly over the last twenty years (De Onis et al., 2010). Children with overweight usually maintain their overweight status into adolescence and adulthood (e.g. Hesketh et al., 2004; Katzmarzyk et al., 1999) and are at risk for negative psychological outcomes (Pulgarón, 2013). Childhood overweight has been found to relate to premature death and increased odds of illness in adulthood, regardless of adult adiposity (e.g., Reilly and Kelly, 2011). Furthermore, it has been argued that primary prevention of adult overweight should take place between the ages of two to six years, because weight gain in this critical period is the best predictor of adult adiposity (De Kroon et al., 2010). Therefore, it is important to determine which factors relate to the origin of childhood overweight. Possible relevant factors are internalizing and externalizing behavior, which at the age of five years are related to adult overweight, regardless of childhood overweight, nutrition and lifestyle (Mamun et al., 2009). Furthermore, a parenting intervention on behavioral problems in four-year olds had beneficial effects on obesity rates three to five years later (Brotman et al., 2012). The association between behavior problems and overweight can be explained by shared risk factors, but also by adverse parenting practices in which parents react to problem behavior by encouraging unhealthy behavior. In early childhood, this association has been studied (e.g., Bradley et al., 2008; Garthus-

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Niegel et al., 2010; Lawlor et al., 2005), but without taking into account the ‘adiposity rebound’, which is the turning point of Body Mass Index (BMI) that occurs in early childhood. Children's BMI does not increase linearly over time: It first increases until it reaches a peak in the first 9 months (Johnson et al., 2013), after which it decreases, before starting to increase again between three and seven years of age. This last turning point is called the adiposity rebound (Cole, 2004). An early adiposity rebound is a risk factor for subsequent overweight because it identifies the children with a high BMI centile, which in its turn is related to prospective overweight (Cole, 2004; Rolland-Cachera et al., 2006). It is relevant to take the adiposity rebound into account, because it may affect the interpretation of associations between body mass and behavior. The current study examines the prospective association between body mass and behavior problems in early childhood, while taking into account the adiposity rebound.

There are several mechanisms that may explain associations between behavior and overweight. These mechanisms may be different for internalizing behavior (e.g., social withdrawal, anxiety, depression), than for externalizing behavior (e.g., impulsivity, aggression, and hyperactivity). High BMI and *externalizing* behavior could share a number of risk factors (e.g., low socioeconomic status, diminished self-regulation skills, and difficult temperament), and may therefore simply be related to each other without one *causing* the other. However, externalizing behavior could also lead to overweight through mechanisms such as inadequate parenting behavior, behavior of parents or parental reactions to their children. Parents of children with externalizing behavior may give in to certain demands for sweets and sedentary activities such as gaming or watching television to avoid the child's difficult behavior, which in turn may lead to childhood overweight (Mamun et al., 2009). This is also in line with previous research by Rodgers et al. (2013), who indicated that instrumental feeding practices, such as using food as positive and negative reinforcement, is related to weight gain of the child.

The literature is scarce and inconsistent concerning whether there is an association between BMI and externalizing behavior in early childhood: Only a limited number of studies have focused on the association between overweight and externalizing behavior in early childhood, and these studies are mostly cross-sectional and show inconsistent results (e.g., Lawlor et al., 2005; Mackenbach et al., 2012). In addition, three studies adopted a symmetric longitudinal design – a design that permits conclusions on bidirectional effects over time – and their findings are contradictory as well (Anderson et al., 2010; Bradley et al., 2008; Garthus-Niegel et al., 2010). Therefore, this association should be investigated further, while taking the adiposity rebound into account.

Similar to the association between overweight and externalizing behavior, shared risk factors (e.g., low socioeconomic status, parental internalizing behavior, and serotonin and cortisol levels) could also explain the association between overweight and *internalizing* behavior. It has also been suggested, however, that overweight could indirectly *lead to* internalizing behavior. Children with overweight may be frustrated, because they have more difficulty in participating in certain physical activities with other children (Trost et al., 2003), or because they are rejected by peers due to their weight status (Puhl and Latner, 2007). In contrast, internalizing behavior could also lead to overweight. Studies in adolescence and adults indicate that individuals with internalizing behavior often show emotional eating, which is a coping mechanism whereby eating is used to deal with emotional problems (Ouwens et al., 2009), which could lead to weight increase. In early childhood, parents may use ‘comfort food’ as well to comfort their child, and reduce stress and anxiety (e.g., Stifter et al., 2011), potentially leading to overweight.

