Received: 6 December 2021 | Revised: 22 March 2022 | Accepted: 10 April 2022
DOI: 10.1002/oby.23466

Obesity A Research Journal | THE OBESITY SOCIETY | WILEY

ORIGINAL ARTICLE
Clinical Trials and Investigations

Coparenting-focused preventive intervention reduces postnatal maternal BMI and buffers impact of cortisol

Lisa J. Moran[1] | Jin-Kyung Lee[2] | Damon Jones[3] | Kaitlin Fronberg[4] | Mark E. Feinberg[4]

[1]Monash Centre for Health Research and Implementation, Monash University, Melbourne, Victoria, Australia

[2]Institute for Poverty Alleviation and International Development, Yonsei University, Seoul, South Korea

[3]Edna Bennett Pierce Prevention Research Center, Pennsylvania State University, State College, Pennsylvania, USA

[4]College of Health and Human Development, Pennsylvania State University, State College, Pennsylvania, USA

Correspondence
Lisa J. Moran, Monash Centre for Health Research and Implementation, Monash University, Level 1, 43-51 Kanooka Grove, Clayton VIC 3168, Australia.
Email: lisa.moran@monash.edu

Funding information
National Heart Foundation Future Leader Fellowship, Grant/Award Number: 101169; National Institute of Child Health and Human Development, Grant/Award Numbers: K23 HD042575, R01 HD058529-01A1; National Institute of Mental Health, Grant/Award Number: R21 MH064125-01

Abstract

Objective: The postpartum period is a key life stage, contributing to increased maternal obesity risk. Current lifestyle interventions do not consider the role of a woman's partner in reducing stress and supporting lifestyle change. The objective of this study was to assess the effect of an intervention that seeks to enhance coparenting relationship quality on maternal BMI from before conception to 12 months post partum and whether the intervention moderated the association of changes in cortisol and BMI.

Methods: A randomized controlled trial was used to assess an intervention (eight classes: four during and four following pregnancy) focusing on enhancing couple coparenting relationships during pregnancy and post partum ($n = 57$) compared with standard care ($n = 53$).

Results: The main outcome measures were changes in maternal BMI and cortisol. There was a smaller increase in BMI for mothers in intervention compared with control groups (mean [SE], -1.03 [0.42] kg/m^2, $p = 0.015$). There was an interaction between intervention status and cortisol change predicting BMI change ($p = 0.026$), such that cortisol change significantly predicted BMI change among mothers in the control ($p = 0.049$) but not the intervention groups ($p = 0.204$).

Conclusions: A coparenting intervention improved maternal postpartum BMI, with this effect potentially related to ameliorating the negative effect of stress, as measured by cortisol, on BMI. The role of enhanced coparenting in improving maternal anthropometry warrants urgent attention.

INTRODUCTION

Overweight and obesity are crucial public health problems affecting 67% of adults [1], and they are associated with an elevated risk of chronic diseases (including type 2 diabetes mellitus, cardiovascular disease, and cancer), poor mental health, infertility, and pregnancy complications. Reproductive-aged women have the highest risk of weight gain compared with other population groups [2], with the perinatal period a specific high-risk period. Up to 50% of women who give birth have overweight or obesity at their first antenatal visit [3], with 25% to 47% of women retaining ≥4.5 kg by 1 year post partum [4]. Weight retention after pregnancy is associated with poorer maternal, fetal, and child outcomes in subsequent pregnancies and adverse maternal outcomes, such as longer-term maternal cardiovascular disease and obesity [4]. Maternal obesity also has consequences for fetal development and offspring, increasing the risk of being born large for gestational age, having overweight or obesity as children or adults (and developing type 2 diabetes), developing premature cardiovascular disease, and having premature mortality in adult life [5]. The perinatal period is a critical window for weight management interventions to improve maternal health to prevent long-term chronic disease risks and prepare for healthy pregnancies.

International evidence-based guidelines for weight management following pregnancy [5] recommend women follow population-based lifestyle (diet, exercise, and sedentary behavior) recommendations to gradually lose weight after pregnancy and achieve and maintain a healthy weight long term. A meta-analysis of randomized controlled trials reported that postpartum lifestyle interventions decrease postpartum weight by 2.24 kg (95% CI: −3.03 to −1.45; 33 studies and $n = 4{,}960$ women) [6]. However, significant gaps exist regarding translation of these interventions from research into practice, and these gaps are related to additional barriers to maintaining a healthy lifestyle after pregnancy [7, 8]. Women face competing demands on their personal time such as raising children and managing the household, which are often prioritized over personal health [9], making it difficult to participate in interventions that produce the best weight loss outcomes [7, 9, 10]. Given the obstacles faced by women in the perinatal stage, their ability to make and sustain behavioral lifestyle changes depends in large part on support and cooperation from their partner [8]. It is important to consider how to involve a woman's partner in supporting a healthy lifestyle and weight management during pregnancy and after birth. Existing research has indicated that father support (and presumably that of other partners and coparenting figures) has a positive influence on healthy behaviors among their partners during [11] and following [12] pregnancy. However, postpartum lifestyle and weight management interventions have been designed and implemented focusing on women working in isolation without the support of their partners, which may limit their efficacy and impact.

