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Can Allostatic Load Cross Over? Short-Term Work and Nonwork Stressor Pile-Up on Parent and Adolescent Diurnal Cortisol, Physical Symptoms, and Sleep

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Grounded in and expanding upon the allostatic load model, the present study examined how repeated exposure to work and nonwork stressors (i.e., stressor pile-up) across an 8-day study period relates to daily strain-related outcomes—diurnal cortisol, physical symptoms, and sleep quantity and quality—in both parents and their adolescent children. Nonlinear associations between daily stressor pile-up and daily strain were explored. Data from the Work, Family, and Health Network study ($N = 131$ parent–child dyads, $n = 1{,}014$ daily survey observations, $n = 465$ daily observations with cortisol) were used to test the study hypotheses. Parent work stressor pile-up and adolescent stressor pile-up were associated with increased daily physical symptom likelihood in parents and adolescents, respectively. Counter to expectations, parent nonwork stressor pile-up was associated with steeper daily cortisol slopes. Additionally, we found curvilinear crossover effects for sleep quantity, such that parent nonwork stressor pile-up and adolescent stressor pile-up were associated with shorter sleep duration among adolescents and parents (respectively), but this relationship plateaued and reversed as daily pile-up increased to more extreme levels. Our article explores conceptual and operational pile-up definitions (level of analysis, length of time window, inclusion of the current-day stressor events). Individual-level analyses supported more consistent, positive linear relationships between stressor pile-up and strains. Time window had little consequences for conclusions, but inclusion of the current day yields some alternative conclusions. We discuss implications for understanding stressor pile-up across domains and across parent–child dyads as it relates to daily strain within the family system.

Keywords: allostatic load, crossover, cortisol, physical symptoms, sleep

The stressor–strain link is fundamental to organizational science research. However, methodological limitations in previous research (Ganster, 2008; Ganster & Rosen, 2013) block our ability to describe how stressors are experienced and the impact they have on health within a complex social environment. For one, the existing literature largely overlooks that we do not start our lives anew each day, free of yesterday's worries. Strain is colored not only by today's stressors but also by those from the recent past (e.g., Bolger et al., 1989; Gartland et al., 2014; Schilling & Diehl, 2014). This coloring is impossible to see with our typical acute (within-day or a single-day lag), longitudinal (weeks, months, or years), or chronic (between-people) approaches. Further, stress is not an isolated experience but, rather, may also be transmitted within a family, such that parents' stress crosses over to their children's health (Lawson et al., 2014; Ohu et al., 2019).

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To better understand the effects of stressors as they are experienced, it is necessary to shift focus to how stressors accumulate within individuals over time, known as *stressor pile-up* (Smyth et al., 2023). Stressor pile-up arises when there is repeated, or compounding, exposure to stressors over time (Grzywacz & Almeida, 2008; Smyth et al., 2023), encompassing both previous and currently experienced stressors. Pile-up is represented as a sum of the number or the severity of stressors across hours (Almeida et al., 2020; Marcusson-Clavertz et al., 2022), days (e.g., Keller & Meier, 2024; Schilling & Diehl, 2014; Schilling et al., 2022), or months (Infurna et al., 2023). Using the allostatic load model (McEwen, 1998) as a guiding framework, we posit that short-term stressor pile-up since the start of the study period (i.e., over 8 days) experienced by parents and their adolescent children may be related to their own worsened daily physical and physiological strain, indicated by daily diurnal cortisol regulation, physical symptoms, and sleep. Moreover, we explore whether these early allostatic load processes bidirectionally cross over within the parent–adolescent dyad (Westman, 2001), such that parent stressor pile-up is associated with daily adolescent strain and adolescent stressor pile-up is associated with daily parent strain. We also explore nonlinear relationships between pile-up and daily strain, allowing us to speak to whether daily strain fluctuations are exacerbated or tempered as pile-up levels increase.

Our work makes three major contributions. Most research testing the allostatic load model focuses on acute within-day stressor–strain relationships or long-term allostatic load (Ganster & Rosen, 2013; Guidi et al., 2021; Juster et al., 2011; Mauss et al., 2015). We conduct a rare test of how the allostatic load process begins by examining how snowballing of daily stressors since the start of our study period predicts fluctuations in daily strain. To expand knowledge of allostasis outcomes and test robustness of allostatic load tenets, we include multiple possible indicators of strain: diurnal cortisol, physical symptoms, and sleep. Finally, we expand the allostatic load model by examining parent–adolescent crossover of stressor pile-up, newly positioning allostatic load as both an intrapersonal and interpersonal process.

We also expand the crossover literature from its predominant focus on spouses or coworkers (e.g., Steiner & Krings, 2016) to adolescent children. Existing child crossover studies are limited in their outcome scope, primarily focused on psychological perceptions or parent–child time (e.g., Cho & Allen, 2012; Crouter & Bumpus, 2001; French et al., 2016; Roeters et al., 2010; Steiner et al., 2023) and exclude the possibility of child-to-parent crossover (e.g., French et al., 2024). We extend these by investigating physiological and physical strain outcomes (Lucente & Guidi, 2023) as well as *bidirectional* crossover among parents and adolescents.

Finally, pile-up is an increasingly popular approach to studying stress (Keller & Meier, 2024), yet this literature is plagued by implicit disagreement over appropriately defining and modeling pile-up. We bring these disagreements to light and empirically explore multiple modeling options to provide informed guidance within this growing research area. First, we question the assumption that the effects of stressor pile-up are linear, exploring exponential patterns based on theoretical and practical arguments. On the one hand, daily strain fluctuations may be weaker or plateau as stressors pile up, consistent with the notion of adaptation (Matthews et al., 2014; McEwen, 1998; Smith et al., 2022). On the other hand, daily strain may become exponentially more strongly associated with pile-up as it increases, indicating loss spirals or accelerated damage consistent with the notion of accumulation (Hobfoll, 1989; Marcusson-Clavertz et al., 2022; Smyth et al., 2018). Second, we explore and compare results across multiple plausible operationalizations of pile-up, varying (a) level of analysis (within-person vs. between-person), (b) pile-up period length, and (c) the inclusion of the current day in the pile-up index. We highlight these critical, yet implicit decision points and their implications, identifying a critical need for stressor pile-up definition and measurement clarifications.

The Allostatic Load Model

The allostatic load model describes how everyday stressor exposure (i.e., events or conditions that require mental or physical energy) yields short-term changes in psychological and physiological function, which can lay the groundwork for disease and mortality over time (Juster et al., 2010; McEwen, 1998; McEwen & Seeman, 1999). Exposure to an acute stressor (e.g., an interaction with an aggressive customer) elicits these primary responses, in which the body mobilizes to cope with the stressor (Ganster & Rosen, 2013). In a normal stress response (allostasis), individuals react and recover relatively quickly. However, with repeated exposure to stressors over time (e.g., repeated aggressive customers), allostasis patterns may become dysfunctional and manifest as strain. For example, primary hormonal and psychological states may become exaggerated or persistent as stressors pile up (McEwen & Seeman, 1999).

Several scholars have commented on why repeated stressor exposure, across days, months, or even years, might affect current strain. McEwen and Seeman (1999, p. 34) pointed to "long-term consequences of hormone action on cell function" resulting from chronic activation as a mechanism that explains why repeated exposure is uniquely harmful to the brain and body. Cognitive appraisal theory suggests past stressors can heighten the degree to which current stressors produce negative appraisals and strain (Meurs & Perrewé, 2011). From a resource and recovery perspective, ongoing exposure may restrict time and ability to recover from previous stressors and increase vulnerability to additional harm and loss (Hobfoll, 1989). A common thread connecting these theoretical arguments is that although primary allostatic load responses certainly depend on current stressors, they are just the top of a pile of recently experienced stressors, which may not fade immediately and can compound to influence on strain.

According to the allostatic load model, repeated stressor exposure eventually leads to secondary, subclinical allostatic load and lasting health decline (e.g., hypertension, chronically elevated immune markers, chronically heightened anxiety; Ganster & Rosen, 2013; Juster et al., 2010). Day-to-day links between stressor exposures and strain (e.g., anxiety, cortisol) therefore represent a theoretical prerequisite for allostatic load and long-term health outcomes (Ganster & Rosen, 2013). Yet existing allostatic load research is not designed to capture short-term stressor pile-up. Many studies use either cross-sectional or experimental (e.g., lab) designs that cannot capture the "complex and nonlinear" trends that unfold in allostatic load processes over time (Ganster & Rosen, 2013, p. 10). Alternatively, allostatic load studies use long-term longitudinal designs that account for stressor–strain relationships across months and years (Guidi et al., 2021; Mauss et al., 2015) but miss more immediate links between stressor pile-up and strain. Altogether, it is currently unclear whether or how quickly stressors snowball and begin to contribute to daily strain fluctuations, especially in younger populations (Lucente & Guidi, 2023).

Accordingly, our first aim is to examine the relationship between pile-up of both work and nonwork stressors and daily strains indicative of physiological health across the span of our 8-day study in both parents and adolescents. We examine three types of strain: daily cortisol slope, daily physical symptoms, and daily sleep. Cortisol is a glucocorticoid hormone released by the hypothalamic–pituitary–adrenal axis throughout the day, regulating many physiological systems (e.g., metabolism, cardiovascular activity; Kaltsas & Chrousos, 2007). Cortisol peaks 30 min after waking and gradually declines throughout the remaining 24-hr period (referred to as diurnal cortisol slope; Kirschbaum & Hellhammer, 1989). Psychosomatic strain includes a variety of everyday physical symptoms such as pain, eye strain, and stomach problems (Nixon et al., 2011; Spector & Jex, 1998), which develop due to a physiological dysregulation (Nixon et al., 2011) and psychological perceptions (Spector & Jex, 1998). Sleep is a fundamental health behavior (Grandner, 2017) that is underpinned by physiological processes and can be disrupted by stress (Benham, 2010; Marcusson-Clavertz et al., 2022). Both sleep time (sleep quantity) and perceptions of restful sleep (sleep quality) are critical for healthy functioning (Buysse, 2014).

