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Perception of Whole Day Workload as a Mediator Between Activity Engagement and Stress in Workers with Type 1 Diabetes

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Abstract

Associations between various forms of activity engagement (e.g. work, leisure) and the experience of stress in workers have been widely documented. The mechanisms underlying these effects, however, are not fully understood. Our goal was to investigate if perceived whole day workload accounted for the relationships between daily frequencies of activities (i.e. work hours and leisure/rest) and daily stress. We analyzed data from 56 workers with type 1 diabetes (T1D) who completed approximately two weeks of intensive longitudinal assessments. Daily whole day workload was measured with an adapted version of the National Aeronautics and Space Administration Task Load Index (NASA-TLX). A variety of occupations were reported including lawyer, housekeeper, and teacher. In multilevel path analyses, day-to-day changes in whole day workload mediated 67% ($p<.001$), 61% ($p<.001$), 38% ($p<.001$), and 55% ($p<.001$) of the within-person relationships between stress and work hours, rest frequency, active leisure frequency, and day of week, respectively. Our results provided evidence that whole day workload perception may contribute to the processes linking daily activities with daily stress in workers with T1D. Perceived whole day workload may deserve greater attention as a possible stress intervention target, ones that perhaps ergonomists would be especially suited to address.

Keywords

workload; stress; rest; work hours; type 1 diabetes

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Introduction

Stress continues to be an issue that needs to be addressed in the U.S. According to the 2015 American Psychological Association report "Stress in America", thirty-four percent of adults reported that their stress increased over their past year, with approximately 24% of adults experiencing extreme stress (Anderson et al., 2016). The COVID pandemic has worsened matters, with a 2021 Gallup poll finding that 57% of U.S. and Canadian workers felt stressed on a daily basis (Gallup, 2021). There has been consistent evidence that exposure to excessive stress can contribute to the development of conditions such as cardiovascular disease and depression (Ganster & Rosen, 2013) as well as decrements in job performance (Jamal, 2011; Rosen et al., 2010).

Stress has different conceptualizations, but here we use its Transactional Model of Stress definition as the judgment that particular environmental demands may tax an individual's resources and threatens his/her well-being (Holroyd & Lazarus, 1982). According to the Transactional Model, the appraisal of potential threat is a transaction between person and environment (Lazarus, 2001). Primary appraisal involves the judgment that something of value (e.g. well-being) is being threatened by the environment (Lazarus, 2001). If a threat is perceived, then a secondary appraisal is made of whether coping resources are available, after which varying degrees of the stress experience may arise (Lazarus, 2001).

Stress and Activity Engagement

Longer engagement in work activities may be associated with both higher perception of threat to well-being (primary appraisal), and use of more resources (e.g. physical and mental energy) to meet demands of often taxing job tasks (secondary appraisal), resulting in a higher magnitude of stress experienced as per the Transactional Model of Stress. Consistent with this line of reasoning, the activities workers engage in are associated with the amount of stress experienced. For instance, longer work hours have often been associated with higher stress. In a review of 21 studies, Sparks et al. (Sparks et al., 2001) found small but significant positive correlations between work hours and various psychological symptoms, including stress. Compared to those working shorter hours, workers with longer working hours have been found to perceive more stress (Lee et al., 2017; Maruyama & Morimoto, 1996).

Apart from engagement in work activities, greater engagement in recovery activities may be associated with a decrease in perceived threats (primary appraisal) and an increase in the perception of personal resources (secondary appraisal), lowering experienced stress. Recovery has been defined as return of psychobiological systems to baseline after changes they had undergone due to the experience of stress (Meijman & Mulder, 1998). It is important to distinguish between different types of recovery, as their relationships with stress may differ. Both rest and active forms of casual leisure (e.g. play and socializing) (Stebbins, 1997) are frequently examined forms of recovery from work (Sonnentag & Fritz, 2007; Trenberth & Dewe, 2002). Rest is defined here as tasks accompanied by increases in parasympathetic activity (Tindle & Tadi, 2021). Active casual leisure is casual leisure activities characterized by a greater degree of action and effort (mental or physical) exerted compared to passive casual leisure pursuits, such as relaxation and passive entertainment

(Stebbins, 1997). Examples of active casual leisure are play, active entertainment, and socializing (Stebbins, 1997). Casual leisure can be distinguished from serious leisure, which is leisure requiring special training and thus greater effort for its enjoyment (Stebbins, 1997). Relative to casual leisure, serious leisure may have a greater chance of at times being associated with greater stress, especially forms with high pressure for performance due to associated social evaluation (e.g. sports) (Kimball & Freysinger, 2003). Decreased stress has been associated with more time resting (Esch et al., 2003; Sianoja et al., 2018) and in active forms of casual leisure (Winwood et al., 2007; Zawadzki et al., 2015).

Workload as a Mediator between Activity Engagement and Stress at the Daily Level

Perception of workload should theoretically inform the primary appraisal of environmental threats (i.e. demands) that precede the experience of stress, making workload a potential mediator between activity engagement and stress. Results of a few prior studies support the workload as a mediator. In one cross-sectional study, a significant association between overtime work and stress was much reduced and became nonsignificant after statistical adjustment for self-reported workload and sleeping time (Sato et al., 2009).The authors concluded that engagement in overtime work may have in part impacted stress through workers' perceptions of the overall workload of their positions. Another study with repeated daily measures found that engagement in recovery activities was moderately correlated with both lower stress and lower perceived whole day workload (Hernandez, Pyatak, et al., 2021), suggesting the possibility that workload may also in part account for the relationship between recovery activity frequency and stress at the daily level.