Little research has examined the role of partner support in lifestyle behavior change during the perinatal period. It is possible that partner support may impact maternal lifestyle behaviors and weight status by improving maternal antenatal and postpartum depression, anxiety, and stress [13, 14], given previously reported associations between partner support and maternal mental health [15] and between antenatal and postpartum mental health and postpartum weight retention [16]. Emerging research on partners' influence on maternal mental health has found that "coparenting support," conceptualized as support or coordination that parental figures exhibit in child-rearing activities, is a primary influence on maternal mental health. Coparenting relationships can be conceptualized as comprising four overlapping domains: 1) agreement on child-rearing principles and practices; 2) support versus undermining of each other in the parenting role; 3) parental division of labor; and 4) joint family management, referring to family system theory's "executive subsystem," the coparental unit that ideally operates cohesively to shape family culture, guide interaction, and achieve goals [14].

Study Importance

What is already known?

- Although existing research indicates that women's lifestyle during and following pregnancy is positively influenced by partner support, lifestyle and weight management interventions in these life stages have been designed focusing on women in isolation, which may limit their efficacy.

What does this study add?

- This study highlights that the novel strategy of promoting partner support and establishing high-quality coparenting relationships at the transition to parenthood can improve maternal postpartum anthropometry, even in the absence of specific diet, physical activity, and behavioral advice.

How might these results change the direction of research or the focus of clinical practice?

- This intervention effect may be related to the intervention eliminating the link between changes in maternal cortisol and BMI across the postpartum transition.

We have previously reported that an intervention designed to improve coparenting practices also enhances parent–child relationship quality and children's health, including sleep patterns, self-soothing, and long-term (5-7 years) emotional, behavioral, and school adjustment [13, 14, 17]. These improvements in child health are related to durable improvements in parental stress, depression, and anxiety and in parenting quality [13, 14]. We hypothesize that enhanced coparenting support leading to healthy ways to cope with stress would also lead to improvements in maternal lifestyle and anthropometry.

However, to our knowledge, there is currently no research examining the effect of coparenting intervention on improving maternal lifestyle and weight management following birth. Here, we extend our previously published reports on the effect of a coparenting-focused intervention on parental stress and mental health [13, 14] to report now, for the first time to our knowledge, on the effect of the intervention on postpartum maternal anthropometry. We also assess whether the intervention impacted relations between stress and anthropometry. As stress can result in physiological changes to the hypothalamic pituitary axis, including alterations in cortisol metabolism, we assess stress via salivary cortisol. This research will support our future goals of adapting coparenting interventions to include an additional focus on support for maternal lifestyle behaviors.

TABLE 1 Demographic and health-related characteristics at baseline

	All (n = 110)	Control (n = 53)	Intervention (n = 57)
Mother's age (y)	28.6 (4.8)	28.8 (5.4)	28.3 (4.2)
Marital status			
Married	93 (84.5%)	46 (86.8%)	47 (82.5%)
Nonmarried	17 (15.5%)	7 (13.2%)	10 (17.5%)
Mother's race/ethnicity			
White	103 (93.6%)	50 (94.3%)	53 (93.0%)
Non-White	7 (6.4%)	3 (5.6%)	4 (7.0%)
Gestation weeks	22.2 (5.6)	22.7 (5.6)	21.7 (5.6)
First trimester	3 (2.7%)	2 (3.8%)	1 (1.8%)
Second trimester	83 (75.5%)	38 (71.7%)	45 (79.0%)
Third trimester	24 (21.8%)	13 (24.5%)	11 (19.3%)
Child gender			
Girl	44 (40.0%)	19 (35.9%)	25 (43.9%)
Boy	66 (60.0%)	34 (64.2%)	32 (56.1%)
Household income (US$)	64,105.5 (34,445.9)	65,518.9 (36,100.0)	62,767.9 (33,075.9)
Mother's education (y)	15.2 (1.8)	15.4 (1.9)	15.0 (1.7)
Mother's depression	0.5 (0.5)	0.4 (0.4)	0.5 (0.6)
Mother's anxiety	7.0 (3.8)	6.7 (3.9)	7.3 (3.6)
Mother's cortisol	−0.03 (0.4)	−0.03 (0.5)	−0.03 (0.4)
Mother's sleep (h/night)	7.7 (1.3)	7.6 (1.3)	7.7 (1.4)
Mother's physical activity (times/wk physically active)	1.6 (1.8)	1.6 (1.8)	1.6 (1.9)

Note: Data are presented as mean (SD) or n (%). All variables were measured at wave 1 (in pregnancy) only except for child gender. Child gender was measured at wave 2 after childbirth.

METHODS

Participants and procedures

The Family Foundations study was a randomized, two-arm, controlled trial exploring how supporting a coparenting relationship in first-time parents influences child and parent outcomes [14]. The study was conducted over 2003 to 2006. Recruitment and methodology have been described previously [14]. Participants included 169 heterosexual couples recruited through hospitals located in Altoona and Harrisburg in Pennsylvania. At the time of enrollment, participants were first-time expectant parents, at least 18 years old and living together. Couples were recruited at an average gestational age of 22.9 (5.3) years (Table 1). In this study, a post hoc analysis was performed, in which data from 110 mothers who participated in survey and saliva sample collection at wave 1 (pregnancy) and wave 3 (12 months post partum) were analyzed to examine the intervention effect on maternal BMI change from before conception to 12 months post partum. Between the final sample analyzed in this study (N = 110 couples) and the sample excluded due to the unavailability of saliva data (n = 59 couples), there were no significant group differences in mothers' weight at preconception, pregnancy, or 12 months after childbirth or in demographic characteristics, such as mothers' age, race, education, and household income. The study was approved by the Pennsylvania State University Institutional Review Board. All participants provided signed informed consent.

