

# Maternal stress and depressive symptoms and adolescents' body mass index: A prospective study.

Maaïke Koning (✉ [m.koning@pwo.ru.nl](mailto:m.koning@pwo.ru.nl))

Windesheim university of applied sciences <https://orcid.org/0000-0002-3927-2359>

Jacqueline Vink

Radboud Universiteit Behavioural Science Institute

Tommy L.S. Visscher

Christelijke Hogeschool Windesheim

Junilla Larsen

Radboud Universiteit Behavioural Science Institute

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## Research article

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# Abstract

**Background** Growing evidence suggests that maternal mental health issues are associated with (young) children's weight outcomes. However, most studies have been limited by cross-sectional designs and have been aimed at (younger) children. The current prospective study focuses on the link between maternal mental health (i.e., psychological stress and depressive symptoms) and adolescents' zBMI development.

**Methods** The participants in the present study were part of wave 1 and 2 of a longitudinal study on Dutch adolescents' and their parents' health behavior. Adolescents (aged 10-14) and their parents were recruited through six secondary schools in the South and the East of the Netherlands. For this study, we only included biological mothers and their adolescent children who participated in both waves, with data on the main measures on both waves, leaving a final sample of 336 biological mother child dyads. Adolescents height and weight were measured, and both parents and adolescents filled in validated questionnaires on perceived stress and depressive symptoms and answered additional questions concerning domain-specific stress. Regression analyses were performed in R to examine longitudinal links between maternal stress and depressive symptoms at baseline (T1) and adolescents' BMI standard deviation scores (zBMI) 6 months later (T2), corrected for baseline zBMI and covariates.

**Results** Maternal general perceived stress ( $b=.20, p=.002$ ) at T1 preceded higher adolescents' zBMI at T2, after controlling for baseline zBMI and other covariates, whereas maternal depressive symptoms at T1 ( $b=-.05, p=.44$ ) and other domain-specific stress did not (maternal financial stress, maternal stress at work, maternal stress at home). Additionally, lower educational level among adolescents ( $b=.16, p=.001$ ) and adolescent depressive symptoms ( $b=.16, p=.001$ ) was associated with a higher zBMI at T2.

**Conclusions** Results suggest that maternal general stress, but not depressive symptoms, may influence adolescents' weight development. Our findings warrant future investigation on whether and how general stress among mothers may predict weight increases of their adolescent offspring.

## Background

Adolescence is a vulnerable period for the development of overweight, a pressing public health issue [1-8]. While overweight and obesity have multifactorial causes, parents have a substantial influence on the development of children's and adolescents' eating behaviors [9, 10], food consumption [11-13], and weight gain trajectories [14, 15]. The role of mothers is especially important because in most households nowadays, mothers are still the most important caregivers [16], and manage most of the day-to-day child-care tasks [17]. They are considered to be the primary gatekeeper of the home food environment [18]. To date, growing evidence suggests that maternal mental health issues (i.e., psychological stress and depressive symptoms) are associated with increased risk rates of weight gain, obesity and related weight-related behaviors (i.e., eating, physical activity and sleep patterns) in children and adolescents [19-29]. However, most studies have been limited by cross-sectional designs and have been aimed at (younger) children. The current prospective study focuses on the link between maternal mental health and adolescents' weight development.

It has been hypothesized that maternal stress and depressive symptoms may influence their child's weight related behaviors through three primary pathways [30]. First, maternal stress may alter mothers' own physical

activity, sedentary behavior and dietary intake, which may impact children's and adolescents' behaviors through modelling and household exposure (e.g., less healthy family meals) [31]. Additionally it is known that depressed mothers have difficulty providing healthful food choices [32-34], and modeling physical activity behaviors relative to non-depressed mothers [35]. There is evidence that changes in maternal feeding styles and patterns due to stress and depression can have a significant impact on children's food composition and energy intake by for example preparing convenient but unhealthy meals to help manage time [16, 36]. Second, maternal stress and depression may affect parenting behaviors or mother child interactions. Mothers experiencing high levels of stress may spend less time with their children [37] and may be less responsive in their interaction with their children [38]. Maternal depressive symptoms, such as negative affect and inactivity, can influence child weight related behaviors by directly affecting parenting behaviors, reducing maternal sensitivity to and nurturance of the child's needs [28, 39] and by facilitating less positive parent-child interactions and less family cohesion [40-42]. Third, maternal stress and depression can directly influence children's behavior through alterations in the stress response of the child itself [31], responding to maternal stress with an increased biological or psychological stress response .