Examination of whether whole day workload acts as a mediator between activity engagement and stress, with ambulatory assessments completed over multiple days, may lead to insights potentially useful for ergonomics. Ambulatory assessments completed daily allow for examining phenomena in people's natural environments, and account for daily fluctuations in the phenomena being measured (Trull & Ebner-Priemer, 2013). Thus, ambulatory assessment data for activity engagement, workload, and stress, allows us to investigate the dynamic within-person relationships among these variables across time, and in real world contexts. There has been evidence supporting the use of the NASA-TLX to assess workload experienced *over whole days*, inclusive of both work and non-work periods (Hernandez, Roll, et al., 2021). In a two week longitudinal study, daily workload ratings as captured by the NASA-TLX were found to demonstrate convergent validity as evidenced by theoretically expected associations with a variety of daily activity engagement and well-being measures (Hernandez, Roll, et al., 2021). We build on this prior work to examine whether perceptions of whole day workload may account for the relationships between day-to-day changes in work and recovery activities and corresponding changes in workers' daily stress levels.

The present study

We hypothesized that engagement in work, rest, and active casual leisure may impact daily stress in part *through* their effects on whole day workload (Figure 1). From here on, we will refer to active casual leisure as "leisure" or "active leisure". Four different operationalizations of activity engagement were used. The first three are daily frequencies of work hours, rest, and leisure, which could differ in the degree to which they impact stress through whole day workload. Weekends versus weekdays may also influence daily stress through whole day workload given how highly they are related to work hours, rest, and leisure activity frequency (Sonnentag et al., 2017). Thus, we also examined weekend versus weekday as an activity engagement variable.

Our hypotheses align with the literature described prior. We anticipated that greater work hours would increase perceived whole day workload, which in turn could increase experienced stress. That is, we expected the perception of whole day workload to act as a partial mediator between work hours and same day stress.

Hypothesis 1: Perception of whole day workload acts as a partial mediator between work hours and same day stress.

Furthermore, we also anticipated that rest and active leisure (both during and after work hours) may *reduce* stress, also in some part through their effects on whole day workload. We anticipated that greater frequency of rest in a day would decrease stress experienced indirectly via less experienced whole day workload. Additionally, we hypothesized that a greater frequency of active leisure would also decrease stress, but that only a small portion of this relationship would be attributable to a decrease in same day workload. That is, we expected active leisure to decrease stress only in small part due to associated workload, because of their higher demands relative to restful engagements, and more so through other pathways such as the intrinsic pleasure of play (Stebbins, 1997).

Hypothesis 2a: Perception of whole day workload acts as a partial mediator between recovery activities (rest and leisure) and same day stress.

Hypothesis 2b: Whole day workload mediates a greater portion of the relationship between rest and stress, as compared to the proportion mediated between leisure and stress.

Finally, we hypothesized that weekends were less stressful than weekdays, in part through their relationship with whole day workload. The weekday/weekend distinction often brings with it corresponding frequencies in work /rest/leisure engagement, with work hours typically lower and rest/leisure participation higher on weekends for workers with the traditional five- day work week.

Hypothesis 3: Perception of whole day workload partially mediates the decreased stress typically associated with weekends compared to weekdays.

We examine our hypotheses in a population for whom whole day workload may be particularly relevant, workers with type 1 diabetes. In addition to the daily demands of their jobs, these workers also contend with persistent demands from management of their diabetes (Hansen et al., 2018). Their self-management responsibilities include managing insulin intake, monitoring their blood glucose, problem-solving issues that may arise with diabetes management equipment, and planning ways of continuing diabetes management in various contexts (Beck et al., 2017). Thus, workload experienced over whole days may be especially appropriate to consider for workers with diabetes as a mediator between activity engagement and daily stress.

Methods

Study overview

We analyzed data collected as part of a multisite study investigating the relationship between function, emotion, and blood glucose in adults with type 1 diabetes (T1D), described elsewhere in greater detail (Pyatak et al., 2021). Participants aged 18 and older with T1D were recruited from three clinical sites through mailings, phone calls, email invitations, and health provider referrals. Only participants that identified as workers were included in analyses. Participants completed the following: electronic informed consent remote though the REDCap e-consent framework (Harris et al., 2009), baseline surveys, 14 days of ecological momentary assessment (EMA) and end of day survey data collection with 5–6 surveys per day, and follow-up surveys. EMA is repeated measurement of participant's momentary experiences in their real world environment (Shiffman et al., 2008). The data collection procedures were approved by the [authors'] Institutional Review Board.

Measures

Participants were asked to complete 5–6 surveys per day on smartphones, for approximately 2 weeks. The Mobile EMA application (mEMA: ilumivu.com) was the platform through which surveys were completed, and was also the source of alarm notifications every three hours for when to complete surveys. Table 1 lists all the EMA questions utilized in this paper's analyses. At each survey, participants reported type of activity they were presently engaging in and momentary feelings of stress. At the last assessment of each day, work hours and a subjective assessment of whole day overall workload were obtained. For a full list of the items administered, please refer to (Pyatak et al., 2021).