Intervention

Couples were randomly assigned to the intervention group (n = 89, n = 57 for this sub-analysis) or to the control group (n = 80, n = 53 for this subanalysis). Parents in the intervention group participated in Family Foundations, a series of four sessions including didactic material, exercises, and behavioral rehearsal before childbirth and four sessions after childbirth designed to help expectant parents discuss effective coping and support mechanisms after childbirth [14]. Given the intervention design as a couple-based program, mothers and fathers attended sessions together the majority of the time, with attendance rates highly correlated (r = 0.95). The program included key themes such as emotional self-management, conflict management, problem-solving, communication, and mutual support strategies that foster positive joint parenting of an infant applied to issues such as dividing labor, facilitating emotional security, and providing stimulation [14]. Each group consisted of 6 to 10 couples. Sessions were led by a male–female team who received 3 days of training. Expectant parents in the control group received a mailed brochure about how to select quality childcare services and children's developmental stages.

Couples in both conditions participated concurrently in standard childbirth education classes. The intervention and delivery have been described in detail elsewhere [14]. The average number of prenatal and postpartum sessions attended were 3.3 and 2.3, respectively, with 84.2% and 56.1% of couples attending at least three prenatal and postpartum sessions, respectively.

Outcomes

Data were collected at home visits for wave 1 (pregnancy), wave 2 (6 months post partum), and wave 3 (12 months post partum, average 13.6 [0.9] months). Collected outcomes have been described previously [17], including demographic factors of maternal age, marital status, ethnicity (White [non-Hispanic White]/non-White [Black, Asian, Hispanic, or other]), household income ($US), and maternal education (years). These included depressive symptoms measured with a subset of seven items from the Center for Epidemiological Studies Depression Scale [18], anxiety measured with the 20-item short form of the Taylor Manifest Anxiety Scale [19], hours of sleep in the past 2 weeks (including nighttime and naps), physical activity (how many times per week were you physically active), and breastfeeding for longer than 6 months (coded as breastfeeding or not breastfeeding). Height and weight were self-reported, with BMI calculated as weight in kilograms divided by height in meters squared at all waves in addition to a self-reported preconception weight, which was asked with the question "What was your weight and height prior to your pregnancy?" with separate free text fields for pounds and feet/inches.

Salivary cortisol was measured as previously reported [20] at wave 1 (pregnancy) and wave 3 (12 months post partum). This study used the first (baseline) sample. Participants were asked not to eat for 1 hour before sample collection. Samples were collected in the afternoon or early evening (80% after 4 PM) to restrict variations of cortisol with the typical circadian rhythm. Collected saliva samples were kept on ice, frozen within 8 hours, stored at −20°C, and transported to Salimetrics Laboratories (State College, Pennsylvania). After arriving at the laboratories, samples were stored at −70°C and processed within 2 weeks for saliva cortisol assay. On the day of cortisol assay, saliva samples were thawed and centrifuged at 3,000 rpm for 15 minutes to exclude mucins. Using an enzyme immunoassay for saliva cortisol, saliva samples were assayed without any modification to the manufacturer's recommended protocol: 25 μL of saliva was used in this test, and the sensitivity of saliva ranged from 0.007 to 3.0 μg/dL. After that, as maternal baseline cortisol levels vary depending on maternal gestation week and data collection time of the day, regression models were run with these two predictors and constructed residualized cortisol scores. Five outliers were truncated to threshold levels based on distributional box plots. Residualized scores were multiplied by a factor of 10 in order to generate comparable variation across variables. The same procedures were repeated at 12 months post partum, with the exception that maternal gestation did not factor into residualized wave 3 baseline cortisol.

Statistical analysis

The aim of the analyses was to examine the association between maternal BMI change from before conception to 12 months post partum, maternal cortisol change between pregnancy and 12 months post partum (calculated as study end values [wave 3 at 12 months post partum] minus study commencement values [preconception or wave 1 at pregnancy for BMI and cortisol, respectively]), and intervention status. As maternal BMI in pregnancy is predicted by the week of gestation, residualized BMI scores were generated by a regression model using gestation week as a continuous predictor and BMI in pregnancy as a continuous outcome variable. This residualized BMI score was included in all our analyses to represent maternal BMI in pregnancy. Independent *t* tests were used to determine whether cortisol, weight, and BMI at each time point and the change from before conception or at pregnancy (for cortisol) to 12 months post partum differed by intervention status. Univariate regressions tested the association between each predictor and maternal BMI change. Variables significant at $p < 0.10$ in the univariate analysis or based on hypothesis testing were included as covariates in the multivariate regression analysis, with the final model including mothers' BMI in pregnancy, sleeping hours in pregnancy, physical activity in pregnancy, marital status at baseline, and breastfeeding at 6 months post partum. To examine whether a psychosocial couple-based prevention program could make a significant change, we also tested an interaction between maternal cortisol change and intervention status in a multivariate regression model. In this study, B indicates unstandardized regression coefficient, β indicates standardized regression coefficient, and SE indicates standard error (SE) of the regression coefficient. We also conducted simple slope analysis for the significant interaction between maternal cortisol change and intervention status in the multivariate regression model. In *Results*, dy/dx indicates the change of y when a unit of x increased. In addition, we included the continuous variable of attendance rate in the analytic models and confirmed that findings did not change. In the sample of 110 mothers, 87% were complete cases. A total of 12 mothers (10.9%) were missing in breastfeeding at wave 2, 2 mothers (1.8%) were missing in BMI at wave 1 or at wave 3, and 1 mother (0.9%) was missing in physical activity at wave 1. Multiple imputation using multivariate normal distribution was used to handle missing data (the number of imputations performed = 10 imputations). All data analyses were conducted in Stata 14 (StataCorp, College Station, Texas).

