J Behav Med (2022) 45:894–903
https://doi.org/10.1007/s10865-022-00338-x

Examining negative affect, sleep duration, and using food to cope as predictors of weight in midlife women

Dana R. Riedy[1] · **Ashley R. MacPherson**[1] · **Sahar Sabet**[1] · **Natalie D. Dautovich**[1]

Received: 6 January 2021 / Accepted: 20 June 2022 / Published online: 6 August 2022

Abstract Midlife women are vulnerable to developing obesity. Behavioral and psychosocial factors including sleep duration, stress eating, and negative emotionality are risk factors. However, little is known about the complex daily interplay between sleep, eating, emotion, and weight among midlife women. The current study examined how daily sleep, using food to cope, and negative emotionality are associated with weight using a daily process research design. An archival analysis was performed using the Midlife in the United States-II study (MIDUS II). The sample consisted of 489 midlife women (40–64 years of age). Variables included ecological momentary assessments of daily sleep duration, using food to cope, and negative affect (means and intraindividual variability) and a standardized measurement of BMI. Sleep duration variability was a significant predictor of BMI, albeit the model only accounted for .8% of the variance in BMI (b = .019, $p < .05$). In the final adjusted model, sleep duration variability, using food to cope, age, and physical activity were all significant predictors of BMI $F(5, 559) = 21.503$, $p < .001$, $R^2 = .161$, $\bigotimes R^2 = .024$, $p = .001$. Variability in negative affect, mean sleep duration or negative affect and the interactions between sleep duration (mean, variability) and negative affect (mean, variability) were not significant. Greater variability in sleep duration and greater use of food to cope predicted higher BMI in this sample across age and physical activity levels. Results highlight that daily health and psychosocial factors play an important role in weight.

Keywords Weight · Emotions · Eating behavior · Sleep · Midlife women

Introduction

Obesity is a complex, multifactorial health condition that is a major cause of morbidity and mortality (Ogden et al., 2015). Although obesity is prevalent across age groups, sexes, and demographic factors, the condition is particularly prevalent for women in midlife with 42% of women between the ages of 40–60 years old classified as obese (Ogden et al., 2015). Specifically, women in midlife have high rates of obesity measured via BMI (i.e., BMI greater than or equal to 30; Ogden et al., 2015) and also have high rates of central adiposity defined as excessive abdominal fat around the stomach and abdomen area (i.e., greater than 88 cm; Grundy et al., 2005). Both obesity and central obesity are risk factors for poor health conditions in midlife including cardiovascular disease, breast cancer, metabolic syndrome, and depression (de Wit et al., 2010; Grundy et al., 2005).

Multiple explanations exist concerning the prevalence of obesity in midlife women. Women in midlife experience biological changes associated with aging and menopause including decreases in estrogen and increases in body fat distribution in the abdominal area (Heymsfield et al., 1994). However, evidence suggests that biological and developmental changes due to menopause and aging do not alone account for changes in weight at midlife (Davis et al., 2012a). As such, modifiable lifestyle factors such as eating behaviors, sleep, and psychosocial functioning (i.e., social support, mental health, stress) show promise as mechanisms

---

✉ Dana R. Riedy
schreibedr@vcu.edu

✉ Ashley R. MacPherson
macphersona@vcu.edu

[1] Department of Psychology, Virginia Commonwealth University, 800 West Franklin Street, P.O. Box 842018, Richmond, VA 23284-2018, USA

leading to weight gain in this population (Crawford et al., 2011; Torres & Nowson, 2007). For example, using food to cope with stress is common in midlife women and is associated with higher BMI (van Strien et al., 2016). Additionally, problematic eating behaviors like stress eating are shown to be interrelated with other daily processes such as negative emotionality (van Strien et al., 2016) and sleep problems in midlife women (Trace et al., 2012). As problematic eating behaviors, sleep, and emotions are interrelated processes, it is necessary to disentangle their individual contributions to weight gain in midlife women.

Negative emotionality is another daily process of particular interest in their relation to weight gain. Women in midlife experience high and fluctuating rates of negative emotionality which is a risk factor for maladaptive eating behavior and weight gain (Crawford et al., 2011; Konttinen et al., 2010). Specifically, women in midlife are at risk for the development of depressive symptoms and anxiety, with particular risk during the perimenopausal and early postmenopausal time period (Bromberger et al., 2007; Cohen et al., 2006). Although biological factors such as decreases in estrogen play a role in mood continuity (Avis et al., 1994), negative emotional outcomes are also linked to work-life responsibilities, changes in caregiving roles, marital dissatisfaction, lack of social support, and psychological concerns due to the aging (Earle et al., 1997).

In addition to negative emotionality as a risk factor for weight gain in this population, women in midlife also experience high rates of sleep disturbance and disruption (Polo-Kantola, 2011) which is an additional risk factor for obesity. Between 33 and 51% of women report sleep problems during midlife with prevalence associated with vasomotor symptoms, changes in hormone levels, mood, perceived health, and stress (Kravitz et al., 2003). Poor and inadequate sleep is regarded as a core symptom of menopause (National Institutes of Health, 2005) and is a risk factor for poor weight outcomes in midlife women (Hall et al., 2012; Lee & Shin, 2015; Taylor et al., 2016). Although poor and inadequate sleep can include short sleep duration (i.e., less than six hours; Choi et al., 2011), unstable sleep timing (Taylor et al., 2016), reduced sleep quality (Jennings et al., 2007) and/or poor sleep efficiency (Buysse, 2014), sleep duration is a consistent and independent contributor to weight gain in this population (Hall et al., 2008; Patel & Hu, 2008). In particular, short sleep duration increases desire to consume energy dense food choices, increases levels of appetitive hormones, and interferes with emotional-cognitive reasoning involving food choices (Spiegel et al., 2004).

