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Short communication

A comparison of objective and subjective measures of physical activity, sedentary and sleep behaviors between persons with and without depressive symptoms

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ABSTRACT

Background: Major Depressive Disorder (MDD) is characterized by negative recall biases, which may impact how individuals with depressive symptoms report physical activity (PA), sedentary, and sleep behaviors. Additionally, there are discrepancies between subjective and objective behaviors in MDD. Thus, the current study investigated whether individuals with depressive symptoms differ in their subjective and objective PA, sedentary, and sleep behaviors, and whether the magnitude of these discrepancies differ from those in individuals without depressive symptoms.

Methods: Participants from the 2011–2014 National Health and Nutrition Examination Survey ($N = 8367$; $N_{depressed} = 762$) with one-week of passively-collected, wrist worn actigraphy data and self-reported questionnaires assessing PA, sedentary, and sleep behaviors were analyzed.

Results: Three negative binomial models investigated the effects of group, measurement type, and their interaction on PA, sedentary, and sleep behaviors. Individuals with depressive symptoms exhibited lower PA and sleep than individuals without depressive symptoms but did not differ in sedentary behaviors. Measurement type differed across all models: self-reported PA and sleep were lower, and self-reported sedentary behaviors were greater, than objective measurements. The interaction was significant only for PA; whereas objective PA was greater than subjective measurements for all individuals, the difference was far greater for individuals with depressive symptoms.

Limitations: The absence of a clinically depressed sample and current manner of assessing subjective and objective measures may limit our generalizability and conclusions.

Conclusion: Our study highlights discrepancies in objective and subjective reports across domains and emphasizes the importance of incorporating objective measurements to improve psychopathology assessment.

1. Introduction

Major Depressive Disorder (MDD) is a highly burdensome disorder, with about one in five adults diagnosed with lifetime MDD in the United States (National Institute of Mental Health, 2023). MDD is characterized by several symptoms that are present nearly every day for at least two weeks, and individuals with depressive symptoms may experience significant difficulties in their social, occupational, and recreational domains (National Institute of Mental Health, 2023). Beck's cognitive theory suggests that individuals with depressive symptoms hold negative biases or cognitions (Beck and Bredemeier, 2016). Memory and related recall difficulties are common deficits for persons with depressive symptoms, which might impact memory encoding and cognitive deficits (Gotlib and Joormann, 2010). These cognitive biases may also impact how individuals with depressive symptoms self-report physical activity (PA), sedentary and sleep behavior. However, the discrepancy

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between actigraphy, an objective measure of PA, sedentary, and sleep behaviors, and self-reported questionnaires (SRQs) of these domains in individuals with depressive symptoms has not been thoroughly investigated. This discrepancy has largely been investigated in the context of other psychiatric disorders, including schizophrenia, post-traumatic stress disorder, and bipolar disorder, and findings indicate that individuals with psychopathology may underestimate or overestimate their subjective PA and sleep behaviors compared to their objective data (Oakes et al., 2022).

For studies including individuals with depressive symptoms, findings are consistent and suggest clinical features of MDD may interfere with accurate reporting on SRQs. For example, a meta-analysis of PA and sedentary behavior in individuals with depressive symptoms found that SRQ studies tended to report higher amounts of PA (compared to objective measures), and studies using objective measures reported higher amounts of sedentary behaviors (compared to SRQs; Schuch et al., 2017). Further, individuals with depressive symptoms may overestimate the intensity and frequency of their PA levels compared to individuals without depressive symptoms, which may be attributed to cognitive deficits characteristic of MDD (Schuch et al., 2017). Similar discrepancies are found when individuals with depressive symptoms self-reported their sleep; they exhibit lower correlations between subjective and objective sleep durations relative to those without a mood disorder (Biddle et al., 2015), potentially suggesting that individuals with mood disorders are less accurate when self-reporting PA and sleep behaviors. Indeed, when engaging in rumination before going to sleep, higher MDD symptom severity was predictive of worse *subjective* sleep quality (Pillai et al., 2014).