Cortisol, Physical Symptoms, and Sleep Quantity and Quality as Strains

Past research (largely using acute, long-term, and chronic approaches) points to cortisol, physical symptoms, and sleep as empirically supported strains. Daily diary studies examining the link between stressors and cortisol tend to show hyperactivation patterns (increased reactivity, increased awakening response, flattened diurnal cortisol slope; Adam et al., 2006; Jacobs et al., 2007; Miller et al., 2007; Schlotz, 2019). There is also some evidence that increased person-level work, nonwork, and interrole stressors are associated with greater daily cortisol output (and flattened diurnal decline indicating worse health) for adults (e.g., Almeida et al., 2016; Stawski et al., 2013; Zilioli et al., 2016) and adolescents (Lippold et al., 2016). However, some studies find no association between (work) stressors and momentary cortisol (Hanson et al., 2000; Smyth et al., 2017) or daily cortisol indicators (Fay & Hüttges, 2017; Volmer & Fritsche, 2016). Further, there is some evidence that nonwork stressors drive daily cortisol patterns more than work stressors (Stawski et al., 2013), yet another study finds work and nonwork stressors are similarly associated with momentary cortisol (van Eck et al., 1996). In sum, daily stressors from work and nonwork domains are typically, but not always, associated with a flattened decline (i.e., dysregulation) in cortisol throughout the day.

Research more conclusively links stressors to physical symptoms and sleep. People who are exposed to work stressors report more physical symptoms and reduced sleep quantity and/or poorer sleep quality using cross-sectional (e.g., Åkerstedt et al., 2002; Barnett et al., 1991; Spector & Jex, 1998) and lagged designs (e.g., Pereira & Elfering, 2014) at the between-persons level (for reviews, see Åkerstedt, 2006; Crain et al., 2018; Linton et al., 2015; Litwiller et al., 2017; Nixon et al., 2011; Sonnentag et al., 2016; Van Laethem et al., 2013). Daily exposure to workplace stressors and everyday hassles outside of work are also associated with increased physical symptoms on the same day and the next day for adults and adolescents (e.g., Almeida, 2005; DeLongis et al., 1988; Lippold et al., 2016; Pindek et al., 2019; Tran et al., 2021). Similarly, a sizeable body of literature finds nonwork exposure to stressful and traumatic events is cross-sectionally and prospectively associated with reduced sleep quantity and quality in both adults and adolescents using between- and within-person (daily) designs (e.g., Crain et al., 2018; Hall et al., 2015; Marcusson-Clavertz et al., 2022; Sadeh et al., 2004; Sadeh & Gruber, 2002).

Our study expands beyond this previous research by (a) directly testing stressor pile-up across several days rather than cross-sectional or lagged daily associations, (b) examining both work and nonwork stressors, and (c) testing physical and physiological strains, rather than psychological strains (e.g., negative affect, fatigue). Based on previous research and the tenets of the allostatic load model, we expect daily pile-up of parents' work stressors and daily pile-up of both parents' nonwork stressors and adolescents' stressors to be associated with each strain indicator.

Hypothesis 1: Parent work stressor pile-up is positively associated with parent (a) flattened diurnal cortisol slope and (b) physical symptoms and negatively associated with (c) sleep quantity and (d) sleep quality.

Hypothesis 2: Parent nonwork stressor pile-up is positively associated with parent (a) flattened diurnal cortisol slope and (b) physical symptoms and negatively associated with (c) sleep quantity and (d) sleep quality.

Hypothesis 3: Adolescent stressor pile-up is positively associated with adolescent (a) flattened diurnal cortisol slope and (b) physical symptoms and negatively associated with (c) sleep quantity and (d) sleep quality.

Crossover Between Parents and Adolescents

In addition to eliciting strain within individuals, stressors can also be socially transmitted, eliciting strain within others in the social environment. This social transmission of stress has taken on many names, including contagion, transmission, and crossover (e.g., Larson & Almeida, 1999; Repetti et al., 2009; Westman, 2016). Westman's (2001) crossover theory offers three explanations for why and how crossover occurs, including spread through emotions (e.g., Song et al., 2008), dysfunctional interpersonal behaviors, (e.g., Repetti et al., 2009; Wang et al., 2011), or shared stressor exposure (Westman, 2001). All three mechanisms suggest stressors experienced by one individual can elicit strain for others in their social sphere.

Within the organizational literature, crossover has typically been studied within romantic couples and has focused largely on the transmission of negative emotions, attitudes, or psychological states such as burnout (Li et al., 2021; Steiner & Krings, 2016; Westman, 2016). However, research conducted primarily within developmental, clinical, and family science disciplines suggests parent-to-adolescent crossover can also occur (Cho & Ciancetta, 2016; Larson & Almeida, 1999; Repetti et al., 2009). Repetti et al.'s (2002) risky families model combines the concepts of crossover and allostatic load, suggesting that repeated exposure to family stressors over time can damage children's physiological, behavioral, and psychological regulation and, in turn, a host of behavioral and physiological risks (i.e., elevated chronic hostility, cortisol, and immune markers; Repetti et al., 2011).

In support, several studies suggest parents' negative emotions, chronic work stressors (e.g., overload, nonstandard work, job insecurity), and daily stressors (e.g., interpersonal conflict) are associated with negative emotions, risky health behaviors, and well-being in children (Johnson & Allen, 2013; Larson & Almeida, 1999; Repetti et al., 2009,

2011), including adolescents (Barling & Mendelson, 1999; Crouter et al., 1999, 2005; French et al., 2016; Larson & Gillman, 1999; Lawson et al., 2014; Ransford et al., 2008). Family/parent stressors are linked to both parent and adolescent cortisol patterns (Lippold et al., 2016; Papp et al., 2009), lower adolescent sleep quantity and/or quality (Khor et al., 2021; Lawson et al., 2014; Zapata Roblyer & Grzywacz, 2015), and increased adolescent daily physical symptoms (Lawson et al., 2014). More rarely, studies have also suggested adolescents' behaviors and physiological activity drive changes in parents' behavior and physiology (Lippold et al., 2020; Varma et al., 2021). However, the crossover from adolescent stressors to parental strains remains underexplored. We integrate allostatic load perspectives into this body of research to examine crossover of work and nonwork stressors as they pile up in real life from the beginning to the end of our study period.

Hypothesis 4: Parent work stressor pile-up is positively associated with adolescent (a) flattened diurnal cortisol slope and (b) physical symptoms and negatively associated with (c) sleep quantity and (d) sleep quality.

Hypothesis 5: Parent nonwork stressor pile-up is positively associated with adolescent (a) flattened diurnal cortisol slope and (b) physical symptoms and negatively associated with (c) sleep quantity and (d) sleep quality.

Hypothesis 6: Adolescent stressor pile-up is positively associated with parent (a) flattened diurnal cortisol slope and (b) physical symptoms and negatively associated with (c) sleep quantity and (d) sleep quality.

Exploring Nonlinear Trends

As a final contribution, we explore the possibility of nonlinear relationships between stressor pile-up and strain within and across parents and adolescents. Allostatic load and the larger stress literature (e.g., Warr, 1994) posit possible nonlinear trends: those in which the relationship between stressors and strains plateaus at certain levels of stressors, reverses direction, or accelerates at extreme levels of stressors.

Specifically, people might habituate or become desensitized to repeated stressors as they become more familiar with the stressor and/or learn to cope (Lyubomirsky, 2011). The allostatic load model theorizes such that habituation patterns reflect "normal adaptation" wherein additional pile-up still predicts greater strain but more weakly as pile-up increases (i.e., a *decelerated decrement* pattern; McEwen & Seeman, 1999, pp. 35–36). Indeed, there is some evidence that people adapt or habituate to work stressors (Bolger et al., 1989; Matthews et al., 2014; Matthews & Ritter, 2019; Ritter et al., 2016; Smith et al., 2022) and life events (e.g., Lucas, 2007; Luhmann et al., 2013) over the course of days, months, and years. The decelerating decrement pattern was found in a recent study showing a curvilinear link between pile-up of sleep loss with both positive affect and physical symptoms (Lee, 2022). Other curvilinear patterns indicative of well-being improvement at higher pile-up may also emerge. For instance, a meta-analysis on lagged stressor–strain relationships found a *decrement-to-improvement turning point* pattern for well-being, suggesting that the stressor–strain link is positive for approximately 3 years before plateauing and reversing (Ford et al., 2014).

Furthermore, the allostatic load model suggests that repeated stressor exposure may be associated with increasingly worse strain at higher degrees of pile-up, as effective recovery becomes more difficult and strain more exaggerated with each stressor added to the pile (McEwen & Seeman, 1999). Such an *accelerated decrement* pattern is discussed in the stressor pile-up literature (e.g., Lee, 2022; Smyth et al., 2018) and is reflected in theories that posit loss spirals (e.g., Hobfoll, 1989). For example, Hobfoll's loss spirals corollary suggests "loss spirals gain in momentum as well as magnitude" (Hobfoll et al., 2018, p. 106). Another possibility is echoed in the vitamin model (Warr, 1994). Similar to appropriate and toxic dosages of a vitamin, the vitamin model posits low levels of job demands are helpful whereas too high levels of job demands are especially harmful for employee strain (i.e., *improvement-to-decrement turning point*; De Jonge & Schaufeli, 1998; Warr, 1994). Although the vitamin model has received inconsistent support (e.g., De Jonge & Schaufeli, 1998; Jeurissen & Nyklíček, 2001; Pindek et al., 2023; Rydstedt et al., 2006) when studying typical (non-pile-up) chronic stress exposure in cross-sectional and longitudinal designs, one recent daily pile-up study found an improvement-to-decrement turning point pattern in the association between cumulative sleep deprivation and negative affect (Lee, 2022).

In sum, it is plausible that the relationship between stressor pile-up and strain changes in magnitude and/or direction as stressors pile up, but existing research solely tests linear associations (Almeida et al., 2020; Almeida & McDonald, 1998; Grzywacz & Almeida, 2008; Schilling & Diehl, 2014). Given a lack of studies on this topic and complexity of possible nonlinear relationships between stressor pile-up and strain, we explore whether the hypothesized stressor pile-up and strain relationships are nonlinear (e.g., decelerated decrement, decrement-to-improvement, or accelerated decrement patterns).

Research Question 1: Are hypothesized stressor pile-up and strain relationships nonlinear (following decelerated decrement, decrement-to-improvement, accelerated decrement, or improvement-to-decrement patterns)?

Method

Transparency and Openness

This project uses secondary data from the Work, Family, and Health Network (WFHN) Study. We describe our sampling plan, all data exclusions, and measures in the study, and we adhered to the *Journal of Applied Psychology* methodological checklist. Data are available through the WFHN (https://workfamilyhealthnetwork.org/data), and analysis code, output, and online additional materials are available at https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e. Data were analyzed using R, Version 4.2.1 (R Core Team, 2022), primarily using the lme4 (Bates et al., 2015) and glmmTMB packages (Brooks et al., 2017). We did not preregister the study design and analysis. Previous publications using the WFHN data can be found at https://workfamilyhealthnetwork.org/publications. To our knowledge, the specific hypotheses and variables tested in this study do not overlap with previously published research.

