Martoccio Tiffany (Orcid ID: 0000-0001-8705-0489)
Peterson Karen (Orcid ID: 0000-0003-0471-1427)

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Tiffany L. Martoccio, PhD[1], Neda Senehi, PhD[2],

Holly E. Brophy-Herb, PhD[3], Alison L. Miller, PhD[4, 5],

Mildred A. Horodynski, RN, PhD[3], Niko Kaciroti, PhD[4, 6],

Dawn Contreras, PhD[7], Karen E. Peterson, DSc[4, 8],

Julie C. Lumeng, MD[4, 8, 9]

[1]Department of Human Development and Quantitative Methodology, University of Maryland College Park; [2]Department of Psychiatry, University of Colorado Anschutz Medical Campus; [3]Department of Human Development and Family Studies, Michigan State University; [4]Center for Human Growth and Development, University of Michigan; [5]Department of Health Behavior and Health Education, University of Michigan School of Public Health; [6]Department of Biostatistics, University of Michigan School of Public Health; [7]Michigan State University Extension; [8]Department of Nutritional Sciences, University of Michigan School of Public Health; [9]Department of Pediatrics, University of Michigan Medical School

Correspondence

Tiffany L. Martoccio, Ph.D., Department of Human Development and Quantitative Methodology University of Maryland College Park, 3942 Campus Drive, Benjamin Building, Suite 3304 College Park, MD 20742, USA.

Email: tiffany.martoccio@gmail.com

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Correspondence

Tiffany L. Martoccio, Ph.D., Department of Human Development and Quantitative Methodology University of Maryland College Park, 3942 Campus Drive, Benjamin Building, Suite 3304 College Park, MD 20742, USA.

Email: tiffany.martoccio@gmail.com

Abstract

Background: Behavior problems and obesity are related but research findings have been inconclusive regarding the direction of effects.

Objectives: This study examined the cross-lagged associations between behavior problems, body mass index (BMI) and obesity in preschoolers, and whether sex modified these associations.

Methods: Repeated measures of teacher-reported externalizing (EXT) and internalizing (INT) behavior problems (clinically significant *T* scores were >90th percentile), BMI z-scores (BMI-Z) and obesity status (BMI ≥95th for age and sex) were assessed in the fall (T1) and spring (T2) of the school year in Head Start preschoolers (*N* = 423). Associations were examined with cross-lagged modeling.

Results: Prospective paths from T1 clinically significant EXT to both T2 BMI-Z (β = 0.05) and obesity (β = 0.18) were significant. There was no evidence that T1 BMI-Z or obesity preceded T2 behavior problems. However, sex-specific models indicated that T1 BMI-Z was prospectively associated with higher T2 EXT for boys (β = 0.13), but not girls. T1 EXT was predictive of subsequent BMI-Z (β = 0.09) and obesity (β = 0.33) at T2 for girls only.

Conclusion: Findings suggests that behavior problems, particularly externalizing behaviors, are prospectively related to childhood obesity, and early prevention methods should reflect sex-specific modifications.

Keywords: BMI; cross-lagged analysis; behavior problems; Head Start; preschoolers; obesity

1. Introduction

Childhood obesity is a significant public health concern that disproportionately affects low-income and minority children.[1] Approximately one in eight children in the Unites States are obese.[2] Accumulating evidence suggests that behavior problems (e.g., externalizing and internalizing behaviors) frequently co-occur with obesity in children[3-5] but the directionality of effects remains unclear, compromising the efficacy of early prevention methods.[6] Most studies of behavior problems and childhood obesity have focused on school-age children and adolescents (5 to 18 years)[5] while neglecting the preschool period of development during which rapid weight gain and obesity,[7] as well as behavior problems, particularly externalizing behaviors,[8] often emerge. Given the especially high risk of obesity among low-income children, it is critical to identify the directional pattern of association with behavior problems and sex-specific variations in this link. The current study examined associations between behavior problems and BMI and obesity and whether child sex modified these associations in low-income preschoolers. Clarifying directionality in these associations may be used to inform targeted prevention and intervention efforts in reducing risk for behavior problems in the context of childhood obesity.

Longitudinal associations from behavior problems to obesity

The association between children's problem behaviors and obesity may be explained by common underlying mechanisms including child (e.g., impulsivity[9]) and family characteristics (e.g., higher risk demographic or parenting factors[10]). In our own work we have found that non-optimal caregivers' feeding styles (e.g., uninvolved, authoritative) were more often observed in families with greater demographic (e.g., food insecurity) and psychosocial risk (e.g., maternal

depression) and this increased risk for overweight in preschoolers.[11] A number of longitudinal population-based studies have examined bidirectional associations between externalizing and internalizing behavior problems and body mass index (BMI) and obesity in early childhood.[12-14] These studies have yielded mixed results. Two prospective studies found that early-occurring externalizing behaviors predicted subsequent increases in BMI z-scores and overweight/obesity status in early childhood[13] and early adolescence.[8] Greater externalizing behaviors at 24 months of age were associated with higher BMI, and this difference in BMI persisted into middle childhood.[8]

Moreover, in a sample of European children with low demographic risk (e.g., high family income and maternal education), Camfferman et al.[13] tested bidirectional effects between behavior problems and overweight status and found that internalizing behaviors at ages 1.5 and 3 years were associated with subsequent overweight status at 3 and 6 years, respectively. These bidirectional associations, however, have not been tested in low-income racial and ethnic minority preschoolers with disproportionately greater risk for both obesity and behavior problems. Two additional prospective studies observed no longitudinal associations between externalizing and internalizing behaviors and BMI z-scores across toddlerhood[14] and from age 2 to 12 years.[12] Mackenbach et al.[15] indicated a negative relation between internalizing behaviors at age 3 and later BMI at age 4. This contradictory inverse finding was, however, mostly explained by children's emotion-related eating behaviors such that high emotional undereating may contribute to lower BMI in children with internalizing behaviors. Obesogenic eating behaviors, such as food responsiveness and emotional overeating were also suggested mechanisms through which internalizing behaviors link to BMI z-scores in children between

ages 3.5 and 4 years.[16] Thus, prospective associations examined in the current study address limited understanding of bidirectionality of links in a sensitive developmental stage (e.g., preschoolers) from low-income racial and ethnic minority families experiencing socioeconomic adversity.