The frequency of rest and active leisure engagements in a day were calculated from the activity type item using an approach with preliminary evidence of validity (Hernandez, Pyatak, et al., 2021). Reports of engagement in "relaxing/chilling" and "sleeping/napping" contributed to the daily frequency count for rest, and "socializing" and "fun/play/leisure" increased the count for active leisure. Daily activity frequencies were calculated by dividing activity counts for a day, by number of surveys taken in the same day, only on days with four or more surveys completed. As an example, if a participant took six surveys in a day, reporting engaging in "fun/play/leisure" during one and "socializing" in one, then the rest activity frequency for that day would be 2/6=.33.

We could have assessed the daily frequency of work using the approach applied for rest and leisure engagements, but instead opted to use the report of work hours. Self-report of work hours is a frequently used measure with evidence supporting its accuracy (Imai et al., 2016; Todd et al., 2010), while calculating work hours from an EMA activity item is a more novel approach (Hernandez, Pyatak, et al., 2021). Thus, we opted to use self-report of work hours, as it was the more established measure.

Whole day workload was assessed with an adapted version of the National Aeronautics and Space Administration Task Load Index (NASA-TLX) with some evidence supporting its validity (Hernandez, Roll, et al., 2021). Like the original TLX, six items addressing different contributors to task load were used (Hart & Staveland, 1988), but the period being asked about was changed to a whole day rather than a particular task (e.g. How much mental activity was required for your whole day?). An overall workload score was calculated based on the summation of the six items addressing an individual's perception of mental demand, physical demand, temporal demand, performance, effort, and frustration level (Hart, 2006). The raw, as opposed to weighted, sum is used because of prior research supporting this approach (Hart, 2006; Hernandez, Roll, et al., 2021). Response options for all items was a 0 to 100 slider scale.

Our item for stress was derived from a prior EMA study (Dunton et al., 2018), and asked in all EMA surveys ("How stressed are you right now?"). Single item measures are often used in EMA contexts (Dunton et al., 2018; Tung et al., 2022) to avoid burdening participants with repeatedly answering long sets of questions, and some evidence supports the validity of a single stress item for capturing momentary stress (King et al., 2019). We assumed that our participants' understanding of the term stress would align with its conceptualization in the Transtheoretical Model of Stress, in part based on prior qualitative research finding that lay interpretations of stress often involved a focus on stressors, and/or strain reactions to the stressors (Mark & Smith, 2018; Mazzola et al., 2011). The ideas of stressors (i.e. threat) and strain reactions (i.e. stress experience after the evaluation of a threat) align well with the Transtheoretical Model of Stress. The average of the stress ratings in a day was used to indicate stress experienced during that day. A previous study found a high correlation between the average of momentary stress ratings, and an end of day overall stress question (Lourenco et al., 2021).

Statistical Analyses

To help characterize the participants in our sample and possibly aid in interpretation of results of the primary analyses, we calculated a variety of descriptive statistics: demographic characteristics, frequency various activities were reported, mean values of study measures by day of week, and between and within-person correlations between study measures. Between and within-person correlations were calculated using the "statsBy" function in the "psych" package, available for the statistical software R (Revelle & Revelle, 2015). The focus of our analyses is on the within-person level, but between-person correlations were calculated to comprehensively represent the relationships between variables.

Multilevel structural equation modeling (MSEM), specifically multilevel path analysis, was used to investigate if whole day workload mediated the relationship between activity engagement variables (work hours, rest frequency, active leisure frequency, weekday vs. weekend) and stress (Figures 2 and 3). Note that, unlike the other activity variables, the "weekend versus weekday" distinction is binary, and the model coefficients for the weekend model will be comparisons to weekdays. Analyses were run with the software M*plus* (L. K. Muthén & Muthén, 1998) and R package M*plus* automation (Hallquist & Wiley, 2018). Multi-level path analysis is a special case of MSEM where only measured variables are used and no latent variables are modeled (Stoelting, 2002). Direct effects (c’), indirect effects (a*b), and total effects (c’+a*b) were examined. MSEM is able to accommodate nested data structures (Huang, 2017), as was necessary for our data as it had multiple surveys observations nested in individuals. Had we used single level SEM, resultant parameter estimates would have been biased as the non-independence of survey observations from the same person would not have been accounted for (Huang, 2017). To account for potential non-independence in observations stemming from proximity in time (i.e., autocorrelated residuals), a residual dynamic structural equation modeling (RDSEM) structure was added in all models, where the residuals of the main variables of interest were regressed on their respective residuals from the day prior, at the within-person level (Asparouhov et al., 2018). Mediation in figures 2 and 3 occur within-person, or at level 1. The primary variables at level 1 are also regressed on study day to account for potential effects of time since data collection commencement. At the between-person level (level 2), only correlations between person specific averages (intercepts) of variables measured at level 1 were modeled, which accounts for dependencies of observations nested within individuals that may affect the standard errors of the within-person mediation (Preacher et al., 2010).

MSEMs were tested with Bayesian parameter estimation using the M*plus* default non-informative priors. Like bootstrapping, this procedure appropriately takes the non-normal distribution of indirect (mediated) effects into account (Muthén & Asparouhov, 2012). Statistical significance of mediated effects was determined using the product of coefficients method and inspecting 95% credible intervals.

One notable benefit in our use of MSEM was that it allowed us to take full advantage of our longitudinal dataset to analyze the within person relationships between activity engagement, workload, and stress. MSEM allows for disaggregation of within-person and between-person effects (Curran & Bauer, 2011). Without such disaggregation, one could not disentangle, for instance, whether experiencing greater leisure than average decreases stress (within-person effect), or if people that on average have greater participation in leisure activities experience less stress (between-person effect).