Although current literature suggests that there may be a discrepancy between self-reported and objectively-recorded PA, sedentary, and sleep behaviors in individuals with depressive symptoms, further investigation is required to determine how these measurement types differ from one another. This investigation is especially important for improving clinical assessment of depression, given the negative correlation between physical activity and depressive symptoms (Galper et al., 2006; Josefsson et al., 2014), and evidence indicating long term sedentary behavior and poor sleep quality as risk factors for increased depressive symptoms (Guo et al., 2024; Li et al., 2020). Moreover, given that individuals with depressive symptoms demonstrate memory deficits and recall biases, it is important to consider how bias may undermine the utility of subjective reports. The goal of the current study, therefore, is to investigate how subjective and objective reporting of PA, sedentary, and sleep behaviors differ from each other in individuals with depressive symptoms, and from individuals without depressive symptoms, using a large, nationally-representative sample with proprietary-grade accelerometry. Extrapolating from previous studies (Biddle et al., 2015; Oakes et al., 2022; Schuch et al., 2017), we hypothesized the following:

1. Main effect of group: individuals with depressive symptoms will demonstrate lower PA and sleep behaviors, but greater sedentary behaviors than individuals without depressive symptoms.
2. Main effect of measurement type: objective measurement will yield greater PA and sleep behaviors, whereas the subjective measurement will yield greater sedentary behavior.
3. Interaction effect (group x measurement type): individuals with depressive symptoms will report lower PA, lower sleep behaviors, and greater sedentary across both measurement types than individuals without depressive symptoms, with a greater discrepancy between their subjective and objective measurements compared to individuals without depressive symptoms.

2. Methods

2.1. Sample

The data from the current study was collected for the nationally-representative National Health and Nutrition Examination Survey (NHANES; Centers for Disease Control and Prevention, 2020a, 2020b). Individuals with objective and subjective measurements of PA, sedentary and sleep behaviors, and a completed Patient Health Questionnaire-9 (PHQ-9) were included in the present analysis (N = 8367, 51.2 % Female, Age_{Mean} = 47.57 years; Age_{Range} = 18–80 years). Ethics approval for NHANES was received from the NCHS Research Ethics Review Board (Protocol #2011–2017).

2.2. Study measures

2.2.1. Depression screener

Participants completed the PHQ-9 during their mobile examination center (MEC) interview. The PHQ-9 is a SRQ that assesses the nine symptoms of MDD on a Likert scale, ranging from 0 to 3, over the past two weeks and has demonstrated good internal consistency (Kroenke and Spitzer, 2002). To identify presence of depressive symptoms, the validated threshold of a PHQ-9 composite score ≥ 10 was implemented (Moriarty et al., 2015). This resulted in two subgroups: a group with elevated depressive symptoms (n = 766; 65.35 % Female; 34.65 % Men; 42.65 % non-Hispanic White; 22.70 % non-Hispanic Black; Age_{Mean} = 48.57 ± 16.92) and a group without elevated depressive symptoms (n = 7612; 49.78 % Female; 50.22 % Men; 40.33 % non-Hispanic White; 23.92 % non-Hispanic Black; Age_{Mean} = 47.48 ± 18.69).

2.2.2. Objective measurements of behavior

Objective PA, sedentary and sleep behaviors were passively-collected for one week via an Actigraph GT3X+, which was provided upon completion of the MEC interview and worn on participants' non-dominant hands for at least seven full days (midnight to midnight). Daily minutes of moderate-vigorous PA and sedentary behavior were calculated using MIMS unit thresholds and Metabolic Equivalent for Tasks (METs) (John et al., 2019). Daily minutes of sleep were calculated as the average number of minutes of wear time predicted as sleep (Table 1).