Participants

We used daily survey and salivary cortisol data collected from parent–adolescent dyads as part of the WFHN Study. Data collection took place between 2009 and 2011. Parents were employed as information technology workers by a U.S. Fortune 500 organization. Of the 823 employees who completed the baseline interview, 209

parents along with one of their adolescent children were invited to participate in a diary study. Eligibility was thus exclusive to employed parents of adolescents (i.e., 9–17 years old). If parents had multiple adolescents, the one closest to age 13 was selected to participate. Of the 209 eligible parents, 131 participated (62.7% response rate). We also removed two participants who responded to four or fewer days. This resulted in an analytic sample of 129 parent–adolescent dyads. The parent sample (n = 1,014 daily survey observations, n = 465 daily observations with cortisol) was 44.19% female, 70.54% White (10.08% Asian Indian, 8.53% Hispanic, 6.20% other Asian, 2.33% other Pacific Islander, 1.55% Black or African American, non-Hispanic, 0.78% more than one race), and 81.40% married. On average, parent participants were 45.02 years old (SD = 6.19) and had 2.11 children (SD = 1.08). Participants worked 45.98 hr per week on average (SD = 5.86) and had a median personal income of $120,000–$129,999 per year. The adolescent sample (n = 1,026, n = 398 daily observations with cortisol) was 53.49% female and 13.39 years old on average (SD = 2.34).

Procedure

Data were collected from both parents and adolescents across 8 days via once-daily telephone interviews and multiple-daily saliva collections. Start days varied for each participant.[1] The phone interviews occurred in the evenings and assessed daily experiences since the previous day's interview. The saliva collections occurred on four of the eight diary study days (i.e., Days 2–5), four times each day for adolescents and five times each day for parents. The waking and bedtime salivary measurements were used to calculate cortisol slope over a given day. An instructional DVD guided participants to abstain from eating, drinking, smoking cigarettes, and brushing their teeth for 30 min before each saliva collection. The collection procedure, also guided by the DVD, instructed participants to collect their own saliva by rolling a cotton swab across their tongues for 2 min before placing the swab immediately into a refrigerated collection. Participants were instructed to write the date and time of data collection on the salivettes, which contain the cotton swabs, and on the Saliva Home Collection Sheet. Ten percent of the sample received time stampers; this group was instructed to use the time stamper instead of handwriting dates and times of collection on the sheet. The WFHN research team also asked standard saliva collection compliance questions, for example, substance use 30 min before collecting any samples and sample(s) taken at the wrong time. Responses to these questions were used in cortisol assay data management in conjunction with information written by the participants' home saliva collection sheets and salivettes to ensure the accuracy of the cortisol data. At the end of the study period, all swabs were mailed overnight to a laboratory and frozen until analysis. EIA kits (Salimetrics LLC, State College, Pennsylvania) were used to run assays. Each parent–adolescent dyad received $150 for participation. This study was approved by Institutional Review Boards at each relevant center (https://projects.iq.harvard.edu/files/wfhn/files/2016_01_14_mop_with_updated_logo.pdf?m=1452890215).

Measures

All variables used for hypothesis testing were collected during the eight daily telephone interviews except cortisol (collected via saliva swabs) and statistical controls (collected at baseline). All scales are formative (stressor pile-up, physical symptoms) or single item.

Stressor Pile-Up

Daily stressors were assessed with an adapted version of the Daily Inventory of Stressful Events (Almeida et al., 2002). The WFHN Study researchers adapted the five-item Daily Inventory of Stressful Events instrument to measure (a) *parent-reported work stressors*, (b) *parent-reported nonwork stressors*, and (c) *adolescent-reported stressors*. In the evening phone interviews, parents were each asked to report the occurrence of stressful events in the work domain (e.g., "Did you have an argument or disagreement with anyone at work since this time yesterday?") and in nonwork domain (e.g., "Did you have an argument or disagreement with anyone outside of work since this time yesterday?"), and adolescents reported stressful events for the day (e.g., "Did you have any arguments or disagreements with your parent since this time yesterday?"). Items included having arguments, avoiding arguments, new demands, or other stressful events. Following an affirmative response, participants were then asked to indicate the severity of that event (i.e., "How stressful was this for you?" 1 = *not at all* to 4 = *very stressful*).

To calculate daily stressor pile-up, we first summed severity across stressful events of a given type reported on that day. Days that participants reported no stressors were scored as 0. Days with missing data were scored as missing, except that work stressors were coded as 0 on nonworking days. All previous days' stressor scores were weighted according to temporal distance from the focal day (Infurna et al., 2023; Keller & Meier, 2024; Schilling & Diehl, 2014). Linear decay weights reflect our assumption that stressors can have reverberating effects over time and that proximal stressors contribute to the pile-up index more than distal stressors to account for stressor timing (Schilling & Diehl, 2014; Schilling et al., 2022). We then summed the current-day and all previous days' daily weighted severity sums, and we divided this total sum by eight (number of total days) to scale the pile-up index.[2] The current day was included in our index, because we wanted the index to reflect current, up-to-the-moment feelings of pile-up. The first day was scored as missing, as we did not have data available for multiple days. The stressor pile-up index was scored as missing if the focal day had no stressor data. If the day after a missing day had stressor data, previous days (including before the missing day) were added. This approach essentially assumes the missing value had a score of 0 (no stressors).[3]

[1] Most study days were weekdays (74.03% of total sampled days, 65.51% of cortisol days) and/or work days (73.26% of total sampled days, 67.05% of cortisol days).

[2] Our formula follows Schilling and Diehl (2014), with the exception of the scaling factor. While Schilling and Diehl (2014) used the sum total of the weights, we divide by the number of possible days (eight) to keep the scaling factor constant across days. Please see Appendix A and our HTML output on our additional online material (https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e) for sample coding.

[3] To evaluate the impact of this assumption, we examined the number of missing observations per person. For both work and nonwork stressor pile-up, 17 people were missing observations (n = 14 missing one observation, n = 2 missing two observations, n = 1 missing three observations). For adolescent stressor pile-up, 13 people were missing observations (n = 10 missing one observation, n = 3 missing two observations). Overall sample missing rates were between 1% and 2%. Moreover, the median and modal number of work stressors that occurred was zero for each stressor type. We conclude the number of missing observations per person was low, with most people missing a single observation and that no stressor occurrence is most likely for these missing observations based on our sample data.

Thus, the stressor pile-up index scores reflected a combination of the number and severity of repeatedly experienced stressors on and before the focal day, accounting for the passing of time. We interpret pile-up as the amount of stress experienced since the start of the study. To calculate nonlinear stressor pile-up trends, we squared each stressor pile-up index to create a quadratic pile-up term, and we cubed each stressor pile-up index to create a cubic pile-up term (French & Allen, 2020; Lee, 2022). Our additional online Appendix A (https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e) contains sample coding.

Diurnal Cortisol Slope

Parent and adolescent diurnal cortisol slope was computed by subtracting waking cortisol levels from cortisol levels before bed. Because duration between these two daily collections differed across participants depending on their wake and bed times, the difference scores were divided by the time difference between the two time points to account for duration between same-day cortisol measurements. Cortisol levels naturally decrease over the course of the day, indicating a healthy diurnal cortisol rhythm (Polk et al., 2005). Thus, a larger negative value in diurnal cortisol slope indicates a steeper decline and healthier physiological functioning.

Physical Symptoms

Parent physical symptom severity was assessed via a 10-item checklist adapted from the National Study of Daily Experiences (Larsen & Kasimatis, 1991). Example symptoms included headache, fatigue, and cold or flu symptoms. Adolescents were presented with a similar six-item list adapted for their age group. For each experienced symptom, participants rated severity (1 = *very mild* to 10 = *very severe*). Severity ratings were summed.

Sleep Quantity

Parent sleep quantity was assessed via one item, "How many hours did you sleep (last night)?" (Buysse et al., 1989). Adolescents' sleep quantity was calculated in hours based on their bedtime and wake time. We selected adjusted measures of sleep quantity for each age group, as time in bed may be more accurate for adolescents whereas time asleep may be more accurate for adults (Ohayon et al., 2004).

Sleep Quality

Parent sleep quality was assessed via one item asking participants "How would you rate last night's sleep quality overall?" (Buysse et al., 1989). Participants responded on a 4-point scale (1 = *very badly* to 4 = *very well*). Adolescents were presented with a slightly adapted item ("How well did you sleep last night?") on the same response scale.

Controls

Age, gender, and race were included as controls, as they may confound the relations between stressors and strain in adults (e.g., Assari & Lankarani, 2016; Hajat et al., 2010; Lippold et al., 2020; Neupert et al., 2007) and adolescents (e.g., M. T. Allen & Matthews, 1997; DeSantis et al., 2007; Sigfusdottir & Silver, 2009). We also controlled for the number of children who live in the household for three or more days/week, as the number of children is often associated with both stressors (e.g., Buddelmeyer et al., 2018; Muhammad & Gagnon, 2010) and strain (e.g., Gove & Geerken, 1977) in adults and adolescents (Lockwood et al., 2002). Parent body mass index (in units of kg/m^2) was also included as a control in analyses predicting parent strain, given that higher body mass index was found to be associated with shorter and lower quality sleep (Vgontzas et al., 2008) and more physical symptoms (Okifuji & Hare, 2015), and may confound results on cortisol (Björntorp & Rosmond, 2000).[4] For cortisol analyses, we additionally controlled for medication use in adults (Granger et al., 2009) and adolescents (Blake Woodside et al., 1991) which can threaten the accurate measurement of salivary cortisol. Additionally, person mean pile-up level was also included as a control to account for individual-level pile-up variance and isolate within-person effects of pile-up on strain (Antonakis et al., 2021; Schilling & Diehl, 2014; Schilling et al., 2022). Level 1 linear day was included as a control to account for daily rhythms in dependent variables, as is recommended for adults (e.g., Kirschbaum & Hellhammer, 1989; Palada et al., 2020) and adolescents (Hruschka et al., 2005).

Analytic Approach

Hypotheses were tested using general linear mixed effects modeling in R (using the lme4 package; Bates et al., 2015). We used the restricted maximum likelihood estimator and specified random intercepts (Bliese, 2016; Bliese & Lang, 2016). This approach considers the nested nature of the data, wherein study days (i.e., Level 1) are nested within individuals[5] (i.e., Level 2; Raudenbush & Bryk, 2002). In total, 1,032 daily observations were nested within 129 parents and their respective adolescents.[6] Based on a relatively standard missingness rate (see Enders, 2003), all available daily data were used—including days on which no stressors were reported—to capture the full range of daily experiences (Curran et al., 2010). There was substantial day-level variance for all outcomes (intraclass correlations [ICCs] ranging from .25 to .72), and null random intercept (i.e., no predictor) models fit the data better than fixed intercept models ($p < .01$ for all log likelihood model comparisons), indicating support for multilevel analyses (Raudenbush & Bryk, 2002; see Table 1).