These pathways explaining the link between maternal mental health and child weight development may particularly be important during adolescence. That is, parents continue to play a decisive role in this age period, for instance through weight-related parenting and specific rules that are associated with greater adolescent nutrition knowledge [43]. This nutrition knowledge may, in turn, prevent unhealthy choices during adolescence when children become more autonomous [43] and are increasingly exposed to more diverse (unhealthier) food environments. Thus, what parents do, both in terms of their own behaviors as well as their food parenting, may prepare adolescents to deal with these more diverse unhealthy food environments, preventing excessive food intake and subsequent weight gain. Moreover, the third pathway explaining the link between maternal mental health and child weight development through child mental health issues may also be particularly important during adolescence, when depression and stress symptoms are more prevalent compared to childhood [44].

Although stress may represent one generalizable phenomenon, there are many sub-classifications of stress, including general perceived stress and perceived stress limited to a specific domain (e.g., financial, health, work-related or social) [25]. It is possible that a mother's experience of each of these different types of stress may differentially relate to their children's weight-related behaviors and weight development. To date, previous studies have found that maternal general stress was consistently associated with greater risk for childhood overweight and obesity [19], while the association between depressive symptoms and child overweight was found to be more inconsistent [45], varying by gender and age [46] and measure of depression [45]. Importantly, the majority of studies so far have focused on maternal stress or maternal depression or depressive symptoms exclusively, while longitudinal assessment of both maternal stress and depressive symptoms in relation to childhood and adolescents' BMI are rare. The main aim of the current prospective study is to examine the link between diverse forms of stress and depressive symptoms with adolescents' weight outcomes.

## Methods

### Participants

The participants in the present study were part of wave 1 and wave 2 of the “G(F)OOD together” research project, a longitudinal study on Dutch adolescents’ and their parents’ health behaviour. Data for the first three waves were collected in fall 2017, spring 2018, spring 2019 respectively. Parents of 1,657 adolescents were invited to participate, and mothers or fathers provided consent for themselves and their adolescents to participate in the study. Parental consent was provided for 718 children. Moreover, 777 parents also provided consent for themselves. In the first wave 667 adolescents from six secondary schools in the South and the East of the Netherlands participated and in the second wave 688 adolescents participated (95.8% participated in both waves). Because some adolescents were absent at wave 1 due to illness or other appointments, more adolescents actually participated in wave 2. Moreover, 593 mothers and fathers took part in Wave 1 and 586 parents took part in wave 2 (N =480; 80,9% in both waves). Details of the study procedures can be found elsewhere [47].

For this study, we only included mothers, as they are still the most important caregivers in the family, and are more prone to stress and depression [16, 48, 49] than fathers. In total, 442 mothers took part in Wave 1, 438 in wave 2 (as an extra school was recruited at Wave 2), and 358 (81%) in both waves. Of the N = 358 with complete maternal data on both waves, we excluded data from non-biological mothers for this study (n=3) and data from mothers of whom there was no anthropometric and questionnaire data available of their adolescent child (n=22), leaving a final sample of 336 biological mother child dyads who participated in both waves.

Most mothers (97.0%) were born in the Netherlands. Mean age of mothers at the first wave was 44.6 years ( $SD_{age} = 4.2$ ; age range = 29.8 to 55.5). Most mothers finished higher professional education (39.9%) or secondary vocational education (39.4%) and performed a payed job of less than 32 hours per week (52.5%) or 32 hours per week or more (19.4%).