Although negative emotionality, short sleep duration, and problematic eating behaviors influence weight gain in midlife independently, there is also evidence of a detrimental association between negative emotionality and sleep whereby negative affect is exacerbated by high rates of sleep disruption in midlife women (Pimenta et al., 2014; Torres & Nowson, 2007). As such, the concomitant higher rates of negative emotionality and sleep disruption in midlife women may interact to elevate the risk for maladaptive eating behaviors and subsequent weight gain (van Strien et al., 2016). Despite this risk, little is known about the complex daily interplay between sleep, emotion, and weight gain among midlife women. In particular, both sleep and emotion tend to vary considerably day-to-day (Gómez-Santos et al., 2016; Gordon et al., 2016, Gordon & Sander, 2021; Zolfaghari et al., 2020). Despite this variability, most research investigating sleep and emotion relies on mean estimates via cross-sectional and retrospective self-report. As such, it is possible that the measurement of central tendency may fail to fully capture the complex nature of sleep and emotionality in this population. As research investigating day-to-day variability is sparse, it is unclear whether mean scores or variability is a better predictor for weight outcomes. Furthermore, it is also unclear how day-to-day variability in sleep and emotion interact to predict weight outcomes. Therefore, given the likelihood of poor sleep duration and negative emotionality in this population, poorer overall mean levels of sleep and/or emotional functioning could be compounded by greater variability in these behaviors.

To date, research linking sleep, emotion, eating behaviors, and weight has relied on cross-sectional, retrospective self-report methodology and/or laboratory-based methodology. As behavioral weight gain comprises daily habits and tendencies, there is a need to identify the daily lifestyle factors that influence weight gain on a micro level. Additionally, given the lack of research regarding daily processes of sleep, emotion, eating behaviors, and weight, and their interrelatedness, the unique contributions of these variables remains unclear. Therefore, the current studies attempt to disentangle the relative predictiveness of variability versus mean values and the role of affect versus sleep duration versus eating behaviors in predicting BMI. Understanding micro-level changes in daily habits and affect can ultimately lead to changes in individual-level prevention and intervention strategies as well as macro-level public health concerns such as obesity and its associated morbidities such as diabetes, breast cancer, and metabolic syndrome.

First, we examined whether a central tendency measurement of negative emotionality, using food to cope, and sleep duration were strong predictors of BMI. Next, we examined whether variability in negative emotionality via negative affect, and/or variability in sleep duration is a predictor of BMI. Then, we tested the interactions of sleep duration, using food to cope, and negative emotionality in their association to BMI. Given the strong link between sleep (Trace et al., 2012) and affect (van Strien et al., 2016) with eating behaviors, we also explored the role of problematic eating behaviors as a further predictor of BMI.

It was hypothesized that shorter and more variable sleep duration, higher and more variable negative affect and greater use of food to cope would be associated with higher weight outcomes. It was also hypothesized that there would be an interaction between sleep duration and negative emotionality, such that more negative or variable emotionality would interact with shorter and/or more variable sleep to increase weight. Results from this study will provide insight into daily lifestyle and behavioral factors that influence weight outcomes in midlife women using EMA methodology within natural environments.

Methods

Design

Data was obtained from a secondary data from the Midlife in the United States (MIDUS-II) dataset. MIDUS-II is funded by the National Institute on Aging at the University of Wisconsin Madison (P01-AG020166). Specifically, midlife women who participated in the MIDUS II daily dairy study (NSDE II), an eight-day daily diary study where participants reported their daily stress, emotions, sleep, and experiences across eight consecutive days through completion of nightly assessments and telephone interviews were included in the current study.

Participants

Participants completed the Midlife in the United States (MIDUS) II study, a longitudinal telephone and paper-and-pencil study designed to examine the roles of behavioral, psychological, and social factors in aging and health. Data collection for MIDUS-II took place from 2004 to 2006. All eligible participants were non-institutionalized, English-speaking adults, and between 35 and 86 years of age.

The current study consists of a sub-sample of 489 female community-dwelling MIDUS-II participants between the ages of 40–64. On average, participants were 52.72 (7.2) years of age, primarily white (93.5%), with an average annual income of $74,982 (58,489; Table 1). Participants were eligible if they completed both Project 1 and Project 2 (daily diary sub-study, “The National Study of Daily Experiences”) of the MIDUS-II study. Project 1 involved the completion of telephone and paper and pencil questionnaires while Project 2 investigated day-to-day life stressors and daily physical and emotional reactivity using ecological momentary assessment (EMA). Demographic information and participant characteristics including, BMI, race, income, education, and self-rated health was collected during Project 1 of the MIDUS-II study (see Table 1.). Daily physical activity, sleep, stress, and mood were collected during Project 2. There was at least 3 months between the data collection for Project 1 and Project 2, however the exact timing of data collection for participants is unknown.

Table 1 Participant sociodemographic and health characteristics

Variable (*M, SD*)	*N*	Percentage (%)
Age (52.72,7.2)		
Race/ethnicity		
White	420	93.5
Black	10	2.2
Native American	5	1.1
Asian	3	.7
Other	9	2.0
Annual income ($74,982, 58,439)		
Highest level of education		
Professional degree	9	2.0
Master’s degree	58	12.9
Some Graduate School	19	4.2
Bachelors	83	18.5
Two-year degree	32	7.1
Some College	115	25.7
High school/GED	117	26.1
Did not graduate high school	15	3.3
Average Sleep Duration (hours; 7.05, .99)		
Average Negative Affect (.21, .25)		
Average Using Food to Cope (4.28, 2.00)		

Measures

Daily negative affect

A state negative affect measure assessed symptoms of depression and anxiety nightly across eight nights to assess daily negative affect. Daily negative affect was calculated as both mean negative affect across the eight-day period as well as variability in negative affect across eight days. The scale was administered in the morning or evening, depending on each participant’s availability. A 6-item questionnaire asked participants, “how much of the time today did you feel: worthless; hopeless; nervous; restless or fidgety; that everything was an effort; and so sad that nothing could cheer you up”. Participants rated their response on a 5-point scale from 0 (none of the time), to 4 (all of the time), and scores were summed across items (Kessler et al., 2002). Cronbach’s alpha values calculated for each day of data collection ranged from 0.75 to 0.85. In previous studies, the measure of daily negative affect yielded Cronbach’s alpha values between 0.92 (Almeida et al., 2001) and 0.94 (Seltzer et al., 2009).