Statistical Power—To determine the magnitude of between- and within-person correlations that could be detected, power analyses were conducted using Monte Carlo simulations in M*plus* version 8.8 (L. K. Muthén & Muthén, 1998). Based on prior research, we assumed that study measures had intraclass correlation coefficients (ICCs) of 0.5 (Podsakoff et al., 2019). Given a sample size of 56 people and assuming 12 observations per person, results of the simulation indicated 80% power to detect within-person correlations of at least 0.12 and between-person correlations of at least 0.39.

The MSEMs appeared sufficiently powered to detect the extent to which whole day workload mediated the relationship between activity engagement and stress. There is no consensus yet on sample size requirements for different types of MSEM, and research in this area is ongoing (Sadikaj et al., 2021), but we may be able to follow recommendations for SEM. In MSEM with paths at both the between- and within-person levels, at least 50 clusters has often been suggested as the minimum required (B. O. Muthén, 1989). The MSEMs in this paper however are like single level mediation models, because only intercepts and no paths are modeled at the between-person level. Thus, we may be able to follow sample size recommendations for single level mediation modeling (SEM). In SEM, simulations found that a sample size of 562 observations is required to be able to detect a small indirect effect (with a and b paths jointly as small as .14) with 80% power (Fritz & MacKinnon, 2007). At the within-person level, with approximately 60 observations from each participant, we calculated that n=50 would yield 50*60=3000 observations. Because this figure is higher than 562, our MSEM analyses should have sufficient power to detect small within-person mediation effects.

Results

Analyses were conducted on 56 workers who primarily worked full-time and had an average age of 39.4 (SD=12.8) years. Participants were diverse with regards to gender, ethnicity, education, and annual income (Table 2). Reporting of vocations was not required, but participants that responded to this question disclosed a variety of occupations including lawyer, engineer, housekeeper, teacher, and security guard. In terms of EMA compliance, the median EMA completion percentage was 92%, and four or more EMA surveys were completed on 83% of all data collection days across the participants. On average, we received 12.5 days of survey data from participants with at least four EMA surveys completed. In total, 4,051 EMA surveys were completed by participants across 843 days. Among these, the distribution of responses within each activity type is provided in Table 3.

Full between and within-person correlation matrices are shown in Tables 4a and 4b respectively. At the within-person level, where mediation was tested in our models, intercorrelations between all study measures were small or moderate (Cohen, 2013), except for the relationship between rest frequency and active leisure frequency ($r=-.05$, $p=.173$).

The mean values of work hours, daily rest/active leisure, and stress/workload by day of week appeared to be in line with what would be expected for the typical five- day work week (Figure 4). Mean work hours were higher on weekdays as compared to weekends, and the opposite was seen for rest/active leisure. Across all days, rest had a higher mean frequency as compared to active leisure. Both mean stress and whole day workload were also lower on weekends as compared to weekdays.

Primary Analyses: MSEM to test mediation

Table 5 shows results of MSEM testing the models in Figures 2 and 3. More work hours in a day was associated with higher stress, as indicated by the positive total effect on stress (total effect=.91, 95% C.I. 0.67 to 1.16, standardized estimate =.26). Whole day workload was found to be a partial mediator between work hours and stress, with 67% of work hours' effect on stress attributable to whole day workload. Conversely, a higher frequency of both rest and active leisure was associated with less stress, as evidenced by their total effects on stress of −14.78 (95% C.I. −19.45 to −10.03, standardized estimate=−0.22) and −16.67 (95% C.I. −23.31 to −9.99, standardized estimate=−0.17), respectively. Whole day workload again acted as a significant partial mediator for these relationships, with workload accounting for 61% of rest frequency's negative effect on stress, and 38% of active leisure frequency's negative effect on stress. Relative to weekdays, weekends were associated with lower stress (total effect=−6.78, 95% C.I. −8.75 to −4.75, standardized estimate=−0.23). Perception of whole day workload mediated 55% of the effect (compared to weekdays) of weekends on stress. Study day was not significantly associated with any of the primary variables. Autocorrelated residuals were statistically significant and positive for all variables (with the exception of leisure, p=.06), and their estimates ranged from 0.16 to 0.42.

Discussion

The correlations between study measures were consistent with our model assumptions. Whole day workload was theorized to be a precursor to stress, consistent with the large correlation between the two at both the between-person (r=.74) and within-person (r=.45) levels. Furthermore, at the within-person level, a significant positive association was seen between stress and work hours (r=.31), and negative associations were observed between stress and both rest (r=−.26) and active leisure (r=−.21).