[4] This control variable was not available for adolescents. This is a limitation, as body mass index is related to cortisol reactivity to stressors in adolescents (Dockray et al., 2009) and may account for some of the variance in daily cortisol slope.

[5] The individual level includes both parents and adolescents in the parent–adolescent dyad. Our study does not include any variables that truly reside at the dyad level, as each individual reflects on their own stressors and strains, and controls are individual difference demographics. Thus, we have no dyad-level variance, and instead we have each distinguishable member of the dyad's strain predicted by their personal or social stressor exposure from their adolescent/parent dyad partner.

[6] After excluding cortisol which was only measured on 4 days, missingness on any one of the hypothesis testing variables ranged from 2.84% (30 observations, adolescent physical symptom severity) to 28.10% (297 observations, work stressor pile-up). Most (57.5%) individuals had complete data, and an additional 22.30% of individuals were only missing one observation. Pairwise deletion was used for analyses. The range of sample sizes for each analysis is provided in the Tables 3 and 4.

Table 1
Unconditional Model Parameters, ICCs, −2 Log Likelihood Difference for Each Dependent Variable

	Parent reported				Adolescent reported			
Parameter	Diurnal cortisol slope	Physical symptom	Sleep quantity	Sleep quality	Diurnal cortisol slope	Physical symptom	Sleep quantity	Sleep quality
Intercept	−0.0145**	2.32**	7.24**	3.02**	−0.01523**	1.73**	8.91**	3.48**
σ^2	0.0004	3.30	1.34	0.34	0.0003	4.92	1.52	0.23
τ_{00}	0.0002	2.10	0.49	0.12	0.0001	1.60	0.84	0.16
ICC	0.31	0.39	0.27	0.25	0.26	0.25	0.35	0.42
LL ratio	60.89**	348.15**	179.56**	106.27**	36.80**	227.22**	229.01**	271.44**

Note. All models estimated using restricted maximum likelihood to allow for comparison to a general linear model. σ^2 = day (Level 1) variance; τ_{00} = dyad (Level 2) variance; ICC = intraclass correlation; LL ratio = difference in log likelihood from the random effects unconditional model compared to the fixed-effects general linear model.
** $p < .01$.

Because we did not test moderation, all predictor slopes were estimated as fixed effects. All models included the aforementioned control variables.[7] Per recommendations (Bliese & Lang, 2016; Singer & Willett, 2003), increasingly complex models were built when predicting each strain outcome. To test Hypotheses 1–6, we computed linear models by entering pile-up as a time-varying, fixed linear predictor of strain, and we interpret the significance of this linear estimate as support for our hypotheses (Bliese & Ployhart, 2002). To test the research question, we computed nonlinear models by entering quadratic, followed by cubic effects as time varying fixed predictors of each strain outcome. The model for each outcome with the most complex statistically significant pile-up term was retained for research question interpretation. Models that returned invalid parameters were not interpreted. In the event that no pile-up parameters were statistically significant, we defaulted to the model containing only linear pile-up (Bliese & Lang, 2016; French & Allen, 2020).

Parent and adolescent physical symptoms were both zero-inflated, meaning many participants reported no physical symptoms on a given day. For these variables, we used a hurdle model, specifying a Gaussian distribution for nonzero responses (using the glmmTMB package; Brooks et al., 2017). The hurdle model produces coefficients that indicate the extent predictors are associated with (a) the binary outcome of having/not having physical symptoms and (b) the degree of severity of physical symptoms among those who reported them (Feng, 2021; Min & Agresti, 2002; Yau & Lee, 2001). These two associations are represented with two distinct models: (a) a zero-inflated model predicting the binary likelihood of nonoccurrence (i.e., *not* having physical symptoms) and (b) a conditional model, predicting the continuous degree of physical symptom severity among those who reported physical symptoms.

Results

Descriptive Statistics and Correlations

Descriptive statistics, ICCs, and bivariate correlations are reported in Table 2. More than half of the variance in each dependent variable is attributable to the day level (ICCs < .50). Participants typically reported zero, one, or two stressors of each type per day (see Table 3).

Stressor Pile-Up Predicting Parent and Adolescent Daily Strain

All unstandardized coefficients from the final retained models are reported in Table 4 (parent strain) and Table 5 (adolescent strain). Linear and nonlinear models not shown in Tables 3 and 4 can be found on additional online material (https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e). Table 6 is a summary of all findings. Significant nonlinear effects are depicted in Figure 1.

Parent Intrapersonal Strain

Hypothesis 1 expected parents' greater work stressor pile-up to relate to their own daily (a) flatter (worse) diurnal cortisol slope, (b) more physical symptoms, (c) shorter sleep duration, and (d) poorer sleep quality (see Table 4, top panel). In the linear models, no significant effects emerged connecting parent work stressor pile-up to parent cortisol slope, physical symptoms, sleep quantity, or sleep quality ($p > .05$), showing no support for Hypothesis 1. Regarding exploratory nonlinear analyses for parent physical symptoms, the cubic effect was statistically significant (cubic pile-up estimate = −0.0027, $p < .001$) in the zero-inflated model (i.e., likelihood of *not* having any physical symptoms). That is, parent work stressor pile-up was associated with *higher* likelihood of any physical symptom, although the rate of increase decelerated and then accelerated again in rate at relatively high levels of pile-up (decelerated decrement, followed by accelerated decrement pattern; see Figure 1A). Thus, exploratory analyses showed a nonlinear decrement pattern for work stressor pile-up and parent daily physical symptoms.

Hypothesis 2 expected parents' nonwork stressor pile-up to also relate to their own strain outcomes (see Table 4, middle panel). In the linear models, parents' nonwork stressor pile-up exhibited a significant linear relationship with their diurnal cortisol slope (linear pile-up estimate = −0.0017, $p < .001$), such that their cortisol slopes became *steeper* (i.e., healthier) as nonwork stressors pile-up (linear improvement pattern). Hypothesis 2a was therefore not supported. Hypotheses 2b–2d were also not supported, as nonwork stressor pile-up was not associated with parents' daily physical symptoms,

[7] Results with and without control variables reach the same conclusions and are available on additional online material (https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e).

Table 2

Descriptive Statistics, Intraclass Correlations, and Bivariate Correlations for Key Study Variables

Variable	Between (individual) level		Within (day) level		1	2	3	4	5	6	7	8	9	10	11	12
	M	*SD*	*M*	*SD*												
1. Daily work stressor severity	1.37	1.27	0.00	2.01	—	**.52****	.16	**.97****	**.50****	.17	.09	.09	**.45****	.02	**−.19***	−.03
2. Daily nonwork stressor severity	1.60	1.53	0.00	1.96	**.15****	—	**.26****	**.51****	**.99****	**.29****	**.19***	.16	**.44****	.02	**−.19***	−.09
3. Daily adolescent stressor severity	0.88	0.96	0.00	1.51	**.18****	**.24****	—	.16	**.24****	**.98****	**.25****	.14	**.22***	**.38****	.07	**−.18***
4. Work stressor pile-up	4.67	4.26	0.00	0.46	**.54****	.02	.01	—	**.50****	**.18***	.12	.10	**.44****	.03	**−.20***	−.03
5. Nonwork stressor pile-up	5.74	5.51	0.00	0.49	−.05	**.43****	**.07***	**.11****	—	**.26****	**.19***	.15	**.43****	.01	**−.20***	−.08
6. Adolescent stressor pile-up	3.13	3.43	0.00	0.35	−.04	**.08***	**.52****	**.07***	**.24****	—	**.27****	.17	**.23****	**.34****	.06	−.17
7. Parent cortisol slope	−0.01	0.02	0.00	0.02	.07	−.07	−.04	−.02	**−.15****	−.06	*.31*	**.19***	.12	.09	−.09	**−.21***
8. Adolescent cortisol slope	−0.02	0.02	0.00	0.01	−.05	−.03	−.04	.02	.04	.04	.09	*.27*	.12	.03	.08	−.17
9. Parent physical symptom severity	2.31	1.65	0.00	1.64	**.11****	**.11****	**.08***	**.08***	−.02	−.01	−.04	.02	*.48/.72*	.05	−.01	−.09
10. Adolescent physical symptom severity	1.71	1.63	0.00	1.98	**.07***	**.08***	**.19****	−.02	.06	**.10****	**−.16****	−.01	**.08***	*.43/.33*	.03	**−.21***
11. Parent sleep quantity	7.26	0.88	0.00	1.03	**−.10****	−.00	−.02	.03	.00	.02	−.06	.01	.02	.01	*.27*	.17
12. Adolescent sleep quantity	8.92	1.06	0.00	1.11	**−.09***	−.00	−.02	.02	−.01	.01	.05	−.06	.01	−.01	**.26****	*.35*
13. Parent sleep quality	3.02	0.42	0.00	0.55	−.01	.04	.01	.00	.03	.05	−.02	.02	.03	.04	**.24****	**.08***
14. Adolescent sleep quantity	3.48	0.45	0.00	0.43	**.07***	−.01	−.01	−.04	**−.08***	−.02	.06	.08	−.01	.00	.01	**.08***
15. Parent age			45.02	6.19												
16. Parent gender[a]			1.44	0.50												
17. Parent race[b]			0.71	0.46												
18. Parent BMI			28.52	5.60												
19. Parent medication[c]			0.27	0.45												
20. Adolescent age			13.39	2.34												
21. Adolescent gender[a]			1.53	0.50												
22. Adolescent race[b]			0.60	0.49												
23. Adolescent medication[c]			0.10	0.30												
24. Number of children			2.11	1.08												

Variable	13	14	15	16	17	18	19	20	21	22	23	24
13. Parent sleep quality	*.25*	.11	−.06	.13	.01	.02	−.11	.03	.11	.04	−.06	−.07
14. Adolescent sleep quantity	.04	*.42*	**−.19***	−.06	.11	−.01	.15	**−.31****	−.10	−.08	−.13	.04
15. Parent age			—	−.08	.04	.04	.03	**.32****	**.20***	.06	.12	**−.25****
16. Parent gender[a]				—	−.14	.06	.12	.12	−.05	**−.18***	.07	−.15
17. Parent race[b]					—	.10	.13	.08	−.09	**.75****	.16	.10
18. Parent BMI						—	.10	−.01	.01	.13	.14	−.03
19. Parent medication[c]							—	.01	−.17	.15	**.32****	−.05
20. Adolescent age								—	.14	.07	**.21***	**−.26****
21. Adolescent gender[a]									—	−.04	.00	−.11
22. Adolescent race[b]										—	.17	**.18***
23. Adolescent medication[c]											—	−.08
24. Number of children												—

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. Statistically significant effects are in bold for ease of interpretation. Correlations below the diagonal are at the day level (Level 1). Correlations above the diagonal are at the individual level (Level 2). Italicized values along the diagonal are intraclass correlations (ICCs). ICCs not shown for predictor variables. For physical symptoms, the conditional model ICC is on the right of the slash, and the zero-inflated model ICC is on the left of the slash. Individual level *n* ranges from 120 to 129. Daily level *n* ranges from 374 to 1,016. BMI = body mass index.