Longitudinal associations from obesity to behavior problems

Some studies suggest that overweight and obesity may contribute to subsequent behavior problems, although the magnitude of reported effects is modest. Most of this research has been conducted with school age children, adolescents, and young adults. Other studies have examined behavior problems and BMI in early childhood but not found predictive relationships until the school age years. For example, BMI at age 7 years predicted internalizing symptoms at age 11.[17] Bradley et al.[12] also found that higher BMI was associated with subsequent internalizing, but not externalizing behavior problems in girls and boys, although this association was not evident in early childhood from 24 to 54 months and only emerged by first grade. Research on putative pathways linking early obesity to behaviors problems are limited and require longitudinal studies to be examined. Current understandings of mechanisms point to early internalization of social stigma and consequent difficulties in peer relations. Children with obesity are more likely victims of peer rejection, social marginalization, and bullying as they transition into school-age classroom environments, and coping with these difficulties can be manifested as externalizing and internalizing behavior problems in middle childhood.[18,19] However, internalization of social rejection may be absent in preschoolers, buffering them from its effects on behavior.[20,21] Overall, there is not robust evidence that greater BMI predicts behavior problems, although relatively little research has examined BMI and behavior problems

in early childhood, particularly in low-income populations that are at disproportionately higher risk for obesity and behavior problems.

Sex-specific pathways

Associations between behavior problems and BMI and obesity may differ by child sex. Girls and boys are socialized differently, and, adults may often hold different sex-specific behavioral expectations. For instance, girls' externalizing behaviors may be viewed as more problematic for parents,[22] potentially relating to parents' use of food to manage behavior.[10] Research to date has revealed sex differences in associations between behavior problems and BMI, although results are often inconsistent. For instance, Datar and Sturm found that behavior problems and obesity were linked in school-age girls, but not in school-age boys.[4] However, prospective studies that examined temporal relations between obesity and behavior problems in boys and girls (<4 years) have shown contradictory results. For example, Chilean boys aged 1-5 years with overweight, compared to boys with normal weight, showed concurrently less internalizing behavior; this association was not present in girls.[23] Conversely, girls with overweight/obesity had fewer depressive symptoms than boys with overweight/obesity at ages 2-3 years, with a developmental increase in both aggressive and depressive symptoms between ages 5-8, surpassing boys with overweight.[24] These findings may suggest, for example, that girls become attuned to social stigma about weight during the preschool years that may in turn increase risk for externalizing and internalizing behaviors.[25,26]

Additional research highlights overweight boys' greater risk for later problem behaviors. Compared to normal weight boys, 3 year old boys with obesity display greater conduct problems concurrently and greater problems in peer relationships longitudinally (age 5). In contrast, 3 year

old girls with obesity display more prosocial behaviors than their normal weight counterparts.[27] These findings suggest that boys and girls with obesity may approach peer relationships differently. Given that girls are often socialized to be more attuned to the social nuances of social interactions and utilize peer relationships as emotional support systems, it could be that overweight/obese girls are less likely to externalize behaviors than boys in order to conform socially.

Mixed results in current literature may reflect inconsistencies in the analytic design, age of participants, and behavioral assessments across prior studies. Sex differences in the links between behavior problems and obesity suggest varying risk for boys vs. girls that must be further tested. Proposed sex-specific pathways underlying *bidirectional links* between obesity and behavior problems are not well known but may include sex differences in shared contributing factors to obesity and behavior problems. For instance, girls tend to have both biological and behavioral advantage in emotional and behavioral regulation[28,29] that may reduce engagement in obesity-related behaviors (e.g., emotional overeating). Boys' greater risk for externalizing and girls' greater risk for internalizing may make it easier for teachers to notice and be required to manage overweight boys' difficult behaviors. Moreover, children's emotional and behavioral adjustment varies via sex-differences in peer relationships (e.g., girls' greater tendency for support seeking, boys' greater engagement in physical activity and play[30]). These findings point to risk-protective or risk-augmenting roles of peer-relationships for boys vs. girls that may further increase risk for overweight/obesity. Therefore, we aimed to examine sex differences in bidirectional links between obesity and problem behaviors.

The present study

Elucidating the temporality of the association between preschoolers' behavior problems and measures of BMI and obesity in community-based samples may lead to the development of more comprehensive and better targeted early childhood interventions. To address inconsistencies in the literature, the current study tested the association between preschoolers' behavior problems and BMI and obesity. It is also imperative to identify associations using clinically significant behavior problems.[31] By focusing on an under-studied developmental stage (early childhood) in this literature, we drew on a longitudinal (i.e., two time points), community-based study of Head Start preschoolers (3-4 years). In addition, we considered sex as a variable that may contribute to differences in associations between behavior problems and BMI and obesity. We hypothesized that more behavior problems would be associated with subsequent increased BMI z-score and obesity in preschoolers and that higher BMI z-score and obesity would be associated with later increases in behavior problems. We also hypothesized that the directionality of effects will differ in boys vs. girls.

