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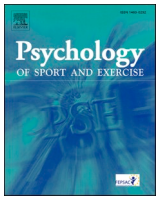

Within-person associations between daily stress and physical activity during working and non-working hours

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ABSTRACT

People experience stressors on 40% of days, and emotional responses to stressors increase the risk for poor health, in part by impacting health behaviors like physical activity (PA). However, whether associations of daily psychological stressors with PA after the self-reported stressor occurs (post-stressor PA) differ across working and non-working hours is unclear. This study used the National Study of Daily Experiences III (2017–2019) to examine within-person associations between stressors and post-stressor PA during working and non-working hours and moderation by age and biological sex. Participants completed interviews across eight consecutive days about daily stress and the amount and timing of PA participation during the past 24 hours. Multilevel models with days nested in people examined the within-person associations of stressors with the odds and amount of post-stressor PA participation, with separate models during versus outside of working hours on working days and for non-working days. Participants (N = 564) had higher odds of post-stressor PA during working hours when they experienced greater than usual anger (OR = 3.24, $p < .001$), sadness (OR = 2.41, $p < .001$), or shame (ORs = 2.59, $p < .001$) due to stress. Sex moderated the within-person associations between stressor frequency (OR = 0.29, $p < .001$), intensity (OR = 0.49, $p < .001$), and anxiety (OR = 0.58, $p = .002$) on odds of post-stressor PA during working hours, such that the increased odds were higher in males. Participants had higher odds of post-stressor PA outside of working hours when they experienced greater stress intensity, anger, sadness, shame, or anxiety (OR = 3.94–7.35, $p < .001$). Research clarifying how age, sex, and/or occupation intersect with individuals' daily stress experiences and PA could inform occupational health policies and/or interventions.

1. Introduction

Experiencing stressors in daily life is ubiquitous, with individuals reporting stressors on approximately 40% of days (Almeida, Wethington, & Kessler, 2002). This extends into the workplace, whereby the prevalence of work-related stressors is high, with 77% of workers having experienced a work-related stressor in the past month and 36% reporting a perception of feeling stressed-out during the typical workday (Colligan & Higgins, 2006; Lazarus, 1995; Schütte et al., 2014; Stress in the Workplace, 2011). The broad prevalence of daily stressors significantly affects individuals' mental and physical health. This impact encompasses conditions like depression, anxiety, overall psychological well-being, and various physical ailments such as cardiovascular and cerebrovascular diseases (Goetzel et al., 1998; Heslop et al., 2001; Mahan et al., 2010; Schütte et al., 2014; Steptoe & Kivimäki, 2013; van der Doef & Maes, 1999). One contributing factor to this impact of daily stressors on health outcomes is the effect of stressors on individuals' health behaviors (Carr & Umberson, 2013; Jones, O'Connor, Conner, McMillan, & Ferguson, 2007; Stults-Kolehmainen & Sinha, 2014). The effect of daily stressors on health outcomes and behaviors has garnered substantial attention in the fields of psychology and public health (Almeida et al., 2002, 2011; Carr & Umberson, 2013). These effects on health outcomes and behaviors may be influenced by different features of daily stressful experiences. These include the number of stressors an individual experiences on a given day (i.e., stressor frequency) or the magnitude of the initial affective response to the stressor (i.e., stress intensity load), such as the degree of anger experienced due to the stressor (e.g., anger load) (Almeida et al., 2020; Smyth et al., 2018).

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Emerging evidence suggests that negative affective responsivity to these daily stressors plays a crucial role in shaping health behaviors, particularly in the realm of physical activity (PA), as experiencing more stressors increases negative affect and greater negative affect predicts less PA participation (Almeida et al., 2020; Jones et al., 2007; Smyth et al., 2018; Stults-Kolehmainen & Sinha, 2014).

Physical activity is a cornerstone of health promotion efforts across a variety of contexts, including leisure-time PA participation occurring at home or in fitness centers and workplace PA participation (Grimani, Aboagye, & Kwak, 2019; Klatt, Norre, Reader, Yodice, & White, 2017; Proper & van Oostrom, 2019). Health promotion efforts target PA participation in part due to its relationship with several features of daily stress experiences, a relationship that is reciprocal in nature (Stults-Kolehmainen & Sinha, 2014). On one hand, engaging in PA has been associated with numerous physical and mental health benefits, including reduced stress reactivity (Hamer, Stamatakis, & Steptoe, 2009; Hamer & Stamatakis, 2009; Teychenne, Ball, & Salmon, 2008). On the other hand, individuals often face challenges in maintaining regular PA routines when confronted with stressors in their daily lives (Epel et al., 2018; Oman & King, 2000; Stetson, Rahn, Dubbert, Wilner, & Mercury, 1997). This tension between the potential benefit of PA in reducing stress reactivity and the potential negative impact of daily stressors on PA raises important questions about how daily stressors affect PA participation. Most research indicates that greater stressor frequency, severity, and negative affective responses to stressors are associated with reduced PA levels (Almeida et al., 2020; Brown, Wilson, Sweeney, & Van Horn, 2021; Burg et al., 2017; Schultchen et al., 2019; Stults-Kolehmainen & Sinha, 2014).

However, few studies have examined whether these effects of daily stressors on PA vary across different time periods within the day, specifically during working and non-working hours in employed adults (Almeida et al., 2020). This is notable given that, on workdays, employed adults spend over 50% of their waking hours (~8.4 h/day) working (American Time Use Survey, 2022) and one-third of workers experience occupational stressors daily (Colligan & Higgins, 2006; Lazarus, 1995; Stress in the Workplace, 2011). Additionally, work-related daily stressors and PA are among the most frequently mentioned health concerns in the workplace because greater stress and less PA participation contribute to reduced job involvement, absenteeism, and poor psychological well-being and physical health (Schütte et al., 2014; The Workplace and Health, 2016), and employers continue growing investments in workplace health promotion interventions (Grimani et al., 2019; Klatt et al., 2017; Proper & van Oostrom, 2019). In one systematic review, the majority of studies found negative cross-sectional and prospective associations between stress and PA participation; however, a minority of studies found the opposite, whereby PA levels increased in response to stressors, possibly due to individuals using PA to cope with stress (Stults-Kolehmainen & Sinha, 2014). Although a few studies have examined workplace stressors or job strain as they relate to PA (Stults-Kolehmainen & Sinha, 2014) there remains a paucity of research delving into the timing and context of the association between stress and PA, specifically during working and non-working hours. Differentiating between working and non-working hours is important given that, despite declines in overall PA participation and occupational PA over time (Ng & Popkin, 2012), occupational PA still accounts for ~40% of daily PA participation and occupational PA may influence non-occupational PA participation (Gay, Buchner, Smith, & He, 2017; Van Tienoven et al., 2018). Additionally, stress may be associated with occupational PA due to the nature of a person's job. Consider a blue-collar worker – they are rushing to complete a task involving activities like lifting, moving, or carrying objects – this could result in a positive association between stressors and PA specifically during work hours because these variables co-occur as part of the same experience. In contrast, there may be no association between PA and stress outside of working hours or, if such an association exits, it might suggest a person volitionally used PA to manage stress (Childs & de Wit, 2014; Kilpatrick, Hebert, & Bartholomew, 2005a; Nies, Vollman, & Cook, 1999; Schultchen et al., 2019; Smith & Storandt, 1997; Steptoe, Lipsey, & Wardle, 1998; Stetson et al., 1997; Stress in America, 2009). Understanding such nuances is crucial because they have implications for tailoring public health messaging and workplace health promotion interventions to effectively address daily stressors, stress responses, and PA participation.

These potential associations between stress and PA may differ by age and sex due to differences in daily stressors and PA participation by these characteristics (Almeida et al., 2023; Gross et al., 1997; Jiang et al., 2023; Löckenhoff & Carstensen, 2004; Neubauer & Schmiedek, 2020; Pedrelli et al., 2018; Schieman, Glavin, & Milkie, 2009; Schütte et al., 2014; Villada, Hidalgo, Almela, & Salvador, 2016). For instance, Löckenhoff and Carstensen (2004) observed that older individuals tend to experience fewer stressors compared to younger ones. Similarly, Almeida et al.'s (2023) longitudinal cohort study in middle-aged adults found that the frequency of daily stressor exposures decreased 11% from baseline across the 20-year study period. Participation in occupational and non-occupational PA also differs across age, such that younger working adults (18–34 years) are overrepresented in blue-collar jobs and occupations with high PA demands (Nakayama, Van Dyke, Quinn, & Whitfield, 2024; Simpson, 2018). Younger males (18–24 years) also spend more time in non-occupational leisure activity, whereas younger (18–24 years) and older females (55–64 years) spend less time in non-occupational household PA (Van Tienoven et al., 2018). These age differences in stressors and occupational and non-occupational PA could influence the within- and between-person associations between stress and PA.