[a] 1 = men/boys, 2 = women/girls. [b] 0 = non-White, 1 = White. [c] 1 = yes, 0 = no.

* $p < .05$. ** $p < .01$.

sleep quantity, or sleep quality ($p > .05$). No significant nonlinear effects emerged in exploratory analyses.

Adolescent Intrapersonal Strain

Hypothesis 3 expected adolescents' stressor pile-up to relate to their own adverse health outcomes (see Table 5, top panel). In the linear models, greater adolescent stressor pile-up related to lower likelihood of not having any physical symptom (i.e., higher likelihood of symptom presence; linear pile-up estimate = −0.16, p = .003), in line with Hypothesis 3b. Hypotheses 3a, 3c, and 3d were not supported, as linear effects were nonsignificant across diurnal cortisol slope, sleep quantity, and sleep quality ($p > .05$). No significant nonlinear effects emerged in exploratory analyses.

Table 3
Frequency of Work, Nonwork, and Child Work Stressors per Day Across 8 Study Days

Total number of stressors per day	Work	Nonwork	Adolescent
0	67.85% (686)	61.03% (617)	72.93% (741)
1	20.47% (207)	27.70% (280)	20.97% (213)
2	8.41% (85)	8.90% (90)	4.92% (50)
3	3.07% (31)	1.68% (17)	1.08% (11)
4	0.20% (2)	0.59% (6)	0.10% (1)
5	0.00% (0)	0.10% (1)	0.00% (0)

Note. Percentage of study days with a given number of stressors reported outside of parentheses. Raw frequencies are in parentheses.

Parent and Adolescent Interpersonal Strain (Crossover Effects)

Hypothesis 4 proposed parent-to-adolescent crossover such that parent work stressor pile-up is associated with their adolescents' adverse health outcomes (see Table 5, middle panel). Hypothesis 4 was not supported, as linear models showed no significant associations were found between parents' work stressor pile-up and adolescents' daily diurnal cortisol slope, physical symptoms, sleep quantity, or sleep quality ($p > .05$). Exploratory analyses showed a nonlinear decrement-to-improvement turning point pattern on adolescent sleep quantity (cubic pile-up estimate = −0.00072, $p = .008$; see Figure 1B).

Hypothesis 5 proposed additional parent-to-adolescent crossover such that parent nonwork stressor pile-up relates to their adolescents' adverse health outcomes (see Table 5, bottom panel). No significant linear effects emerged at the day level for parents' nonwork stressor pile-up and adolescent strain ($p > .05$). Thus, Hypothesis 5 received no support. No significant nonlinear effects emerged in exploratory analyses.

Hypothesis 6 proposed adolescent-to-parent crossover such that adolescent stressor pile-up predicts their parents' adverse health outcomes (see Table 4, bottom panel). Linear models showed Hypothesis 6 was not supported, as the associations between adolescent pile-up and parent cortisol slope, physical symptoms, and sleep quantity and quality were not significant ($p > .05$). Exploratory models showed a significant cubic effect for parent sleep quantity (cubic pile-up estimate = −0.0012, $p = .001$), showing a decrement-to-improvement turning point pattern.

Supplementary Analyses

Robustness Checks Using Random Slopes and Excluding Controls

We ran several post hoc analyses to test the robustness of our main findings, including (a) exploring whether significant relationships between pile-up and strain randomly varied, (b) whether significant results held after controlling for other stressors (e.g., controlling for nonwork and adolescent stressors when using work stressors to predict strain), and (c) testing all models without controls. Regarding random effect slopes, only the linear relationship between parent nonwork stressor pile-up and their own cortisol slope fit better when the slope was allowed to randomly vary, $\Delta\chi^2(2) = 28.26$, $p < .001$; all other random effects were nonsignificant or the random effects models failed to converge. When including other sources of pile-up, all significant findings remained. When omitting control variables, conclusions were also the same as our main analyses. We conclude stressor pile-up in one domain predicts strain above and beyond stressor pile-up in other domains, as well as with and without controls.

Between-Level Associations

We also post hoc examined between-level associations between stressor pile-up and strain using regression (using the stats package; R Core Team, 2022). These analyses show whether hypotheses might be supported when comparing stressor pile-up across parents/adolescents, rather than looking day-to-day within individuals. Here we summarize the results (Table 6; see additional online material at https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e for full results).

Regarding intrapersonal hypothesized relationships, for both parents and adolescents, we found individuals who had greater pile-up on average also had worse physical symptoms and lower sleep quality compared to those with less pile-up. For parents, greater pile-up was associated with their own shorter sleep hours (work and nonwork pile-up) and flattened cortisol slope (nonwork pile-up only). We also found three nonlinear exploratory trends, each suggesting the relationship between pile-up and strain becomes weaker for individuals with higher levels of pile-up.

Regarding crossover hypothesized relationships, parents whose adolescents had greater pile-up reported more flattened cortisol slopes and more severe physical symptoms than those whose adolescents had less pile-up. Similarly, parent nonwork pile-up was associated with more flattened adolescent cortisol slope. Exploratory nonlinear trends showed adolescent strains were associated with parent work pile-up but in distinct, nonlinear ways. Both adolescent cortisol slope and sleep hours showed strain decrement at relatively low levels pile-up and strain improvement as parent work stressors pile up at more extreme levels. Parent work stressor pile-up was also curvilinearly related to adolescent sleep quality, showing strain improvement at low levels but then strain decrement as parents have more extreme work pile-up. Additionally, parent nonwork pile-up was associated with more severe adolescent physical symptoms in a decelerating-to-accelerating decrement pattern. Overall, results are more often significant and more consistent with our hypotheses at the between level as compared to the within level.

Alternative Pile-Up Measurement

While conceptual articles have defined pile-up and discussed its distinction from other aspects of the stress process (Smyth et al., 2018, 2023), specific suggestions for how to most accurately or rigorously compute pile-up are unfortunately absent, and methods

Table 4

Final Interpreted Model Estimates for Stressor Pile-Up Predicting Parent Cortisol, Physical Symptoms, Sleep Quantity, and Sleep Quality

	Parent diurnal cortisol		Parent physical symptom[a]		Parent sleep quantity		Parent sleep quality	
Parameter	Unstandardized estimate	*SE*	Unstandardized estimate	*SE*	Unstandardized estimate	*SE*	Unstandardized estimate	*SE*
Work pile-up models								
Intercept	−0.0150	0.0166	1.54	2.08	**7.79*****	**0.82**	**3.06*****	**0.42**
Linear time	−0.0009	0.0009	**0.11***	**0.05**	**−0.06***	**0.03**	−0.02	0.01
Parent age	−0.0002	0.0003	−0.00	0.03	0.00	0.01	−0.00	0.01
Parent gender	0.0018	0.0034	0.19	0.42	0.32	0.16	0.13	0.08
Parent race	−0.0023	0.0036	−0.40	0.44	−0.03	0.17	0.06	0.09
Parent body mass index	0.0004	0.0003	−0.02	0.04	−0.02	0.01	0.00	0.01
Number of children	−0.0002	0.0015	−0.11	0.19	−0.03	0.07	−0.02	0.04
Medication use	−0.0066	0.0036						
Average parent work pile-up	0.0005	0.0007	**−0.16***	**0.08**	**−0.07***	**0.03**	−0.02	0.01
Linear work pile-up	−0.0001	0.0006	**−0.48****	**0.16**	0.03	0.02	0.00	0.01
Quadratic work pile-up			**0.06*****	**0.02**				
Cubic work pile-up			**−0.003*****	**0.001**				
Nonwork pile-up models								
Intercept	−0.0137	0.0166	0.03	0.46	**7.78*****	**0.83**	**2.84*****	**0.41**
Linear time	0.0002	0.0009	0.08	0.05	**−0.07***	**0.03**	−0.02	0.01
Parent age	−0.0003	0.0003	0.01	0.02	0.00	0.01	0.00	0.01
Parent gender	0.0016	0.0033	0.03	0.39	0.28	0.16	0.13	0.08
Parent race	−0.0027	0.0035	**−0.25*****	**0.00**	−0.06	0.17	0.06	0.09
Parent body mass index	0.0004	0.0003	−0.01	0.03	−0.02	0.01	0.00	0.01
Number of children	−0.0004	0.0015	0.16	0.17	−0.01	0.08	0.00	0.04
Medication use	−0.0067	0.0035						
Average parent nonwork pile-up	**0.0003*****	**0.0001**	**−0.03*****	**0.01**	**−0.01***	**0.004**	**−0.005****	**0.002**
Linear nonwork pile-up	**−0.0017*****	**0.0005**	−0.03	0.06	0.03	0.02	0.01	0.01
Adolescent pile-up models								
Intercept	−0.0172	0.0162	3.06	2.24	**8.15*****	**0.83**	**3.18*****	**0.42**
Linear time	−0.0005	0.0009	**0.11***	**0.05**	**−0.07***	**0.03**	**−0.03***	**0.01**
Parent age	−0.0002	0.0003	−0.03	0.04	0.00	0.01	−0.00	0.01
Parent gender	0.0009	0.0033	−0.17	0.45	0.20	0.16	0.09	0.08
Parent race	−0.0007	0.0035	−0.64	0.48	−0.06	0.18	0.05	0.09
Parent body mass index	0.0004	0.0003	−0.04	0.04	−0.02	0.01	0.00	0.01
Number of children	0.0002	0.0015	−0.23	0.21	−0.05	0.08	−0.03	0.04
Medication use	−0.0065	0.0036						
Average adolescent pile-up	**0.0003***	**0.0001**	−0.01	0.01	−0.00	0.01	−0.00	0.00
Linear adolescent pile-up	−0.0007	0.0008	−0.01	0.07	−0.15	0.08	0.02	0.01
Quadratic adolescent pile-up					**0.03****	**0.01**		
Cubic adolescent pile-up					**−0.001****	**0.0004**		

Note. Parameters in bold are statistically significant ($p < .05$). Due to pairwise deletion, sample sizes range when predicting cortisol (between $n = 122$–124; within $n = 314$–455), physical symptoms (between $n = 130$; within $n = 752$–1,006), sleep quantity (between $n = 129$; within $n = 621$–863), and sleep quality (between $n = 129$; within $n = 621$–863). For gender, 1 = male and 2 = female. For race, 1 = White and 0 = not White. For Medication use, 1 = yes and 0 = no. The effect of each stressor pile-up type (work, nonwork, and child) on each strain outcome (cortisol, physical symptoms, sleep quantity, and sleep quality) was run as a separate model. *SE* = standard error.