To measure mean negative affect, the average rating of negative affect across the eight-day time period was calculated. To assess variability negative affect, intraindividual variability calculations were obtained for each participant's negative affect score across the eight-day time period. This resulted in intraindividual standard deviations (IISD). All IISD variables were detrended for time to control for any variations due to the effects of observing behaviors over time. Specifically, detrending for time produces a variable that reflects variability that is not due to the effects of time, per se (e.g., practice effects, participation fatigue, etc.), but rather due to inherent variations in the behavior. Detrending was conducted via linear regression analyses for all participants with time (linear, quadratic, and cubic functions) as the independent variables and the negative affect as the dependent outcome. IISD values were then calculated for the negative affect variables using the time-independent residuals from the aforementioned linear regression analyses. This detrending process resulted in affect variability that consisted of within-person standard deviations that are independent of any influences of time.

Using food to cope with stress

Using food to cope with stress was measured via a coping questionnaire where participants were asked to indicate how they ''usually experience a stressful event.'' Two choices included, ''I eat more of my favorite foods to make myself feel better,'' and ''I eat more than I usually do." Responses ranged from 1 = a lot to 4 = not at all. The sum of the two questions were obtained and reverse coded so higher scores indicated greater stress eating. Scores ranged from 2 (not all) to 8 (a lot). The correlation between the two items was 0.80 in the full MIDUS-II analytical sample.

Daily sleep

Daily sleep was obtained through daily self-report of sleep duration where participants indicated the amount of sleep they had obtained (in hours and minutes) during the previous sleep period. Although the self-reported sleep duration measure does not contain the additional indices of sleep found in other questionnaires such as sleep quality or satisfaction with sleep, previous research identifies self-reported sleep duration as a standard index in epidemiological studies (Kripke et al., 2002). Daily sleep duration was assessed over an eight-day time period. For analyses, both mean sleep duration and variability in sleep duration was calculated. Mean sleep duration was calculated as the average time, in minutes participants reported the amount of sleep they had obtained across eight days. Variability in sleep duration was quantified by calculating intraindividual variability in sleep duration for each participant's minutes of sleep across eight days using the same process outlined above for the negative affect variable. This process resulted in sleep duration variability that consisted of within-person standard deviations that are independent of any influences of time.

Weight

Weight in the current study was assessed using body mass index (BMI), which was measured during a physical exam using a standardized procedure. BMI was calculated by dividing body weight in kilograms by height in meters squared. Having a BMI of 18.5 to 24.9, is considered healthy. A BMI of 25 to 29.9 is considered overweight, and a BMI of 30 or higher is considered obese (Ogden et al., 2015). BMI was used as a continuous variable in the current study in order to better understand sleep and mood's association with BMI along a continuum of different indices.

Covariates

Analyses were conducted to identify covariates that were potential confounders with daily emotion/stress, sleep, and weight. These included age, physical activity, annual income, education, and race/ethnicity (Campbell & Samaras, 2000; Lahmann et al., 2000; Owens & Matthews, 1998). Age was included as both a predictor of affect, sleep, and BMI as well as a rough indicator of menopause status given the lack of menopause status indicators in our dataset. Physical activity was assessed by daily diaries with the question, "How many minutes of moderate to vigorous exercise did you engage in today?" A score of weekly physical activity was obtained by summing the score of physical activity, in minutes, across the seven days of data collection. Annual income, education, and race/ethnicity was obtained from demographic questionnaires.

Statistical analyses

Data preparation and data cleaning

SPSS 27.0 was used for all data analyses. Power calculations using G*Power (Faul et al., 2009) suggested that for a regression analysis, a sample size of at least 109 participants was needed to predict an R^2 of at least 0.15 at an alpha level of 0.05, with a power of 0.80 ($1—\beta$). In the current study, assuming a medium effect size, 489 participants was sufficient to detect an effect.

Results

Data preparation and data cleaning

Data were cleaned and descriptive statistics (means, standard deviations, and frequencies) were calculated to verify that data met the assumptions of the planned analyses. A review was conducted to assess skewness, kurtosis, and outliers for all main variables and covariates of interest. Skewness and kurtosis values for sleep duration and affect variables were close to or below an absolute value of 2, indicating that they were approximately normally distributed (George & Mallery, 2010). Additionally, assumptions of independence, normality, multicollinearity, and linearity were sufficiently met. A Little's Missing Completely at Random (MCAR) test was conducted to determine missingness of data. Data was determined to be MCAR (χ^2 (4) = 3.09, $p = 0.543$).

Next, Pearson correlation analyses were calculated to identify significant bivariate associations between covariates and BMI. To increase power and degrees of freedom for analyses, only variables with significant bivariate associations were included in the final statistical models ($p < 0.05$). In final analyses, covariates included age and average physical activity per day. Annual income, race/ethnicity, and highest level of education achieved were not included in statistical models given that they were not statistically related to BMI in the sample.

Mean sleep duration, negative affect, using food to cope, and BMI

First a three-step hierarchical regression was used to identify whether age and physical activity was a significant predictor of BMI (Step 1), followed by average sleep duration or average negative affect across an eight-day time period (Step 2), and using food to cope (Step 3). Mean negative affect and sleep duration were not significant predictors of BMI. In the final model, however, using food to cope, age, and physical activities were significant predictors of BMI, $F(5, 602) = 22.934$ $p < 0.001$, $R^2 = 0.160$, $\otimes R^2 = 0.025$, $p = 0.001$ (Table 2). Being more likely to use food to cope with stress, being of older age, and engaging in less physical activity was associated with higher BMI (predicted 16% of the variance in BMI).