2. Methods

2.1 Study sample

Data for this study were collected as part of a cluster-randomized community-based obesity intervention trial among 697 preschoolers participating in Head Start programs located in urban and rural Michigan from 2011 to 2015.[32,33] In accordance with Head Start program eligibility guidelines, participants' family incomes were at or below the federal poverty level. Study randomization occurred in the fall of the school year into one of three study arms embedded in Head Start (HS). One arm consisted of exposure to the Preschool Obesity Prevention Series (POPS), which focused primarily on nutrition education for children and

parents and healthy mealtime planning for parents (HS+POPS). The second arm included POPS exposure in addition to the Incredible Years Series (IYS), a program that emphasizes positive behavioral management techniques (HS+POPS+IYS).[34] The interventions consisted of classroom lessons for children during HS, as well as parent groups. The control arm consisted of usual HS exposure (HS/Control). Exclusion criteria were significant medical problems or developmental disabilities, foster case, or non-fluency in English. Although there were no significant intervention effects on child's weight status in the larger study,[32] we took a conservative approach to account for any potential intervention effects and excluded participants allocated to the second arm (HS+POPS+IYS) from the current study. Thus, data from 442 participants, 224 (51%) allocated to HS+POPS and 218 (49%) allocated to HS/Control, were retained for further analyses.

2.2 Procedure

Data collection occurred in the fall between September—October (pre-assessment; T1) and in the spring between April—May (post-assessment; T2). Demographic factors, anthropometry, and behavior problems were measured at both time points. Data were collected from teachers, parents and their children either in the home or classroom setting. Parents received up to $150 for data collection activities. Prior to data collection, the study received institutional review boards of the University of Michigan and Michigan State University approval and written informed consent was obtained.

2.3 Measures

The Social Competence and Behavior Evaluation (SCBE) Scale,[35] composed of 60 items, was used to measure children's externalizing (EXT) and internalizing (INT) behavior

problems via teacher report. Normalized *T* scores (*M* = 50, *SD* = 10) for age and sex were generated, with higher scores corresponding to more problematic behaviors. Teacher-reported behavior problem scores ranged from 30 to 70. Internal consistency was high for teacher-reported EXT (α_{T1} = 0.92; α_{T2} = 0.93) and INT (α_{T1} = 0.83; α_{T2} = 0.84) scales. *T* scores were categorized as "clinically significant"[31] behavior problems when they were >90th percentile for the entire sample.

Research staff measured participants without shoes or heavy clothing. Measures were taken twice and averaged. BMI was calculated and child BMI z-score (BMI-Z) derived.[36] Obesity was defined as a BMI ≥95th percentile for age and sex.

Parents reported child sex, age, race and ethnicity, and child birth weight (kg) at study intake. Parent BMI was calculated based on weight and height measured by research staff.

2.4 Statistical analyses

Data were inspected for potential outliers using an interquartile range approach (above 3 quartiles). One child was 72 months of age at intake and dropped from further analyses. The current study also excluded children who were categorized as underweight (BMI $\leq$ 5th percentile for age and sex) at either T1 or T2 (*n* = 18). A total of 423 children were retained for further analyses. Of the total sample, 80% had complete data or missed data on only one or two key study variables. Fewer than 5% of the cases were missing all T2 key measures. No key variables were missing for more than 25% of the sample.

To examine the bidirectional longitudinal associations between behavior problems and BMI and obesity, cross-lagged analyses were conducted within a structural equation modeling (SEM) framework using M*plus* 8.[37] The proposed model depicting cross-lagged paths is

presented in Figure 1. By drawing on longitudinal data, cross-lagged analysis models the relation between T1 BMI and obesity and T2 behavior problems, while simultaneously modeling the relation between T1 behavior problems and T2 BMI and obesity. In order to examine unique effects of EXT and INT, these variables were modeled simultaneously, with each controlling for the effects of the other. Using multivariate SEM, four models were computed using combinations of continuous and categorical (clinically significant) EXT and INT variables with BMI-Z and obesity variables (Model 1 used continuous EXT, INT, and BMI-Z variables; Model 2 used continuous EXT and INT variables and categorical obesity variable; Model 3 used categorical EXT and INT variables and continuous BMI-Z variable; Model 4 used categorical EXT, INT, and obesity variables). A second set of analyses examined these models using multi-group mixture modeling with known classes to test sex-specific associations between boys and girls.

Employing Bayesian estimation technique, model fit was evaluated with Bayesian posterior predictive checks using χ^2 statistics and the corresponding posterior predictive *p* values (PPP). A *p* value within 0.05-0.95 range is indicative of acceptable model fit.[38] Bayesian techniques were found to increase model power, particularly when estimating binary outcomes, and to increase the likelihood of unbiased parameter estimates.[39] Missing data were handled using full information maximum likelihood (FIML) estimation. Models controlled for T1 measures of child's sex, age, race and ethnicity, and birth weight, parent BMI, and intervention assignment (HS+POPS vs. HS/Control).

3. Results

Characteristics of the current analytic sample are shown in Table 1. Children (51% girls) were on average 4.1 years old (*SD* = 0.5) and the cohort was 44% White (non-Hispanic), 30% Black (non-Hispanic), and 25% Hispanic or other. Parents were on average 30 years old at the intake interview (*SD* = 6.7). About half of all parents had a high school education or less (49%) and about half were obese (46%). About one-third (38%) of families were living in single parent households.

Cross-lagged associations in full sample

Fit statistics of the four full sample cross-lagged models indicated good model fit (PPP's ranged from 0.12-0.23; see Figure 2). Time stability path estimates were moderate to highly stable over time. In models 1-2, T1 EXT and INT were not associated with T2 BMI-Z and obesity. T1 BMI-Z and obesity were not associated with T2 EXT and INT. There was a significant cross-sectional association between EXT and BMI-Z at T1 (β = 0.12, 95% CI: 0.02 to 0.21); there were no other significant cross-sectional associations between EXT or INT and BMI-Z and obesity at T1 or T2.