Cross-sectional studies show diverging results concerning the association between BMI and internalizing behavior in early childhood (e.g., Mackenbach et al., 2012; Sawyer et al., 2006). Only three longitudinal studies have investigated the association between BMI and internalizing behavior using symmetrical longitudinal designs, and none of these found significant associations in early childhood (Bradley et al., 2008; Garthus-Niegel et al., 2010; Lawlor et al., 2005).

All in all, although theoretically plausible, there is no consistent evidence to indicate whether or not there is an association between a high BMI and behavioral problems in early childhood. An important reason for this might be that previous studies covered only part of the adiposity rebound period and did not account for the timing of the rebound, which may have led to erroneous conclusions. The timing of the adiposity rebound usually takes place between three and seven years, but its timing is different for each child (Cole, 2004). Depending on where a child is situated on the adiposity rebound curve, BMI could be either decreasing or increasing, which could affect the strength and even the direction of prospective associations with other variables.

The aim of the current study was to investigate the association between the development of body mass and the development of externalizing and internalizing problems during early childhood in a longitudinal study, taking into account for each participant the individual adiposity rebound and their relative position to it. In addition, it was tested whether gender, ethnicity or timing of adiposity rebound moderate these associations. We employed a symmetrical design with three waves of data collection (one-and-a-half, three, and six years). Data were collected within the Generation R study (Jaddoe et al., 2012), a large prospective birth cohort study situated in Rotterdam (The Netherlands).

1. Method

1.1. Study design

This study was embedded within the Generation R study, a multi-ethnic population-based prospective cohort study from early fetal life onwards in Rotterdam, The Netherlands, that investigates growth, development, and health (Jaddoe et al., 2012). The study has been approved by the Medical Ethical Committee of the Erasmus Medical Center in Rotterdam. Written consent was obtained from all parents of participating children. All participating children were born between 2002 and 2006. In the Generation R study there is a prenatal phase and two postnatal phases (zero–four years, and five–six years). The current study utilizes data from three waves that took place within those two postnatal phases. The first wave was conducted at age one-and-a-half years, the second wave at three years, and the third wave at six years.

1.2. Participants

In total, 6624 children participated in both postnatal phases (zero–four years, and five–six years) and had data on at least one of the three waves included in the current study. Of this sample, 50.2% of the children were boys, 66% had a Western (primarily Dutch) ethnicity and 34% had a Non-Western ethnicity (Turkish, Surinamese, Moroccan, Antillean, and other). In addition, 16.5% of the sample had a low monthly net income (less than €2000), 43% had a middle net income (between €2000 and €4000) and 40.5% had a net income more than €4000. Sixty-six percent of mothers had a higher education, 32% finished secondary education and 2% finished only primary school. The average age of the children in each wave was 18.45 months ($SD = 1.13$) for wave 1, 36.67 months ($SD = 1.46$) for wave 2, and 71.81 months ($SD = 4.60$) for wave three.

1.3. Measures

1.3.1. Behavior problems

Internalizing and externalizing behavior were measured with the Child Behavior Checklist 1½ –5 (CBCL, Achenbach and Rescorla, 2000) and was mostly filled out by mother (>90% of cases). Internalizing behavior consists of 36 items from the following subscales: 'emotional reactive,' 'anxious/depressed,' 'somatic complaints,' and 'withdrawn.' Externalizing behavior consists of 24 items from the scales 'attention problems' and 'aggressive behavior.' Weighted sum scores were used in the analyses in which a higher score indicated a higher rate of behavior problems.

1.3.2. Child body mass

Child weight and height during the first and second wave were measured by trained staff of Children's Health Centers as part of a routine health care program. For the first wave, the data were obtained from the participating children who visited the health centers between 16 and 20 months of age ($M = 18.33$ months, $SD = 0.64$), and for the second wave between 34 and 38 months of age ($M = 36.50$ months, $SD = 0.70$). Child weight and height on the third wave were measured at the Generation R research center at six years of age ($M = 72.60$ months, $SD = 4.08$). The children were measured without shoes or heavy clothing. Weight was measured to the nearest gram by using an electronic personal scale (SECA 888, Almere, The Netherlands) and height to the nearest 0.1 cm by a Harpenden stadiometer (Holtain Limited, Crosswell, Crymych, UK). Body Mass Index Standard Deviation Scores (SDS-BMI), which is standardized BMI (kg/m^2) corrected for sex and age, were calculated according to the Dutch national growth references in the Growth Analyzer program (http://www.growthanalyser.org; Fredriks et al., 2000). Because a continuous weight measure also includes variations within the healthy weight range, we additionally used the dichotomous variable 'overweight status' to reflect more clinically relevant differences. Overweight status was determined by the standard definition by Cole et al. (2000): Child cut-off scores were defined by placing the adult cut off (BMI > 25) on the centile curves of the child. Since no accepted cut-off scores are available at age one-and-a-half years, cut-off scores of two years were used at the first wave.