[a] Zero-inflated Poisson model coefficient presented for all physical symptom models; no conditional effect models were significant for hypothesized daily effects, but full results can be found on additional online material (https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e).

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

vary across studies (for comparisons, see "Pile Up Research" on our study additional online material at https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e). We post hoc examined the extent to which results might depend on key measurement decisions: length of the pile-up time window (a 4-day moving window vs. the 8-day study-length window). We also post hoc examined whether pile-up predicts strain *above and beyond* the current-day stressors (e.g., Schilling & Diehl, 2014) by calculating pile-up excluding the current day's stressor severity sum and adding current-day stressor severity sum as an additional predictor. A summary of these findings is available in Table 6.

When using a 4-day moving window, 23 of our 24 hypothesis tests reach the same conclusion. As an exception, the linear relationship between work pile-up and parent physical symptoms was newly statistically significant, in line with our hypothesis. Regarding Research Question 1, 21 of 24 conclusions remained the same. Two exploratory nonlinear effects became nonsignificant (work pile-up/parent physical symptoms and parent work stressor pile-up/adolescent sleep quantity), and one new nonlinear effect emerged (cubic work pile-up/parent cortisol slope, indicating a decrement-to-improvement turning point pattern). We also ran analyses using a 4-day window, marking Days 1–3 as "missing" to

Table 5

Final Interpreted Model Estimates for Stressor Pile-Up Predicting Adolescent Cortisol, Physical Symptoms, Sleep Quantity, and Sleep Quality

	Adolescent diurnal cortisol		Adolescent physical symptom[a]		Adolescent sleep quantity		Adolescent sleep quality	
Parameter	Unstandardized estimate	*SE*	Unstandardized estimate	*SE*	Unstandardized estimate	*SE*	Unstandardized estimate	*SE*
Adolescent pile-up models								
Intercept	**−0.0361*** **	**0.0091**	1.45	1.09	**13.00*** **	**0.55**	**4.46*** **	**0.29**
Linear time	0.0008	0.0007	**0.21*** **	**0.05**	**−0.06***	**0.03**	−0.00	0.01
Adolescent age	0.0009	0.0005	−0.01	0.07	**−0.27*** **	**0.03**	**−0.05****	**0.02**
Adolescent gender	0.0032	0.0024	**−0.67***	**0.30**	−0.16	0.15	−0.06	0.08
Adolescent race	−0.0038	0.0025	0.39	0.31	−0.06	0.15	−0.03	0.08
Number of children	0.0003	0.0012	−0.14	0.14	0.08	0.07	−0.01	0.04
Medication use	0.0001	0.0038						
Average adolescent pile-up	−0.0000	0.0001	0.002	0.01	−0.01	0.01	−0.00	0.00
Linear adolescent pile-up	0.0009	0.0006	**−0.16****	**0.05**	0.02	0.03	−0.00	0.01
Work pile-up models								
Intercept	**−0.0359*** **	**0.0096**	1.39	1.15	**13.07*** **	**0.58**	**4.49*** **	**0.29**
Linear time	0.0005	0.0008	**0.21*** **	**0.05**	−0.05	0.03	−0.00	0.01
Adolescent age	0.0010	0.0006	−0.03	0.07	**−0.27*** **	**0.03**	**−0.06****	**0.02**
Adolescent gender	0.0037	0.0025	**−0.72***	**0.31**	−0.18	0.15	−0.07	0.08
Adolescent race	−0.0038	0.0025	0.27	0.32	−0.11	0.16	−0.06	0.08
Number of children	0.0001	0.0013	−0.11	0.15	0.11	0.07	−0.01	0.04
Medication use	−0.0001	0.0039						
Average parent work pile-up	−0.0003	0.0006	−0.04	0.05	−0.00	0.03	−0.00	0.01
Linear parent work pile-up	0.0007	0.0005	0.03	0.04	**−0.18***	**0.07**	−0.01	0.01
Quadratic parent work pile-up					**0.02****	**0.01**		
Cubic parent work pile-up					**−0.001****	**0.0003**		
Nonwork pile-up models								
Intercept	**−0.0334*** **	**0.0094**	1.25	1.14	**12.90*** **	**0.57**	**4.43*** **	**0.29**
Linear time	0.0003	0.0008	**0.22*** **	**0.05**	−0.05	0.03	−0.00	0.01
Adolescent age	0.0010	0.0006	−0.03	0.07	**−0.26*** **	**0.03**	**−0.06****	**0.02**
Adolescent gender	0.0030	0.0024	**−0.71***	**0.31**	−0.18	0.15	−0.06	0.08
Adolescent race	−0.0036	0.0025	0.26	0.32	−0.10	0.16	−0.06	0.08
Number of children	−0.0005	0.0013	−0.12	0.15	0.11	0.07	0.00	0.04
Medication use	−0.0014	0.0039						
Average parent nonwork pile-up	0.0000	0.0001	0.01	0.01	−0.00	0.00	0.00	0.00
Linear parent nonwork pile-up	0.0003	0.0004	−0.06	0.04	0.00	0.02	−0.01	0.01

Note. Parameters in bold are statistically significant ($p < .05$). Due to pairwise deletion, sample sizes range when predicting cortisol (between $n = 115$–120; within $n = 271$–388), physical symptoms (between $n = 129$; within $n = 744$–1,002), sleep quantity (between $n = 127$; within $n = 615$–852), and sleep quality (between $n = 127$; within $n = 620$–861). For gender, 1 = male and 2 = female. For race, 1 = White and 0 = not White. For Medication use, 1 = yes and 0 = no. The effect of each stressor pile-up type (work, nonwork, and child) on each strain outcome (cortisol, physical symptoms, sleep quantity, and sleep quality) was run as a separate model. *SE* = standard error.

[a] Zero-inflated Poisson model coefficient presented for all physical symptom models; no conditional effect models were significant for hypothesized daily effects, but full results can be found on additional online material (https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e).

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

ensure all pile-up values are computed with a full 4 days of data. Excluding cortisol models,[8] 13 of 18 conclusions remained the same. The same two nonlinear effects became nonsignificant, and three new nonlinear effects emerged (cubic work pile-up/parent sleep hours and quadratic adolescent pile-up/adolescent sleep hours, both indicating a decrement-to-improvement turning point pattern; parent nonwork pile-up/parent physical symptom likelihood, indicating an improvement-to-decrement turning point pattern). We conclude the pile-up time length (4 vs. up to 8 days) has relatively little effect on our findings.

Analyses examining whether previous days' pile-up predicts strain above and beyond the current day meaningfully changed the results. The two significant hypothesis tests remained the same, but five new hypothesis tests also emerged as statistically significant. Among parents reporting physical symptoms, symptoms worsened as their own nonwork stressors piled up, and parent sleep hours increased as their work stressors piled up. Additionally, adolescent cortisol slope flattened as their own stressors piled up, and their sleep quality worsened as their parents' work and nonwork stressors piled up. Regarding exploratory nonlinear models, the three nonlinear trends in our main analyses became nonsignificant. We also found three newly significant nonlinear trends. Two trends indicated decrement-to-improvement turning point patterns (parent work stressors/parent cortisol slope and parent nonwork stressors/adolescent sleep

[8] After marking Days 1–3 as "missing," cortisol analyses would only have a maximum of two within-person observations per person. We chose not to interpret these models due to insufficient within-person sample size. Results including cortisol models can be found on our additional online material (https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e) HTML and Summary excel sheet.

Table 6

Summary of Significant Effects for Main Results and Supplementary Results

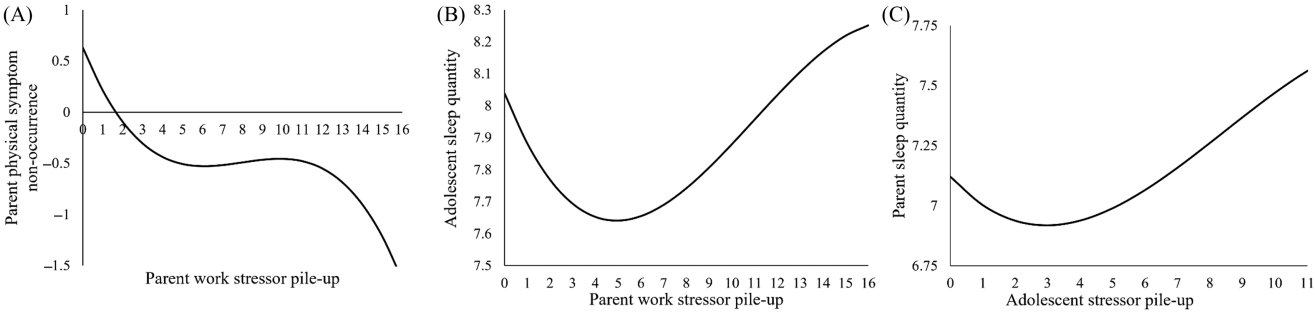
Hypotheses				Supplementary result		
Number	Type of stressor pile-up	Hypothesized association with daily strain	Main result Significant trend	Four-day pile-up window[a]	Previous days' pile-up controlling for current-day stressor severity	Association between persons
H1a	Parent work	Parent dampened cortisol slope	NS	**Decrement-to-improvement turning point[b]**	**Decrement-to-improvement turning point[c]**	NS
H1b		Parent increased physical symptoms	**Decelerating-to-accelerating decrement[b]**	Linear decrement	NS	Linear decrement
H1c		Parent decreased sleep hours	NS	NS	Linear improvement	**Improvement-to-decrement turning point[b,d]**
H1d		Parent decreased sleep quality	NS	NS	NS	Linear decrement[e]
H2a	Parent nonwork	Parent dampened cortisol slope	Linear improvement	Linear improvement	Linear improvement	Linear decrement
H2b		Parent increased physical symptoms	NS	NS	Linear decrement in conditional model	**Decelerating decrement[c,d]**
H2c		Parent decreased sleep hours	NS	NS	NS	Linear decrement
H2d		Parent decreased sleep quality	NS	NS	NS	Linear decrement
H3a	Adolescent	Adolescent dampened cortisol slope	NS	NS	Linear decrement	NS
H3b		Adolescent increased physical symptoms	Linear decrement	Linear decrement	Linear decrement	**Decelerating decrement[b,d]**
H3c		Adolescent decreased sleep hours	NS	NS	NS	NS[f]
H3d		Adolescent decreased sleep quality	NS	NS	NS	Linear decrement
H4a	Parent work	Adolescent dampened cortisol slope	NS	NS	NS	**Decrement-to-improvement turning point[b,e]**
H4b		Adolescent increased physical symptoms	NS	NS	NS	NS[g]
H4c		Adolescent decreased sleep hours	**Decrement-to-improvement turning point[b]**	NS	NS	**Decrement-to-improvement turning point[c,e]**
H4d		Adolescent decreased sleep quality	NS	NS	Linear decrement	**Improvement-to-decrement turning point[c]**
H5a	Parent nonwork	Adolescent dampened cortisol slope	NS	NS	NS	Linear decrement[e]
H5b		Adolescent increased physical symptoms	NS	NS	NS	**Decelerating-to-accelerating decrement[b]**
H5c		Adolescent decreased sleep hours	NS	NS	**Decrement-to-improvement turning point[b]**	NS
H5d		Adolescent decreased sleep quality	NS	NS	Linear decrement	NS
H6a	Adolescent	Parent dampened cortisol slope	NS	NS	**Accelerating-to-decelerating decrement[b]**	Linear decrement
H6b		Parent increased physical symptoms	NS	NS	NS	Linear decrement
H6c		Parent decreased sleep hours	**Decrement-to-improvement turning point[b]**	**Decrement-to-improvement turning point[b]**	NS	NS
H6d		Parent decreased sleep quality	NS	NS	NS	NS