Similarly, differences in stereotypical gender roles result in males and females experiencing different types of stressors and in females experiencing stressors more frequently and reporting higher average stress levels than males (Almeida & Kessler, 1998; American Psychological Association, 2023). In the workplace context, females experience a greater prevalence of emotional demands, sexual harassment, and discrimination at work, whereas males experience a greater prevalence of high demands for responsibility, long and asocial working hours, and job insecurity (Schütte et al., 2014). Additionally, males report stronger negative responses to work and financial stressors, whereas females report stronger negative responses to interpersonal stressors (Almeida & Kessler, 1998). Outside of work, females report a higher prevalence than males of stressors due to family responsibilities and relationships (American Psychological Association, 2023). There are also sex differences in PA participation, such that males spend more time in occupational PA, whereas females spend more time in domestic PA (Van Tienoven et al., 2018). These differences may be related in part to occupational demands, as males are more likely than females to have blue-collar jobs (Evans, 2021; Gabriel & Schmitz, 2007), and males with longer working hours spend less time in leisure, domestic, and travel-related PA whereas there is no effect of long working hours on females' PA participation (Van Tienoven et al., 2018). Therefore, sex differences in both PA and stress may influence the associations between stress and PA both during and outside of working hours. These sex differences may interact with age differences in stress and PA, because males and females experience different types and trajectories of work-non-work interference across the life span, in part due to differences in gender roles and beliefs (Damaske & Frech, 2016; EIGE, 2024; Schieman et al., 2009). Despite these potential differences, it remains unclear whether the associations between daily stressor experiences (i.e., stressor frequency, intensity, negative affect responsivity) and PA behaviors vary across different contexts, such as during working versus non-working hours, or how they vary by age and sex.

Traditionally, research investigating the associations between stressors, stress responses, and PA has heavily depended on self-reported retrospective questionnaires, which are vulnerable to various biases, including retrospective reconstruction bias (Bolger & Laurenceau, 2013; Myin-Germeys & Kuppens, 2021; Stults-Kolehmainen & Sinha, 2014).

Cross-sectional retrospective self-report methods fail to account for the large day-to-day variations in stressor experiences (e.g., stressor frequency, stress responses) (Almeida et al., 2002, 2020) and PA among working adults, with females showing greater day-to-day variability in occupational PA than males (JaKa, Haapala, Wolfson, & French, 2015). To address these limitations, an alternative approach involves shifting the focus to the immediate present using intensive longitudinal methods (ILMs) (Bolger & Laurenceau, 2013). ILMs encompass various techniques such as ecological momentary assessments and daily diary methods in which multiple subjective assessments are collected within a relatively short time frame (Bolger & Laurenceau, 2013; Myin-Germeys & Kuppens, 2021). ILMs provide a closer and more immediate understanding of individuals' real-life experiences, enabling the exploration of an individual's daily stress experiences, such as stressor frequency, stress responses and PA experiences, their temporal fluctuations, and the specific contexts in which stressors and PA occur (Almeida et al., 2020; Bolger & Laurenceau, 2013; Do, Wang, Courtney, & Dunton, 2021; Flueckiger, Lieb, Meyer, Witthauer, & Mata, 2016; Neubauer & Schmiedek, 2020; Yap, Slavish, Taylor, Bei, & Wiley, 2020).

Therefore, this study used intensive longitudinal data from the National Study of Daily Experiences III (NSDE-III) (Almeida et al., 2002; Ryff & Almeida, 2022) to examine within-person associations between daily stress experiences (e.g., stressors, stress responses) and PA after a stressor occurred (i.e., post-stressor PA) during working and non-working hours and the moderating effects of age and sex. We aim to advance understanding of the complex interplay between daily stressors, PA, and working experiences in working adults.

2. Methods

2.1. Sample

Participants were working adults ages 43–89 years of age from the Midlife Development in the United States (MIDUS-III, $N = 3294$) study who participated in the NSDE-III ($N = 1236$) (Ryff & Almeida, 2022). The MIDUS study included a subsample from Milwaukee County, Wisconsin to increase the representation of African Americans in MIDUS. The NSDE-III, collected from 2017 to 2019, consisted of daily telephone interviews across eight consecutive days where people were asked about the events of their day (e.g., time spent working, stressful experiences, affect responsivity, and physical activity) (Ryff & Almeida, 2022). Participants were identified as workers if they reported at least one day of work in the NSDE-III survey (see *Daily Work Time* below). A full description of the parent studies is available at http://www.midus.wisc.edu/. The secondary analyses for this study were deemed exempt by the Institutional Review Board (#23–66596).

2.2. Daily work time

During the NSDE-III, participants reported their time in daily work-related activities. This included quantifying the duration of time spent on business, paid work, or school-related tasks each day, as well as specifying the times when they started and finished work activities each day. These data were used to distinguish between working and non-working days, and to distinguish between working and non-working hours on working days. Days on which participants reported spending any time in business, paid work, or school-related tasks were considered 'working' days, and days without any time spent in these activities were considered 'non-working' days. Any participant who reported at least one workday over the eight-day survey period and had occupational data ($N = 564$) was included in subsequent analyses. We used the reported start and end times of work activities each day to separate days into segments for 'working hours', time intervals when work occurred on workdays, and 'non-working hours', time intervals when work did not occur on workdays. As participants were not asked to include information about lunch or other breaks during the workday, we were unable to remove lunch or breaks from the 'working hours' segment. All subsequent analyses were conducted separately for three distinct time blocks: 1) work hours on workdays, 2) non-working hours on workdays, and 3) non-workdays.

2.3. Daily stress

Daily stressor experiences were assessed using the Daily Inventory of Stressful Events (DISE), which evaluates the day-to-day fluctuations in daily stress processes (Almeida et al., 2002; Ryff & Almeida, 2022). The DISE evaluates multiple elements of self-reported stressors, including frequency, content, and subjective appraisal characteristics such as stressor intensity and stressor-related emotions (Almeida et al., 2002; Epel et al., 2018; Ryff & Almeida, 2022). The DISE was administered using an interview-based technique to assess these various aspects of daily stress through morning telephone interviews. Participants completed the DISE interview every day for eight consecutive days and reported whether they experienced ('yes') or did not experience ('no') any of the seven types of naturally occurring psychosocial stressors within the previous 24 hours. These stressors include argument, non-argument tensions, stressful events at work or school, stressful events at home, stressful events related to racial/ethnic/sexual discrimination, network stressors, and an "any other stressful events" category. On a given day, responses were recorded as a 'yes' or 'no' for experiencing each stressor, and stressor frequency was calculated by summing the total number of 'yes' responses on a given day (range: 0–7). For each stressor, participants reported the time the stressor occurred, rated the severity of the stressor (4-point Likert scale ranging from Not at all (0) to Very (3)) and negative affective responsivity for four negative emotions (i.e., angry, sad, nervous, shameful) experienced as a result of the stressful event (4-point Likert scale ranging from Not at all (0) to Very (3)).

Daily stress intensity load, which reflects a person's immediate appraisal of a stressful experience, was calculated for stressor severity to encapsulate the effect of all stressors experienced across a given day. Daily stress intensity load was determined by calculating the sum of the stress severity response experienced across all stressors on a given day. For example, if a participant experienced three stressors with respective stress severity values of 1, 2, and 3, their daily stress intensity load was 6. Similarly, the daily load for each form of negative affect (angry, sad, nervous, shameful) was determined by summing the negative affective responsivity across all stressors experienced on a given day. Stressor frequency, stress intensity load, anger load, sadness load, nervous load, and shame load were used as predictors in subsequent analyses.

2.4. Daily physical activity

During the daily diary phone interview, participants were asked to report whether they engaged in PA within the last 24 h. Three types of activity intensities – vigorous, moderate, and light PA – were assessed using the following questions: 1) How much time was spent performing the activity (hours and minutes), and 2) what time did you start the activity (AM/PM, hours, and minutes)? Participants were only able to report once for each PA intensity level, such that participants could report at most three PA reports per day, one each for vigorous, moderate, or light PA. These data were used to determine the length of time spent engaging in each type of activity on a given day, to identify if the activity occurred before or after a stressor, and to identify the time frame during which the activity occurred relative to when the participant reported working on a given day. The total amount of time spent in PA after a stressor was experienced on a given day was calculated by summing daily time spent in vigorous, moderate, and light PA. Individual intensities of PA were combined into a total PA variable as a precaution against potential misclassification of intensity type, as the survey questions only offered a definition for vigorous intensity physical activity, and the definition provided ("activities that would cause you to

break a sweat") overlaps with moderate intensity physical activities (Ainsworth et al., 2012; Institute of Medicine, 2014).

The time frame during which PA occurred on a given day was used to determine when PA occurred relative to the three distinct time blocks: 1) work hours on workdays, 2) non-working hours on workdays, and 3) non-workdays. For instance, if PA started during non-working hours on a workday, it was categorized as occurring within that specific time block. This same rationale was applied consistently to the other time blocks, including working hours and non-workdays. If the timing of PA participation overlapped with multiple work-related time blocks, it was assigned to occur during the time block corresponding to when the PA started. For instance, if PA started during working hours and extended beyond the end of the working hours (i.e., into 'non-working hours'), the PA was categorized as occurring during working hours on a workday. Binary variables were created for each PA variable to indicate whether the person engaged in any PA (i.e., >0 min of PA) after the time they self-reported experiencing a psychological stressor for each time block. If a person did not engage in PA, they were coded as a 0 and if they did engage in PA, they were coded as a 1 for the given time block. The binary variables for engaging in any PA and the continuous variables for total time spent in PA after a stressor occurred (hereafter referred to as 'post-stressor PA') during work hours on workdays, non-working hours on workdays, and non-workdays were used as outcome variables in subsequent analyses.