RESULTS

Participant characteristics

Demographic and health-related characteristics of participating mothers are presented in Table 1. Average age of mothers was 28.6 (SD 4.8) years at baseline. Of 110 mothers, 84.5% were married, the average annual household income at baseline was $64,105.5 (SD $34,445.9), average duration of mothers' education was 15.2 (SD 1.8) years, the majority (93.6%) were non-Hispanic White individuals,

TABLE 2 Changes in maternal cortisol, weight, and BMI

	Preconception	Pregnancy (w1)	12 months post partum (w3)	Unadjusted difference—Preconception to 12 months post partum[a]
Cortisol (μg/dL)				
Intervention	–	−0.03 (0.04)	0.05 (0.06)	0.08 (0.08)
Control	–	−0.03 (0.06)	−0.06 (0.10)	−0.03 (0.12)
Difference	–	−0.01 (0.08)	0.10 (0.11)	0.11 (0.14)
p	–	0.913	0.370	0.436
Weight (kg)				
Intervention	69.1 (2.0)	76.3 (2.2)	70.9 (2.3)	1.8 (0.9)
Control	66.2 (2.2)	73.9 (2.2)	70.5 (2.5)	3.9 (0.8)
Difference	2.9 (3.0)	2.5 (3.1)	0.3 (3.4)	−2.2 (1.2)
p	0.329	0.431	0.921	0.075
BMI (kg/m^2)				
Intervention	25.6 (0.7)	28.3 (0.8)	26.3 (0.9)	0.7 (0.3)
Control	24.3 (0.7)	27.2 (0.7)	25.9 (0.8)	1.4 (0.3)
Difference	1.3 (1.0)	1.1 (1.1)	0.4 (1.2)	−0.8 (0.4)
p	0.209	0.301	0.753	0.082

Note: Data were analyzed by independent *t* test and are presented as mean (SEM).
Abbreviations: w1, wave 1; w3, wave 3.
[a]Unadjusted difference from wave 1 (pregnancy) to wave 3 (12 months post partum).

TABLE 3 Univariate and multivariate regression models for the change in maternal BMI before conception to 12 months post partum (wave 3)

	Crude B (95% CI)	β	p	Adjusted B (95% CI)	β	p
Cortisol change (w3-w1)	0.30 (−0.30 to 0.90)	0.24	0.319	0.27 (−0.32 to 0.85)	0.21	0.366
Intervention status						
Control	(Reference)			(Reference)		
Intervention	**−0.77 (−1.65 to 0.10)**	**−0.39**	**0.082**	**−1.03 (−1.86 to −0.20)**	**−0.51**	**0.015**
BMI residual (w1)	0.12 (0.04 to 0.19)	0.64	0.002	0.11 (0.03 to 0.19)	0.59	0.006
Marital status (w1)						
Non-married	(Reference)			(Reference)		
Married	**−1.25 (−2.47 to −0.03)**	**−0.52**	**0.046**	**−1.18 (−2.39 to 0.03)**	**−0.50**	**0.056**
Sleeping h (w1)	−0.04 (−0.36 to 0.29)	−0.06	0.819	−0.04 (−0.35 to 0.26)	−0.07	0.778
Physical activity (w1)	−0.14 (−0.38 to 0.10)	−0.23	0.248	−0.08 (−0.30 to 0.15)	−0.12	0.508
Breastfeeding (w2)	−0.97 (−1.88 to −0.07)	−0.54	0.035	−0.70 (−1.56 to 0.17)	−0.39	0.111

Note: Data were analyzed by univariate (crude regression coefficients) and multivariate regression results (adjusted regression coefficients).
Abbreviations: w1, wave 1; w2, wave 2; w3, wave 3.

average week of gestation at recruitment was 22.2 (SD 5.6) weeks, and 60% had a boy. As previously reported, there were no significant differences in age, income, education, marital status, gestation weeks, and mental health between these two groups.

Maternal weight and BMI

Table 2 reports maternal anthropometry (weight and BMI) at preconception, pregnancy, and 12 months after childbirth. The proportion of women who had overweight or obesity (BMI >25) at preconception was 41.8% for the overall group (45.6% for intervention group and 37.7% for the control group, with no significant differences by group). There was no significant difference by intervention status in maternal weight or BMI at preconception, pregnancy, or 12 months after childbirth in unadjusted analyses, with a trend for a lower difference in weight (−2.2 [SEM 1.2] kg) and BMI (−0.8 [SEM 0.4]) change for the intervention group compared with the control group from before conception to 12 months post partum.

TABLE 4 Simple slope analysis for the interaction between maternal cortisol change and intervention status predicting maternal BMI change

	Categorical moderator	
	Control group	Intervention group
Simple slope	0.70	−0.61
SE	0.35	0.48
Significance	0.049	0.204
Degrees of freedom	94.03	

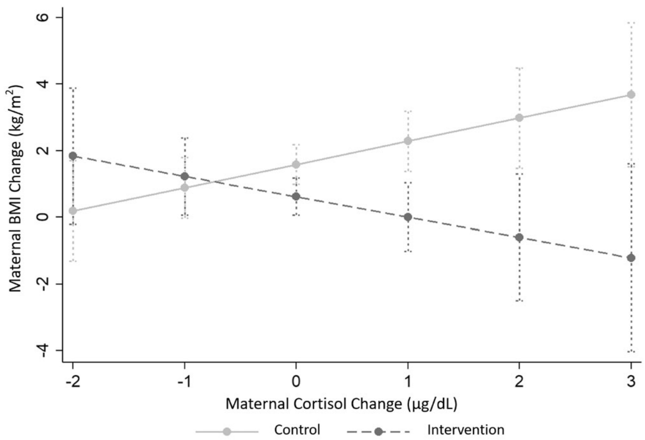

FIGURE 1 Interaction plot between maternal cortisol change, maternal BMI change, and intervention status. Data are presented as mean and SD and were analyzed using simple slope analysis. The light gray solid line indicates significant slope ($p = 0.049$) between mothers' cortisol change and BMI change for the control group, whereas the dark gray dotted line indicates nonsignificant slope ($p = 0.204$) for the intervention group.