Cross-lagged models were underpowered to sufficiently test categorical INT. Therefore, full sample models 3-4 omitted clinically significant INT and examined clinically significant EXT associations with BMI-Z and obesity only. T1 clinically significant EXT was prospectively associated with higher T2 BMI-Z (β = 0.05, 95% CI: 0.00 to 0.09) and obesity (β = 0.18, 95% CI: 0.04 to 0.31). No relations were found for either BMI-Z or obesity at T1 and subsequent clinically significant EXT at T2. Concurrently, the association between clinically significant EXT and BMI-Z was significant at T1 (β = 0.14, 95% CI: 0.04 to 0.23).

Multi-group cross-lagged associations by child sex

Similarly, fit statistics of multi-group cross-lagged models 1 (PPP = 0.19) and 2 (PPP = 0.25) indicated good model fit. Models 3-4 were underpowered to sufficiently test cross-lagged associations in a multi-group structure and thus no further discussion. As shown in Table 2, time stability estimates were moderate to highly stable over time for both boys and girls.

Cross-lagged associations among boys. T1 BMI-Z was significantly associated with T2 EXT (β = 0.13, 95% CI: 0.01 to 0.25). There were no other significant cross-lagged or cross-sectional associations between INT or EXT and BMI-Z and obesity.

Cross-lagged associations among girls. T1 EXT was significantly associated with T2 BMI-Z (β = 0.09, 95% CI: 0.01 to 0.16) and obesity (β = 0.33, 95% CI: 0.10 to 0.53). T1 EXT was associated with T1 BMI-Z (β = 0.21, 95% CI: 0.07 to 0.35). There were no other significant cross-lagged or cross-sectional associations between INT or EXT and BMI-Z and obesity.

It should be noted that no significant HS+POPS program effects were observed in the full sample models. However, in the multi-group models, HS+POPS impacted girls' EXT at T2 (β = -0.17, 95% CI [-0.28 to -0.05]). To test the robustness of our findings, models were re-calculated including families allocated to the HS/Control group only. Model estimates did not change appreciably when excluding the HS+POPS sample.

4. Discussion

The purpose of the current study was to examine cross-lagged associations between teacher-reported behavior problems and BMI-Z in a sample of preschool children from low-income families participating in Head Start. The results confirm our hypothesis that clinically significant externalizing behaviors at T1 were associated with subsequent BMI and obesity at T2. Findings also confirmed our hypothesis that the temporal directionality of pathways between

externalizing behaviors and BMI and obesity differed between boys and girls. While boys with higher BMI were at an increased risk of exhibiting subsequent externalizing behavior problems, girls with higher BMI were not. However, girls with higher early externalizing behavior problems were at greater risk for later obesity. No associations were observed between internalizing behaviors and BMI or obesity.

The associations seen in the current sample, after accounting for several relevant covariates, attest to the robust nature of externalizing behaviors as a risk factor for future obesity, particularly for girls. Elucidating the mechanisms through which externalizing behaviors are associated with obesity risk is imperative to practical implications. For instance, externalizing behaviors may confer relatively greater risk for later obesity as it may be more difficult for parents of children with externalizing to successfully regulate and respond to frequent food requests. Parents with difficulties in limit-setting may use food to manage their child's difficult behaviors[10] or allow more unhealthy foods or screen time. Girls with high externalizing behaviors may posit challenges for parents and elicit less supportive socialization behaviors from adults in part because externalizing behaviors are often less expected or accepted in girls than in boys.[22]

Another mechanism through which externalizing behaviors may be associated with obesity risk is poor self-regulation. Dysregulated emotions and behaviors, present in externalizing children, particularly girls, may interfere with children's ability to respond appropriately to their internal feelings of hunger, which may result in overeating and ultimately becoming obese.[9] As preschool boys and girls often differ in their regulatory skills, [28,29] these preliminary findings may shed light on sex-related differences in underlying pathways that must

be further examined and addressed in obesity prevention programming for preschool boys vs. girls.

Children with obesity are more likely to be victims of peer rejection, social marginalization, and bullying as they transition into school-age classroom environments and these difficulties can be manifested in externalizing behavior problems.[18,19] Children with obesity are often perceived more negatively by adults[40] and such biases could contribute to teachers' perceptions of behavior problems in boys with obesity. Given this, the relation between BMI and later externalizing behaviors in boys only, but not in girls, is somewhat surprising. Prior research has shown that girls become aware of societal preference for thinness in the preschool years[25] and are attuned to the stigma of obesity by the school age years.[26] Hence, we might have expected any negative messages about obesity to contribute to girls' behavioral problems. Additionally, evidence for links between child sex and physical activity point to boys' greater tendency for engagement in physical activity compared to girls.[41] However, lack of physical activity observed in preschool boys with obesity may limit peer interactions and increase feelings of social isolation and peer rejection which, in turn, contributes to behavior problems.[27] Such problematic peer relations may also contribute to teachers' negative perceptions of behavior problems in boys with obesity. Additionally, girls generally tend to exhibit more optimal emotional and behavioral regulation[42] which may have buffered them against possible social stigma (e.g., well-behaved girls may be perceived as less problematic regardless of BMI). Furthermore, it may be that for girls, peer pressure for thinness and social expectations for optimal appearance increase with age and contribute to emergence of internalizing symptoms in later stages of development such as preadolescence.[25,26]

There are several limitations to be noted in the current study. Parent-child mealtime interactions, dietary intake, and eating behaviors were not included in the current study models. As such, we cannot determine how associations with children's behavior problem and BMI measures may have varied per such contexts. The current study was limited by its reliance on teacher report for child behavior problems. Although we did assess children's adiposity over the school year, multi-year longitudinal cohort studies would provide a more comprehensive examination of development and allow for consideration of the role of nonlinear growth in obesity (e.g., adiposity rebound). Furthermore, the intervention study context of the sample and the fact that all children were low-income and also attending Head Start limits generalizability.