2.5. Covariates

Sociodemographic variables were collected from the participants within the NDSE-III (Table 1). Several of these variables that are typically associated with stress and PA were included as covariates in analyses, including age, sex assigned at birth (0 = *male,* 1 = *female*), and occupation. The participant's age was calculated by using the date of birth and the date when the daily diary survey occurred. Occupational codes were used to categorize participants as being in a blue- or white-collar occupation (0 = *white collar,* 1 = *blue collar*).

2.6. Statistical analysis

Multilevel models (MLM) with days nested in people were used to examine within-person effects of daily stress on post-stressor PA, with separate models for work hours on workdays, non-working hours on workdays, and non-working days. Intraclass correlations (ICC) were calculated to determine the within- and between-person variability in post-stressor PA (Hayes, 2006; Peugh, 2010). To examine how the daily stressor-related variables were related to post-stressor PA in various work and non-work contexts, and to account for the distribution of the PA data with a large proportion of zeros and positive skew, we performed two-part MLMs with logistic (part 1) and gamma (part 2) regressions[1] using the glmmTMB (version 1.1.9) package in RStudio (version 4.2.764) (Baldwin, Fellingham, & Baldwin, 2016; R Core Team, 2020). The multilevel logistic regression for zeros (part 1) predicts the probability of a person participating in post-stressor PA on a given day with the results reported as an odds ratio (OR) with a 95% confidence interval (CI). The multilevel gamma regression for positive values (part 2) predicts the expected change in time spent in post-stressor PA with results reported as a prevalence ratio (PR) with a 95% CI. The PR gives the rate increase in activity. For example, a PR = 1.1 reflects a 1.1 rate increase or a 10% increase in minutes of post-stressor PA participation. Separate models were used for each daily stress-related variable due to moderate to high collinearity between these variables (r = 0.39–0.91). Each of the stress-related variables on a given day was centered on the person-mean to test within-person, day-level effects. Between-person effects of stress-related variables were assessed by centering participant means to the sample grand mean. All models controlled for age (centered to the sample mean), sex (reference group: males), and occupation (reference group: white collar). Models were tested with and without random slopes, and random slopes were retained if they significantly improved model fit (i.e., significant F-test for model comparisons). Exploratory analyses examined two- and three-way interactions between age and sex with the within- and between-person stress variables. Simple slopes and regions of significance for significant interactions were calculated using tools available at Quantpsy.org (Preacher, 2010). To control for the false discovery rate that occurs with multiple comparisons, the Benjamini-Hochberg procedure was used and p-values were compared to the Benjamini-Hochberg critical alpha, with all p-values less than the critical alpha considered statistically significant (Benjamini & Hochberg, 1995).

Table 1
Descriptive statistics for demographics (N = 564).

Age (Mean ± SD)	57.72 ± 8.78
Income (Mean ± SD) [a]	$106,042 ± $72,234
Sex (n, %)	
Female	304, 53.9%
Male (ref)	260, 46.1%
Race (n, %) [b]	
White	506, 89.7%
Black	22, 3.9%
Other	32, 5.7%
Occupation (n, %)	
White-collar (ref)	442, 78.4%
Blue-collar (ref)	122, 21.6%
Education (n, %)	
Some high school or less	7, 1.2%
High school graduate or GED	96, 17.0%
Some college	172, 30.5%
College graduate	164, 29.1%
Graduate school and beyond	125, 22.2%
Marital status (n, %)	
Married	393, 69.7%
Widowed/Separated or Divorced	119, 21.1%
Never married	52, 9.2%

Notes: General educational development, GED; number, n; reference, ref; standard deviation, SD.
[a] 7.1% of participants had missing data for income.
[b] 0.7% of participants had missing data for race.

3. Results

Table 1 includes descriptive statistics for participant demographic characteristics. Participants were working adults 57.7 ± 8.8 years, 54% female, primarily White (90%, n = 506), white-collar workers (78%, n = 442), and most reported some college education or higher (82%). Table 2 includes descriptive statistics for daily stress, work time, and post-stressor PA participation. Participants, on average, experienced at least one stressor on 42% (n = 1889) of the daily diary days. More than half of reported daily diary days were workdays (62%, n = 2798), with working time lasting on average 6 hours and 48 minutes. Participants reported participating in post-stressor PA on 24% of non-workdays, 22% of workdays outside of working hours, and 18% of workdays during

[1] Comparison of a linear MLM to a two-part MLM (Baldwin et al., 2016) support the choice of the two-part model. The two-part model had significantly better model fit based on the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) for each PA outcome. Total PA during working hours on a working day: Linear model: AIC = 34103.756, BIC = 34121.785; Logistic model: AIC = 2660.459, BIC = 2672.479; Gamma model: AIC = 5983.431, BIC = 5996.249. Total PA outside of workings hour on a working day: Linear model: AIC = 32592.399, BIC = 32610.428; Logistic model: AIC = 3062.038, BIC = 3074.058; Gamma model: AIC = 6971.418, BIC = 6984.890. Total PA on non-working days: Linear model: AIC = 2154.789, BIC = 21562.426; Logistic model: AIC = 1980.121, BIC = 1991.214; Gamma model: AIC = 5039.316, BIC = 5051.563.

Table 2
Descriptive statistics for daily stress and physical activity on working and non-working days.

	Work Days (N = 2798)	Non-Working Days (N = 1683)
Worktime (h) (Mean ± SD)	6.8 ± 3.6	–
Stressor Day (n, %) [a]		
Yes	1329, 47.5%	560, 33.3%
No	1469, 52.5%	1123, 66.7%
Daily Stressor Variables (Mean ± SD) [b]		
Stressor Frequency	0.6 ± 0.8*	0.4 ± 0.6*
Stress Intensity Load	1.1 ± 1.5*	0.7 ± 1.3*
Anger Load	0.6 ± 1.1*	0.4 ± 0.9*
Sadness Load	0.4 ± 0.9	0.3 ± 0.9
Shame Load	0.1 ± 0.5	0.1 ± 0.5
Anxiety Load	0.6 ± 1.1*	0.4 ± 0.9*
Stressor Day with Post-stressor PA (n, %) [c]		
All Days	983, 35.1%*	411, 24.4%*
Outside worktime	619, 22.1%	–
During worktime	512, 18.3%	–
Daily Post-stressor PA (Mean ± SD) [d]		
Total PA minutes	43.3 ± 92.9*	32.1 ± 75.7*
PA minutes outside worktime	19.5 ± 56.4	–
PA minutes during worktime	23.9 ± 74.5	–

Notes: hours, h; standard deviation, SD; physical activity, PA.
*Significant difference between working and non-working days.
[a] There were significant differences in the number of stressor days between working versus non-working days ($\chi^2 = 86.615$, $p < .001$).
[b] There were significant differences in stressor frequency ($\chi^2 = 93.9$, $p < .001$), stress intensity load ($t = 8.248$, $p < .001$), anger load ($t = 5.283$, $p < .001$), and anxiety load ($t = 6.888$, $p < .001$) on working versus non-working days. There were no differences in sad load ($t = 1.288$, $p = .198$) or shame load ($t = -0.013$, $p = .989$) on working versus non-working days.
[c] This reflects the proportion of days with stressors on which participants engaged in physical activity after the stressor. There were significant differences in the number of days with physical activity after a stressor occurred between working versus non-working days ($\chi^2 = 55.763$, $p < .001$).
[d] This reflects the time spent in PA after a stressor occurred, including total minutes of post-stressor PA throughout the day, and minutes spent in post-stressor PA outside of and during worktime. There were significant differences in total time spent in physical activity after a stressor occurred between working versus non-working days ($t = 4.399$, $p < .001$).

working hours. Participants spent less time in post-stressor PA on non-workdays (32 min) compared to workdays (43 min on workdays, with 20 min outside work time and 24 min during work time). All stressor-related variables were positively correlated with one another at the between-person level ($r = 0.40$–0.90).

When examining post-stressor PA participation on workdays, we found that 27.1% of participants (n = 153) did not ever engage in post-stressor PA on workdays, 26.7% (n = 151) only engaged in post-stressor PA outside of working hours on workdays, 14.0% (n = 79) only engaged in post-stressor PA during working hours on workdays, and 27.1% (n = 153) engaged in post-stressor PA during and outside of working hours on workdays. In comparing participants who never engaged in post-stressor PA during working hours on workdays to those who did, we found that they had more stress days ($\chi^2 = 183$, $p < .001$), had a higher stress intensity load ($t = 11.070$, $p < .001$), higher anger load ($t = 6.700$, $p < .001$), higher sadness load ($t = 2.856$, $p = .004$), and a higher anxiety load ($t = 8.455$, $p < .001$).