Adolescent boys (n=161) and girls (n=175) were approximately equally represented. Most adolescents were born in the Netherlands (%). All participants attended regular secondary education ( $M_{age} = 12.9$  years;  $SD_{age} = 0.6$ ; age range = 11.3 to 14.8). In the Netherlands, children in secondary schools follow education based on their academic level and interests. Dutch secondary schools are divided into three streams which represent different educational paths: one to prepare students for vocational training, another to prepare students for university, and a middle stream to prepare students to study at universities of applied sciences (higher vocational education). More than half of the participants (57.6%) were in pre-university education, 8.2% of the participants was in higher general secondary education, and 34.2% of the participants was in pre-vocational education.

## **Procedures**

Adolescents and their parents were recruited through secondary schools. We randomly invited 40 secondary schools in the South and the East of the Netherlands to participate in the study. Six secondary schools agreed to participate in wave 1, and all adolescents attending the first and second grade and their parents were invited to participate in this study by means of an active parental consent procedure. A letter describing the four-wave study was mailed to the parents and they were asked to return a (paper or online) consent form indicating whether they agreed to their child participating in the study and if they agreed to participate in the study

themselves. Children were rewarded with a small incentive, if at least one of their parents' forms was returned, regardless of whether permission was given. Before participation, adolescents and parents were informed that participation was voluntary, that answers would be processed anonymously, and that they could withdraw from the study at any moment. Inclusion criteria for participants were being enrolled in a high school, being in the first and second grade of this high school, being proficient in the Dutch language and parents and children both having given active informed consent. Exclusion criteria for participants were not being proficient in the Dutch language, attending special education and not having given active (parental) consent.

Adolescents completed an online survey at school during one classroom hour (approximately 45 minutes), and height and weight were measured outside the classroom by trained research assistants. Parents completed an online survey, which took approximately 20 minutes to complete. The questionnaires were administered through Qualtrics Survey Software (Qualtrics, Provo, UT, USA) and were in Dutch language. Children received a small present after completing the survey, and several prizes were raffled among participating parents. The Institutional Review Board of the Faculty of Social Sciences of the Radboud University, Nijmegen, The Netherlands approved the study protocol (reference number ECSW20170805-516) in 2017.

## **Measures**

### **Depressive symptoms**

Maternal depressive symptoms were assessed with the 10-item short version of the Center for Epidemiological Studies-Depression (CES-D) scale. Although the (shortened) CESD is used as a self-reported measure of depressive symptoms, it is a reliable and valid instrument to screen for the presence or absence of a depressive disorder [50]. The CES-D is widely used and has adequate internal reliability [50]. Respondents rated items on a 4-point Likert scale (rarely or none, to most or all the time). The scale includes positive (I was happy) and negative (I could not get going) items. Higher total CES-D scores reflect greater maternal depressive symptomology. In the current study, Cronbach's alpha for the CES-D was .77 at T1 and .80 at T2.

### **General perceived stress**

Maternal general stress levels were assessed using the 4 item Perceived Stress Scale (PSS). The PSS is a self-report questionnaire measuring a person's evaluation of stressful situations in the previous 1 month of his or her life. It is a global measure of stress that is simple to use, and there are many studies confirming its reliability and validity in a variety of settings and in multiple languages [51-56]. Although it is used as a self-reported measure of general stress, it is a reliable and valid instrument to screen for general perceived stress [51, 53, 54, 56]. The instrument contains 4 statements which measure how unpredictable and uncontrollable respondents feel their lives are, for example: In the last month, how often have you felt confident about your ability to handle your personal problems? Respondents rate how often they experience stressful situations on a 5-point Likert scale ranging from 'never' to 'very often'. Answers of the 4 items were summed into a total PSS score. The higher the score on the PSS, the greater the respondent perceives that their demands exceed their ability to cope. Cronbach's alpha was calculated to investigate the internal reliability of the Perceived Stress Scale and was .70 at T1 and .69 at T2.

### **Financial stress, stress at work and at home**

Three types of domain specific stress were measured through three items: financial stress (How often did you experience financial stress in the past year?), stress at work (How often have you felt stress at work in the past year?), and stress at home (How often did you experience stress at home in the past year?). These questions have been used in previous studies to measure different types of stress and are worded in the same manner [57, 58]. Respondents rated how often they experienced stress in the different contexts on a 4-point Likert scale (never, sometimes, regularly, all of the time).