1.3.3. Timing of adiposity rebound

For every child, an estimation of the adiposity rebound was made. The weight and height of the children were measured at multiple time points at the Children's Health Centers. Mother and child visited the center when the child was between zero–two months, two months, three months, four months, five–ten months, 10–13 months, 13–17 months, 17–23 months, 23–29 months, 29–35 months, 35–44 months, 44–56 months, and between 60 and 72 months. These data were used to estimate a growth trajectory for each child. Next, the age at the local minimum of each child's BMI growth curve was determined. For some children the adiposity rebound could not be estimated due to a lack of multiple time points ($N = 564$): Data of at least four of the 13 time points were required, in combination with at least two time points between the age of 10 months and 72 months.

1.4. Covariates

The models were adjusted for family-based socio-demographic factors (maternal age at intake, maternal education, monthly income, and marital status). In addition, child factors (gender, ethnicity, birth weight, gestational age at birth, being breastfed, timing of start of solid food, timing of adiposity rebound), and parent characteristics (parity, prenatal maternal depression at three years (BSI, Derogatis, 1993), prenatal paternal depression (BSI, Derogatis, 1993), maternal parenting stress (NOSI-K, De Brock et al., 1992), and pre-pregnancy BMI of father and mother, family functioning (FAD, Epstein et al., 1983) were included as covariates. Ethnicity was a nominal variable with the following categories: Dutch, Cape Verdian, Maroccan, Antillean, Surinamese, Turkish, other European, and Non-Western. Pre-pregnancy BMI of mother was determined by measured weight during pregnancy corrected for gestational age at that time and average weight gain in each trimester (Rasmussin and Yaktin, 2009). Finally, for the internalizing behavior analyses, the score of externalizing behavior at one-and-a-half years was used as a covariate, and the other way around. This correction is based on our different theoretical frameworks for internalizing and externalizing behavior in relation to overweight.

1.5. Statistical analysis

1.5.1. Data inspection

Analyses were performed using SPSS version 21 and the lavaan package in R version 3.1.3. Descriptive statistics for SDS-BMI, overweight status, adiposity rebound, internalizing and externalizing behavior are presented in Table 1.

Pearson's correlation coefficients were used to indicate cross-sectional and longitudinal correlations between internalizing/externalizing behavior and child overweight status. Cross-lagged modeling was applied to determine bidirectional paths. Behavior problems showed a skewed distribution. Thus, the estimation of the models was done by using maximum likelihood estimation with robust standard errors (MLR). This was preferred over applying a nonlinear transformation prior to analysis for the benefit of interpretation based on the original scales.

Of the total sample, 59% had complete data or missed data on only one or two variables (including all covariates). Less than 2% of the cases were missing more than 35% of the data (max 56% missing), and most of these missing data were within the covariates. Full information maximum likelihood (FIML) procedures were applied to account for these missing values in overweight status, internalizing and externalizing behavior, and covariates. In this method, model parameters are estimated by using all available data while adjusting for the uncertainty associated with missing data (Enders and Bandalos, 2001).

Finally, Bollen-Stine bootstrapping methods were used to estimate the properties of the distribution (i.e., the standard errors) from the sample data by producing 1000 simulation samples (Bollen and Stine, 1992). Deviations of normality in SDS-BMI and problem behavior were checked; any potential differences were undetectable.

1.5.2. Main analyses

The associations between SDS-BMI/overweight status and internalizing or externalizing behavior problems were tested by comparing two sets of four models (one set of models for SDS-BMI and one for overweight status; see Fig. 1). The first model is the stability model, which includes only associations between the three waves of SDS-BMI/overweight status and the three waves of internalizing/externalizing behavior. In addition, cross-sectional correlations between SDS-BMI/overweight status and internalizing or externalizing behavior in each wave were included. The stability model was the baseline model for the other three models. In Model 2, lagged effects of SDS-BMI/overweight status on internalizing/externalizing behavior in the subsequent wave were added to the stability model. In Model 3 lagged effects of internalizing/externalizing behavior on the subsequent SDS-BMI/overweight status wave were added, and finally in Model 4, all three models were merged into one *cross*-lagged model.

Table 1
Descriptive statistics.