Table 2 Mean and variability models predicting BMI

	BMI					
	Overall mean model (Model 1)			Variability model (Model 2)		
	Coefficient (*SE*)	95% CI	sr^2	Coefficient (*SE*)	95% CI	sr^2
Step 1						
Age *(U1)*	.069 (.035)*	.000, .138	.079	.079 (.037)**	.006, .151	.097
Physical Activity *(U2)*	− .017 (.005)***	− .027, − .007	− .137	− .019 (.005)*	− .030, − .008	− .123
	$F(2, 605) = 7.692$, $p < .001$, $R^2 = .025$			$F(2, 562) = 8.297$, $p < .001$, $R^2 = .029$		
Step 2						
Age *(U1)*	.071 (.035)*	.002, .140	.081	.086 (.037)*	.014, .159	.097
Physical Activity *(U2)*	− .017 (.005)**	− .027, − .007	− .136	− .019 (.005)**	− .030, − .008	− .145
Negative Affect *(X1)*	.055 (.071)	− .084, .195	.031	− .061 (.209)	− .471, .349	− .012
Sleep Duration Model *(X2)*	− .004 (.004)	− .012, .005	− .034	.021 (.009)*	.003, .039	.096
	$F(4, 603) = 4.226$ $p = .002$, $R^2 = .027$, $\Delta R^2 = .002$, $p = .465$			$F(4, 560) = 5.517$, $p < .001$, $R^2 = .038$, $\Delta R^2 = .009$, $p = .069$		
Step 3						
Age *(U1)*	.073 (.033)*	.009, .138	− .116	.087 (.035)*	.019, .155	.097
Physical Activity *(U2)*	− .015 (.005)**	− .024, − .005	.084	− .016 (.005)**	− .026, − .006	− .123
Negative Affect *(X1)*	− .016 (.066)	− .146, .114	− .009	− .085 (.195)	− .468, .299	− .017
Sleep Duration Model *(X2)*	− .006 (.004)	− .013, .002	− .053	.023 (.009)**	.007, .040	.106
Using Food to Cope *(X3)*	1.161 (.119)***	.927, 1.394	.364	1.116 (.123) ***	.874, 1.358	.351
	$F(5, 602) = 22.934$ $p < .001$, $R^2 = .160$, $\Delta R^2 = .133$, $p < .001$			$F(5, 559) = 21.503$, $p < .001$, $R^2 = .161$, $\Delta R^2 = .123$, $p < .001$		

Model 1 = overall means model with mean negative affect and mean sleep duration as the predictors; Model 2 = variability model with variability in negative affect and variability in sleep duration as the predictors; sr^2 represents the squared part correlation

*$p < .05$, **$p < .01$, ***$p < .001$

Sleep duration variability, negative affect variability, using food to cope, and BMI

Another three-step hierarchical regression was used to identify whether age and physical activity was a significant predictor of BMI (Step 1), followed by variability in sleep duration or negative affect across an eight-day time period (Step 2), and using food to cope (Step 3). In step 2, sleep duration variability, not affective variability, was a significant predictor of BMI, albeit the model only accounted for 4% of the variance in BMI. In the final model with all predictors, sleep duration variability, using food to cope, age, and physical activity were all significant predictors of BMI $F(5, 559) = 21.503$, $p < 0.001$, $R^2 = 0.161$, $\otimes R^2 = 0.123$, $p < 0.001$. The final model predicted 16% of the variance in BMI and indicated that greater sleep duration variability, more reliance on using food to cope with stress, older age, and less physical activity was associated with higher BMI. After adjustment for covariates and converting the sleep duration variability variable from minutes to hours, it was calculated that each hour of more variable sleep duration was associated with 1.26 kg/m^2 greater BMI.

Interactions between sleep and affect

Finally, moderation analyses identified whether any significant interactions existed among the sleep and negative affect variables. In order to parse the multiple avenues by which mean and variability may combine to predict BMI, we examined the interaction between mean levels, between variability, and between mean and variability in sleep duration and emotionality. We wanted to explore if worse mean levels, higher variability, or a combination of worse mean and greater variability was more predictive of BMI as variability or mean levels may have more relevance for sleep or mood in this group. Moderation analyses used Hayes' (2013) SPSS PROCESS macro, which is a tool which allows for the examination of the conditional effects of a moderation using a bootstrapping process. This process includes resampling 5,000 times in order to estimate the bias-corrected sampling distribution of the conditional effects identified in the model. In the mean model (i.e., aim 1), the interaction among mean sleep duration and mean negative affect was not significant ($p = 0.397$; $b = -0.001$; 95% CI − 0.002, 0.001). Similarly, in the variability model (i.e., aim 2) the interaction among sleep duration variability and negative affect variability, was not significant ($p = 0.680$; $b = 0.003$; 95% CI − 0.010, 0.015). Lastly, the combined interactions of mean affect and variability in sleep duration ($p = 0.115$; $b = -0.002$; 95% CI − 0.005, 0.001) and variability in affect and mean sleep duration were also non-significant ($p = 0.854$; $b = -0.001$; 95% CI − 0.006, 0.005) (Table 3).

Discussion

The current study examined the association of daily processes of negative emotionality, sleep duration, and using food to cope with BMI in a sample of midlife women. Specifically, the study hypothesized that shorter and more variable sleep duration, higher and more variable negative affect, and greater use of food to cope would be associated with higher weight outcomes. It was also hypothesized that there would be an interaction between sleep duration and negative emotionality. The current study did not find a significant association between mean sleep duration, mean negative affect, and variability in negative affect with weight outcomes. Results indicated that sleep duration, but

Table 3 Interaction models predicting BMI

	Model 1 Coefficient (*SE*)	Model 2 Coefficient (*SE*)	Model 3 Coefficient (*SE*)	Model 4 Coefficient (*SE*)
BMI				
Mean negative affect × mean sleep duration	− .001 (.001)			
Variability in negative affect × variability in sleep duration		.019 (.014)		
Mean negative affect × variability in sleep duration			− .002 (.001)	
Variability in negative affect × mean sleep duration				− .001 (.003)
Using food to cope	1.160 (.119)***	.113 (.123)***	1.123 (.120)***	1.138 (.123)***
Age	.073 (.033)*	.086 (.035)*	.087 (.034)**	.073 (.034)*
Physical activity	− .012 (.005)**	− .016 (.005)**	− .016 (.005)**	− .016 (.005)**
	$R^2 = .161$ F (6, 601) = 19.222, $p < .001$	$R^2 = .162$ F (6, 558) = 17.921, $p < .001$	$R^2 = .165$ F (6, 584) = 19.193, $p < .001$	$R^2 = .158$ F (6, 567) = 17.761, $p < .001$

Model 1 = mean × mean model; Model 2 = variability × variability model; Model 3 = mean × variability model; Model 4 = variability × mean model

*$p < .05$, **$p < .01$, ***$p < .001$

not negative affect, was significantly associated with weight outcomes. Specifically, higher variability in sleep duration was associated with higher BMI.