Univariate and multivariate models for the change in maternal BMI

Table 3 presents multivariate regression results. BMI residual was positively associated with the change in maternal BMI from before conception to 12 months post partum. Furthermore, mothers in the intervention group were likely to experience a significantly smaller increase in BMI change from before conception to 12 months post partum compared with mothers in the control group (B $= -1.03$, SE $= 0.42$, $p = 0.015$).

On further assessment of an interaction between intervention group status and maternal cortisol change from pregnancy to 12 months post partum, the direct effect of intervention group status on maternal BMI change remained significant (B $= -0.97$, SE $= 0.41$, $p = 0.020$), and the direct effect of maternal cortisol change on maternal BMI change became significant (B $= 0.70$, SE $= 0.35$, $p = 0.049$). The interaction between intervention status and maternal cortisol change was also significant to predict maternal BMI change (B $= -1.31$, SE $= 0.58$, $p = 0.026$). This indicates a significant group difference in the effect of maternal cortisol change on BMI change. As the next step, simple slope analysis was used to reveal more detailed information about the association between maternal cortisol change and BMI change in each group. Table 4 demonstrates that the cortisol change significantly predicted BMI change among mothers in the control group ($dy/dx = 0.70$, $p = 0.049$); specifically, mothers who experienced a greater change in cortisol were more likely to experience a greater change in BMI. However, among mothers in the intervention group, BMI change was not associated with maternal cortisol change ($dy/dx = -0.61$, $p = 0.204$). Figure 1 demonstrates two separate regressions of the outcome, maternal BMI change, on the predictor of maternal cortisol change at specific values of the intervention status as a moderator (control or intervention group).

DISCUSSION

We report here for the first time, to our knowledge, that a preventive intervention designed to improve coparenting practices at the transition to parenthood also improved postpartum maternal anthropometry, resulting in a smaller increase in maternal BMI from before conception to 12 months after pregnancy. We also found that randomization to the coparenting intervention eliminated the inverse association of change in maternal cortisol with change in maternal BMI observed in the control group. This finding suggests that intervention participants were better able to maintain a healthy lifestyle and consequently retain less weight in the face of elevated levels of stress.

For families who were randomized to Family Foundations, there was an improvement in postpartum BMI retention, specifically a 0.8-kg/m^2 difference in the change in maternal BMI from before conception to 12 months after childbirth. This finding did not change when rate of attendance was included in the analysis. To our knowledge, this is the first time that an effect of improving coparenting relationships on maternal anthropometry has been reported. Existing literature reporting on the impact of coparenting-related interventions has focused predominantly on child and parental social, psychological, and clinical health outcomes [13, 14, 17]. The literature assessing interventions to reduce postpartum weight retention has focused solely on an individual mother's lifestyle interventions encompassing diet, physical activity, and/or behavioral change [6]. In a meta-analysis, such interventions achieved impacts on weight change of 2.24 kg [6], which is comparable to our finding of an intervention impact of 2.2 kg. We highlight here the novel strategy of achieving improvements in maternal anthropometry through promoting support from partners and establishing high-quality coparenting relationships at the challenging life stage of the transition to parenthood in the absence of specific diet, physical activity, and behavioral advice.

It is possible that incorporating aspects of coparenting interventions into lifestyle interventions may augment the magnitude of weight or BMI change already achieved in lifestyle programs (either in an additive or possibly a multiplicative manner). The latter may come about as greater coparenting support would likely facilitate increased support and coordination among parents regarding healthy eating and activity routines. A prior study of daily fluctuations in family relationships in the postpartum period found that on days when mothers exercised more than usual, mothers and fathers reported more conflict; the same was not true for days on which fathers exercised more than usual [21]. Furthermore, the benefits of Family Foundations on child social and psychological health were demonstrated to be sustained at least to 7 years after birth by teacher report [17]. Given that postpartum lifestyle interventions showed benefits for maternal anthropometry only up to 15 months as the longest follow-up [22], it is also possible that the benefits of coparenting interventions for maternal anthropometry may be sustained over a longer term. This warrants further investigation.

Exploring the mechanisms of improved maternal anthropometry in the intervention group relative to the control group is of crucial importance. In this study, expectant parents in the control group were mailed a brief pamphlet including general information on selecting childcare, while the intervention group participated in the Family Foundations program designed to foster a supportive coparenting relationship. The beneficial effect of a coparenting intervention on maternal lifestyle could be related to the positive influence of fathers supporting their partners' healthy behaviors. Although weight management is recognized as challenging, postpartum women face additional barriers to maintaining a healthy lifestyle [7], including loneliness, lack of motivation and time due to parenting and domestic tasks, and prioritization of own health below that of their families [23]. A systematic review of 28 qualitative and quantitative studies identified a lack of physical and emotional support from partners for cooking, exercise, housework, or childcare as a barrier to adopting and maintaining a healthy lifestyle [23]. Partner support has been associated with improved maternal diet and physical activity in lifestyle interventions with pregnant women [11] or mothers with preschool-aged children [12]. This is also consistent with prior research that a couples-based approach to reducing cardiovascular disease risk was more effective in improving lifestyle factors than an approach focused solely on the patient [24]. It is therefore crucial to involve a woman's partner in both parenting and in supporting a healthy lifestyle following birth.