3.1. Daily stressors predicting total post-stressor physical activity during working hours

The null model for post-stressor PA during working hours on workdays indicated that 68.1% of the variability for engaging in any post-stressor PA (ICC = 0.319) and 28.7% of the variability in post-stressor PA minutes (ICC = 0.713) occurred at the within-person level.

Table 3 displays the results of the two-part MLMs regressing daily stress-related variables on post-stressor PA during working hours. Participants had higher odds of engaging in post-stressor PA during working hours on days when they experienced greater than usual anger (OR = 3.24, 95% CI [2.68, 3.92]), sadness (OR = 2.41, 95% CI [1.95, 2.97], or shame (OR = 2.59, 95% CI [1.71, 3.91] load and when they had higher than average stressor frequency (OR = 87.16, 95% CI [47.78, 159.02]), anger (OR = 6.46, 95% CI [4.36, 9.56]), sadness (OR = 4.77, 95% CI [3.06, 7.44]), or shame (OR = 5.29, 95% CI [2.63, 10.63]) load.

Sex modified the positive within-person association between stressor frequency and odds of engaging in post-stressor PA during working hours (OR = 0.29, 95% CI [0.13, 0.65]) such that it was larger in males (OR_{simple} = 57.34, 95% CI [29.45, 111.63]) than females (OR_{simple} = 16.90, 95% CI [9.73, 29.35]). As shown in Fig. 1, males had a higher probability (0.80) than females (0.50) of engaging in post-stressor PA during working hours on days they experienced one more stressor than usual.

Sex modified the positive within- (OR = 0.49, 95% CI [0.39, 0.63]) and between-person (OR = 0.39, 95% CI [0.22, 0.69]) associations between stress intensity load and odds of engaging in post-stressor PA during working hours, such that they were larger in males (OR_{simple_within} = 5.42, 95% CI [4.38, 6.71]; $OR_{simple\_between}$ = 7.88, 95% CI [5.12, 12.11]) than females (OR_{simple_within} = 2.68, 95% CI [1.45, 4.95], $OR_{simple\_between}$ = 3.06, 95% CI [2.67, 3.51]). Fig. 2 shows that males had a higher probability than females of engaging in post-stressor PA during working hours when they had a stress intensity load 1-4 points higher than usual on a given day (2A) or had an average stress intensity 1–4 points higher than the sample average (2B).

Sex modified the positive within- (OR = 0.58, 95% CI [0.42, 0.82]) and between-person (OR = 0.30, 95% CI [0.16, 0.56]) associations between anxiety load and odds of engaging in post-stressor PA during working hours, such that they were larger in males (OR_{simple_within} = 2.70, 95% CI [2.05, 3.54], $OR_{simple\_between}$ = 3.51, 95% CI [2.15, 5.75]) than females (OR_{simple_within} = 1.58, 95% CI [1.28, 1.95], $OR_{simple\_between}$ = 1.04, 95% CI [0.64, 1.70]), and the between-person effect was non-significant in females. Fig. 3 shows that males had a higher probability than females of engaging in post-stressor PA during working hours when they experienced an anxiety load 1-6 points higher than usual on a given day (3A) or when they had an average anxiety load 1-3 points higher than the sample average (3B). There were no significant within- or between-person associations between daily stress experiences and the amount of PA engaged in during working hours.

Daily Stressors Predicting Total Post-stressor Physical Activity Outside of Working Hours on Workdays.

The null model indicated that 76.5% of the variability for engaging in any post-stressor PA (ICC = 0.235) and 43.2% of the variability for minutes of post-stressor PA (ICC = 0.568) outside of working hours on workdays occurred at the within-person level.

Table 4 displays results of the two-part MLMs regressing daily stress-related variables on post-stressor PA participation outside of working hours on workdays. Participants had higher odds of engaging in post-stressor PA outside of working hours on days when they experienced greater than usual levels of stress intensity (OR = 7.35, 95% CI [5.93, 9.10]), anger (OR = 3.59, 95% CI [3.12, 4.14]), sadness (OR = 5.13, 95% CI [4.07,6.46]), shame (OR = 3.60, 95% CI [2.62, 4.94]), or anxiety (OR = 3.94, 95% CI [2.99, 5.18]) load and when they had higher average levels of stress intensity (OR = 7.71, 95% CI [5.83, 10.21]), anger (OR = 3.79, 95% CI [2.72, 5.30]), sadness (OR = 7.39, 95% CI [4.96, 11.02]), shame (OR = 5.94, 95% CI [3.19, 11.06]), or anxiety

Table 3
Daily stress experiences predicting odds of engaging in post-stressor PA and time spent in post-stressor PA during working hours on workdays [a].

		Stressor Frequency [d]	Stress Intensity Load [d]	Anger Load [d]	Sadness Load [d]	Shame Load [d]	Anxiety Load [d]
	Zero Portion	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Main Effects	Intercept	0.02 (0.01, 0.06)***	0.04 (0.02, 0.09)***	0.13 (0.07, 0.23)***	0.15 (0.08, 0.26)***	0.15 (0.09, 0.26)***	0.06 (0.04, 0.11)***
	Age	1.00 (0.98, 1.03)	0.99 (0.96, 1.01)	0.98 (0.96, 1.00)	0.97 (0.95, 0.99)**	0.97 (0.96, 0.99)**	0.98 (0.96, 1.00) ¥
	Sex	0.92 (0.58, 1.55)	1.01 (0.68, 1.52)	0.76 (0.54, 1.07)	0.79 (0.57, 1.10)	0.98 (0.72, 1.33)	1.37 (0.98, 1.92)
	Blue Collar	1.61 (0.91, 2.84)	1.28 (0.80, 2.04)	0.94 (0.62, 1.42)	0.92 (0.62, 1.37)	0.92 (0.63, 1.33)	1.36 (0.90, 2.05)
	Within-Person [b]	57.34 (29.85, 110.14)***	5.42 (4.39, 6.68)***	3.24 (2.68, 3.92)***	2.41 (1.95, 2.97)***	2.59 (1.71, 3.91)***	2.70 (2.07, 3.52)***
	Between-Person [c]	87.16 (47.78, 159.02)***	7.88 (5.04, 12.31)***	6.46 (4.36, 9.56)***	4.77 (3.06, 7.44)***	5.29 (2.63, 10.63)***	3.51 (2.13, 5.81)***
Interactions	Sex*Within	0.29 (0.13, 0.65)**	0.49 (0.39, 0.63)***	–	–	–	0.58 (0.42, 0.82)**
	Sex*Between	–	0.39 (0.22, 0.69)**	–	–	–	0.30 (0.16, 0.56)**
Main Effects	Positive portion	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)
	Intercept	36.03 (24.00, 54.11)***	35.50 (23.92, 52.70)***	36.68 (24.94, 53.93)***	37.04 (25.23, 54.37)***	36.94 (25.13, 54.30)***	37.19 (25.25, 54.76)***
	Age	1.01 (0.99, 1.02)	1.01 (1.00, 1.02)	1.01 (0.99, 1.02)	1.01 (0.99, 1.02)	1.01 (0.99, 1.02)	1.01 (0.99, 1.02)
	Sex	0.99 (0.80, 1.23)	0.98 (0.79, 1.23)	0.97 (0.77, 1.21)	0.95 (0.76, 1.19)	0.99 (0.80, 1.24)	0.99 (0.79, 1.23)
	Blue Collar	2.14 (1.63, 2.82)***	2.16 (1.64, 2.84)***	2.16 (1.64, 2.84)***	2.16 (1.64, 2.84)***	2.15 (1.64, 2.84)***	2.15 (1.63, 2.83)***
	Within-Person [b]	1.07 (0.95,1.21)	1.03 (0.98, 1.09)	1.00 (0.95, 1.06)	1.00 (0.94, 1.08)	1.01 (0.89, 1.14)	1.00 (0.95, 1.07)
	Between-Person [c]	0.95 (0.68, 1.32)	1.03 (0.87, 1.22)	1.16 (0.90, 1.48)	1.29 (0.98, 1.71)	1.30 (0.78, 2.18)	1.01 (0.82, 1.25)

Notes: ***$p < .001$. **$p < .01$. *$p < .05$. ¥p-value not significant after correction. Odds ratio, OR; Confidence interval, CI; Prevalence ratio, PR.

[a] ORs represent the change in odds of participating in any PA (>0 min) on a given day with respect to its associated model, indicated by the column header. For example, an OR = 2.5 reflects 2.5 times the odds of or 150% higher odds of participating in post-stressor PA. PRs represent the predicted expected change in the amount of post-stressor PA participation. For example, a PR = 1.1 reflects a 1.1 rate increase or a 10% increase in minutes of post-stressor PA. All models controlled for age (sample-mean centered), sex (reference: male), and occupation (reference: white collar). Separate models were conducted for stressor frequency and each form of negative reactivity due to moderate to high collinearity between these variables ($r = 0.40–0.90$). All p-values were adjusted to control for the false discovery rate using the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995).

[b] Within-person effects are day-level measures centered on participant means.

[c] Between-person effects are participant means centered to the grand (sample) mean.

[d] Zero portion models included 2798 observations nested in 564 participants and a random slope for within-person effects, and the positive portion models included 530 observations nested in 273 participants.