In conclusion, our study contributes to the growing body of literature on associations between behavior problems with BMI and obesity in preschool children and may inform early prevention and intervention programs addressing childhood obesity. Reducing the prevalence of childhood obesity is a public health challenge, and prevention and intervention services targeting early-occurring externalizing behavior problems may have the potential to play a powerful role in diminishing risk for this serious health crisis. Finally, sex-specific associations suggest greater risk for obesity in girls presenting with early behavior problems while boys with obesity may be at greater risk for later behaviors problems.

Table 1 Demographic and study assessment data (*N* = 423)

Table 2 Standardized path coefficients for the associations between teacher-reported behavior problems and BMI-Z/obesity by child sex

Figure 1 Proposed path model examining cross-lagged associations between behavior problems (assessed by the Social Competence and Behavior Evaluation Scale completed by teacher), BMI-Z and obesity at fall and spring of school year in preschoolers. BMI-Z indicates body mass index z-score.

Figure 2 Cross-lagged associations between BMI-Z/obesity and teacher-reported behavior problems for full sample models. Bold paths are significant at $P < 0.05$. Proportion of children with clinically significant internalizing behaviors was low and, thus, excluded from models 3-4. PPP indicates posterior predictive p-values; BMI-Z, body mass index z-score; EXT, externalizing behaviors; INT, internalizing behaviors.

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Conflict of interest

No conflict of interest was declared.

References

1. Isong IA, Rao SR, Bind MA, Avendaño M, Kawachi I, Richmond TK. Racial and Ethnic Disparities in Early Childhood Obesity. *Pediatrics.* 2018;141(1).
2. Centers for Disease Control and Prevention. Vital signs: obesity among low-income, preschool-aged children--United States, 2008-2011. *MMWR Morbidity And Mortality Weekly Report.* 2013;62(31):629-634.
3. Sawyer MG, Miller-Lewis L, Guy S, Wake M, Canterford L, Carlin JB. Is there a relationship between overweight and obesity and mental health problems in 4- to 5-year-old Australian children? *Ambul Pediatr.* 2006;6(6):306-311.
4. Datar A, Sturm R. Childhood overweight and parent- and teacher-reported behavior problems: Evidence from a prospective study of kindergartners. *Arch Pediatr Adolesc Med.* 2004;158(8):804-810.
5. Pulgaron ER. Childhood obesity: a review of increased risk for physical and psychological comorbidities. *Clin Ther.* 2013;35(1):A18-32.
6. Rankin J, Matthews L, Cobley S, et al. Psychological consequences of childhood obesity: psychiatric comorbidity and prevention. *Adolescent health, medicine and therapeutics.* 2016;7:125-146.
7. De Kroon ML, Renders CM, Van Wouwe JP, Van Buuren S, Hirasing RA. The Terneuzen birth cohort: BMI changes between 2 and 6 years correlate strongest with adult overweight. *PLoS One.* 2010;5(2):e9155.

8. Anderson SE, He X, Schoppe-Sullivan S, Must A. Externalizing behavior in early childhood and body mass index from age 2 to 12 years: Longitudinal analyses of a prospective cohort study. *BMC Pediatr.* 2010;10(49):1-8.

9. Graziano PA, Calkins SD, Keane SP. Toddler self-regulation skills predict risk for pediatric obesity. *Int J Obes.* 2010;34(4):633-641.

10. Baughcum AE, Burklow KA, Deeks CM, Powers SW, Whitaker RC. Maternal feeding practices and childhood obesity: a focus group study of low-income mothers. *Arch Pediatr Adolesc Med.* 1998;152(10):1010-1014.

11. Horodynski MA, Brophy-Herb HE, Martoccio TL, et al. Familial psychosocial risk classes and preschooler body mass index: The moderating effect of caregiver feeding style. *Appetite.* 2018;123:216-224.

12. Bradley RH, Houts R, Nader PR, et al. The relationship between body mass index and behavior in children. *Pediatrics.* 2008;153(5):629-634.

13. Camfferman R, Jansen PW, Rippe RCA, et al. The association between overweight and internalizing and externalizing behavior in early childhood. *Soc Sci Med.* 2016;168:35-42.

14. Garthus-Niegel S, Hagtvet KA, Vollrath ME. A prospective study of weight development and behavior problems in toddlers: The Norwegian Mother and Child Cohort Study. *BMC Public Health.* 2010;10:626-626.

15. Mackenbach JD, Tiemeier H, van der Ende J, et al. Relation of emotional and behavioral problems with body mass index in preschool children: The Generation R study. *J Dev Behav Pediatr.* 2012;33(8):641-648.

16. Mallan KM, Daniels LA, Nicholson JM. Obesogenic eating behaviors mediate the relationships between psychological problems and BMI in children. *Obesity (Silver Spring, Md).* 2017;25(5):928-934.

17. Patalay P, Hardman C. Comorbidity, codevelopment, and temporal associations between body mass index and internalizing symptoms from early childhood to adolescence. *JAMA Psychiatry.* 2019;76(7):721-729.

18. Janssen I, Craig WM, Boyce WF, Pickett W. Associations between overweight and obesity with bullying behaviors in school-aged children. *Pediatrics.* 2004;113(5):1187-1194.

19. Zeller MH, Reiter-Purtill J, Ramey C. Negative peer perceptions of obese children in the classroom environment. *Obesity* 2008;16(4):755-762.

20. Puhl RM, Latner JD. Stigma, obesity, and the health of the nation's children. *Psychol Bull.* 2007;133(4):557–580.

21. Puhl RM, Brownell KD. Psychosocial origins of obesity stigma: toward changing a powerful and pervasive bias. *Obes Rev.* 2003;4(4):213-227.

22. Wright AW, Parent J, Forehand R, Edwards MC, Conners-Burrow NA, Long N. The relation of parent and child gender to parental tolerance of child disruptive behaviors. *Journal of Child and Family Studies.* 2013;22(6):779-785.