		N (and/or %)	*M*	*SD*	Minimum	Maximum
Adiposity Rebound		4486	43.32	10.24	20	62.74
Externalizing	1½ year	4961	10.58	6.71	0	42
	3 years	4772	8.29	6.19	0	42
	6 years	5225	7.22	6.35	0	43
Internalizing	1½ year	4930	5.04	4.62	0	45
	3 years	4769	5.03	4.93	0	55.64
	6 years	5203	5.72	5.68	0	48
SDS-BMI	1½ year	4140	0.24	1.02	−4.01	5.51
	3 years	3739	0.12	0.99	−4.62	5.76
	6 years	5493	0.24	0.91	−3.26	4.08
Overweight (including obesity)	1½ year	18% (737)				
	3 years	10% (364)				
	6 years	16% (898)				
Internalizing problems (borderline & clinical)	1½ year	7% (339)				
	3 years	8% (362)				
	6 years	11% (552)				
Externalizing problems (borderline & clinical)	1½ year	13% (644)				
	3 years	7% (312)				
	6 years	6% (322)				

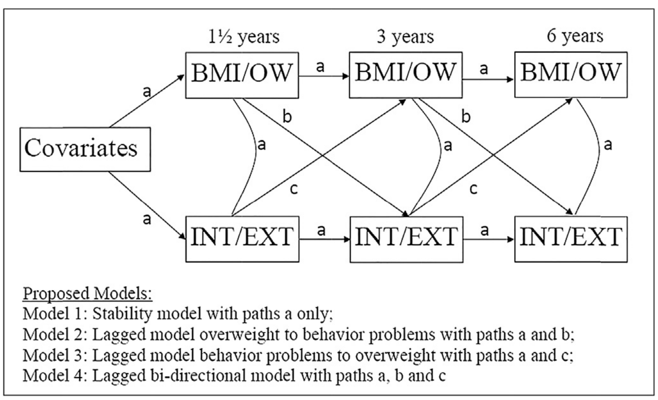

Fig. 1. Proposed models. *Note.* BMI = Body Mass Index. OW = Overweight. INT= Internalizing. EXT = Externalizing.

We used comparative fit index (CFI) > 0.90 and a root mean square error of approximation (RMSEA) < 0.08 to indicate an acceptable-to-good fit (Browne and Cudeck, 1993). Furthermore, model improvement was indicated by a significant difference in χ^2 ($p < 0.05$). Models 2 and 3 were compared to Model 1, and Model 4 was compared to Models 1, 2, and 3. All models were tested on the imputed data ($N = 6624$). However, a large part of this sample had missing data. Therefore, the models were also tested in the participants who had complete data on the main variables on two out of the three waves ($N = 4017$). Furthermore, the model was also tested with a dichotomous variable of problem behavior (normal range vs. borderline/clinical) and body mass. Finally, we used multigroup analyses to examine moderation by gender, ethnicity, and timing of adiposity rebound. A model in which all parameters were free to vary between the groups (A) was compared to a model in which regression coefficients were constrained to be equal for the groups (B). A lack of significant improvement indicates equivalence in the model parameters. Child ethnicity was dichotomized in Western (European and North-American) and Non-Western (e.g., Turkish, Surinamese, Moroccan). The moderation of timing of adiposity rebound was measured by creating two groups: rebound between one-and-a-half years and three years ($N = 1191$), and rebound between three and six years old ($N = 3278$).

2. Results

2.1. Preliminary analyses

Bivariate correlations between all variables used in the present study are shown in Table 2. Noteworthy are the high correlations for SDS-BMI over the three time points, indicating a certain stability over time ($r = 0.54$ to 0.73). All potential covariates were related to SDS-BMI overweight, as well as internalizing and externalizing behavior and were therefore included as covariates, except for breastfeeding which was not significantly related to overweight or behavior problems, see online supplement. All nominal/ordinal covariates (maternal education, income, ethnicity, and parity) were also significantly related to overweight and behavior problems ($p < 0.05$ on the ANOVA's of each variable).

2.2. Main analyses

2.2.1. SDS-BMI and problem behavior

When estimating models for SDS-BMI, a problem occurred with interpretation. In the models for both internalizing and externalizing behavior, bidirectional paths were best fitting. However, the paths were contrasting: Problem behavior was positively associated with higher future SDS-BMI (β ranged between 0.03 and 0.06), while SDS-BMI was negatively associated with future problem behavior (β ranged −0.02 between −0.05). This statistical artifact is known to occur in models where the stability coefficients over time are substantially higher than the coefficients of the cross-lagged paths (Maassen and Bakker, 2001; Saris and Stronkhorst, 1984). Therefore, it was decided not to interpret the results for SDS-BMI.