Notably, the current study found that for every one hour increase in sleep duration variability, there is a 1.26 kg/m^2 increase in BMI. This finding is similar to current research on the relation between mean sleep duration and BMI in midlife women, as one study found that for each one hour less sleep was associated with 0.86 kg/m^2 greater BMI (Appelhans et al., 2013). In addition to the importance of mean sleep duration on weight in midlife women, the current study suggests that sleep duration variability is of relatively equal importance. Although there is little other research on sleep duration variability in midlife women, the finding that variability in sleep duration was associated with higher likelihood of being overweight or obese is supported by research on social jet lag. Social jetlag, defined as a measure of discrepancy in sleep outcomes between work days and "free" days, was found to increase BMI due to misalignment between the circadian system and metabolic functioning (Roenneberg et al., 2012). Similarly, the current study found sleep duration variability was associated with BMI in a specific sample of midlife women. The finding that sleep duration variability is significantly associated with weight is novel in that the role of sleep duration variability in association with obesity risk has not yet been investigated in this population. As sleep in midlife women is highly disrupted and unstable as a result of biological and psychosocial factors (e.g., vasomotor symptoms, stress; Kravitz et al., 2008; Woods & Mitchell, 2010), it is of value to further explore the impact of sleep duration variability on weight in future research.

Notably, the current study found that the relationship between using food to cope and BMI was particularly strong in this sample of midlife women. This finding is in line with previous research that stress eating is associated with higher BMI in midlife women (van Strien et al., 2016). Using food to cope with stress is especially important to examine as this behavior is common in midlife women (van Strien et al., 2016). Using food to cope with stress and emotions is referred to as emotional eating or stress eating (van Strien et al., 2007) and often involves greater consumption of foods higher in fat, sugar, and calories (Elfhag & Rossner, 2005). In addition to stress eating being associated with higher BMI, stress eating also has the potential to impact other health outcomes that are of particular importance to midlife women, such as diabetes and heart disease (Melanson, 2007; Wang et al., 2010). As eating behaviors are tied to both sleep duration and affective states, the current study adds to existing literature by investigating the unique contributions of interrelated daily processes like sleep, emotion, and eating behaviors to weight. Even when considering daily, fluctuating factors such as sleep and mood, eating behaviors, like stress eating, emerged as a particularly strong individual predictor of weight in midlife women.

Although the current study adds to previous literature by providing support for the association of variability of sleep duration and weight outcomes, mean sleep duration was not associated with weight. This finding is in opposition with previous cross-sectional studies which have found an association between mean sleep duration and BMI. Appelhans et al. (2012) found that mean sleep duration across a one-month time period was associated with increased BMI in midlife women using a combination of sleep diaries and actigraphy. Similarly, Hall et al. (2008), found an association between mean sleep duration and weight outcomes in a specific sample of midlife women using self-report methodology. Although the current study did not replicate these findings, the aforementioned study utilized a retrospective self-report of sleep duration which is comparable, albeit less valid when compared to daily sleep measures. Importantly, how sleep is measured in research can greatly affect findings. In fact, subjective reports of sleep may be less accurate than objective measures of sleep such as actigraphy of polysomnography, which suggests the self-report of sleep data within the current study is a limitation (Silva et al., 2007). As such, future work is needed using daily sleep methodology to further explore this discrepant finding.

Additionally, the current study did not find that mean or variability in negative affect was associated with BMI. This result is surprising given that previous research has found associations between negative emotionality and weight. Specifically, women with depressive symptoms were found to be more likely to gain weight across the adulthood compared to women without depressive symptoms (Sutin & Zonderman, 2012), and a review of weight gain in midlife found depressive symptoms to be a significant predictor of higher BMI values (Crawford et al., 2000). Although previous work has highlighted the role of negative emotionality in weight gain in midlife women, most work has examined depressive symptoms as a predictor to weight outcomes. Depressive symptomology is prevalent in midlife women (Bromberger et al., 2003), and depressive symptoms have been associated with weight outcomes (Crawford et al., 2011). However, this is the first study to clarify how day-to-day experiences of negative emotions influence subsequent weight outcomes.

Lastly, the current study hypothesized that sleep duration and negative affect would interact to predict weight outcomes. The current study did not find an interaction between sleep duration and negative affect. It is likely that although weight may be influenced by sleep and emotion across time, the interaction among sleep duration and emotion may have a more immediate effect on behavior and may influence alternative outcomes other than weight. Eating behavior, for example, is associated with both sleep duration and emotion

(Crawford et al., 2011). Future work should examine more immediate consequences of sleep duration and emotionality on weight-related behaviors. Furthermore, the current study is limited in that weight was only measured at one time point. To further uncover the complex relationships between sleep, emotion, and weight, future work should consider using a repeated measures design which includes multiple assessments of weight.

Although the current study has many strengths, several limitations must be addressed. First is the overall lack of racial diversity in the current sample. As a majority of the women are White, the homogeneity of the sample prevents broad generalizability of the results to midlife women of different races and ethnicities. Additionally, due to the use of secondary data, we could not control for potentially relevant covariates. These include biological factors (i.e., menopausal status, hormonal fluctuation), and behavioral factors (i.e., eating behaviors), which influence sleep, emotion, and weight outcomes in midlife women. Thus, the current study cannot address biological mechanisms, menopausal factors, and potential behavioral factors that link sleep and emotions to weight outcomes in this population. The current study is also cross-sectional, and models are operating in a temporal conceptual framework. As such, causality cannot be determined. Furthermore, the timing between data collection for Project 1 and Project 2 varied between participants. As this difference in timing may have impacted participant's experiences, other research designs would be beneficial for future work in this area. In particular, future research using prospective designs and controlled timelines for data collection would be beneficial for investigating the direct association between sleep, emotion and weight outcomes. Lastly, the current study did not assess for sleep-and-wake promoting substances or screen for sleep disorders. Although the prevalence of sleep-and-wake promoting substance use has not been examined, use of these substances is fairly common. In a sample of adults, 12.5% reported using at least 1 wake-promoting substance and 30.2% reported using at least 1 sleep-promoting substance in the past month (Ogeil et al., 2019). Additionally, sleep disorders are common in midlife women. For example, obstructive sleep apnea and insomnia are present in 20% and 50% of midlife women, respectively (Hall et al., 2015). Future research should consider screening for sleep-and-wake promoting substance use and sleep disorders when investigating sleep behaviors in populations of midlife women.