We report here that the intervention appeared to eliminate the link between changes in maternal cortisol and BMI across the transition found in the control group. Stress is defined as when perceived demands exceed the capacity of an individual to adapt to the demands. Parenting stress occurs when the demands associated with parenting exceed the personal and social resources available to meet the demands [25]. Stress can result in endocrine system responses, including alterations in the metabolism of cortisol, a glucocorticoid and steroid hormone with production controlled by the hypothalamic pituitary adrenal axis [26]. Our results therefore indicate that a worsening of maternal anthropometry from preconception to the postpartum period was associated with a worsening in markers of maternal stress for mothers in the control group. This suggests that mothers experiencing increased stress following childbirth may have less improvement in postpartum BMI and therefore higher risk of obesity and long-term comorbidities [27]. This is consistent with prior research in the general population reporting that both higher stress and cortisol were associated with weight gain [28] through mechanisms including activation of the hypothalamic pituitary adrenal axis, sympathoadrenal activity, and increased reward-related or emotional eating [29]. An association between stress and both lower physical activity and higher weight retention also was reported after childbirth [30]. Higher serum morning cortisol in late pregnancy in women with obesity was also associated with greater weight retention at 3 months after pregnancy [31], and higher conversion of cortisone to cortisol was associated with a lesser decrease in 12-month postpartum BMI [32]. Although we note these associations have not been consistently reported [33,34], our research supports that cortisol, as a marker of stress, is related to worsened maternal anthropometry after childbirth, with implications for increasing long-term maternal obesity risk.

Although the transition into parenthood is recognized as a highly stressful period for both mothers and fathers [35], maternal parenting stress or poorer mental health was shown to be predicted by the level of perceived emotional or financial parenting support from partners [8]. Our previous research reported that Family Foundations reduced levels of parental stress from 6 months through 3.5 years after childbirth [13], likely by increasing support and reducing conflict. Other research has demonstrated that social [36] or family support [37] weakens the association between psychological [36] or economic stress [37] and higher maternal cortisol in women during pregnancy [36] or the postpartum period [37]. Here we report a similar finding, in that Family Foundations protected mothers from the putative negative effects of cortisol on maternal BMI. This is also consistent with prior research reporting that greater partner support [8] and positive emotions during discussions with partners [38] are associated with improved dietary intake (higher fiber and lower trans fat intake) [8] and higher levels of walking [8] or leisure time physical activity [39] in women at 6 to 8 months after childbirth as key behaviors associated with improved postpartum weight management. Furthermore, in the general population, stress-management interventions, including mindfulness, resulted in decreases in cortisol awakening responses and smaller increases in weight over 4 months [39].

We note study limitations, including self-reported anthropometry and retrospective preconception weight report, which can contribute to response and recall bias; we recommend use of prospective and objective measures in future research. We note that our population was largely non-Hispanic, White, heterosexual couples from one geographic region. As such the generalizability of these findings to other settings is currently limited. Although we controlled for a wide range of factors potentially associated with postpartum BMI including sleep [40], breastfeeding [41], and physical activity [42], we lack data on other factors such as dietary intake. Although coparenting was the predominant focus of the intervention, it is possible that the participants may have learned other skills or information in the intervention that contributed to improvements in stress or anthropometry. Gestational weight gain is a key predictor of postpartum weight retention [43] and, in prior research, mediated the association between third-trimester perceived stress and postpartum weight retention [44]. Further research is therefore warranted examining the interrelationship between coparenting relationships, stress, cortisol, and weight management across both pregnancy and the postpartum period. Future research should also consider factors potentially associated with alterations in cortisol, including gestational age, seasonality, and gestational weight gain and use of multiple samples, diurnal responses, or stress-related activity. In addition to the demonstrated benefits of Family Foundations for birth outcomes and child emotional and psychological health, which may be mediated by improvements in maternal psychological health [13, 14, 17], there may also be potential benefits for other outcomes, including childhood and paternal obesity [35], which should be explored.

CONCLUSION

Maternal postpartum weight retention is a significant public health problem associated with adverse maternal, obstetric, fetal, and child consequences, including increased risk of long-term maternal cardiovascular disease and obesity. A coparenting-focused intervention, Family Foundations, improved maternal postpartum anthropometry, with this effect potentially related to the intervention ameliorating the negative effect of stress (as measured by cortisol) on lifestyle, weight, and BMI. The potential of coparenting relationship enhancement for improving maternal anthropometry therefore warrants urgent attention. Future research should investigate whether combining coparenting and lifestyle interventions could augment and sustain postpartum anthropometric improvements and provide additional benefits on child and paternal anthropometry.O

ACKNOWLEDGMENTS

Restrictions apply to the availability of some or all data generated or analyzed during this study to preserve patient confidentiality or because they were used under license. The corresponding author will, on request, detail the restrictions and any conditions under which access to some data may be provided. This secondary analysis differs from the previous analysis using the Family Foundations study data. In this study a post hoc analysis was performed in which the data from 110 mothers who participated in the survey and saliva sample collection at wave 1 (pregnancy) and wave 3 (12 months post partum) were analyzed to examine the intervention effect on maternal BMI change from before conception to 12 months post partum. The authors of this paper (Jin-Kyung Lee, Damon Jones, Kaitlin Fronberg, and Mark E. Feinberg) have shared the data from the Family Foundations study in order to complete this post hoc analysis.