2.2.3. Subjective measurements of behavior

The Global Physical Activity Questionnaire (GPAQ) was used to assess PA and sedentary behaviors (Centers for Disease Control and Prevention, 2020a, 2020b). The GPAQ is a valid SRQ that has been used to monitor PA in adults in the general population (Armstrong and Bull, 2006). Daily moderate-vigorous PA was calculated as the sum of reported time in moderate-intensity and vigorous-intensity work and recreational activities on a typical day (i.e., "How much time do you spend doing vigorous-intensity sports, fitness or recreational activities on a typical day?") (Armstrong and Bull, 2006). Daily sedentary

Table 1
Descriptive statistics of physical activity, sedentary and sleep behaviors.

Measurement Type	Depressed Group		Nondepressed Group	
	Objective Measurement	Subjective Measurement	Objective Measurement	Subjective Measurement
Moderate-to-Vigorous Physical Activity Behavior (minutes)	141.48 ± 94.37	89.33 ± 163.65	156.78 ± 96.69	130.95 ± 188.39
Sedentary Behavior (minutes)	256.26 ± 182.15	412.94 ± 221.96	250.58 ± 188.22	389.32 ± 198.78
Sleep Behavior (minutes)	488.86 ± 114.06	385.91 ± 111.19	468.17 ± 109.65	415.68 ± 82.02

Note. Descriptive statistics (mean ± standard deviation) of Moderate-to-Vigorous Physical Activity, Sedentary and Sleep behaviors by group and measurement type.

behavior was determined from the sedentary activity item, which reflected the number of minutes an individual reported sitting on a typical day (Centers for Disease Control and Prevention, 2020a, 2020b). The GPAQ has demonstrated adequate test-retest reliability and both daily moderate-vigorous PA and sedentary behavior on the GPAQ have been shown to be associated with actigraphy-recorded moderate-vigorous PA and sedentary behavior (Herrmann et al., 2013). Daily sleep behavior was determined from a question related to sleep duration (i.e., "How much sleep do you get (hours)?"). Descriptives of subjective measurements are provided in Table 1.

2.3. Statistical analyses

Upon completion of data collection, the actigraphy data was externally reviewed for data quality, and minute-level Monitor-Independent Movement Summary (MIMS) units were calculated (Centers for Disease Control and Prevention, 2022). Following prior work (Price et al., 2024), minute-level triaxial MIMS values were calculated to represent MIMS measurements from the x-, y-, and z-axes, respectively. MIMS-units are a single summary matric that can be compared across different devices, including accelerometers, and they minimized external data noise from the environment to maximize accuracy of the activity data (Belcher et al., 2021; John et al., 2019). Data was collected from midnight to midnight across seven days, which resulted in a total of 10,080 min of continuous actigraphy data per participants (for further detail of processing of the actigraphy data, see Price et al., 2024).

To compare the objective and subjective measurements for PA, sedentary and sleep behaviors, we implemented three negative binomial models (See Table 1). Specifically, we used the *statsmodels* package in Python (Seabold and Perktold, 2010),[2] which can handle count variables (i.e., our objective outcomes). For each of our three models (i.e., PA, sedentary, and sleep behaviors), we entered in group (i.e., depressed or non-depressed) as the between-subjects variable and measurement type (i.e., subjective/SRQ or objective/actigraphy) as the within-subjects variable.

3. Results

Results from the PA behavior model revealed significant main effects of group and measurement type, as well as the interaction (Table 2). The sedentary behavior and sleep behavior models revealed significant main effects of measurement type, and the main effect of group evidenced a trend in the sleep behavior model; however, the interaction of group and measurement type was not statistically significant in either model.