23. Kagawa RM, Fernald LC, Behrman JR. Weight status and behavioral problems among very young children in Chile. *PLoS One.* 2016;11(9):1-15.

24. Cerniglia L, Cimino S, Erriu M, Jezek S, Almenara CA, Tambelli R. Trajectories of aggressive and depressive symptoms in male and female overweight children: Do they

share a common path or do they follow different routes? *PLoS One.* 2018;13(1):e0190731.

25. Worobey J, Worobey HS. Body-size stigmatization by preschool girls: In a doll's world, it is good to be “Barbie”. *Body Image.* 2014;11(2):171-174.
26. Di Pasquale R, Celsi L. Stigmatization of overweight and obese peers among children. *Front Psychol.* 2017;8(524).
27. Griffiths LJ, Dezateux C, Hill A. Is obesity associated with emotional and behavioural problems in children? Findings from the Millennium Cohort Study. *Int J Pediatr Obes.* 2011;6:e423-e432.
28. Matthews JS, Ponitz CC, Morrison FJ. Early gender differences in self-regulation and academic achievement. *J Educ Psychol.* 2009;101(3):689-704.
29. Wanless SB, McClelland MM, Lan X, et al. Gender differences in behavioral regulation in four societies: The United States, Taiwan, South Korea, and China. *Early Childhood Research Quarterly.* 2013;28(3):621-633.
30. Rose AJ, Rudolph KD. A review of sex differences in peer relationship processes: Potential trade-offs for the emotional and behavioral development of girls and boys. *Psychol Bull.* 2006;132(1):98–131.
31. Lumeng JC, Gannon K, Cabral HJ, Frank DA, Zuckerman B. Association between clinically meaningful behavior problems and overweight in children. *Pediatrics.* 2003;112(5):1138-1145.
32. Lumeng JC, Miller A, Horodynski M, et al. Improving self-regulation for obesity prevention in Head Start: A randomized controlled trial. *Pediatrics.* 2017;139(5):1-10.

33. Miller A, Horodynski M, Brophy-Herb HE, et al. Enhancing self-regulation as a strategy for obesity prevention in Head Start preschoolers: The Growing Healthy Study. *BMC Public Health.* 2012;12(1):1040.

34. Webster-Stratton C, Reid MJ. The Incredible Years parents, teachers and children training series: A multifaceted treatment approach for young children with conduct problems. In: Weisz J, Kazdin A, eds. *Evidence-based psychotherapies for children and adolescents.* New York: Guilford Publications; 2010:194–210.

35. LaFreniere PJ, Dumas JE. *Social competence and behavior evaluation.* Preschool ed. Los Angeles, CA: Western Psychological Services; 1995.

36. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth charts: United States. *Advanced Data from Vital and Health Statistics.* 2000;314:1-27.

37. Muthén LK, Muthén BO. *Mplus User's Guide.* Eighth ed. Los Angeles, CA: Muthén & Muthén; 1998-2017.

38. Gelman A, Carlin J, Stern H, Dunson D, Vehtari A, Rubin D. *Bayesian Data Analysis.* 3rd ed. New York: Chapman and Hall/CRC; 2013.

39. Muthén BO, Asparouhov T. Bayesian structural equation modeling: A more flexible representation of substantive theory. *Psychol Methods.* 2012;17(3):313-335.

40. Lynagh M, Cliff K, Morgan PJ. Attitudes and Beliefs of Nonspecialist and Specialist Trainee Health and Physical Education Teachers Toward Obese Children: Evidence for "Anti-Fat" Bias. *J Sch Health.* 2015;85(9):595-603.

41. Nielsen G, Pfister G, Bo Andersen L. Gender differences in the daily physical activities of Danish school children. *European Physical Education Review.* 2011;17(1):69-90.

42. Hosseini-Kamkar N, Bruce Morton J. Sex differences in self-regulation: An evolutionary perspective. *Front Neurosci.* 2014;8:1-8.

Table 1 Demographic and study assessment data (*N* = 423)

	Mean ± *SD* or *n* (%)
Demographic data	
Child age, y	4.10 ± 0.50
Child sex	
Boys	208 (49.2)
Girls	215 (50.8)
Child race/ethnicity	
White, non-Hispanic	187 (44.2)
Black, non-Hispanic	128 (30.3)
Hispanic or other race	106 (25.1)
Birth weight, kg	3.24 ± 0.57
Parent age, y	29.58 ± 6.66
Parent education	
≤ High school diploma or GED	208 (49.2)
Parent BMI, kg/m^2	31.39 ± 8.79
Parent weight status	
Obese (BMI ≥30)	195 (46.1)
Single parent household	159 (37.6)
Time 1 assessment data	
Externalizing behaviors	
T-score	48.56 ± 10.11
Clinically significant	53 (12.5)

Internalizing behaviors	
T-score	48.08 ± 8.87
Clinically significant	39 (9.2)
BMI-Z	0.698 ± 1.046
Obesity	64 (15.1)
Time 2 assessment data	
Externalizing behaviors	
T-score	50.38 ± 9.52
Clinically significant	54 (12.8)
Internalizing behaviors	
T-score	47.39 ± 8.72
Clinically significant	32 (7.6)
BMI-Z	0.704 ± 0.988
Obesity	54 (12.8)