Note. Dark gray shades indicate significant effects opposite the hypothesis (indicating strain improvement). Light gray shades indicate significant effects supporting the hypothesis (indicating strain decrements). Bold text is used to highlight nonlinear patterns. NS = nonsignificant effects.

[a] Results with a 4-day window, excluding days where we do not have full data to compute pile-up (Days 1–3), are available on our additional online material (https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e); see HTML output and the Summary excel. [b] Significant cubic stressor pile-up effect. [c] Significant quadratic stressor pile-up effect. [d] Linear coefficient is statistically significant in a model with only the linear effect estimated (no quadratic or cubic terms). [e] Becomes nonsignificant without controls, $p > .05$. [f] Cubic effect is significant without controls, suggesting a decelerating decrement pattern. [g] Cubic effect is significant without controls, suggesting a decelerating-to-accelerating decrement pattern.

Figure 1

Nonlinear Relationships Between Stressor Pile-Up and Strain Outcomes Found in the Main Analyses



Note. The most complex model including a significant effect is depicted. The *x*-axis on each figure is graphed to two standard deviations above the mean of each stressor pile-up. Panel (A) shows the relationship between parent work stressor pile-up and parent physical symptom occurrence, Panel (B) shows the relationship between parent work stressor pile-up and adolescent sleep qualtiy, and Panel (C) shows the relationship between adolescent stressor pile-up and parent sleep quantity.

hours). Additionally, adolescent pile-up was associated with parent cortisol slope in an accelerating-to-decelerating decrement pattern. Current-day stressor severity was associated with significant variance in daily strains above and beyond previous days' pile-up in only one out of the 24 analyses, suggesting the importance of previous days' pile-up beyond the current day.

Discussion

A primary tenet of the allostatic load model is that strained psychological, physical, and physiological states are a result of repeated stressor exposure over time (McEwen & Seeman, 1999). The present study is among a small set that tests whether repeated exposure to stressors over time predicts fluctuations in daily strain, and we uniquely examine interpersonal crossover and explore possible nonlinear trends in short-term allostatic load indicators. We also investigate how the pile-up effects differ across levels and plausible operationalizations of pile-up.

Our main analysis finds relatively weak support for the idea that pile-up across days is linearly associated with increased daily strain within and across parents and adolescents. The direction and significance of trends differed depending on the specific stressor, strain, and whether the receiver was a parent or an adolescent. Surprisingly, we found parent nonwork pile-up was associated with steepened (i.e., less dysregulated) parent daily cortisol slope, though, in contrast, exploratory nonlinear analyses suggested parent work pile-up was associated with increased parent physical symptoms. We similarly found adolescent pile-up was associated with their own increased likelihood of experiencing daily physical symptoms. Regarding crossover relationships, we also found two significant exploratory nonlinear results, both with sleep quantity. At lower levels of parent work (adolescent) pile-up, greater daily pile-up was associated with shorter adolescent (parent) sleep, but at higher levels of parent work (adolescent) pile-up, greater daily pile-up was associated with more adolescent (parent) sleep.

Our supplementary findings exploring measurement decisions showed pile-up time length (4 vs. up to 8 days) and excluding incomplete pile-up periods had little systematic impact on our conclusions. Decisions about whether to include/exclude current-day stressors in pile-up more clearly revealed the value of previous stressor pile-up in explaining strain, above and beyond stressors experienced on the current day. Stress—whether at work or home or by parents or adolescents—does pile up over a week, and theory, research, and practice that only consider stressors as an isolated daily occurrence may misrepresent both intra- and interpersonal strain effects. We discuss our overall interpretation of finding patterns and their implications below.

Theoretical Implications

Evidence of Short-Term Pile-Up

Our study is one of the few to test the process by which acute stressor exposure piles up across days to predict daily strain fluctuation (see also Grzywacz & Almeida, 2008; Lee, 2022; Marcusson-Clavertz et al., 2022; Schilling & Diehl, 2014). This short-term pile-up process is a key tenet of the allostatic load model, yet most tests of this model rely on long-term, chronic exposure (e.g., years, months; Ganster & Rosen, 2013; Juster et al., 2010) using cross-sectional or prospective designs, with much less attention on the necessary intermediary step of "pile-up" which occurs over the course of days (e.g., Adam et al., 2017; Almeida et al., 2020). Compared to a person's severity or count of stressors on a given day, pile-up provides different insights as it better reflects the unfolding dynamics of stressors over several days as they compound upon one another. Consistent with the allostatic load model, our findings illustrate that the pile-up of some types of stressors relates to greater likelihood of daily physical symptoms, as well as shorter sleep quantity (though only when pile-up is relatively low). We did not find strong evidence that pile-up predicts dampened daily cortisol slope or sleep quality within parents or adolescents. Short-term pile-up effects outlined by the allostatic load model could occur within a week, but with important boundary conditions depending on strain type.

Allostatic Load as an Interpersonal and Cross-Domain Phenomenon

The present results also newly speak to the interpersonal consequences of stressor pile-up and, thus, the interpersonal nature of allostatic load. We show some evidence that crossover is bidirectional, such that parent and adolescent stressors are related to one

another's daily sleep quantity. These findings augment previous studies which show evidence of "stress contagion" (e.g., Engert et al., 2019; Saxbe et al., 2014) but largely focus on emotional contagion (Mauno et al., 2017; Song et al., 2008; Westman, 2001) and parent-to-child transmission (Cho & Ciancetta, 2016). We also find intrapersonal and interpersonal pile-up relationships emanating from both home and work. Often crossover studies, particularly within the organizational sciences, focus exclusively on the spillover–crossover of work phenomena. Our study points to the importance of a more holistic approach that considers both work and home stressors.

Exploring Nonlinear Effects and Interpreting Improvement Patterns

We found some exploratory, nonlinear pile-up effects which suggest pile-up/strain link differs depending on *how much* pile-up someone is experiencing on a given day. For example, our exploratory analysis shows that low levels of daily stressor pile-up are interpersonally detrimental to sleep quantity, as sleep scheduling is a shared experience within families (Lee et al., 2019); however, this relationship reverses at moderate-to-high levels, such that greater daily pile-up crosses over to longer sleep (see Table 6). Because sufficient sleep is necessary for physical and psychological functioning, we speculate that sleep quantity may show a curvilinear pattern because the body cannot tolerate continuous decrements, whereas people often need to function with extensive aches and pains or poor sleep quality. Instead, parents and adolescent children may stop reacting to one another's pile-up at some point and even recuperate more of their lost sleep time as stressors continue piling up (Nelson et al., 2023). Researchers have speculated that strain is not only shaped by stressor occurrence but also the patterns of stressor severity and proximity to one another over time (T. D. Allen et al., 2019; Smyth et al., 2023). Aligned with these suggestions, our nonlinear patterns suggest strain reactions depend on whether stressor pile-up is low in severity versus high in severity. Detrimental and adaptive stressor responses are often positioned as two opposing possibilities (e.g., Matthews et al., 2014; Zapf et al., 1996), but we show that both responses can occur in the short-term, depending on the combined timing and severity of stressors.

Our findings also suggest distinct differences between parent and adolescent short-term allostatic load. Across all of our analyses, adolescents showed fewer significant but more consistently detrimental relationships between pile-up and strain, whereas parents' significant detrimental relationships tended to plateau and even reverse as pile-up increased to relatively high levels; some results even showed pure improvements (e.g., as nonwork stressors pile up, cortisol response is healthier). On the one hand, this pattern could be interpreted as adolescents showing relatively more resilience than parents, because adolescent strain did not fluctuate with daily stressor pile-up. Parents' plateaus or reversals could be interpreted as reaching "rock bottom." On the other hand, parents' detriment-to-improvement patterns could also be interpreted as parents showing greater resilience than adolescents, such that they are able to curb and even reverse daily reactions as stressors pile up to more extreme levels. Lifespan perspectives explain that parents may be better equipped than adolescents to handle their everyday stress pile-up due to their life experience, a better understanding of coping mechanisms, and a stronger sense of control (Caspi et al., 2005; Conger et al., 2009; Costa et al., 2019; Skinner & Zimmer-Gembeck, 2007). For example, the improved cortisol slopes found in days with more nonwork stressor pile-up may be due to parents effectively coping by mobilizing their energy early in the day and expending it more fully throughout the day.

Measurement Decisions in Pile-Up Research

Our study adds to growing evidence that stressor pile-up enhances understanding about stressor–strain processes and better matches with prevailing theory. Given the fragmented definitions and measurement (see "Pile Up Research" on our additional online material at https://osf.io/dn9zt/?view_only=269a7b67c3ef49c5957194d872db146e), we conducted multiple supplementary analyses using different measurement decisions and approaches. While some of our supplementary analyses yielded conclusions consistent with our primary findings, some differences also emerged. Below, we outline key takeaways from these comparisons to inform and guide future research in this area.