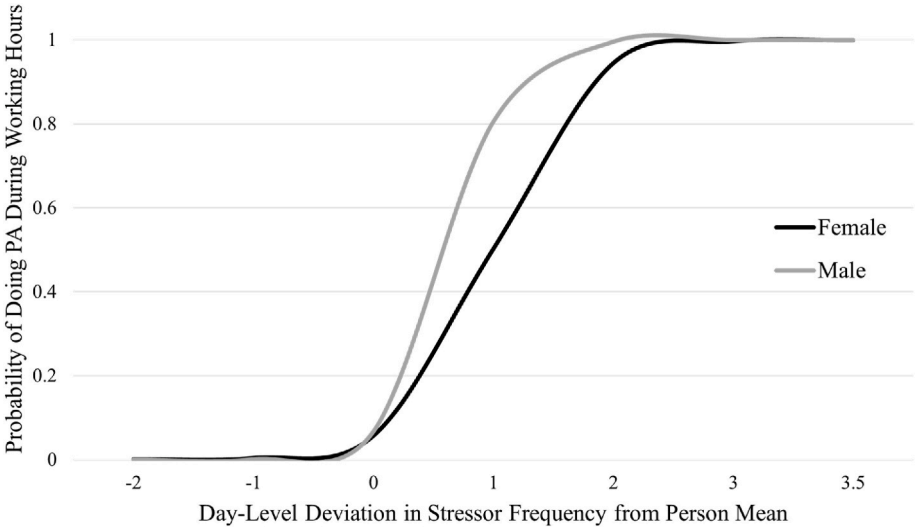

Fig. 1. Sex moderates the within-person effects of stressor frequency on probability of doing post-stressor physical activity during working hours on workdays.

(OR = 5.49, 95% CI [4.07, 7.40]) load.

Age modified the positive within-person association between stressor frequency and odds of engaging in post-stressor PA outside of working hours (OR = 1.13, 95% CI [1.03, 1.23]). The association was significant for participants in the sample age range (43–89 years), but it was larger for older participants (10 years above mean age: $OR_{simple} = 6.19$, 95% CI [4.86, 7.52], mean age: $OR_{simple} = 5.00$, 95% CI [4.21, 5.79], 10 years below mean age: $OR_{simple} = 3.81$, 95% CI [2.82, 4.80]). Fig. 4 shows that participants who were 10 years above the average age had a higher probability of engaging in post-stressor PA outside of working hours relative to younger participants when they experience one more stressor than usual on a given day. There were no significant within- or between-person associations between daily stress experiences and the amount of post-stressor PA engaged in outside of working hours on workdays.

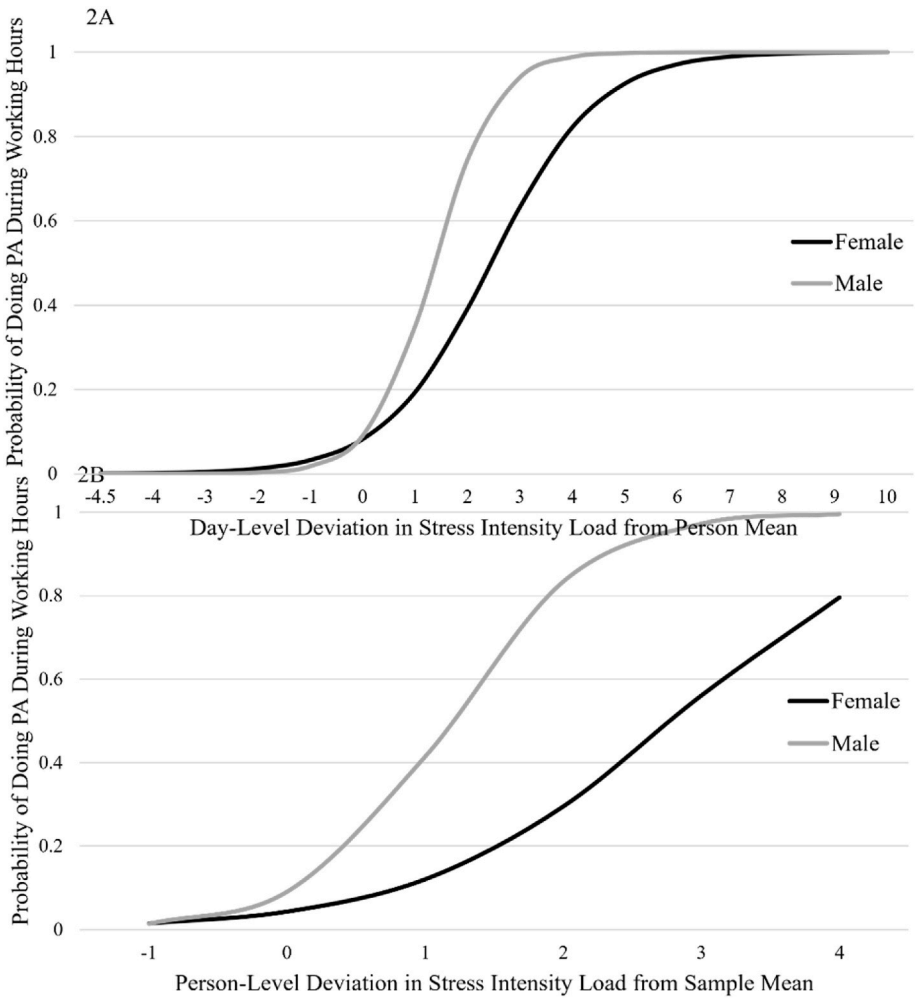

Fig. 2. Sex moderates the within-person (2A) and between-person (2B) effects of stress intensity on the probability of doing physical activity during working hours on workdays.

3.2. Daily stressors predicting total post-stressor physical activity on non-workdays

The null model indicated that 72.5% of variability for engaging in any post-stressor PA (ICC = 0.275) and 60.9% of the variability in minutes of post-stressor PA (ICC = 0.391) on a non-workday occurred at the within-person level. Table 5 displays the results of the two-part MLMs regressing daily stress-related variables on post-stressor PA participation on non-workdays. There were no significant within- or between-person associations and no sex or age interactions of daily stress experiences on the odds of engaging in post-stressor PA or the amount of post-stressor PA participation on non-workdays.

4. Discussion

Understanding the intricate association between daily stress and post-stressor PA within the context of work is essential for developing targeted interventions that promote health and well-being, particularly among working adults (Grimani et al., 2019; Proper & van Oostrom, 2019). This study investigated whether a person's daily experiences, including the frequency of stressors and their affective responses to stressors, were associated with their post-stressor PA behaviors across working and non-working contexts, as well as the moderating effects of age and sex. Using the eight days of survey data collected from working adults in the NSDE-III project (Almeida et al., 2002; Ryff & Almeida, 2022) we were able to detect associations of within- and between-person effects of daily stress variables with post-stressor PA during working hours and outside of working hours on workdays. We consistently found positive within-person and between-person associations between daily stress processes and the odds of post-stressor PA participation during working hours and outside of working hours on working days. There were no within- or between-person associations of daily stress processes with the amount of post-stressor PA participation. One unexpected finding that contrasted with prior research was that greater within- and between-person stress typically corresponded with greater odds of post-stressor PA participation, though there were distinct differences between males and females and across older and younger individuals. These differences in the associations of daily stress processes with post-stressor PA participation across sexes and ages suggest that certain subgroups of the population may benefit most from workplace interventions and public health messaging may need to be tailored to account for an individual's sex, age, or occupation.

Our findings that participants had higher odds of engaging in post-stressor PA during and outside of working hours when they experienced greater daily stress contrast somewhat with literature finding that greater stress predicts decreased PA participation (Almeida et al., 2020; Brown et al., 2021; Burg et al., 2017; Schultchen et al., 2019; Stults-Kolehmainen & Sinha, 2014). However, some studies have found positive associations between stress and PA (Kilpatrick et al., 2005a; Lutz, Stults-Kolehmainen, & Bartholomew, 2010; Stults-Kolehmainen & Sinha, 2014). For example, Stults-Kolehmainen and Sinha (2014) found that stress predicted greater PA participation in 18% of prospective