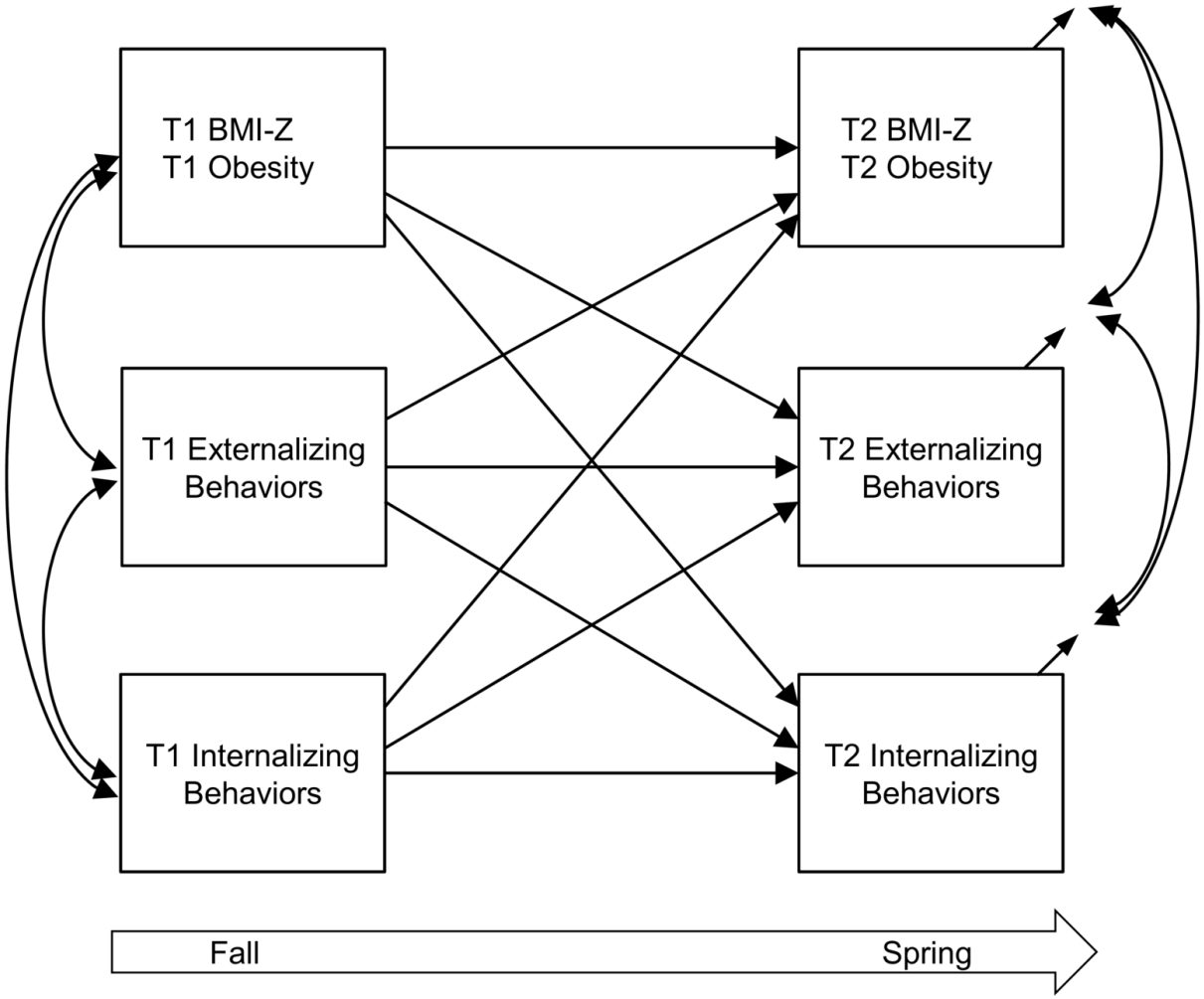
Two participants were missing child race/ethnicity data (<1%). GED, General Educational Development; BMI-Z, body mass index z-score.

Table 2 Standardized path coefficients for the associations between teacher-reported behavior problems and BMI-Z/obesity by child sex

	BMI-Z PPP = 0.19		Obesity PPP = 0.25	
	Boys	**Girls**	**Boys**	**Girls**
Time stability paths				
T1 BMI-Z/Obesity → T2 BMI-Z/Obesity	0.94*	0.87*	0.75*	0.57*
T1 EXT → T2 EXT	0.63*	0.63*	0.63*	0.63*
T1 INT → T2 INT	0.49*	0.43*	0.49*	0.43*
Cross-lagged paths				
T1 EXT → T2 BMI-Z/Obesity	-0.05	0.09*	-0.12	0.33*
T1 INT → T2 BMI-Z/Obesity	0.04	-0.05	-0.07	0.09
T1 BMI-Z/Obesity → T2 EXT	0.13*	-0.02	0.06	-0.01
T1 INT → T2 EXT	0.02	-0.10	0.02	-0.11
T1 BMI-Z/Obesity → T2 INT	0.01	0.09	-0.03	0.02
T1 EXT → T2 INT	0.06	0.04	0.07	0.05
Covariances				
T1 BMI-Z/Obesity ↔ T1 EXT	0.04	0.21*	0.04	0.13
T1 BMI-Z/Obesity ↔ T1 INT	0.02	0.07	0.02	0.00
T1 EXT ↔ T1 INT	0.49*	0.30*	0.49*	0.30*
T2 BMI-Z/Obesity ↔ T2 EXT	0.09	-0.03	0.15	-0.16
T2 BMI-Z/Obesity ↔ T2 INT	-0.08	-0.14	0.09	0.07
T2 EXT ↔ T2 INT	0.23*	0.29*	0.24*	0.28*

PPP, posterior predictive p-values; BMI-Z, body mass index z-score; EXT, externalizing behaviors; INT, internalizing behaviors. *Significant at $P < 0.05$.

No supplemental files.