Our study results supported our hypothesized models in Figures 2 and 3. More than two thirds of the effect of work hours on stress was attributable to whole day workload (67%), suggesting the possibility that the perception of whole day workload is an integral aspect of how stress arises from work hours (hypothesis 1). The high proportion of mediation by whole day workload on the relationship between work hours and stress made theoretical sense, given that much of the stress from work hours is expected to come from associated workload, in contrast to other sources of stress such as workplace harassment (Bowling & Beehr, 2006) and role ambiguity (Fisher & Gitelson, 1983). More than half of the effect of rest frequency on stress was also attributable to whole day workload (61%) (hypothesis 2a). Given that rest (i.e. relaxation experiences) constitutes recovery through low activation activities (Sonnentag & Fritz, 2007) with low associated workload, this high proportion again made sense. Active leisure had a higher proportion of its effect on stress mediated by workload than we had expected (38%) (hypothesis 2b). We hypothesized that active leisure activities would be associated with greater demands relative to rest because of its “active” component, and thus that it would decrease stress through other pathways, such as increased self-efficacy from mastery experiences in learning a new hobby (Bandura et al., 1999). While active leisure does have an active component, perhaps the necessary demands are still much lower compared to those experienced from work, and thus much of its effect on stress still acts through decreased whole day workload. Finally, weekends were found to have a large portion (55%) of their effect on stress attributable to whole day workload (hypothesis 3), which is consistent with their association with less work hours and higher rest/leisure activity engagement frequency compared to weekdays.

Implications

Our results suggest that perceived whole day workload may be useful to research further as a potential stress intervention target in workers with T1D. Firstly, study results provide preliminary evidence that whole day workload is a strong precursor to stress. The two were highly correlated at the between and within-person levels, and constructs with strong relationships to stress (i.e. work hours, rest, and active leisure) were found to impact stress largely through whole day workload. Secondly, whole day workload as it was conceptualized here, may lend itself more readily to intervention efforts as compared to other constructs. Some variables such as number of work hours may be difficult to address in interventions because they often are often not readily adjustable by organizations. The six dimensions of the adapted TLX however may each serve as potentially malleable intervention targets. For instance, mental demands may be reducible in work and non-work contexts by automating cognitively demanding tasks where feasible, or helping to streamline particular steps to minimize cognitive load.

Future research examining if whole day workload also acts as a mediator between activity engagement and stress in the general working population may be beneficial. For workers with T1D, whole day workload may have been particularly impactful on stress levels because of the combined demands from work and health management responsibilities. For the general working population, whole day workload may also be an influential precursor to stress, but not to the extent observed in this study. Replication of the study in a general worker population may help provide a clearer idea of the extent to which whole day workload appears to be a viable stress intervention target for all workers.

Assessment of *both* work specific and whole day workload may be useful in future work stress research. Work specific workload assessment may have particular utility in research or interventions focused purely on the work context. Assessment of whole day workload may be especially useful for holistic research/interventions that consider both work and non-work contexts, as partially evidenced by our study results. When both are measured, additional burden may be placed on participants, but they would provide different information that may provide a more comprehensive understanding of workload exposure.

Limitations

Study analyses were conducted on a sample of workers with T1D experiencing the COVID-19 pandemic. Our sample may be limited to individuals with T1D, but we expect our sample to be similar to populations with chronic condition(s) generally. Living with chronic conditions is often accompanied by self-care duties such as following complex treatment regimens, self-monitoring one's condition(s), and problem solving when/how to access healthcare services (Dixon et al., 2009). This burden shared by many with chronic conditions is why programs targeting that population generally have been created, such as the Chronic Disease Self-Management program (Lorig et al., 1999). The commonality from the shared burden may also be why research is often conducted on populations with any chronic condition (Keles et al., 2007; Schokker et al., 2010). Nearly 45% of all Americans are diagnosed with at least one chronic condition (Raghupathi & Raghupathi, 2018). Regardless, as described prior, replication within other worker populations and settings is needed to confirm and strengthen our findings.

From the mediation models, we cannot determine if work hours, rest, active leisure, and weekends caused stress through whole day workload, given that daily activity engagement, whole day workload, and daily stress were contemporaneous. A variety of other relationships were possible, such as stress acting as a mediator between activity engagement and stress. Even though activity engagement may act as a causal agent of stress, we also cannot exclude that stress experiences throughout the day modulate people's decisions to engage in or disengage from certain types of activities. Stronger conclusions about the direction of mediation effects may be derived from the analysis of temporally lagged effects. However, activity engagement, the perception of demands, and the experience of stress theoretically co-evolve over time, rather than occurring in discrete time frames. The nature of these effects would not have been adequately captured by examining mediated pathways with lagged effects in which activity engagement on one day affects experiences on the subsequent day, and it would have been unclear what an appropriate time lag between the study measures would have been. One possible method of investigating if whole day workload causes stress is a randomized control trial, where an intervention targets perception of whole day workload, and stress is assessed as one of the primary outcome variables.

Conclusion

We found that whole day workload, as measured by an adapted version of the NASA-TLX, mediated the relationship between different daily activity engagement measures (work hours, rest frequency, active leisure frequency, type of day) and same day stress in workers with T1D. A large proportion of each measure's effect on stress was mediated by whole day workload, providing preliminary evidence that the perception of workload over a whole day may be an influential precursor to stress. Active leisure frequency's effect on stress was not as strongly mediated by whole day workload relative to the effect seen for rest, and this weaker mediation was expected given its "active" component. Our results provide preliminary evidence that whole day workload may be worth greater consideration as a potential stress intervention target.

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Relevance to human factors/ergonomics theory

Day-to-day changes in whole day workload accounted for a substantial portion of the relationship between daily activity engagement and daily stress in workers with type 1 diabetes, thus suggesting that the workload dimensions of the whole day NASA-TLX (e.g. mental demands, physical demands, etc.) may warrant greater consideration as potential stress intervention targets. Ergonomists may be particularly suited to address stress by targeting dimensions of whole day workload. For instance, they could help ensure that the systems people interact with are optimized to minimize associated workload.