FUNDING INFORMATION

Lisa Moran is funded by a National Heart Foundation Future Leader Fellowship (101169). These data were funded by grants from the National Institute of Child Health and Human Development (K23 HD042575 and R01 HD058529-01A1) and the National Institute of Mental Health (R21 MH064125-01; Mark E. Feinberg, principal investigator). The funders had no role in the conduct of the study.

CONFLICT OF INTEREST

Mark E. Feinberg created the Family Foundations program and is the owner of a private company, Family Gold, which disseminates the Family Foundations program. His financial interest has been reviewed by the Institutional Review Board and the Conflict of Interest Committee at The Pennsylvania State University. The remaining authors indicated no conflict of interest.

CLINICAL TRIAL REGISTRATION

ClinicalTrials.gov identifier NCT01901536.

REFERENCES

1. Cameron AJ, Welborn TA, Zimmet PZ, et al. Overweight and obesity in Australia: the 1999-2000 Australian diabetes, obesity and lifestyle study (AusDiab). *Med J Aust*. 2003;178:427-432.
2. Williamson DF, Kahn HS, Remington PL, Anda RF. The 10-year incidence of overweight and major weight gain in US adults. *Arch Intern Med*. 1990;150:665-672.
3. Australian Institute of Health and Welfare. Australia's mothers and babies data visualisations. Updated June 21, 2022. Accessed February 20, 2021. https://www.aihw.gov.au/reports/mothers-babies/australias-mothers-babies/contents/about
4. Ehrlich SF, Hedderson MM, Feng J, Davenport ER, Gunderson EP, Ferrara A. Change in body mass index between pregnancies and the risk of gestational diabetes in a second pregnancy. *Obstet Gynecol*. 2011;117:1323-1330.
5. National Institute for Health and Care Excellence. Weight Management Before, During and After Pregnancy. Public health guideline [PH27]. Published July 28, 2010. https://www.nice.org.uk/guidance/ph27
6. Lim S, Liang X, Hill B, Teede H, Moran LJ, O'Reilly S. A systematic review and meta-analysis of intervention characteristics in postpartum weight management using the TIDieR framework: a summary of evidence to inform implementation. *Obes Rev*. 2019;20:1045-1056.
7. Buelo A, Kirk A, Lindsay R, Jepson R. Exploring the effectiveness of physical activity interventions in women with previous gestational diabetes: a systematic review of quantitative and qualitative studies. *Prev Med Rep*. 2019;14:100877. doi:10.1016/j.pmedr.2019.100877
8. Faleschini S, Millar L, Rifas-Shiman SL, Skouteris H, Hivert MF, Oken E. Women's perceived social support: associations with postpartum weight retention, health behaviors and depressive symptoms. *BMC Womens Health*. 2019;19:143. doi:10.1186/s12905-019-0839-6
9. Kragelund Nielsen K, Groth Grunnet L, Terkildsen Maindal H, Workshop DDA, Speakers W. Prevention of type 2 diabetes after gestational diabetes directed at the family context: a narrative review from the Danish diabetes academy symposium. *Diabet Med*. 2018;35:714-720.
10. Jones C, Burns S, Howat P, Jancey J, McManus A, Carter O. Playgroups as a setting for nutrition and physical activity interventions for mothers with young children: exploratory qualitative findings. *Health Promot J Austr*. 2010;21:92-98.
11. Shah MK, Kieffer EC, Choi H, Schumann C, Heisler M. Mediators and moderators of the effectiveness of a community health worker intervention that improved dietary outcomes in pregnant Latino women. *Health Educ Behav*. 2015;42:593-603.
12. Miller YD, Trost SG, Brown WJ. Mediators of physical activity behavior change among women with young children. *Am J Prev Med*. 2002;23:98-103.