Although the study does contain limitations, there are several strengths. First, the MIDUS II dataset represents a national sample of women. Though limited in racial diversity, the use of this dataset allowed us to examine a broad range of women living in the United States. Second, the use of daily sleep and emotion variables across an eight-day time frame allowed us to examine sleep and emotion across multiple days and assess both mean and variability in sleep duration and emotion with reduced recall bias. We also used objective measures of BMI. Lastly, this is one of the first studies to assess sleep variability in sleep duration and negative emotion in midlife women. This is valuable given the detrimental health outcomes that are associated with inadequate sleep and negative emotionality in this population (Hall et al., 2012).

In addition to the sample and measurement strengths, this project extends the current literature in a number of novel ways. This is one of the first studies to investigate the association of daily sleep duration, negative emotion, and using food to cope with obesity outcomes in midlife women. This is important as obesity is prevalent in midlife women and sleep and emotion are modifiable mechanisms which can be targeted in clinical interventions. Although the current study did not find a significant interaction between emotion and sleep duration, this null finding highlights future areas of work that could help extend understanding of how emotion, eating behaviors, and sleep are associated with weight in this population. In particular, it would be of value to use longitudinal designs to investigate the influence of daily emotion and sleep on eating behavior as well as causal mechanisms and moderating influences which lead to and exacerbate weight outcomes in this population.

Author's contributions The study was conceptualized and designed by DRR. Material preparation, data collection and analysis were performed by DR. The first draft of the manuscript was written by DR and all authors commented on previous versions of the manuscript. All authors contributed to revisions of the final manuscript. All authors read and approved the final manuscript.

Funding The MIDUS 1 study (Midlife in the U.S.) was supported by the John D. and Catherine T. MacArthur Foundation Research Network on Successful Midlife Development. The MIDUS 2 research was supported by a grant from the National Institute on Aging (P01-AG020166) to conduct a longitudinal follow-up of the MIDUS 1 investigation.

Data availability Data is publicly available via the MIDUS website.

Code availability All results were obtained using SPSS 27.

Declarations

Conflict of interest Natalie D. Dautovich serves as a sleep consultant for Merck Sharp & Dohme Corp.

Ethical approval This study was approved by an Institutional Review Board (IRB).

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent for publication Not applicable.

References

Almeida, D. M., McDonald, D., & Wethington, E. (2001). Daily variation in father engagement and negative mood: Implications for nurturing and conflictual interactions. *Journal of Marriage and the Family, 63*, 417–429.

Ameratunga, D., Goldin, J., & Hickey, M. (2012). Sleep disturbance in menopause. *Internal Medicine Journal, 42*, 742–747. https://doi.org/10.1111/j.1445-5994.2012.02723.x

Appelhans, B. M., Janssen, I., Cursio, J. F., Matthews, K. A., Hall, M., Gold, E. B., Burns, J. W., & Kravitz, H. M. (2013). Sleep duration and weight change in midlife women: the SWAN sleep study. *Obesity (silver Spring, Md.), 21*, 77–84. https://doi.org/10.1002/oby.20251

Appelhans, B. M., Kazlauskaite, R., Karavolos, K., Janssen, I., Kravitz, H. M., Dugan, S., Burns, J. W., Shipp-Johnson, K., & Powell, L. H. (2012). How well does the body adiposity index capture adiposity change in midlife women? The SWAN fat patterning study. *American Journal of Human Biology, 24*(6), 866–869.

Avis, N. E., Brambilla, D., McKinlay, S. M., & Vass, K. (1994). A longitudinal analysis of the association between menopause and depression. Results from the Massachusetts women's health study. *Annals of Epidemiology, 4*, 214–220. https://doi.org/10.1016/1047-2797(94)90099-X

Benedict, C., Brooks, S. J., O'Daly, O. G., Almen, M. S., Morell, A., Aberg, K., & Schith, H. B. (2012). Acute sleep deprivation enhances the brain's response to hedonic food stimuli: An fMRI study. *Journal of Clinical Endocrinology and Metabolism, 97*, E443–E447. https://doi.org/10.1210/jc.2011-2759

Bromberger Assmann, S. F., Avis, N. E., Schocken, M., Kravitz, H. M., & Cordal, A. (2003). Persistent mood symptoms in a multiethnic community cohort of pre- and perimenopausal women. *American Journal of Epidemiology, 158*, 347–356. https://doi.org/10.1093/aje/kwg155

Bromberger, J. T., Matthews, K. A., Schott, L. L., Brockwell, S., Avis, N. E., Kravitz, H. M., & Randolph, J. F. (2007). Depressive symptoms during the menopausal transition: The Study of Women's Health Across the Nation (SWAN). *Journal of Affective Disorders, 103*, 267–272. https://doi.org/10.1016/j.jad.2007.01.034

Buysse, D. J. (2014). Sleep health: Can we define it? Does it matter? *Sleep, 37*, 9–17. https://doi.org/10.5665/sleep.3298

Campbell, L. V., & Samaras, K. (2000). What is the evidence, reasons for and impact of weight gain during menopause? *The Medical Journal of Australia, 173*, 100–101.

Chaput, J.-P., Despres, J.-P., Bouchard, C., & Tremblay, A. (2011). The association between short sleep duration and weight gain is dependent on disinhibited eating behavior in adults. *Sleep, 34*, 1291–1297. https://doi.org/10.5665/SLEEP.1264

Choi, J.-K., Kim, M.-Y., Kim, J.-K., Park, J.-K., Oh, S.-S., Koh, S.-B., & Eom, A. (2011). Association between short sleep duration and high incidence of metabolic syndrome in midlife women. *The Tohoku Journal of Experimental Medicine, 225*, 187–193. https://doi.org/10.1620/tjem.225.187

Cohen, L. S., Soares, C. N., Vitonis, A. F., Otto, M. W., & Harlow, B. L. (2006). Risk for new onset of depression during the menopausal transition. *Archives of General Psychiatry, 63*, 385. https://doi.org/10.1001/archpsyc.63.4.385

Crawford, S., Casey, V. A., Avis, N., & McKinlay, S. M. (2000). A longitudinal study of weight and the menopause transition: results from the Massachusetts Women's Health Study. *Women's Health Research Faculty Publications*. Retrieved from http://escholarship.umassmed.edu/wfc_pp/16