2.2.2. Overweight and externalizing behavior

Table 3 provides an overview of the fit indices of the models for externalizing behavior and overweight. The stability model had a good fit (RMSEA <0.08, CFI >0.90). The model improved after adding cross-lagged paths: Model 2 did not have a significantly better fit than the stability model ($\Delta\chi^2 = 1.81$, $df = 2$, $p > 0.10$), but Models 3 ($\Delta\chi^2 = 26.28$, $df = 2$, $p < 0.001$) and 4 did ($\Delta\chi^2 = 28.07$, $df = 4$, $p < 0.001$). Model 4 was significantly better than Model 2 ($\Delta\chi^2 = 26.26$, $df = 2$, $p < 0.001$), but not significantly better than Model 3 ($\Delta\chi^2 = 1.69$, $df = 2$, $p > 0.10$); as such, the most parsimonious model was Model 3. This final model is illustrated in panel A of Fig. 2. The regression coefficients of the covariates are shown in

Table 2
Pearson correlations between overweight, internalizing and externalizing behavior problems.

Variable	Period	1	2	3	4	5	6	7	8	9	10	11
SDS-BMI	1) 1½ year											
	2) 3 years	0.72**										
	3) 6 years	0.54**	0.73**									
Overweight	4) 1½ year	0.68**	0.53**	0.38**								
	5) 3 years	0.44**	0.61**	0.47**	0.47**							
	6) 6 years	0.31**	0.46**	0.70**	0.28**	0.48**						
Externalizing	7) 1½ year	-0.02	0.01	0.05**	-0.02	<0.01	0.04**					
	8) 3 years	-0.04*	<0.01	0.04*	-0.03	<0.01	0.06**	0.57**				
	9) 6 years	-0.06**	-0.01	0.03*	-0.05**	<0.01	0.02	0.43**	0.59**			
Internalizing	10) 1½ year	-0.03	0.01	0.07**	-0.01	0.02	0.08**	0.61**	0.40**	0.29**		
	11) 3 years	-0.06**	-0.04*	<0.01	-0.03	<0.01	0.05**	0.39**	0.63**	0.39**	0.54**	
	12) 6 years	-0.07**	-0.05**	-0.01	-0.05**	-0.01	0.01	0.34**	0.44**	0.70**	0.38**	0.54**

*$p < 0.05$. ** $p < 0.01$.

Table 3
Fit indices for externalizing and internalizing FIML models.

		Model 1	Model 2	Model 3	Model 4
Externalizing FIML	*N*	6624	6624	6624	6624
	χ^2	1441.49	1439.68	1415.11	1413.42
	df	108	106	106	104
	CFI	0.96	0.96	0.96	0.96
	RMSEA	0.04	0.04	0.04	0.04
Internalizing FIML	*N*	6624	6624	6624	6624
	χ^2	1497.12	1490.74	1449.22	1443.32
	df	108	106	106	104
	CFI	0.96	0.96	0.96	0.96
	RMSEA	0.04	0.04	0.04	0.04

Note. FIML = Full Information Maximum Likelihood, CFI = Comparative Fit Index, RMSEA = Root Mean Square Error of Approximation.

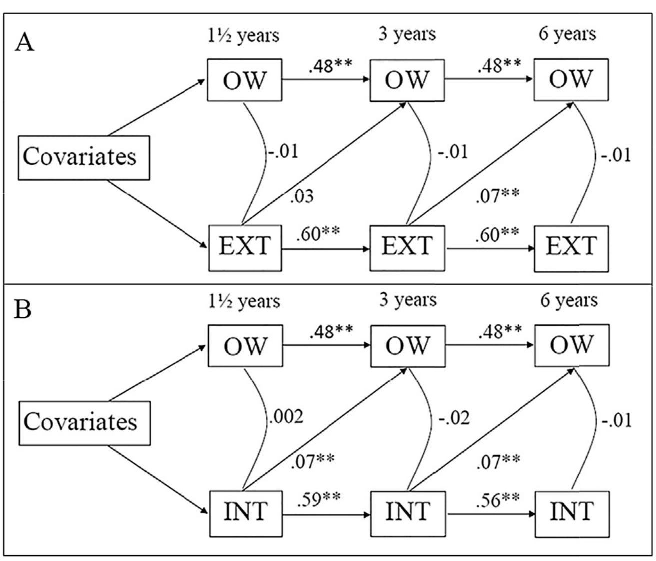

Fig. 2. Best-fitting model results. (A) Best-fitting models for externalizing behavior problems and overweight. (B) Best-fitting models for internalizing behavior problems and overweight. *Note.* **$p < 0.001$. Standardized coefficients are reported.

the Electronic Appendix. A small significant positive association was found for externalizing behavior at three years on overweight status at six years ($\beta = 0.07$, $p < 0.01$). All associations were similar in significance and strength when timing of adiposity rebound was taken into account. In addition, the analyses indicated that results were similar on the subset of participants with complete data on the main variables on at least two out of three waves ($N = 4017$). Finally, in the model with dichotomized externalizing behavior, the same relation between externalizing behavior and overweight was found: Having borderline to clinical levels of externalizing behavior at three years was related to overweight at six years ($\beta = 0.23$, $p < 0.01$).