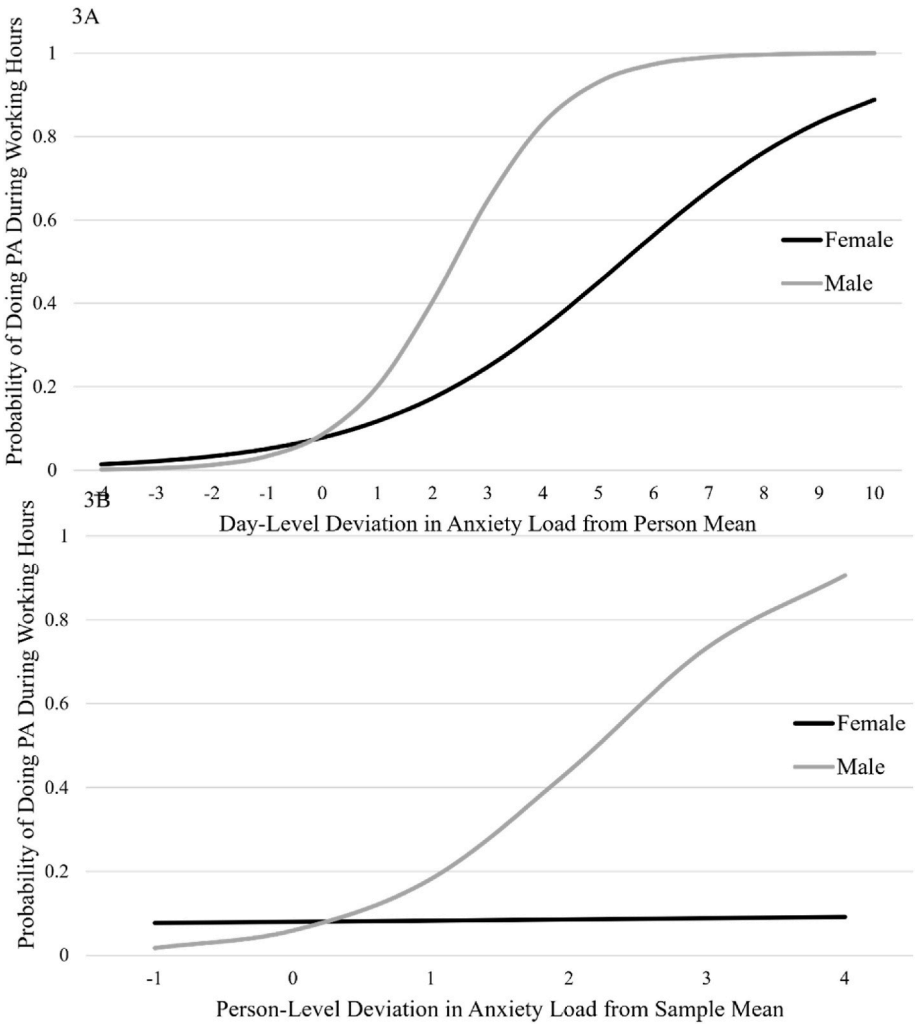

Fig. 3. Sex moderates the within-person (3A) and between-person (3B) effects of anxiety load on the probability of doing post-stressor physical activity during working hours on workdays.

studies. The differences between the current versus previous studies could be due to the current study examining both the odds and amount of PA participation, or due to the current study distinguishing between post-stressor PA that occurred during versus outside of working hours. This distinction is important because about 40% of daily PA participation is due to occupational PA (Gay et al., 2017; Van Tienoven et al., 2018) and, in our sample, 45% of post-stressor PA on workdays occurred during working hours, and 22% of participants were blue-collar workers. Notably, participants who engaged in post-stressor PA during working hours reported greater daily stress, suggesting that the association between stressors and post-stressor PA participation during working hours may be related to a person's occupation. For example, participants in blue-collar or other jobs that require greater occupational PA may show a positive association because stressors and PA co-occur as part of their daily work experiences. This possibility aligns with our finding that blue-collar workers engaged in significantly more post-stressor PA during working hours than white-collar workers. However, this may not fully explain our findings, as only 22% of our sample were blue-collar workers, but 45% of our sample engaged in post-stressor PA during working hours. While it is possible that white-collar workers also engaged in PA as part of their occupation, the positive associations between stress and PA during working hours may not reflect occupational PA, rather it could reflect people using voluntary leisure time PA to cope with stress. For example, after experiencing a stressor, a person might decide to go on a walk to decompress or reflect on the stressful situation, which aligns research finding that 44% of people use PA to help manage stress (Stress in America, 2009; Childs & de Wit, 2014; Kilpatrick et al., 2005a; Lutz, Lochbaum, Lanning, Stinson, & Brewer, 2007, 2010; Nies et al., 1999; Schultchen et al., 2019; Smith & Storandt, 1997; Steptoe et al., 1998; Stetson et al., 1997) and with Lutz et al.'s (2007) findings that people in the maintenance stage of exercise participation engaged in greater frequency, intensity, and duration of exercise in response to stress. Our focus on within-day associations between stress and post-stressor PA may have failed to capture some aspects of this coping response to PA, which could explain the null associations with the amount of post-stressor PA. For example, some people may have engaged in PA the following day to cope with prior day stressors, and others may use morning PA to proactively manage their stress response, particularly if they are a regular exerciser (Lutz et al., 2007, 2010; Schultchen et al., 2019; Stults-Kolehmainen & Sinha, 2014). Alternative modeling approaches, such as growth curve or multilevel structural equation models (Asparouhov, Hamaker, & Muthén, 2018; Curran, Obeidat, & Losardo, 2010) would allow investigating lagged associations of stress with PA. Future studies employing alternative modeling approaches and capturing additional information about the type of PA individuals are participating in during working hours will inform a better understanding of the processes underlying the positive association between daily stressors and PA participation during work hours, particularly given that while leisure time PA participation is associated with health benefits and reduced stress reactivity (Hamer

Table 4
Daily stress experiences predicting odds of engaging in post-stressor PA and time spent in post-stressor PA outside of working hours on workdays [a].

		Stressor Frequency [d,e]	Stress Intensity Load [d]	Anger Load [d]	Sadness Load [f]	Shame Load [d]	Anxiety Load [d]
	Zero Portion	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Main Effects	Intercept	0.10 (0.04, 0.23)***	0.32 (0.16, 0.62)***	0.33 (0.20, 0.54)***	0.40 (0.25, 0.65)***	0.38 (0.25, 0.60)***	0.34 (0.20, 0.56)***
	Age	0.99 (0.95, 1.03)	0.98 (0.96, 1.00)	0.98 (0.96, 1.00)¥	0.97 (0.96, 0.99)**	0.98 (0.96, 0.99)**	0.98 (0.97, 1.00)¥
	Sex	1.28 (0.80, 2.06)	0.91 (0.63, 1.31)	1.20 (0.90, 1.59)	1.11 (0.85, 1.46)	1.37 (1.06, 1.75)¥	1.27 (0.95, 1.70)
	Blue Collar	0.61 (0.34, 1.11)	0.47 (0.28, 0.77)**	0.53 (0.37, 0.76)***	0.55 (0.39, 0.78)***	0.55 (0.40, 0.76)***	0.53 (0.36, 0.78)***
	Within-Person [b]	148.61 (68.49, 322.49)***	7.35 (5.93, 9.10)***	3.59 (3.12, 4.14)***	5.13 (4.07, 6.46)***	3.60 (2.62, 4.94)***	3.94 (2.99, 5.18)***
	Between-Person [c]	93.74 (49.48, 177.57)***	7.71 (5.83, 10.21)***	3.79 (2.71, 5.30)***	7.39 (4.96, 11.02)***	5.94 (3.19, 11.06)***	5.49 (4.07, 7.40)***
Interactions	Age*Within	1.13 (1.03, 1.23)**	–	–	–	–	–
	Sex*Within	1.70 (0.66, 4.40)	–	–	–	–	1.53 (1.08, 2.18)¥
	Age*Sex	0.98 (0.93, 1.04)		–	–	–	–
	Age*Sex*Within	0.87 (0.78, 0.97)¥	–	–	–	–	–
	Positive portion	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)
Main Effects	Intercept	38.58 (28.25, 52.67)***	39.45 (29.43, 52.86)***	39.76 (29.86, 52.94)***	39.40 (29.61, 52.43)***	40.20 (30.22, 53.49)***	40.13 (30.12, 53.46)***
	Age	1.01 (1.00, 1.02)¥	1.01 (1.00, 1.02)¥	1.01 (1.00, 1.02)¥	1.01 (1.00, 1.02)¥	1.01 (1.00, 1.02)¥	1.01 (1.00, 1.02)¥
	Sex	1.21 (1.03, 1.42)¥	1.19 (1.01, 1.41)¥	1.19 (1.01, 1.40)¥	1.18 (1.00, 1.39)¥	1.20 (1.02, 1.41)¥	1.20 (1.02, 1.41)¥
	Blue Collar	1.55 (1.25, 1.93)***	1.55 (1.25, 1.93)***	1.54 (1.24, 1.91)***	1.56 (1.26, 1.94)***	1.53 (1.23, 1.91)***	1.54 (1.24, 1.92)***
	Within-Person [b]	1.00 (0.87, 1.15)	1.00 (0.95, 1.05)	1.03 (0.98, 1.09)	1.00 (0.94, 1.06)	1.08 (0.96, 1.21)	0.99 (0.94, 1.05)
	Between-Person [c]	1.13 (0.87, 1.45)	1.07 (0.94, 1.22)	1.04 (0.87, 1.26)	1.19 (0.97, 1.46)	1.09 (0.76, 1.56)	1.06 (0.91, 1.24)

Notes: ***$p < .001$. **$p < .01$. *$p < .05$. ¥p-value not significant after correction. Odds ratio, OR; Confidence interval, CI; Prevalence ratio, PR.