13. Feinberg ME, Jones DE, Kan ML, Goslin MC. Effects of Family Foundations on parents and children: 3.5 years after baseline. *J Fam Psychol*. 2010;24:532-542.
14. Feinberg ME, Kan ML. Establishing Family Foundations: intervention effects on coparenting, parent/infant well-being, and parent-child relations. *J Fam Psychol*. 2008;22:253-263.
15. Harmon DK, Perry AR. Fathers' unaccounted contributions: paternal involvement and maternal stress. *Fam Soc*. 2011;92:176-182.
16. Hartley E, Hill B, McPhie S, Skouteris H. The associations between depressive and anxiety symptoms, body image, and weight in the first year postpartum: a rapid systematic review. *J Reprod Infant Psychol*. 2018;36:81-101.
17. Feinberg ME, Jones DE, Roettger ME, Solmeyer A, Hostetler ML. Long-term follow-up of a randomized trial of Family Foundations: effects on children's emotional, behavioral, and school adjustment. *J Fam Psychol*. 2014;28:821-831.
18. Radloff LS. The CES-D scale: a self-report depression scale for research in the general population. *Appl Psychol Meas*. 1977;1:385-401.
19. Taylor JA. A personality scale of manifest anxiety. *J Abnorm Psychol*. 1953;48:285-290.
20. Feinberg ME, Roettger ME, Jones DE, Paul IM, Kan ML. Effects of a psychosocial couple-based prevention program on adverse birth outcomes. *Matern Child Health J*. 2015;19:102-111.
21. Feinberg ME, Jones DE, McDaniel BT, Liu S, Almeida D. New fathers' and mothers' daily stressors and resources influence parent adjustment and family relationships. *Monogr Soc Res Child Dev*. 2019;84:18-34.
22. Lioret S, Campbell KJ, Crawford D, Spence AC, Hesketh K, McNaughton SA. A parent focused child obesity prevention intervention improves some mother obesity risk behaviors: the Melbourne inFANT program. *Int J Behav Nutr Phys Act*. 2012;9:100. doi:10.1186/1479-5868-9-100
23. Makama M, Awoke MA, Skouteris H, Moran LJ, Lim S. Barriers and facilitators to a healthy lifestyle in postpartum women: a systematic review of qualitative and quantitative studies in postpartum women and healthcare providers. *Obes Rev*. 2021;22:e13167. doi:10.1111/obr.13167
24. Sher T, Braun L, Domas A, Bellg A, Baucom DH, Houle TT. The partners for life program: a couples approach to cardiac risk reduction. Fam Process. 214;53:131-149.
25. Deater-Deckard K, Scarr S. Parenting stress among dual earner mothers and fathers: are there gender differences? *J Fam Psychol*. 1996;10:45-59.
26. Keller J, Gomez R, Williams G, et al. HPA axis in major depression: cortisol, clinical symptomatology and genetic variation predict cognition. *Mol Psychiatry*. 2017;22:527-536.
27. Linné Y, Dye L, Barkeling B, Rössner S. Long-term weight development in women: a 15-year follow-up of the effects of pregnancy. *Obes Res*. 2004;12:1166-1178.
28. Chao AM, Jastreboff AM, White MA, Grilo CM, Sinha R. Stress, cortisol, and other appetite-related hormones: prospective prediction of 6-month changes in food cravings and weight. *Obesity (Silver Spring)*. 2017;25:713-720.
29. Geiker NRW, Astrup A, Hjorth MF, Sjodin A, Pijls L, Markus CR. Does stress influence sleep patterns, food intake, weight gain, abdominal obesity and weight loss interventions and vice versa? *Obes Rev*. 2018;19:81-97.
30. Whitaker K, Young-Hyman D, Vernon M, Wilcox S. Maternal stress predicts postpartum weight retention. *Matern Child Health J*. 2014;18:2209-2217.
31. Mina TH, Denison FC, Forbes S, Stirrat LI, Norman JE, Reynolds RM. Associations of mood symptoms with ante- and postnatal weight change in obese pregnancy are not mediated by cortisol. *Psychol Med*. 2015;45:3133-3146.
32. Rogers SL, Hughes BA, Tomlinson JW, Blissett J. Cortisol metabolism, postnatal depression and weight changes in the first 12 months postpartum. *Clin Endocrinol (Oxf)*. 2016;85:881-890.
33. Collings R, Hill B, Skouteris H. The influence of psychological factors on postpartum weight retention 12 months post-birth. *J Reprod Infant Psychol*. 2018;36:177-191.
34. Straub H, Simon C, Plunkett BA, et al. Evidence for a complex relationship among weight retention, cortisol and breastfeeding in postpartum women. *Matern Child Health J*. 2016;20:1375-1383.
35. Saxbe D, Rossin-Slater M, Goldenberg D. The transition to parenthood as a critical window for adult health. *Am Psychol*. 2018;73:1190-1200.
36. Giesbrecht GF, Poole JC, Letourneau N, et al. The buffering effect of social support on hypothalamic-pituitary-adrenal axis function during pregnancy. *Psychosom Med*. 2013;75:856-862.
37. Jewell SL, Luecken LJ, Gress-Smith J, Crnic KA, Gonzales NA. Economic stress and cortisol among postpartum low-income Mexican American women: buffering influence of family support. *Behav Med*. 2015;41:138-144.
38. Hutt RL, Moore GA, Mammen MA, Symons DD. Postpartum mothers' leisure-time exercise behavior is linked to positive emotion during partner discussions. *Res Q Exerc Sport*. 2017;88:447-454.
39. Daubenmier J, Kristeller J, Hecht FM, et al. Mindfulness intervention for stress eating to reduce cortisol and abdominal fat among overweight and obese women: an exploratory randomized controlled study. *J Obes*. 2011;2011:651936. doi:10.1155/2011/651936
40. Siega-Riz AM, Herring AH, Carrier K, Evenson KR, Dole N, Deierlein A. Sociodemographic, perinatal, behavioral, and psychosocial predictors of weight retention at 3 and 12 months postpartum. *Obesity (Silver Spring)*. 2010;18:1996-2003.
41. Baker JL, Gamborg M, Heitmann BL, Lissner L, Sorensen TI, Rasmussen KM. Breastfeeding reduces postpartum weight retention. *Am J Clin Nutr*. 2008;88:1543-1551.
42. Ohlin A, Rossner S. Trends in eating patterns, physical activity and socio-demographic factors in relation to postpartum body weight development. *Br J Nutr*. 1994;71:457-470.
43. Rong K, Yu K, Han X, et al. Pre-pregnancy BMI, gestational weight gain and postpartum weight retention: a meta-analysis of observational studies. *Public Health Nutr*. 2015;18:2172-2182.
44. Leonard KS, Adams EL, Savage JS, et al. Influence of prenatal perceived stress on postpartum weight retention is mediated by high gestational weight gain in women with overweight. *Clin Obes*. 2021;11:e12446. doi:10.1111/cob.12446

How to cite this article: Moran LJ, Lee J-K, Jones D, Fronberg K, Feinberg ME. Coparenting-focused preventive intervention reduces postnatal maternal BMI and buffers impact of cortisol. *Obesity (Silver Spring)*. 2022;30(8):1564-1572. doi:10.1002/oby.23466