2.2.3. Overweight and internalizing behavior

Similar to the results of externalizing behavior, the stability model for overweight and internalizing behavior showed a good fit (RMSEA <0.08, CFI >0.90; see Table 3). Model 2 ($\Delta\chi^2 = 6.38$, $df = 2$, $p < 0.05$), Model 3 ($\Delta\chi^2 = 47.90$, $df = 2$, $p < 0.001$), and Model 4 ($\Delta\chi^2 = 53.80$, $df = 4$, $p < 0.001$) all had a significantly better fit compared to the stability model. In addition, Model 4 had a significantly better fit compared to Model 2 ($\Delta\chi^2 = 47.42$, $df = 2$, $p < 0.001$) but was not significantly better than Model 3 ($\Delta\chi^2 = 5.90$, $df = 2$, $p > 0.05$). As such Model 3 is the most parsimonious and best fitting model (see Fig. 2, panel B). The regression coefficients of the covariates are shown in the Electronic Appendix. A small significant positive association was found between internalizing behavior at one-and-a-half years and overweight status at three years ($\beta = 0.07$, $p < 0.01$). This small positive association was also found for internalizing behavior at three years and overweight status at six years ($\beta = 0.07$, $p < 0.01$). In addition, all associations were similar in significance and strength when timing of adiposity rebound was taken into account. Furthermore, analyses indicated that results were similar on the subset of participants with complete data on the main variables on at least two out of three waves ($N = 4017$). Finally, in the model with dichotomized internalizing behavior, the same relation between internalizing behavior and overweight was found: Having borderline to clinical levels of internalizing behavior at 1½ years was related to overweight at three years ($\beta = 0.07$, $p < 0.01$), and internalizing behavior at three years was related to overweight at six years ($\beta = 0.05$, $p < 0.01$).

2.2.4. Moderation of gender, ethnicity and timing of adiposity rebound

Finally, multi-group analyses were performed on the best fitting models to investigate the potential moderating roles of ethnicity, gender, and timing of adiposity rebound. Ethnicity was found to be a significant moderator of the association between externalizing behavior and overweight ($\Delta\chi^2 = 90.42$, $df = 42$, $p < 0.001$), and internalizing behavior and overweight ($\Delta\chi^2 = 181.39$, $df = 42$, $p < 0.001$). The cross-lagged paths between overweight and problem behavior were not significant for the Non-Western children, while for the Western children there was a significant association between externalizing behavior at three years and overweight at six years ($\beta = 0.06$, $p < 0.001$), and internalizing behavior at three years and overweight at six years ($\beta = 0.04$, $p < 0.05$). In addition, the stability of overweight was higher for Non-Western children ($\beta = 0.54$), compared to Western children ($\beta = 0.44$). Furthermore, gender was a significant moderator of the association between internalizing behavior and overweight ($\Delta\chi^2 = 76.63$, $df = 54$, $p = 0.02$), but not between externalizing behavior and overweight ($\Delta\chi^2 = 69.79$, $df = 54$, $p = 0.07$). Stability for overweight was higher for girls (1½–3 years: $\beta = 0.52$, and 3–6 years: $\beta = 0.50$), than for boys ($\beta = 0.43$ and $\beta = 0.45$); the strengths of the cross-lagged paths from internalizing behavior to overweight were similar for boys and girls. Finally, timing of adiposity rebound was also a significant moderator of the associations between externalizing behavior and overweight ($\Delta\chi^2 = 75.29$, $df = 56$, $p = 0.04$), and internalizing behavior and overweight ($\Delta\chi^2 = 75.02$, $df = 56$, $p < 0.05$). In the group of children who had their rebound between one-and-a-half years and three years, there was a significant association (and a trend) of problem behavior at one-and-a-half years on overweight at three years (externalizing: $\beta = 0.06$, $p = 0.06$; internalizing: $\beta = 0.10$, $p < 0.01$), and problem behavior at three years on overweight at six years (externalizing: $\beta = 0.07$, $p = 0.01$, internalizing: $\beta = 0.07$, $p < 0.05$). In contrast, in the group of children who had their rebound between three and six years, there was only a significant association of behavior problems at three years on overweight at six years (externalizing: $\beta = 0.05$, $p < 0.01$, internalizing: $\beta = 0.06$, $p < 0.01$). In addition, there were also important differences between the two rebound groups concerning the level of internalizing behavior problems and percentage of children with overweight: Children with an early adiposity rebound had more internalizing behavior problems ($M_{1½yrs} = 5.23$, $SD_{1½yrs} = 4.84$; $M_{3yrs} = 5.35$, $SD_{3yrs} = 5.45$; $M_{6yrs} = 5.90$, $SD_{6yrs} = 5.88$) across all time points compared to children with a late adiposity rebound ($M_{1½years} = 4.80$, $SD_{1½yrs} = 4.41$; $M_{3yrs} = 4.85$, $SD_{3yrs} = 4.64$; $M_{6yrs} = 5.40$, $SD_{6yrs} = 5.29$; $t_{1½yrs}$ (1,438) = 2.306, $p = 0.02$; t_{3yrs} (1,330) = 2.42, $p = 0.02$; $t_{1½yrs}$ (1,438) = 2.306, $p = 0.02$;; t_{6yrs} (1,509) = 2.30, $p = 0.02$). There was no difference in the level of externalizing behavior problems. Furthermore, in the early rebound group, 8.4% of the children had overweight at one-and-a-half years, 10.3% at three years and 25.2% at six years. In contrast, the later rebound group started with 21% children with overweight, but had 7.8% children left at three years, and 10.5% at six years.