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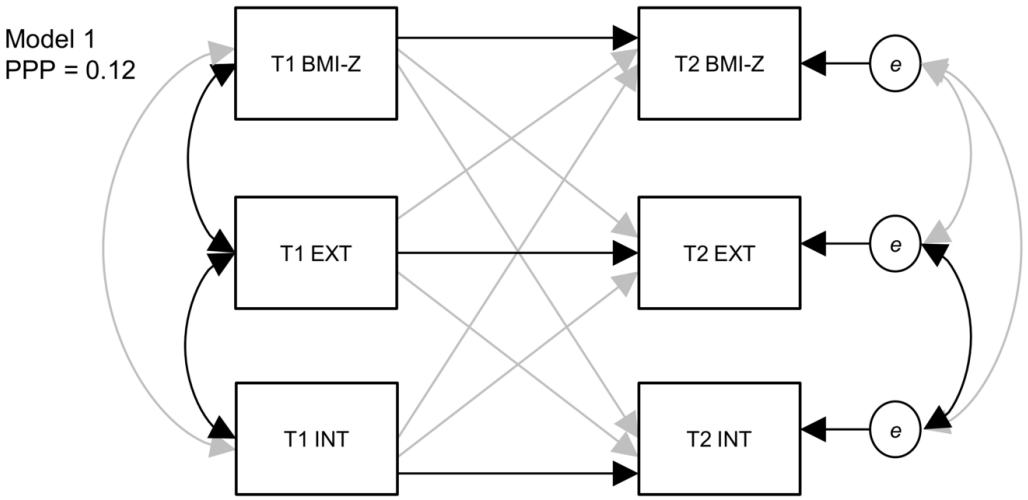

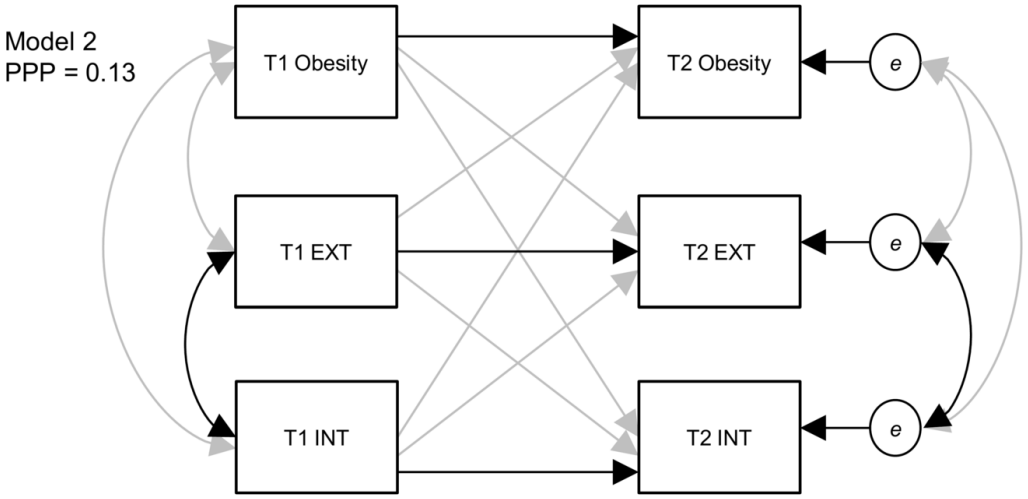

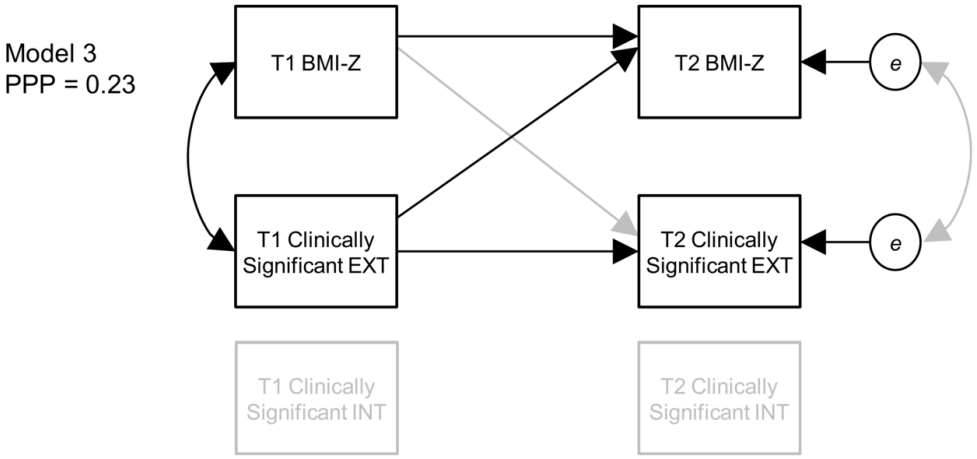

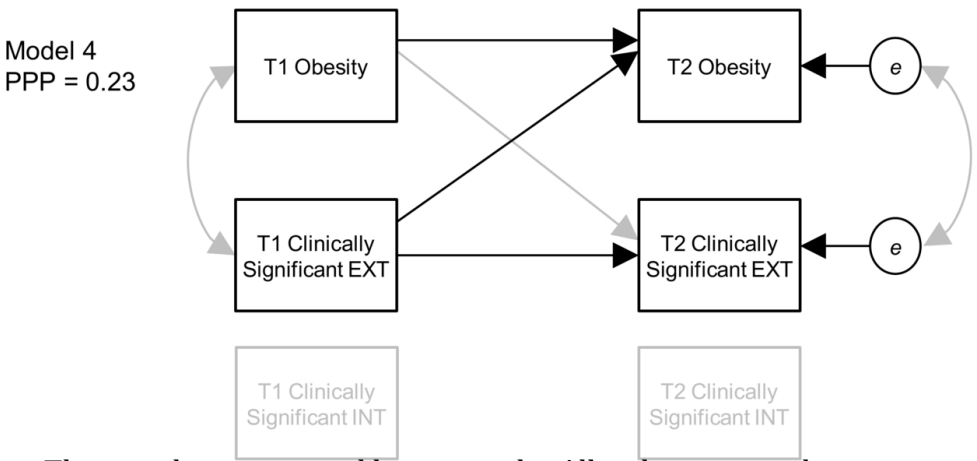

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