## **Anthropometrics**

Adolescents' height and weight were measured according to protocol [59] by trained research assistants. Body Mass Index (BMI) was calculated as weight in kilograms divided by height in meters squared. Individual age and gender-specific BMI standard deviation scores (z-scores) were calculated using a Dutch representative sample of 0-21-year olds [60, 61]. Mothers reported their own height and weight based on which we calculated maternal BMI.

## **Covariates**

We controlled for parent's and adolescents' educational level in our regression analyses, as a higher BMI seems to be more frequent in lower educated youth and in youth with lower educated parents [62-64]. We also controlled for additional covariates showing a potential link with adolescent zBMI [65-70]. As such, the following covariates were added: adolescents' gender, maternal BMI, maternal single household status, adolescent stress and depressive symptoms, as also the quality of the parent-child relationship rated by parents.

## **Statistical analyses**

Statistical analyses were conducted using the PASW 20.0 and R software package. Descriptive statistics were used (mean, standard deviations and percentages) to describe the study sample and to investigate population characteristics (see table 1).

First, cross-sectional associations between mothers' wellbeing and adolescent zBMI and the covariates were examined by calculating Pearson's correlation coefficients using SPSS. Second, to test whether maternal stress or depressive symptoms may precede child zBMI over time, multiple linear regression analyses were performed using the R software package (R Core Team, 2018) with depressive symptoms (CES-D score), general stress (PSS score), financial stress, stress at home or stress at work at T1 as the independent variables, and adolescents' zBMI at T2 as the dependent variable). We examined two models: a multiple linear regression model, adjusted for adolescents' zBMI at baseline and potentially relevant covariates (i.e., educational level of the mother and of the adolescent, gender, maternal BMI, maternal marital status (single household status), the quality of parent/child relationship as rated by parents, child stress, and child depressive symptoms and an unadjusted model without covariates. We checked normality and distribution assumptions of zBMI before performing our regression analysis with a scatter plot, QQ plot and the Shapiro Wilk test. The plots showed no extreme outliers and a linear association. The Shapiro Wilk test showed a normal distribution ( $W = .99$ ,  $p = .53$ ).

A logistic regression analysis comparing those adolescents who participated in the current study (score = 1) with those who could not participate because of lacking maternal data (score = 0) showed no differences in gender, educational level, age and mean zBMI between both groups, we therefore expect no bias. The overall proportion of drop-out from T1 to T2 is relatively low, of the adolescents 95.8% participated in both waves and 80.9% of parents participated in both waves. The proportion of missing data in our study sample is also low (22/358 = 6%). To account for missing values we used the 'na.exclude' function in R which does not use the missing values, but maintains their position for the residuals and fitted values.

For the proposed multiple linear regressions, we conducted a power analysis using G\*Power 3.1 [10]. With a small effect size ( $f^2$ ) of .15, an alpha of .05, a standard power level of .80, and a total of 14 predictors, the results of the power analysis showed that a minimum of 135 participants would be needed to achieve an appropriate power level for this study.

## Results

### Cross-sectional associations and descriptives

The total sample consisted of 336 adolescent-parent dyads. Mean zBMI of the adolescents was .10 (SD 1.06) at T1 and .18 (SD 1.07) at T2. The average change in zBMI from T1 to T2 (6 months interval) was .08 (SD .99), as can be seen in table 1.

### Table 1: Sociodemographic characteristics

	<b>Total study sample (N=336)</b>
Age of the child (years) at T1; mean (SD)	12.9 (.6)
Range	11.3-14.8
Gender (% male)	47.9
Age of the mother (years); mean (SD)	44.6 (4.2)
Range	29.8-55.5
Educational level mother (%)	
Primary school	2.7
Secondary vocational education	43.4
Higher professional education/university	53.9
Educational level child (%)	
pre-vocational education.	34.2
higher general secondary education	8.2
pre-university education	57.6
Adolescent zBMI at T1; mean (SD)	.10 (1.1)
Range	-2.9 - 2.9
Adolescent zBMI at T2; mean (SD)	.18 (1.1)
Range	-2.8 - 2.9
zBMI categories at T1 (%)	
< -2	1.9
-2 to 2	93.7
2+	4.4
zBMI categories at T2 (%)	
< -2	2.4
-2 to 2	91.7
2+	5.8
Maternal BMI score; mean (SD)	24.6 (4.2)
Range	16.6-43.0
Maternal CESD score; mean (SD)	<b>16.6 (3.1)</b>
Range	10-30
Maternal PESS Score; mean (SD)	7.9 (2.2)