3. Discussion

To our knowledge, this study is the first to investigate the association between overweight and internalizing and externalizing behavior in early childhood, while controlling for the adiposity rebound. Findings from this large prospective birth cohort study following children from one-and-a-half to six years of age, suggest that more externalizing and internalizing behavior in early childhood is followed by increases in overweight-status, although effect sizes were small. No association was found between early overweight and later internalizing or externalizing behavior. In addition, moderation effects of gender, ethnicity, and timing of adiposity rebound were found.

Before discussing the directions of these results, it should be noted that the cross-lagged effects that were found to be significant were small in size. It is possible that these effects reached significance simply because of our large sample size, without signifying any relevant associations for the development of overweight in young childhood. Still, it can be defended that small effects are of great importance. First, small effects may cumulate over time, resulting in large effects (Prentice and Miller, 1992). It is likely that our small effects of behavior problems on overweight are precursors of these effects in (young) adulthood. Second, it has been argued that even small effects detected in a population-based rather than a clinical sample can have considerable policy implications when it comes to health-related issues that affect a large number of individuals across the life span (as is the case for overweight), which makes small changes highly cost-effective (McCartney and Rosenthal, 2000), especially considering the substantial mental and physical health gains that effective obesity intervention programs could establish (Reilly and Kelly, 2011). Third, considering the high stability of both weight status and problem behavior over time, in combination with the large number of covariates, it is likely that the small cross-lagged effects found in this study in fact *do* signal potential relevant pathways for the development of overweight at this young age.

The results that we found are partly in line with findings from earlier studies. Similar to our study, Anderson et al. (2010) found an association between externalizing behavior and later elevated BMI. However, other studies did not find any association between problem behavior and overweight at pre-school age (e.g., Bradley et al., 2008; Garthus-Niegel et al., 2010). Nevertheless, the study by Anderson and colleagues is unique because it used a different analytic approach. This study used data of the same cohort as Bradley et al. (2008), but used linear mixed effects models to estimate BMI trajectories (Anderson et al., 2010), while Bradley et al. (2008) used cross-lagged structural equation models. This last method was also used in the other studies (Garthus-Niegel et al., 2010; Lawlor et al., 2005). Our study is methodologically comparable to these studies by also employing cross-lagged modeling, but unlike these studies, we took the adiposity rebound into account to adjust for the trajectory of BMI. However, in the current study the adiposity rebound did not have an effect on the associations between behavior and overweight. Therefore, a different explanation is required. For example, it is possible that the use of a variable reflecting healthy weight versus overweight in our study rather than the use of a continuous BMI variable in other studies can explain the differences in found associations. An approach with a continuous BMI variable also includes the prediction of variations within healthy weight, which may not reflect clinically meaningful differences.

Interestingly, the direction of the associations between problem behavior and overweight was similar for externalizing and internalizing behavior. A first underlying mechanism could be that the association between problem behavior and overweight is mediated by parenting. Children with *externalizing* behavior may be challenging for parents. In response to difficult behavior, parents may give in to their children when they ask for food or screen time, or refuse to eat their vegetables. In contrast, parents of children with *internalizing* behavior may use candy or other desired foods to comfort their child (Stifter et al., 2011). Previous studies have indeed indicated that feeding practices are related to the weight status of the child (Hughes et al., 2008).