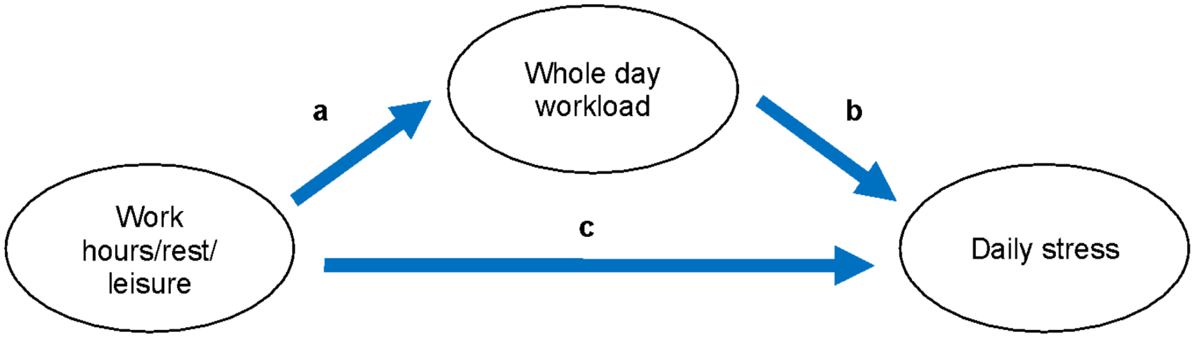

Figure 1.
Whole day workload as mediator between engagement in work hours/rest/leisure and stress.

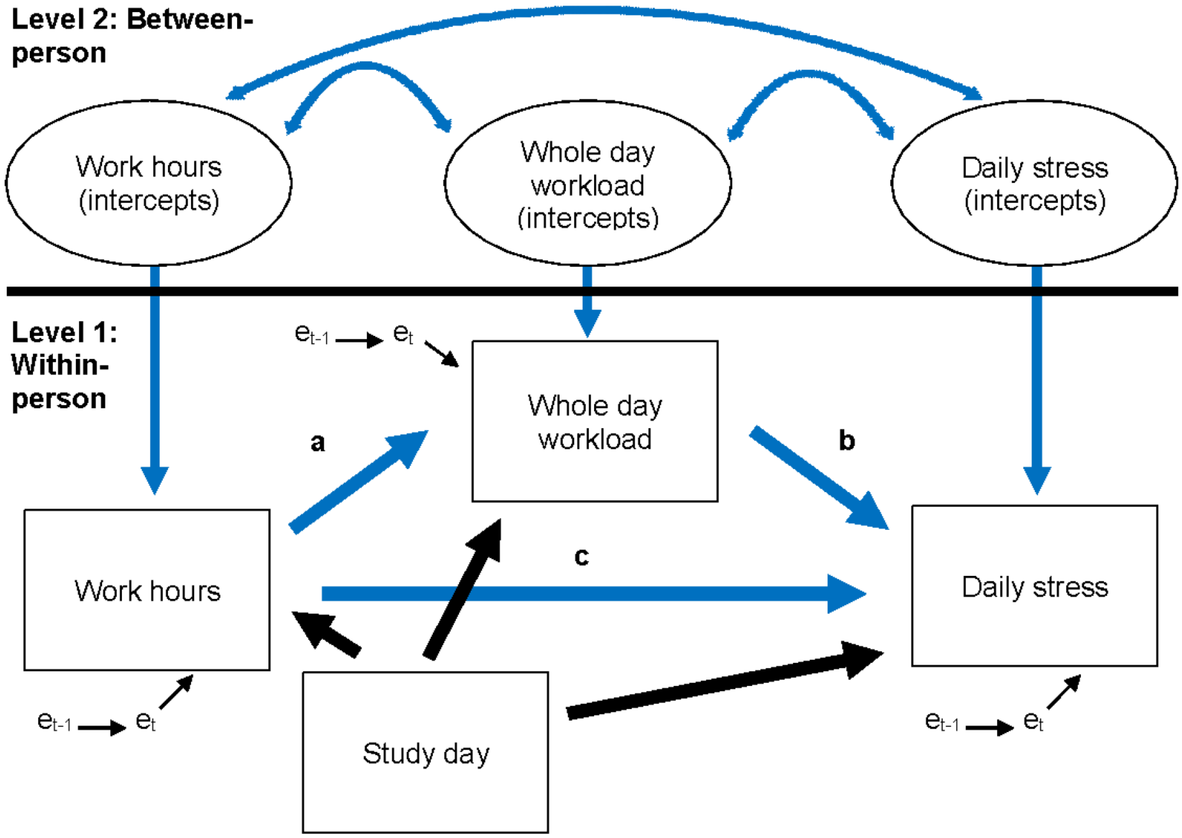

Figure 2.

Hypothesized mediation model relating work hours with stress via whole day workload. Mediation occurs at the within-person level (i.e. for an individual, daily stress is higher on days with more working hours, and part of this effect stems from the perception of whole day workload for the same day). All other aspects of the model account for factors that can impact the accuracy of the estimated mediation effects in the current multilevel (days nested in individuals) study design. Random intercepts shown on the between-person level account for between person variation (i.e. individual differences in work hours, whole day workload, and stress typically experienced). The arrows between these intercepts indicate that they are allowed to correlate with one another. Study day is controlled for at the within-person level. Finally, the residuals of work hours, whole day workload, and daily stress (e^t) are regressed on residuals of the day prior (e^{t-1}) to account for dependencies of observations that are more proximal in time.