[a] ORs represent the change in odds of participating in any post-stressor PA (>0 min) on a given day with respect to its associated model, indicated by the column header. For example, an OR = 2.5 reflects 2.5 times the odds of or 150% higher odds of participating in post-stressor PA. PRs represent the predicted expected change in the amount of post-stressor PA participation. For example, a PR = 1.1 reflects a 1.1 rate increase or a 10% increase in minutes of post-stressor PA. All models controlled for age (sample-mean centered), sex (reference: male), and occupation (reference: white collar. Separate models were conducted for stressor frequency and each form of negative reactivity due to moderate to high collinearity between these variables ($r = 0.40$–0.90). All p-values were adjusted to control for the false discovery rate using the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995).

[b] Within-person effects are day-level measures centered on participant means.

[c] Between-person effects are participant means centered to the grand (sample) mean.

[d] Zero portion models included 2798 observations nested in 564 participants and a random slope for within-person effects, and the positive portion models included 619 observations nested in 332 participants and a random slope for within-person effects.

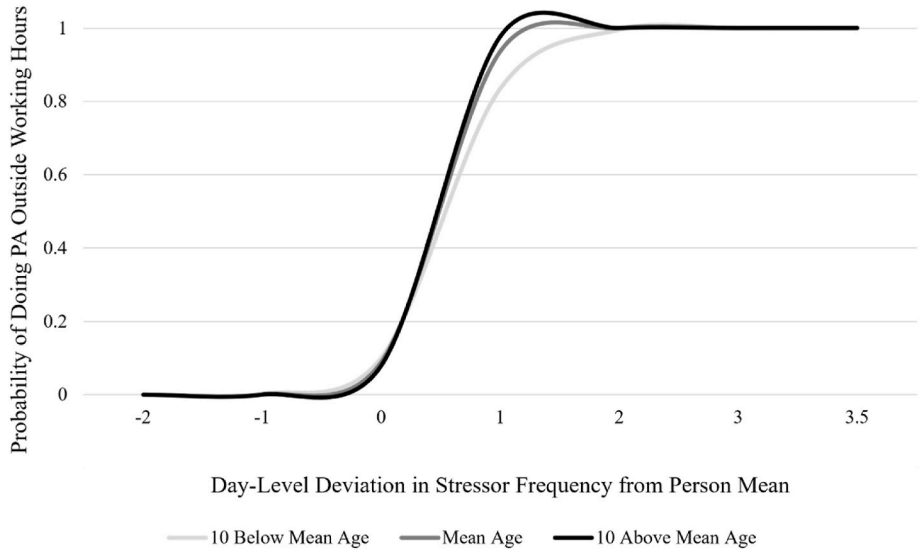

Fig. 4. Age moderates the within-person effects of stressor frequency on the probability of doing post-stressor physical activity outside working hours on workdays.

et al., 2009; Hamer & Stamatakis, 2009; Teychenne et al., 2008), the health effects of occupational PA remain unclear (Cillekens et al., 2020; Holtermann, Krause, Van Der Beek, & Straker, 2018; Jordakieva, Hasenoehrl, Steiner, Jensen-Jarolim, & Crevenna, 2023). Understanding these processes also requires considerations of sex and age differences in daily associations between stress and PA participation.

We consistently found that males showed stronger positive within- and between-person associations than females between daily stress intensity and anxiety due to stressors and odds of post-stressor PA participation during working hours. These findings may reflect sex differences in occupational PA, as males spend more time in occupational PA than do females (Van Tienoven et al., 2018) or in job types, as males

Table 5
Daily stress experiences predicting odds of engaging in post-stressor PA and time spent in post-stressor PA on non-workdays [a].

		Stressor Frequency [d]	Stress Intensity Load [d]	Anger Load [d]	Sadness Load [d]	Shame Load [d]	Anxiety Load [d]
	Zero Portion	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Main Effects	Intercept	7.55^{e-4} (0.00, Inf)	8.76^{e+5} (0.00, Inf)	324.33 (0.00, Inf)	44.07 (0.00, Inf)	1.09 (0.00, 4.61^{e+244})	752.21 (0.00, Inf)
	Age	1.00 (0.00, Inf)	1.01 (0.97, 1.06)	1.02 (1.01, 1.05)	1.01 (0.98, 1.03)	1.00 (0.98, 1.02)	1.02 (0.99, 1.05)
	Sex	1.01 (0.0, Inf)	0.52 (0.21, 1.28)	0.80 (0.50, 1.27)	1.01 (0.67, 1.54)	1.18 (0.83, 1.69)	1.16 (0.72, 1.87)
	Blue Collar	0.96 (0.00, Inf)	1.67 (0.65, 4.29)	0.99 (0.57, 1.72)	1.00 (0.61, 1.64)	0.97 (0.64, 1.49)	1.10 (0.63, 1.92)
	Within-Person [b]	1.95^{e+25} (0.00, Inf)	6.21^{e+11} (0.00, Inf)	2.98^{e+10} (0.00, Inf)	1.68^{e+10} (0.00, Inf)	3.59^{e+09} (0.00, Inf)	5.76^{e+10} (0.00, Inf)
	Between-Person [c]	2.15^{e+24} (0.00, Inf)	1.17^{e+12} (0.00, Inf)	4.57^{e+10} (0.00, Inf)	2.56^{e+10} (0.00, Inf)	5.53^{e+09} (0.00, Inf)	1.06^{e+11} (0.00, Inf)
	Positive portion	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)	PR (95% CI)
Main Effects	Intercept	93.86 (66.22, 133.06)***	91.46 (65.16, 128.36)***	92.92 (66.82, 129.21)***	91.51 (66.01, 126.87)***	94.48 (67.92, 131.42)***	90.22 (64.36, 126.48)***
	Age	0.99 (0.98, 1.00)¥	0.99 (0.98, 1.00)¥	0.99 (0.98, 1.00)¥	0.99 (0.98, 1.00)¥	0.99 (0.98, 1.00)¥	0.99 (0.98, 1.00)
	Sex	0.83 (0.69, 1.00)¥	0.82 (0.68, 0.99)¥	0.82 (0.68, 0.99)¥	0.84 (0.70, 1.00)	0.84 (0.70, 1.01)	0.84 (0.70, 1.01)
	Blue Collar	1.31 (1.05, 1.64)¥	1.32 (1.05, 1.64)¥	1.32 (1.06, 1.65)¥	1.33 (1.07, 1.65)¥	1.31 (1.05, 1.63)¥	1.31 (1.05, 1.64)¥
	Within-Person [b]	1.04 (0.88, 1.22)	1.02 (0.95, 1.09)	1.00 (0.94, 1.08)	0.96 (0.89, 1.03)	0.96 (0.84, 1.09)	1.04 (0.97, 1.13)
	Between-Person [c]	1.07 (0.81, 1.42)	1.07 (0.94, 1.23)	1.13 (0.94, 1.36)	1.28 (1.05, 1.55)¥	1.25 (0.90, 1.72)	1.05 (0.89, 1.24)

Notes. ***$p < .001$; **$p < .01$; *$p < .05$. ¥p-value not significant after correction. Intensity load, IL; Odds ratio, OR; Confidence interval, CI; Prevalence ratio, PR.

[a] ORs represent the change in odds of participating in any post-stressor PA (>0 min) on a given day with respect to its associated model, indicated by the column header. For example, an OR = 2.5 reflects 2.5 times the odds of or 150% higher odds of participating in post-stressor PA. PRs represent the predicted expected change in the amount of post-stressor PA participation. For example, a PR = 1.1 reflects a 1.1 rate increase or a 10% increase in minutes of post-stressor PA. All models controlled for age (sample-mean centered), sex (reference: male), and occupation (reference: white collar). Separate models were conducted for stressor frequency and each form of negative reactivity due to moderate to high collinearity between these variables (r = 0.39–0.91). All p-values were adjusted to control for the false discovery rate using the Benjamini-Hochberg procedure (Benjamini & Hochberg, 1995).

[b] Within-person effects are day-level measures centered on participant means.

[c] Between-person effects are participant means centered to the grand (sample) mean.

[d] Zero portion models included 1683 observations nested in 516 participants and no random slope for within-person effects, and the positive portion models included 411 observations nested in 240 participants and no random slope for within-person effects.

are disproportionately overrepresented in blue-collar jobs that require more physical exertion (i.e., more PA) (Evans, 2021; Gabriel & Schmitz, 2007; Kwak, Berrigan, Van Domelen, Sjöström, & Hagströmer, 2016; Simpson, 2018). Alternatively, if these findings are due to leisure/voluntary PA participation during working hours, rather than occupational PA, they may be related to sex differences in behavioral responses to stressors, as males tend to respond to stress by using distraction techniques, which could include engaging in PA, whereas females tend to ruminate on stressors (Almeida & Kessler, 1998). Lastly, these findings may reflect sex differences in weekday PA, as research indicates that, compared to females in sedentary jobs, males in sedentary jobs demonstrate higher levels of weekday physical activity (Van Domelen et al., 2011), though we did not find any sex differences in the odds or amount of post-stressor PA participation during working hours. If these differences are due to occupational PA, which cannot be confirmed based on the current study's data, it remains unclear how that may impact health outcomes. Indeed, some research suggests that high levels of occupational PA are associated with worse health outcomes, including higher all-cause mortality in males, worse depression and anxiety, greater inflammation, and elevated blood pressure (Cillekens et al., 2020; Holtermann et al., 2018; Jordakieva et al., 2023). Other research has found that more occupational PA corresponded with lower risks for cancer, ischemic stroke and coronary heart disease, and with greater mental well-being and life satisfaction (Cillekens et al., 2020). These mixed findings may be due to health effects varying by the type or intensity of occupational PA (Holtermann et al., 2018; Prince et al., 2021; Jordakieva et al., 2023). Overall, understanding the true import of these findings requires additional research, such as studies investigating the specific roles of job type, intensity and type (i.e., occupational versus leisure time) of worktime PA, and the potential health effects of worktime stress and PA participation.