A second explanation for the association between externalizing behavior and overweight may be found in the traits of externalizing behavior: Children with more externalizing behavior have more problems with self-control and lack of inhibitory control (Eiden et al., 2007). These children may not be able to respond appropriately to their internal feelings of hunger and they may keep eating (e.g., Graziano et al., 2010), which may ultimately lead to overweight. Third, the association between externalizing behavior and overweight, and internalizing behavior and overweight, could also be the result of a common effect of a third variable, such as sedentary behavior (Monshouwer et al., 2012).

Another interesting finding was the lack of prospective associations in the other direction: Overweight at one-and-a-half or three years of age did not lead to more internalizing or externalizing behavior at three or six years, respectively, which contrasts with studies in older samples, in which overweight precedes mental health problems (Bradley et al., 2008; Jansen et al., 2013). Children in early childhood may not yet have the cognitive ability, such as processing that they are different from the group, to feel as unhappy about being overweight as older children do. This explanation is supported by a longitudinal study by Klesges et al. (1992), in which self-esteem was not related to body fat between the ages of three and five years.

Finally, our moderation analyses indicate that the association between problem behavior and overweight is similar for boys and girls, which is in line with previous studies (Anderson et al., 2010; Bradley et al., 2008). However, differences were found for Western and Non-Western children, which is in line with previous studies that found differences for different ethnicity groups (Chang and Halgunseth, 2015; Tillery et al., 2015). In contrast, a different study on externalizing behavior and body mass did not find a difference for ethnicity in early childhood, but did in middle childhood (Anderson et al., 2010). A statistical explanation for these differences could be that the non-significant results are due to the high stability coefficients of Non-Western children, compared to the Western children. Thus, very small non-significant cross-lagged paths may have resulted because all variance on future overweight could already be explained by earlier overweight. Another explanation could be that the underlying mechanisms are different for Western and Non-Western children. For example, parental feeding practices and concerns about eating habits and weight of the child differ according to ethnicity (Evans et al., 2009). Furthermore, differences were found in associations for children with an early adiposity rebound (between one-and-a-half and three years) versus children with a later rebound (between three and six years): An association between problem behavior and overweight was found only for the early rebound group. In addition, these children had more internalizing problem behavior. The differences between the two groups might be explained by individual variation in growth curves. However, this explanation seems less likely, since the model was controlled for individual variation in timing of rebound. Another explanation could be that the two groups are just very different from each other. We have already observed differences in amount of problem behavior, but it is also possible that these children also differ in lifestyle, in line with other studies that have found associations between a sedentary lifestyle and timing of adiposity rebound (Taylor et al., 2005).

3.1. Limitations

This study has three limitations of note. First, a considerable proportion of the sample had missing data on one or more covariates. We used full information maximum likelihood to deal with these missing values and this may have led to some bias, because FIML is a model-based procedure (Graham, 2003), which means that the scores that are imputed are based only on data that is used in the model, and not by all data. However, a large sample was used and similar results were found between the subgroup with less missing data and the total group. Furthermore, procedures for pooling of multiply imputed data are not well validated as an alternative to maximum likelihood estimations. Second, maternal BMI was determined during pregnancy. Even though this score was corrected, maternal weight will have some error, because not all mothers gained an average amount of weight during pregnancy. Finally, the Child Behavior Checklist, as filled out by the parent, was the only measure of problem behavior. It would have been better to have observational measures for problem behavior as well. However, the CBCL is a validated measure (Achenbach and Rescorla, 2000) and observational measures of problem behavior at one-and-a-half years may not be very reliable. For example, observation of aggression in early childhood may be more likely to reflect a state rather than a trait (Mesman et al., 2008).

4. Conclusion

In conclusion, the present study showed a small association between problem behavior and successive overweight in early childhood. This finding contrasts with those from earlier large studies, most of which did not find an association before school entry (e.g., Bradley et al., 2008; Garthus-Niegel et al., 2010). Thus, young children with behavior problems may benefit from careful monitoring of eating behavior and weight development. This principle likely holds true especially for children between of 2- and 6-years old, because other research suggests that it is the best period for primary prevention of adult overweight (De Kroon et al., 2010). Future studies should focus on mechanisms that may underlie this association. Specifically, parental feeding practices should be investigated in this regard.

Finally, the results in this study, together with previous studies, indicate that an early adiposity rebound is associated with an increased risk of obesity in later life (Rolland-Cachera et al., 2006), imply that children with an early rebound have an increased risk of problem behavior and overweight in later life. Therefore, it is important to postpone the adiposity rebound as far as possible, by minimizing weight gain at an early age. Future studies are needed on how to delay the adiposity rebound. In addition, future studies on the development of overweight in early childhood and its antecedents and consequences should take the adiposity rebound into account.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.socscimed.2016.09.001.

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