Range	4-18
Maternal financial stress; mean (SD)	1.5 (.7)
Range	1 - 4
Maternal stress at home; mean (SD)	2.0 (.6)
Range	1 - 4
Maternal stress at work; mean (SD)	2.1 (.7)
Range	1 - 4
Marital status (single household status) (%)	10.1
The quality of parent/child relationship as rated by parents; mean (SD)	89.2 (11.6)
Range	17-100
Child stress; mean (SD)	1.9 (.6)
Range	1-4
Child depressive symptoms	14.7 (3.9)
Range	10-33

Pearson's correlation coefficients between maternal wellbeing, covariates and adolescent zBMI are presented in Table 2. Significant correlations were found between maternal depressive symptoms and most of the stress measures, with exception of the 'stress at work' measure. Mostly non-significant correlations were found between maternal wellbeing (i.e., stress or depressive symptoms) and adolescents' zBMI. Of the covariates, maternal BMI was positively correlated with maternal general stress ( $r=.14, p=.03$ ), with maternal depressive symptoms ( $r=.12, p=.01$ ) and with financial stress ( $r=.18, p=.001$ ). Educational level of the adolescent was negatively correlated with maternal depressive symptoms ( $r=-.17, p=.003$ ) and with maternal general stress ( $r=-.15, p=.009$ ). Single household status was correlated with financial stress ( $r=.22, p=.000$ ). Quality of parent child relationship was negatively correlated with maternal general stress ( $r=-.19, p=.001$ ) and stress at home ( $r=-.22, p=.000$ ).

## Table 2. Correlational associations

\*\* significant at the 0.01 level (2-tailed). \* significant at the 0.05 level (2-tailed).

## Longitudinal Associations between Maternal Mental Wellbeing and Adolescents' zBMI

Maternal general stress ( $b = .20, p = .002$ ) was associated with adolescent's zBMI at T2 after correction for baseline zBMI, gender, educational level of the child, educational level of mothers, maternal marital status (single household status), the quality of parent/child relationship as rated by parents, child stress, and child depressive symptoms and maternal BMI as can be seen in table 2. This effect was still significant in a reduced model without covariates ( $b = .14, p = .01$ ), indicating that maternal general stress is associated with higher zBMI 6 months later. Notably, for the other maternal well-being variables (i.e., maternal financial stress,

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11	12	13	14	15
<b>Adolescent variables</b>															
1. Adolescent zBMI T1	1														
2. Adolescent zBMI T2	.57**	1													
<b>Maternal wellbeing variables</b>															
3. Maternal depressive symptoms	.01	.02	1												
4. Maternal general stress	.003	.08	.55**	1											
5. Maternal stress at work	.000	.000	.10	.17**	1										
6. Maternal financial stress	.09	.03	.19**	.20**	.01	1									
7. Maternal stress at home	.04	-.01	.27**	.34**	.14*	.20**	1								
<b>Covariates</b>															
8. Gender adolescent	-.001	.04	.01	.003	.02	.03	.06	1							
9. Depressive symptoms adolescent	.07	.08	.06	.01	.03	.10	.10	.15**	1						
10. Adolescent stress	.03	-.01	.05	.08	.03	.02	.08	.10	.50**	1					
11. Educational level adolescent	-.15**	.03	-.17**	-.15**	.01	-.09	.01	.05	-.09	-.02	1				
12. Educational level parent	-.10	-.09	-.09	-.07	.18**	-.08	.07	.06	.06	.06	.34**	1			
13. Maternal BMI T1	.30**	.20**	.14*	.12*	-.01	.18**	-.04	.01	.04	.02	-.22**	-.17**	1		
14. Relationship	.02	-.04	-.02	.02	.03	.22**	.10	.05	.14*	.06	-.08	-.02	-.03	1	