4. Discussion

The present study investigated how the self-reported PA, sedentary, and sleep behaviors of individuals with depressive symptoms differed from their objective measures, as well as whether their reporting differed from those without depressive symptoms. Overall, our findings suggest that individuals with depressive symptoms are generally less active than those without depressive symptoms. Moreover, their objective measures suggest they are more active than they are self-reporting, consistent with our hypotheses. Individuals with depressive symptoms demonstrate negative biases, which can impact their memory recall (Beck and Bredemeier, 2016; Gotlib and Joormann, 2010). Thus, it is possible that the current findings are highlighting these negative biases regarding PA as individuals with depressive symptoms may believe they are less active than they are. Group differences and the interaction may, at least partially, reflect the well-established memory deficits that individuals with depressive symptoms demonstrate compared to those without depressive symptoms (Rock et al., 2014). When paired with clinical features like poor sleep quality, which can impair memory consolidation, the ability to recall specific information may be further influenced, resulting in exacerbation in the discrepancy between SRQs and objective behaviors.

Our findings provide partial support for our first hypothesis: individuals with and without depressive symptoms demonstrate different amounts of moderate-vigorous PA and sleep behaviors, although the latter evidenced a trend ($p = 0.05$). Specifically, individuals with depressive symptoms demonstrate lower levels of PA and sleep than those without depressive symptoms, regardless of how this data was collected (i.e., includes both objective and subjective data). The non-significant finding for sedentary behavior indicates that individuals with and without depressive symptoms do not differ in their amounts of sedentary behavior.

When examining main effects across the three models for our second hypothesis, there were consistent differences between measurement, with objective measurements (i.e., actigraphy) showing more vigorous PA and sleep, and less sedentary behaviors, relative to SRQs. These findings are consistent with prior research (Girschik et al., 2012; Prince et al., 2008), suggesting that, regardless of the presence of psychopathology, individuals are not reliable reporters of these behaviors. Inclusion of objective measures, such as actigraphy, may be critical for improving the accuracy of assessments.

Our findings regarding the interaction effects between MDD group and measurement type provide partial support for our third hypothesis. Specifically, individuals with depressive symptoms demonstrated lower overall levels of PA than individuals without depressive symptoms across measurement types, and these differences were far greater in magnitude when examining SRQs compared to objective measurements. Conversely, the interaction effect between group and measurement type were not significant for sedentary and sleep behaviors. Although individuals with depressive symptoms self-reported less sleep than those without depressive symptoms, the objective measurement indicated that individuals with depressive symptoms obtained more sleep. Moreover, given that the effect of measurement type was significant, it is likely that all individuals, regardless of their depression classification, self-reported lower sleep compared to the objective measure. It is possible that the discrepancy between the self- and objective-reported data for individuals with depressive symptoms reflect conflation between sleep

Table 2
Negative binomial modeling results.

	Negative Binomial					
	Physical Activity Behavior		Sedentary Behavior		Sleep Behavior	
	Coef. (95 % C. I)	$P > \|z\|$	Coef. (95 % C. I)	$P > \|z\|$	Coef. (95 % C. I)	$P > \|z\|$
(Intercept)	4.88 (4.85, 4.90)	0.00	5.97 (5.94, 5.99)	0.00	6.03 (6.00, 6.05)	0.00
Depression Presence	−0.38 (−0.46, −0.31)	0.00	0.06 (−0.02, 0.13)	0.12	0.00 (0.00, 0.00)	0.05
Measurement Type	0.18 (0.15, 0.21)	0.00	−0.44 (−0.47, 0.41)	0.00	0.12 (0.09, 0.15)	0.00
Depression Presence: Measurement Type	0.28 (0.17, 0.39)	0.00	−0.04 (−0.14, 0.07)	0.49	0.04 (−0.03, 0.12)	0.24

Note. Negative Binomial modeling results reported as the β coefficient (95 % confidence interval) and *p*-value.