Crawford, G. B., Khedkar, A., Flaws, J. A., Sorkin, J. D., & Gallicchio, L. (2011). Depressive symptoms and self-reported fast-food intake in midlife women. *Preventive Medicine, 52*, 254–257. https://doi.org/10.1016/j.ypmed.2011.01.006

Davis, S. R., Castelo-Branco, C., Chedraui, P., Lumsden, M. A., Nappi, R. E., Shah, D., & Villaseca, P. (2012a). Understanding weight gain at menopause. *Climacteric, 15*, 419–429. https://doi.org/10.3109/13697137.2012.707385

Davis, S. R., Castelo-Branco, C., Chedraui, P., Lumsden, M. A., Nappi, R. E., Shah, D., & Villaseca, P. (2012b). Understanding weight gain at menopause. *Climacteric*. https://doi.org/10.3109/13697137.2012.707385

de Wit, L., Luppino, F., van Straten, A., Penninx, B., Zitman, F., & Cuijpers, P. (2010). Depression and obesity: A meta-analysis of community-based studies. *Psychiatry Research, 178*(2), 230–235.

Earle, J. R., Smith, M. H., Harris, C. T., & Longino, C. F. (1997). Women, marital status, and symptoms of depression in a midlife national sample. *Journal of Women & Aging, 10*, 41–57. https://doi.org/10.1300/J074v10n01_04

Elfhag, K., & Rossner, S. (2005). Who succeeds in maintaining weight loss? A conceptual review of factors associated with weight loss maintenance and weight regain. *Obesity Reviews, 6*, 67–85.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavioral Research Methods, 41*(4), 1149–1160.

Flegal, K. M., Kit, B. K., Orpana, H., & Graubard, B. I. (2013). Association of all-cause mortality with overweight and obesity using standard body mass index categories. *JAMA, 309*, 71. https://doi.org/10.1001/jama.2012.113905

George, D., & Mallery, M. (2010). *SPSS for windows step by step: A simple guide and reference*, 17.0 update (10a ed.) Boston: Pearson.

Gómez-Santos, C., Saura, C. B., Lucas, J. A., Castell, P., Madrid, J. A., & Garaulet, M. (2016). Menopause status is associated with circadian- and sleep-related alterations. *Menopause, 23*(6), 682–690.

Gordon, J. L., Rubinow, D. R., Eisenlohr-Moul, T.A., Leserman, J., & Girdler, S. S. (2016). Estradiol variability, stressful life events, and the emergence of depressive symptomatology during the menopausal transition. *Menopause, 23*(3), 257–266.

Gordon, J. L., & Sander, B. (2021). The role of estradiol fluctuation in the pathophysiology of perimenopausal depression: A hypothesis paper. *Psychoneuroendocrinology, 133*, 105418.

Grundy, S. M., Cleeman, J. I., Daniels, S. R., Donato, K. A., Eckel, R. H., Franklin, B. A., & Costa, F. (2005). Diagnosis and management of the metabolic syndrome. *Circulation*, *112*. Retrieved from http://circ.ahajournals.org/content/112/17/2735.short

Hall, M. H., Kline, C. E., & Nowakowski, S. (2015). Insomnia and sleep apnea in midlife women: Prevalence and consequences to health and functioning. *F1000 Prime Reports, 26*, 63. https://doi.org/10.12703/P7-63

Hall, M. H., Muldoon, M. F., Jennings, J. R., Buysse, D. J., Flory, J. D., & Manuck, S. B. (2008). Self-reported sleep duration is associated with the metabolic syndrome in midlife adults. *Sleep, 31*, 635–643.

Hall, M. H., Okun, M. L., Sowers, M., Matthews, K. A., Kravitz, H. M., Hardin, K., & Sanders, M. H. (2012). Sleep is associated with the metabolic syndrome in a multi-ethnic cohort of midlife women: The SWAN Sleep Study. *Sleep, 35*, 783–790. https://doi.org/10.5665/sleep.1874

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. Guilford Press.

Heymsfield, S. B., Gallagher, D., Poehlman, E. T., Wolper, C., Nonas, K., Nelson, D., & Wang, Z.-M. (1994). Menopausal changes in body composition and energy expenditure. *Experimental Gerontology, 29*, 377–389. https://doi.org/10.1016/0531-5565(94)90018-3

Ho, S. C., Wu, S., Chan, S. G., & Sham, A. (2010). Menopausal transition and changes of body composition: A prospective study in Chinese perimenopausal women. *International Journal of Obesity, 34*, 1265–1274. https://doi.org/10.1038/ijo.2010.33

Jennings, J. R., Muldoon, M. F., Hall, M., Buysse, D. J., & Manuck, S. B. (2007). Self-reported sleep quality is associated with the metabolic syndrome. *Sleep, 30*, 219–223. https://doi.org/10.1093/sleep/30.2.219

Kessler, R. C., Andrews, G., Colpe, L. J., Hiripi, E., Mroczek, D. K., Normand, S.-L., & Zaslavsky, A. M. (2002). Short screening scales to monitor population prevalences and trends in non-specific psychological distress. *Psychological Medicine, 32*, S0033291702006074. https://doi.org/10.1017/S0033291702006074

Konttinen, H., Männistö, S., Sarlio-Lähteenkorva, S., Silventoinen, K., & Haukkala, A. (2010). Emotional eating, depressive symptoms and self-reported food consumption. A population-based study. *Appetite, 54*, 473–479. https://doi.org/10.1016/j.appet.2010.01.014

Kravitz, H. M., Ganz, P. A., Bromberger, J., Powell, L. H., Sutton-Tyrrell, K., & Meyer, P. M. (2003). Sleep difficulty in women at midlife: A community survey of sleep and the menopausal transition. *Menopause, 10*(1), 19–28.

Kravitz, H. M., Janssen, I., Santoro, N., Bromberger, J. T., Schocken, M., Everson-Rose, S. A., & Powell, L. H. (2005). Relationship of day-to-day reproductive hormone levels to sleep in midlife women. *Archives of Internal Medicine, 165*, 2370–2376. https://doi.org/10.1001/archinte.165.20.2370

Kravitz, H. M., Zhao, X., Bromberger, J. T., Gold, E. B., Hall, M. H., Matthews, K. A., & Sowers, M. R. (2008). Sleep disturbance during the menopausal transition in a multi-ethnic community sample of women. *Sleep, 31*, 979–990.