status  
parent

15. Quality of parent/child relationship	-.02	-.05	-.07	-.19**	-.08	.02	-.22**	.10	-.05	-.03	-.003	-.10	-.004	-.08	1
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maternal stress at home, maternal stress at work, maternal depressive symptoms) no significant longitudinal associations were found with adolescents' zBMI, neither in a reduced model nor after controlling for covariates. Additionally, lower educational level among adolescents ( $b = .16, p = .001$ ) and adolescent depressive symptoms ( $b = .16, p = .001$ ) were associated with a higher zBMI at T2. The final model (including all covariates) of maternal general stress explained 31% of the variance of adolescent zBMI.

**Table 3. Linear regressions of maternal stress/depressive symptoms at T1 on adolescent zBMI at T2**

	Unadjusted analyses				Adjusted analyses <sup>a</sup>				
	B	SE B	$\beta$	P value	B	SE B	$\beta$	P value	
<b>Maternal general stress</b>	.08	.03	.14	.01*	.10	.03	.20	.002**	** significant at the 0.01 level (2-tailed). * significant at the 0.05 level (2-tailed). <sup>a</sup> Covariates: Adolescents' zBMI at baseline, educational level, gender; maternal BMI, educational level of mothers, maternal marital status (single household status), the quality of parent/child
<b>Maternal depressive symptoms</b>	-.01	.02	-.03	.49	-.02	.02	-.05	.44	
<b>Maternal financial stress</b>	-.05	.08	-.03	.50	-.07	.08	-.04	.41	
<b>Maternal stress at home</b>	-.07	.09	-.04	.43	-.09	.09	-.06	.30	
<b>Maternal stress at work</b>	-.00	.08	-.00	.97	.004	.08	.003	.95	
<b>Adj R<sup>2</sup></b>	0.31				0.31				

relationship as rated by parents, child stress, and child depressive symptoms

## Discussion

Longitudinal studies that test whether maternal stress or depressive symptoms may precede the development of adolescents' weight outcomes are rare, and this study aimed to fill this gap. We found that maternal general perceived stress at T1 preceded higher adolescents' zBMI at T2, after controlling for baseline zBMI and other covariates, whereas maternal depressive symptoms at T1 and other domain-specific stress did not (maternal financial stress, maternal stress at work, maternal stress at home). Additionally, lower educational level among adolescents and adolescent depressive symptoms were associated with a higher zBMI at T2.

In the past decade, several studies have established the link between maternal well-being and childrens' zBMI [19-22, 24]. However, these studies mostly focused on (early) childhood. During adolescence, particularly early adolescence, parents still play an important role in their children's lives. Maternal stress and depressive symptoms have been linked to barriers to a healthy lifestyle and may reduce pro-active obesity-related parenting practices [20, 71-73] such as less healthy meal preparation and less transportation to and less participation in organized sports by their children, and by for example, negatively influencing mother-child interaction and increasing the risk at modelling possibilities of unhealthy maternal behaviors [16, 27, 30, 31, 36-42, 73, 74]. The present study's aim was to investigate the longitudinal link of both maternal stress and depressive symptoms with adolescents' weight development. We found a small link between maternal general stress and adolescent zBMI over time. We did not find significant associations for maternal depressive symptoms or for domain specific stressors (maternal financial stress, stress at home and stress at work).

Maternal general perceived stress may reflect a broader personality construct on how mothers more generally react to stressful situations, whereas stress from the home and work environment probably is more contextual in nature [25]. This may explain why maternal general stress is associated with development of zBMI in adolescents, having more general impact than specific contextual stress factors. Additionally, adolescents with mothers who experience a lot of general stress may be exposed to less healthy family and peer environments, providing increased opportunities to engage in unhealthy behaviors and may lead to unhealthy weight development.

In contrast, no associations were found between maternal depressive symptoms and adolescent BMI over time. Notably, previous research has already shown some mixed findings particularly with regard to the link between maternal depressive symptoms and children's weight outcomes [45, 46]. A review reports that chronic depression (depression measured on multiple occasions), but not episodic (depression at a single measurement occasion) depression was found to be associated with a greater risk for child overweight [45]. In our study we measured depressive symptoms at one time point, which may explain why we did not find any associations. However, it should be noted that other studies focusing on episodic symptoms did sometimes find a link with children's weight outcomes [75, 76], though these studies were most often conducted among younger children.