Within- Versus Between-Person. Most of the between-level relationships were statistically significant in our post hoc exploration, suggesting relatively more consistent or larger effects when describing *general* pile-up levels and *general* strain across individuals, rather than comparing day-to-day within individuals. In stark contrast to the daily-level fundings, all but two significant findings showed well-being decrement,[9] such that people with greater pile-up had generally higher strain of all types. Proportionally fewer exploratory nonlinear trends emerged, most of which indicated a plateau in physical symptom strain at high levels of pile-up. Whereas the between-person results better supported our traditional linear hypotheses, a greater variety of nonlinear relationships were visible within-persons. Within-person designs are needed to test and revise within-person theory (Gabriel et al., 2019), and, here, between-person analyses may oversimplify stressor pile-up and strain processes that inherently play out day-to-day.

Appropriate Time Window. The timeline of short-term stressor pile-up is not specified in the allostatic load model. As a result, current pile-up research often uses the study period window to guide their decisions, varying from hours-long to month-long time lags (e.g., Infurna et al., 2023; Schilling & Diehl, 2014; Smyth et al., 2023). We compared the study-length window (up to 8 days) to a shorter 4-day moving window, which assumes stressors decay twice as fast. Most results were consistent across time windows, with the few inconsistencies suggesting that adolescents may require slightly longer time frames for strain to manifest (i.e., 8 vs. 4 days). Time-window decisions within a few days fall into the same "meso" time frame (Dormann & Guthier, 2018) and appear relatively inconsequential, though longer windows have similar if not more potential to uncover the lingering effects of stressors over time, particularly for adolescents.

Inclusion or Exclusion of Current Day. Our post hoc results indicate that pile-up of stressors over time seems to drive effects on daily strains rather than the current day alone. Current-day stressor severity only significantly predicts variance above and beyond previous days' pile-up in one analysis (of 24). That said, including versus excluding current-day stressor severity from our stressor pile-up measure meaningfully changed some results. For instance, we found more statistically significant associations between pile-up and

[9] The two exceptions suggested decrement-to-improvement turning point patterns and were not significant without control variables.

diurnal cortisol slope for both parents and adolescents. Because diurnal cortisol serves a mobilizing role starting first thing in the morning (Sapolsky et al., 2000) and is sensitive to anticipation (Juster et al., 2012; Kirschbaum & Hellhammer, 1989; Kramer et al., 2019), perhaps previous days' pile-up of stressors has more consistent effects on diurnal cortisol slope that were confounded by the current day in our main analyses. Also notably, pile-up excluding current day more often predicted adolescent strain (including diurnal cortisol and sleep quality). Past research shows that adolescents ruminate more than adults (Sütterlin et al., 2012), perhaps explaining why previous stressors might weigh more heavily than current ones.

Despite these nuanced differences, our supplementary analyses also replicate two takeaways from our main results: (a) that parents tend to be more susceptible to pile-up than adolescents and (b) that parents show relatively more adaptive (improvement) patterns than adolescents. Overall, though, isolating *previous* days' pile-up as compared to holistic pile-up including the current day is consequential, particularly for early-morning strain (cortisol) and adolescent strain. We argue neither approach is more or less correct. Rather, we urge pile-up researchers to reflect on whether their questions and theory are interested in understanding pile-up as an ongoing experienced state (including current stressors as the top of the experiential "pile") or comparing past experiences to today's (excluding current stressors).

Practical Implications

Our research suggests that addressing stressors in a given moment or day may not be sufficient to protect against strain without consideration of recent past stressors. Organizations should consider adopting a flexible approach to stress management, recognizing that the relationships between stressor pile-up and strains are not always immediate and linear. In fact, daily strain resulting from short-term pile-up may be difficult to detect given our preliminary evidence of some adaptive trends (i.e., less strain at higher levels of pile-up) and exploratory nonlinear trends (e.g., plateau or reversal effects)—making the need for and ultimate effectiveness of interventions also difficult to assess. Our supplementary results comparing between- and within-person effects provide a more straightforward option: target typical (i.e., between-person) pile-up levels, rather than those that fluctuate daily (i.e., within-person) given their seemingly more consistent, negative straining effects.

A variety of empirically validated interventions exist to help employees manage their stress (Tetrick & Winslow, 2015) but not stressor pile-up. Future pile-up interventions should be designed to help employees manage not only current daily stressors but lingering past stressors, for example, building on workshops targeting rumination (e.g., Querstret et al., 2016) and assess effectiveness by comparing pre- and postintervention stressor pile-up and allostatic load indicators (e.g., cortisol, physical symptoms, sleep). Further, Li et al. (2021) recently noted that few interventions consider family members as potential beneficiaries of workplace interventions, but our results suggest that addressing adult employees' stressor pile-up could sometimes benefit their adolescent children's health as well. Short-term stressor pile-up and chronic accumulation appear to affect employee strain in rather distinct ways. Rather than assuming a uniform response, organizations could consider employees' unique work–family dynamics to provide tailored support to maximize effectiveness (Estevez Cores et al., 2021).

The importance of both parents' nonwork stressors and adolescents' stressors found here highlights that purely work-focused interventions may be limited in their effectiveness. Past work suggests that organizations can help employees meet demands outside of work by creating flexible policies that allow workers to align their boundary management behaviors (i.e., the way they manage their work and nonwork demands) with their preferences (Junker & van Dick, 2020) and unique work and personal circumstances (e.g., T. D. Allen et al., 2021; Mustillo et al., 2021). Workers and adolescents themselves can also engage in coping strategies that allow them to manage their home stressors, for example, by engaging in fulfilling recovery experiences (e.g., Mauno et al., 2018) and seeking counseling services, though strategies effective for dealing with pile-up, versus daily stressors, have not yet been tested.

Limitations and Future Directions

There are limitations in this study that may guide future research. While our approach is largely consistent with previous studies of pile-up (e.g., Schilling & Diehl, 2014), our measure does not allow us to disentangle key features such as stressor frequency, timing within the day, or detailed stressor appraisals. Our method also does not allow us to capture a rich understanding of stressor event content, such as the social nature of the stressor (e.g., involving friends, partners, no one) or the specific resources taxed/threatened (e.g., emotional vs. physical vs. cognitively vs. financially taxing/threatening). Stressor event dimensions could also systematically differ by age, income, or family/cultural norms. Future studies could dig further into the nuances of stressor episodes using critical incidents, experience sampling, and objective (e.g., sensor) methodologies. Pile-up research (including our study) uses White, educated samples, offering a narrow view of types of stressors faced (e.g., discrimination, financial insecurity), family structures and dynamics, and cultural norms in stress responses. The allostatic load model makes it clear that chronic stress exposure dysregulates acute stressor–strain processes, including both hypo- and hyperreactivity—an idea that could be integrated with cumulative disadvantage theory (Dannefer, 2003) to explain how both parents and children's early-life stressors may affect their pile-up and strain on a given day. Studying these important questions requires purposeful sampling among non-U.S., low-income, minority, and nontraditional family populations, and we point researchers to published guides on ethically and effectively recruiting and retaining such samples (e.g., Langer et al., 2021). We also encourage dyadic research that examines constellations of stressor content. For example, if members of a dyad are experiencing similar stressors (e.g., work load and school load), is there greater empathy and therefore crossover of strain among the dyad, as compared to when the dyad experiences dissimilar stressors?

Our sleep data are self-report, single items; it would be informative to also examine the degree to which pile-up is associated with changes in physiological and/or actigraphy sleep indicators. Relatedly, although our measurement of parent and adolescent cortisol, physical symptoms, and sleep expand beyond typical affective crossover mechanisms, developmental and family researchers now suggest that a greater variety of interconnected physiological systems are implicated in allostatic load, including immune, metabolic, and cardiovascular responses (Doan, 2021). We urge organizational scientists

to reference best practice recommendations (Ganster et al., 2018) to more thoroughly examine physical and physiological stressor responses, and their co-occurrence, within working parents and their family members.

Typically both parents and adolescents reported no daily stressors. When stressors were reported, it was most often only one or two stressor events on a given day. These frequencies match with relatively low base rates in similar stressor checklist studies (Almeida et al., 2011; French & Allen, 2020). The parent sample had professional jobs and high incomes, which may have contributed to the low base rate (e.g., Businelle et al., 2014). Younger children may also have fewer perceived stressors, but more frequently interact with (and have the opportunity to affect) their parents (Branje et al., 2010). As such, our findings may be limited in that we cannot generalize to families that have high persistent stressor events or children of other ages. Moreover, our estimates at high levels of stressor pile-up are necessarily less precise, as we have few data points. Additionally, there might be some overlap between adolescent and parent stressor events that cannot be discerned. The day-level correlation ($r = .24$, $p < .01$) suggests parent nonwork stressor and adolescent stressor pile-up are likely reporting on different stressor events and/or have meaningfully different appraisals of stressor events.

We strongly encourage research that continues to explore changes in strain as stressors compile over time. Our findings show a number of nonlinear, exploratory trends that ought to be interpreted with caution and warrant replication with other samples, time frames, and/or strain measures. Ties between more short-term, micro time frames like that used here (i.e., several days) and the long-term time frames (e.g., months, years) used by past research may help clarify the overall timeline of allostatic load. Although guided by allostatic load, our specific focus on the 4- to 8-day time frame was based on the availability of the data (e.g., Schilling & Diehl, 2014). Ideally, longer term studies would be able to explore rates at which effects might fade. An important next step would also be incorporating individual and family-level characteristics to explore individual and family-level variation in stressor and strain trends over time. For example, characteristics such as worker autonomy, self-esteem, or parent–adolescent relationship quality might clarify when and for whom stressors result in deteriorating versus improved health. We tested models with random slopes for parameters that were significant in our main hypothesis test. Only one model yielded a statistically significant slope. Longer study periods (i.e., >8 days) may be necessary for detecting these moderator effects.

Our research highlights adolescents' vulnerability to stressors experienced by both parents and themselves. Future research incorporating adolescent resilience and coping or the nature and frequency of family interactions may help to tease apart the exact crossover processes of how this occurs. In general, the asymmetry in spillover and crossover findings across parent–adolescent dyads emphasizes the need for additional dyadic research (i.e., assessing child experiences and outcomes directly, rather than parent reports of child experiences) in the future that untangles why these patterns exist.

Conclusion

Using physical and physiological data from parent–adolescent dyads, our research makes three contributions to the allostatic load model (McEwen & Seeman, 1999). We provide explicit evidence that daily strains fluctuate as stressors pile up over several days, clarifying the development of primary allostatic load. We position allostatic load not only as an intrapersonal process but an interpersonal process wherein stressor pile-up spreads within a family system. We also review and analytically explore conceptual and methodological ambiguities of stressor pile-up to organize and provide guidance in this research area. Finally, our findings shift the framing of stressor relationships with strain by demonstrating pile-up can be both detrimental and beneficial, depending on the individual, stressor source, strain type, and degree of pile-up.

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