Kripke, D. F., Garfinkel, L., Wingard, D. L., Klauber, M. R., & Marler, M. R. (2002). Mortality associated with sleep duration and insomnia. *Archives of General Psychiatry, 59*, 131–136.

Lahmann, P., Lissner, L., Gullberg, B., & Berglund, G. (2000). Sociodemographic factors associated with long-term weight gain, current body fatness and central adiposity in Swedish women. *International Journal of Obesity, 24*, 685–694.

Lee, S., & Shin, C. (2015). Habitual sleep initiation time and metabolic syndrome in middle-aged and elderly adults. *Sleep and Biological Rhythms, 13*, 371–379. https://doi.org/10.1111/sbr.12128

Melanson, K. J. (2007). Dietary factors in reducing risk of cardiovascular diseases. *Nutrition Review, 1*, 24–28.

Mitchell, E. S., & Woods, N. F. (1996). Symptom experiences of midlife women: Observations from the Seattle midlife women's health study. *Maturitas, 25*, 1–10. https://doi.org/10.1016/0378-5122(96)01047-X

National Institutes of Health. (2005). National Institutes of Health State-of-the-Science Conference statement: Management of menopause-related symptoms. *Annals of Internal Medicine, 142*, 1003–1013.

Ogden, C. L., Carroll, M. D., Fryar, C. D., & Flegal, K. M. (2015). Prevalence of obesity among adults and youth: United States, 2011–2014. *NCHS Data Brief*, (219), 1–8. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/26633046

Ogeil, R. P., Phillips, J. G., Savic, M., & Lubman, D. I. (2019). Sleep- and wake- promoting drugs: Where are they being sourced, and what is their impact? *Substance Use and Misuse, 54*, 1916–1928. https://doi.org/10.1080/10826084.2019.1609040

Owens, J. F., & Matthews, K. A. (1998). Sleep disturbance in healthy middle-aged women. *Maturitas, 30*, 41–50. https://doi.org/10.1016/S0378-5122(98)00039-5

Patel, S. R., & Hu, F. B. (2008). Short sleep duration and weight gain: A systematic review. *Obesity, 16*, 643–653. https://doi.org/10.1038/oby.2007.118

Pimenta, F., Maroco, J., Ramos, C., & Leal, I. (2014). Predictors of weight variation and weight gain in peri- and post-menopausal women. *Journal of Health Psychology, 19*, 993–1002. https://doi.org/10.1177/1359105313483153

Polo-Kantola, P. (2011). Sleep problems in midlife and beyond. *Maturitas, 68*, 224–232. https://doi.org/10.1016/j.maturitas.2010.12.009

Roenneberg, T., Allebrandt, K., Merrow, M., & Vetter, C. (2012). Social jetlag and obesity. *Current Biology, 22*, 939–943. https://doi.org/10.1016/j.cub.2012.03.038

Seltzer, M. M., Almeida, D. M., Greenberg, J., Sayla, J., Stawski, R. S., Hong, J., & Taylor, J. L. (2009). Psychological and biological markers of daily lives of midlife parents of children with disabilities. *Journal of Health and Social Behavior, 50*, 1–15.

Silva, G. E., Goodwin, J. L., Sherrill, D. L., Arnold, J. L., Bootzin, R., Smith, R., Walsleben, J. A., Baldwin, C. M., & Quan, S. F. (2007). Relationship between reported and measured sleep times: The sleep heart health study (SHHS). *Journal of Clinical Sleep Medicine, 3*, 622–630.

Spiegel, K., Tasali, E., Penev, P., Cauter, E., & Van, M. R. (2004). Brief communication: Sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. *Annals of Internal Medicine, 141*, 846. https://doi.org/10.7326/0003-4819-141-11-200412070-00008

Sutin, A. R., & Zonderman, A. B. (2012). Depressive symptoms are associated with weight gain among women. *Psychological Medicine, 42*, 2351–2360. https://doi.org/10.1017/S0033291712000566

Taylor, B. J., Matthews, K. A., Hasler, B. P., Roecklein, K. A., Kline, C. E., Buysse, D. J., & Hall, M. H. (2016). Bedtime variability and metabolic health in midlife women: The SWAN sleep study. *Sleep, 39*, 457–465. https://doi.org/10.5665/sleep.5464

Torres, S. J., & Nowson, C. A. (2007). Relationship between stress, eating behavior, and obesity. *Nutrition*. https://doi.org/10.1016/j.nut.2007.08.008

Trace, S. E., Thornton, L. M., Runfola, C. D., Lichtenstein, P., Pedersen, N. L., & Bulik, C. M. (2012). Sleep problems are associated with binge eating in women. *International Journal of Eating Disorders, 45*, 695–703. https://doi.org/10.1002/eat.22003

van Strien, T., Konttinen, H., Homberg, J. R., Engels, R. C. M. E., & Winkens, L. H. H. (2016). Emotional eating as a mediator between depression and weight gain. *Appetite, 100*, 216–224. https://doi.org/10.1016/j.appet.2016.02.034

van Strien, T., van de Laar, F. A., van Leeuwe, J. F. J., Lucassen, P. L. B. J., van den Hoogen, H. J. M., Rutten, G. E. H. M., et al. (2007). The dieting dilemma in patients with newly diagnosed type 2 diabetes: Does dietary restraint predict weight gain 4 years after diagnosis? *Health Psychology, 26*, 105–112.

Wang, H., Shara, N. M., Calhoun, D., Umans, J. G., Lee, E. T., & Howard, B. V. (2010). Incidence rates and predictors of diabetes in those with prediabetes: The strong heart study. *Diabetes/metabolism Research and Reviews, 26*, 378–385.

Woods, N. F., & Mitchell, E. S. (2010). Sleep symptoms during the menopausal transition and early postmenopause: Observations from the seattle midlife women's health study. *Sleep, 33*, 539–549. https://doi.org/10.1093/sleep/33.4.539

Zolfaghari, S., Yao, C., Thompson, C., Gosselin, N., Desautels, A., Dang-Vu, T. T., Postuma, R. B., & Carrier, J. (2020). Effects of menopause on sleep quality and sleep disorders: Canadian Longitudinal Study on Aging. *Menopause, 27*(3), 295–304.