The link between maternal stress and children's weight outcomes have been repeatedly found among families with younger children [19]. To the best of our knowledge, only one previous longitudinal study found this link among adolescents [24]. Our study adds to these previous studies that diverse stress factors have been examined and that only for one specific stress factor longitudinal links have been found (i.e., general stress) in an adolescent population. Thus, it might be that, particularly for adolescents, maternal general stress has more impact on (healthy) family life and adolescents' weight development than maternal stress in other domains and also more impact than maternal depressive symptoms. Future studies including both age groups (i.e., younger children and adolescents) may further examine this.

Socioeconomic factors are also known to be of specific interest in weight development of children and adolescents. We found that a lower educational level among adolescents was consistently associated with a higher zBMI at T2 in all our models. In the Netherlands, children in secondary schools follow education based on their academic level and our study thus suggests that increases in zBMI are most unfavorable in

adolescents with a lower educational level. Previous studies have reported about the educational gap with regard to weight outcomes [77]. It seems that the period of adolescence is a particularly important period because of the autonomy involved in making more independent choices about weight related behaviors. Adolescents with lower educational levels may make more unhealthy choices in their weight related behaviors than highly educated adolescents, and may have less (financial) opportunities for healthy weight related behaviors.

The current study had several strengths and limitations. One particular strength is that height and weight of the adolescents were objectively measured. Moreover, the high participation rates and the prospective repeated measurements add to the strengths of this study. A final strength includes the fact that parents reported on their own mental health. Despite these strengths, also some limitations should be acknowledged. First, maternal mental health was analyzed at one time point only, to assess stability in maternal mental state more time points should be taken into account. Second, the time period between the first two waves was relatively short and may not be representative of longer term weight change developments. Third, the sample consisted of a high percentage of highly educated respondents (57.6%) as well as a high proportion of respondents having a healthy zBMI, possibly influencing the generalizability of the results. Finally, contextual stress factors (i.e., financial, home or work-related stress) were only measured with one item.

## Conclusions

To conclude, our findings suggest that adolescents whose mothers experienced more general stress may be at greater risk for increases in zBMI. In contrast, maternal depressive symptoms do not predict any changes in weight development among adolescents. Interventions to reduce stress and to increase resources for mothers to cope with stress might help reduce overweight and obesity in their adolescent children. Clinicians may consider behavioural interventions, such as mindfulness-based stress reduction, to diminish the effects of stress in mothers on their childrens weight-related behaviors as an additional strategy to address adolescent obesity prevention and intervention. Our findings warrant future longitudinal investigation with longer follow-ups on whether and how general stress among mothers might predict weight increases of their adolescent offspring.

## Abbreviations

BMI: Body Mass Index

CES-D: Center for Epidemiological Studies-Depression scale

PSS: Perceived Stress Scale

## Declarations

**Ethics approval and consent to participate:** All procedures performed were in accordance with the ethical standards of the Institutional Review Board of the Faculty of Social Sciences of the Radboud University, Nijmegen, The Netherlands and with the WMA declaration of Helsinki. The study protocol (reference number

ECSW20170805-516) was approved in 2017. Informed consent was obtained from all parents and of individual participants who were included in the study.

**Consent to publish:** Not applicable.

**Availability of data and materials:** The datasets generated and analysed during the current study are not publicly available due to agreements we have made concerning the exchange and use of our data, but are available from the corresponding author [MK] on reasonable request. These data are primary data acquired by (one of) the authors.

**Competing interests:** The authors declare that they have no competing interests.

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**Author's contributions:** JV and JL were responsible for the study design. JV and JL supervised the data collection. MK was responsible for the statistical analyses and interpretation of the data in agreement with JV, JL, and TV. MK wrote the first version of the manuscript and all authors participated in the revisions of the manuscript. All authors read and approved the final manuscript.

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**Declaration of interest statement:** No potential conflict of interest was reported by the authors.

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