Along with sex differences in associations between stress and post-stressor PA, we found age differences in the association between daily stressor frequency and the odds of participating in post-stressor PA outside of working hours, such that the effect was larger for older versus younger participants. These findings are somewhat contradictory to research suggesting that older individuals spend less time in non-occupational PA (Van Tienoven et al., 2018).

However, they may reflect age-related changes in peoples' work and non-work roles, with corresponding changes in work-non-work interference (Schieman et al., 2009). For example, as people age, their non-work roles may become less demanding as children leave the home, while their work roles may become more demanding as they transition towards higher profile jobs with more responsibilities (Powell, 2002; Schieman et al., 2009; Tammelin, Koivunen, & Saari, 2017). In such a scenario, a higher profile job would likely be accompanied by experiencing more stressors alongside the presence of fewer non-work-related competing demands, which might allow older participants to engage in PA outside of working hours as a means to cope with stressors (Kilpatrick, Hebert, & Bartholomew, 2005b; Lyness, Gornick, Stone, & Grotto, 2012; Powell, 2002; Schieman et al., 2009; Tammelin et al., 2017). However, additional research is needed to understand whether these associations are due to participants intentionally using PA to cope with stress or not, particularly given that these associations were limited to the likelihood of engaging in PA, rather than the amount of PA participation.

In summary, we found within-person daily stress processes were associated with the odds of engaging in post-stressor PA participation during and outside of working hours, with sex differences during working hours and age differences outside of working hours; however, it remains unclear whether these associations reflect the co-occurrence of stressors with occupational PA and/or whether they reflect volitional

leisure time PA participation during working hours as a means to cope with stress. Further research should investigate the processes underlying these associations between daily stress experiences and post-stressor PA across age and between sexes, as well as their ramifications for psychosocial and physiological health. For instance, research suggests that daily stress processes may impact age-related declines in physical health (Piazza, Stawski, & Sheffler, 2019) and physiological reactions to stress vary across age (Almeida, Piazza, Stawski, & Klein, 2011; Piazza, Dmitrieva, Charles, Almeida, & Orona, 2018) and sex and gender roles (Edes & Crews, 2017; Juster et al., 2016; Juster & Lupien, 2012; Villada et al., 2016). Additionally, while leisure time PA participation is associated with health benefits and reduced stress reactivity (Hamer et al., 2009; Prince et al., 2021; Hamer & Stamatakis, 2009; Teychenne et al., 2008), the health effects of occupational PA remain unclear (Cillekens et al., 2020; Holtermann et al., 2018; Prince et al., 2021; Jordakieva et al., 2023). As such, additional research is needed to clarify if/how daily stress processes and PA across working and non-working hours impact short and long-term health outcomes. Such research could inform targeted interventions, public health messaging, or occupational health and safety policies. For example, if these associations are due to the co-occurrence of occupational stressors and PA, a reasonable path forward might be focusing on organizational-level occupational health and safety policies that support lower worker stress. For example, policies that increase worker autonomy, clarify job roles, support reasonable workload expectations, and improve overall working conditions (e.g., addressing factors such as worker safety, noise levels, and providing relaxing break areas) have the potential to reduce stress among all workers (Burke, 1993; Giga, Cooper, & Faragher, 2003; Israel, Baker, Goldenhar, & Heaney, 1996). Organizational-level approaches are preferable to individual-level approaches because the effects of organizational changes are broader – impacting all workers regardless of age, sex, or occupation – and may have a longer-lasting impact on reducing stress than individual-level approaches (e.g., mindfulness training, resilience training) whose effects are often short-lived (Burke, 1993; Giga et al., 2003; Israel et al., 1996).

5. Limitations and future directions

Although these data were drawn from a national sample, the study's sample was 90% white, generally higher income (median = $90,000), and most of the African-American participants were from a single region, Milwaukee County, Wisconsin (Ryff & Almeida, 2022), limiting the generalizability of the findings. Previous studies have examined stress and PA in the MIDUS sample using either MIDUS data and/or NSDE data (Almeida et al., 2023; Piazza et al., 2018; Puterman, Weiss, Beauchamp, Mogle, & Almeida, 2017). Only one of these studies used the same data as the current study (NSDE-III) and it did not examine stress-PA associations (Almeida et al., 2023); however, repeated analyses of the same data should be viewed with caution. Many of the confidence intervals for within- and between-person effects were wide, particularly for the models examining stress and post-stressor PA on non-working days. A wide CI indicates that there is a wide range of population-level effects for the associations between stress and post-stressor PA (Morey, Hoekstra, Rouder, Lee, & Wagenmakers, 2016). These wide range of potential effects may be due to person differences, such as the sex and age differences found in this study, emphasizing the need to interpret the results within the context of the study's sample (Morey et al., 2016). While intensive longitudinal methods are ideal for exploring within-person stress-PA associations (Bolger & Laurenceau, 2013) there were limitations to the approach used in the NSDE-III. The NSDE-III utilized 24-h recall of perceived stressfulness and emotions in the face of stressors, as well as self-reports of PA participation and intensity, which increases the risk of recall bias and precludes examining the temporal associations between daily stress and PA participation (Stone & Shiffman, 2002). Assessing daily stressors in "real-time" using ecological momentary assessments would assist in capturing the temporality and directionality of the relationship between daily stressors and PA, which has important implications for research and interventions (Almeida et al., 2020; Do, Mason, Yi, Yang, & Dunton, 2021; Do, Wang, et al., 2021; Shiffman, Stone, & Hufford, 2008; Smyth & Stone, 2003). Including device-based measures of PA would also minimize reporting bias, increase ecological validity, and permit more accurate classifications of PA intensity (light, moderate, and vigorous) (Ainsworth et al., 2011, 2015; Boudreaux et al., 2018; Dooley, Golaszewski, & Bartholomew, 2017; Stone & Shiffman, 2002). More accurate assessments of daily PA intensity may be an important avenue of investigation as stress may have differing relationships with the intensity of PA (Stults-Kolehmainen & Sinha, 2014) and differential effects of occupational PA on non-occupational PA participation by the intensity of PA (Gay et al., 2017). Specific information about the types of stressors experienced during working hours versus outside of working hours, as well as the types of PA engaged in across these different time frames would enhance understanding of this study's findings. Focusing on within-day associations between stress and post-stressor PA meant that we did not capture potential lagged effects of stress on next day PA participation or idiographic changes in PA that may be due to stress, which limits the study's findings. Alternative modeling approaches, such as growth curves or dynamic structural equation models could account for these lagged effects, which could also inform knowledge about stress recovery, an important component of daily stress processes and PA participation (Asparouhov et al., 2018; Curran et al., 2010; Smyth et al., 2018). Lastly, future work is needed to investigate the temporal structure of stressors on PA occurring in the workplace, outside the workplace, and on non-workdays. The inclusion of this context within future studies can guide more targeted approaches to just-in-time interventions, public health messaging campaigns, and occupational health policies. Additionally, it can be used to better understand if the effects of stressors vary by type of occupation.

6. Conclusion

This study delved deeply into the complex within- and between-person associations between daily stress and post-stressor PA among working adults. Our findings were somewhat contrary to existing literature suggesting that greater stress corresponds with less post-stressor PA participation by revealing positive within- and between-person association between daily stressors and increased odds of post-stressor PA participation during and outside of working hours. The nuances brought to light through the moderating effects of age and sex underscore the complex interplay between stress, emotional responses, and PA participation across different demographic groups. These findings suggest the need for new and expanded avenues of research for clarifying how individual characteristics, such as age, sex, and/or occupation, intersect with individuals' daily stress experiences and their subsequent associations with the type, intensity, and context of PA participation. Such research may pave the way for organizational-level occupational health policies promoting appropriate job demands, better working conditions, and safe levels of occupational PA which have the potential to impact all workers across various ages, sexes, and occupations. These insights are valuable for public health and workplace strategies designed to promote health and well-being by understanding the complexities underlying stress and its association with physical activity.

CRediT authorship contribution statement

J.B. Courtney: Writing – original draft, Visualization, Investigation, Formal analysis, Data curation, Conceptualization. **J.A. Turner:** Writing – review & editing, Formal analysis, Data curation, Conceptualization. **E. Puterman:** Writing – review & editing, Conceptualization. **D.M. Almeida:** Writing – review & editing, Resources, Methodology, Investigation, Conceptualization.

Compliance with ethical standards

This research study included human participants. All participants provided informed consent to participant in the study.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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