[2] Although negative binomial regression may be less appropriate for the Likert-type scales employed by the subjective measures, the pattern of findings were comparable, with presence of statistical significance differing only between the interaction of outcome and group for sleep and the outcome for sedentary when using a traditional two-way ANOVA approach.

quality and quantity. Indeed, individuals with depressive symptoms self-report worse sleep quality (Fabbri et al., 2021), which may not be adequately captured when quantifying sleep duration via actigraphy. Overall, the discrepancies between self-reported and objective data were larger for individuals with depressive symptoms, albeit not significant in the interaction for sedentary and sleep behaviors, indicating incorporating objective assessment of movement-related behaviors is critical for accurate assessment of potential psychopathology, including MDD.

The present work provides additional insight into the utility of leveraging passively-collected accelerometry information compared to subjective SRQs, with an additional emphasis on discrepancies between individuals with and without depressive symptoms. Despite the importance of this analysis and the strengths of using a nationally-representative sample with a proprietary-grade accelerometer for an entire week, there are limitations that should be considered. Firstly, minimal research has investigated the conversion of MIMS units to physical intensity thresholds; however, comparing the METs of known tasks to their corresponding MIMS values provides a suitable proxy, and a method for increasing the transparency of these conversions in the future to further extend the utility of MIMS as an accelerometer unit (John et al., 2019). Secondly, the subjective and objective methods for collecting PA, sedentary and sleep behaviors do not overlap completely in their domains of assessment. Specifically, the GPAQ does not assess daily light work or recreational activity, which likely accounts for a large portion of an individual's daily tasks. Relatedly, our subjective measure of sleep was only measured with one item, rather than a validated scale such as the GPAQ, and our objective measure of sleep was assessed via the Actigraph GT3X+ when it detected wear during sleep. Future research should utilize more advanced, wearable sleep technology, including polysomnography, to measure sleep behaviors and further explore the discrepancies between subjective and objective sleep behaviors in persons with depressive symptoms. Additionally, although the present work was conducted using data collected from a nationally-representative sample, our analysis did not account for the potentially mediating effects of certain sociodemographic variables, such as gender, race, and ethnicity, and physical and psychiatric symptoms. Indeed, both racial identity and physical disease diagnoses have been observed to influence the presentation of depressive symptoms (Cooper et al., 2023; Gayman et al., 2011; Frank et al., 2023), and other psychiatric symptoms, chronic diseases, and medications can impact the behaviors of persons. Thus, future work can expand on our findings and investigate how sociodemographic variables, psychiatric comorbidities, and medical comorbidities or behaviors impact the relationship between depressive symptoms and PA, sedentary, and sleep behaviors. Lastly, although we used a validated cutoff score to assess for depression presence, we were not able to explicitly compare differences in PA, sedentary, and sleep behaviors between a clinically-depressed group (i.e., those with a clinical diagnosis) and a healthy, non-depressed group (i.e., those without a clinical diagnosis). Thus, future investigation with a clinical sample, as assessed via a structured clinical interview, would yield important insights into differences between clinically depressed and healthy individuals.

The current study provides support for discrepancies between self-reported and objectively measured PA, sedentary, and sleep behaviors. Further, our findings show significant differences in this discrepancy between individuals with depressive symptoms and those without depressive symptoms. Taken together, our work highlights biases in self-reported activity, as well as the unique information provided by objective passive sensors. With the growing use of wearable devices, an understanding of the complementary information provided by SRQs and objective measures is crucial for both ongoing research and clinical care.

CRediT authorship contribution statement

Amanda C. Collins: Writing – review & editing, Writing – original draft, Conceptualization. **George D. Price:** Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Victor A. Moreno:** Writing – review & editing, Writing – original draft. **Daniel M. Mackin:** Writing – review & editing, Writing – original draft. **Jenny Y. Oh:** Writing – review & editing, Writing – original draft. **Michael V. Heinz:** Writing – review & editing, Writing – original draft. **Nicholas C. Jacobson:** Writing – review & editing.

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Declaration of competing interest

The authors have no conflicts of interest or acknowledgments to declare.

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