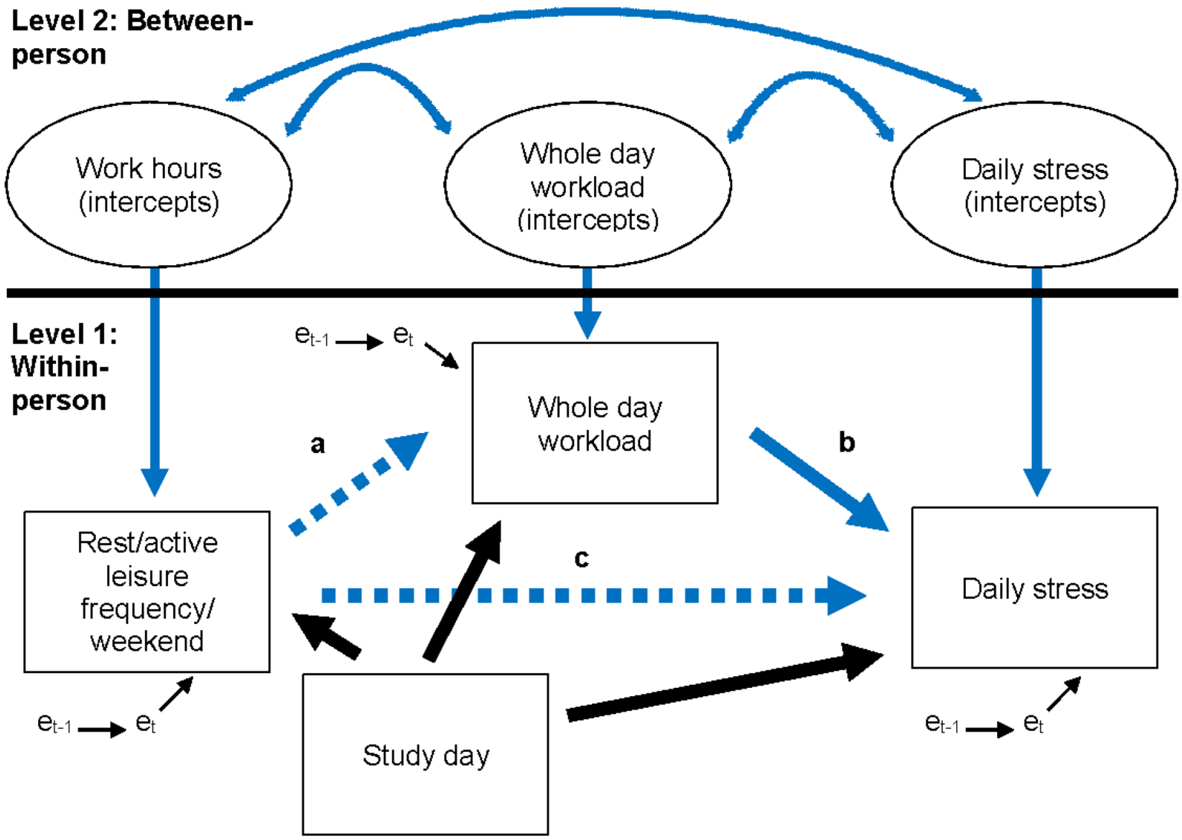

Figure 3.

Theorized within-person mediation model between rest/active leisure frequency/weekend and stress, through whole day workload. Solid lines indicate positive pathways, and dashed ones negative.

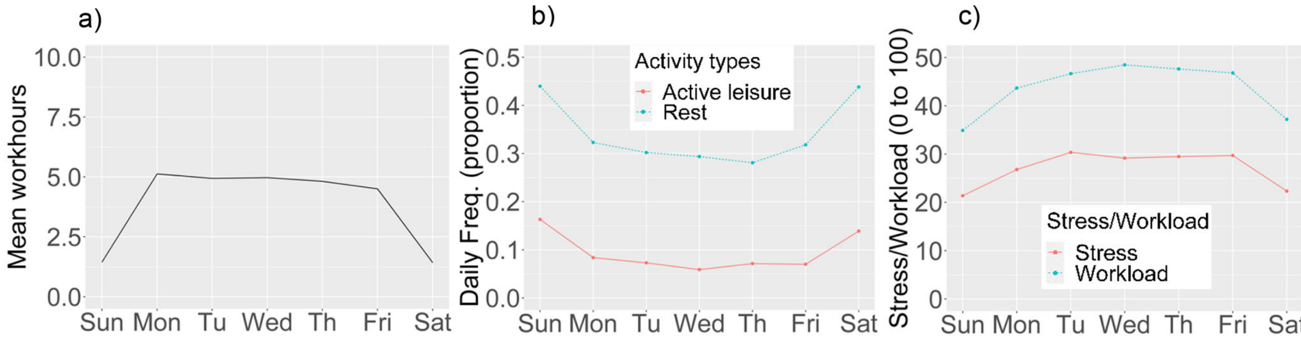

Figure 4.

Day of the week and a) mean work hours, b) rest and leisure activity frequency, and c) stress and workload

Table 1.

EMA and end of day measures to investigate relationship between activity engagement, workload, and stress

Construct	Item(s)	Response Option(s)	Time
Activity type	What were you doing right before starting this survey?	• Work/school activities (e.g. paid labor, volunteer work, and studying) * • Traveling (e.g. driving, riding in a car, walking) • Relaxing/chilling (e.g. passive leisure like watching Netflix, listening to music) • Sleeping/napping • Socializing (e.g. talking with friends/family) • Caring for myself (e.g. eating, dressing, bathing, toileting, personal grooming) • Caring for others (e.g. caring for your children and pets, if you're caring for others as part of work this counts as "work") • Doing housework/errands (e.g. paying bills, washing dishes and clothes, exercising for health) • Fun/play/leisure activities (e.g. active leisure like exercising for fun, video games, reading for fun) • Other (If chosen, please specify)	All survey times
Work Hours	About how many hours did you work?	Hours, whole number, 0 to 24	End of day
Whole Day Workload	Six NASA-TLX items ask about mental demand, physical demand, time pressure, effort, performance satisfaction, and frustration for activities over the whole day. The sum of the ratings indicates total workload.	0 to 100 sliding scale for each item	End of day
Stress	How stressed are you right now?	0 (Not at all stressed) to 100 (Extremely stressed)	All survey times

* Activity examples were not in the actual item, but were explained during training and listed in a manual provided to participants

Table 2.

Demographic characteristics for study on activity engagement, workload, and stress

Characteristic	n	Mean (SD) or Percentage (%)
Age (years)	56	39.4 (12.8)
Gender		
Male	25	45%
Female	31	55%
Ethnicity		
White	23	41%
Latino/x	15	27%
African American	8	14%
Multi-ethnic	4	7%
Other	6	11%
Employment status		
Full-time	44	79%
Part-time	12	21%
Education		
High school grad or less	7	13%
Some college, no degree	10	18%
Associate’s degree	4	7%
Bachelor’s degree	21	38%
Graduate degree	14	25%
Annual household income		
<$50,000	14	25%
$50,000-$99,999	12	21%
≥$100,000	17	30%
Don’t wish to provide	10	18%
Don’t know	3	5%

Table 3.

Frequency distribution of activity types across all datapoints (n= 4,051) for study on activity engagement, workload, and stress

Activity Type	Frequency (%)
Work/school activities	1095 (27.0%)
Relaxing/chilling	852 (21.0%)
Sleeping/napping	535 (13.2%)
Doing housework/errands	448 (11.1%)
Caring for myself	432 (10.7%)
Fun/play/leisure activities	249 (6.1%)
Traveling	202 (4.8%)
Socializing	119 (2.9%)
Caring for others	65 (1.6%)
Other	54 (1.3%)

Table 4a.

Between-person intercorrelation matrix.

	Work Hours	Rest Freq.	Active Leisure Freq.	Whole Day Workload	Stress
Work Hours	1, p<.001				
Rest Freq.	−0.08, p=.577	1, p<.001			
Active Leisure Freq.	−0.14, p=.288	−0.34, p=.011	1, p<.001		
Whole Day Workload	.30, p=.026	−.28, p=.034	−.04, p=.748	1, p<.001	
Stress	.28, p=.039	−.17, p=.215	−.12, p=.396	.74, p<.001	1, p<.001

Table 4b.

Within-person intercorrelation matrix.

	Work Hours	Rest Freq.	Active Leisure Freq.	Whole Day Workload	Stress
Work Hours	1, p<.001				
Rest Freq.	−0.38, p<.001	1, p<.001			
Active Leisure Freq.	−0.30, p<.001	−0.05, p=.173	1, p<.001		
Whole Day Workload	.54, p<.001	−.40, p<.001	−.22, p<.001	1, p<.001	
Stress	.31, p<.001	−.26, p<.001	−.21, p<.001	.45, p<.001	1, p<.001

Table 5.

Whole day workload as a mediator between work hours/rest/leisure frequency and stress.

	EFFECT	EST.	EST. 95% C.I.	STD. EST.
WORK HOURS	Indirect	0.61	(0.46,0.77) *	0.18
a=1.78 (p<.001)	Direct	0.30	(0.04,0.56) *	0.09
b=0.35 (p<.001)	Total	0.91	(0.67,1.16) *	0.26
	Indirect/Total	0.67	(0.48,0.953) *	0.67
REST	Indirect	−9.00	(−11.52,−6.60) *	−0.13
a=−25.42 (p<.001)	Direct	−5.73	(−10.51,−1.15) *	−0.09
b=0.35 (p<.001)	Total	−14.78	(−19.45,−10.03) *	−0.22
	Indirect/Total	0.61	(0.43,0.89) *	0.61
ACTIVE LEISURE	Indirect	−6.21	(−9.23,−3.41) *	−0.06
a=−16.86 (p<.001)	Direct	−10.43	(−16.56,−4.34) *	−0.11
b=0.37 (p<.001)	Total	−16.67	(−23.31,−9.99) *	−0.17
	Indirect/Total	0.38	(0.21,0.61) *	0.38
WEEKEND	Indirect	−3.74	(−4.81,−2.75) *	−0.13
a=−10.70 (p<.001)	Direct	−3.03	(−5.03,−0.98) *	−0.10
b=0.35 (p<.001)	Total	−6.78	(−8.75,−4.75) *	−0.23
	Indirect/Total	0.55	(0.38,0.80) *	0.55

Note:

* CIs don’t contain 0, indicating statistical significance; EST. = Estimate; C.I.= Credible Interval; STD. EST.=Standardized Estimate