

The Role of Physical Activity and Sedentary Behavior in Predicting Daily Pain and Fatigue in Older Adults: A Diary Study

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DOI:

[10.1007/s12160-017-9921-1](https://doi.org/10.1007/s12160-017-9921-1)

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Document Version

Peer reviewed version

Citation for published version (Harvard):

Park, S, Veldhuijzen van Zanten, J, Thogersen-Ntoumani, C & Ntoumanis, N 2017, 'The Role of Physical Activity and Sedentary Behavior in Predicting Daily Pain and Fatigue in Older Adults: A Diary Study', *Annals of behavioral medicine : a publication of the Society of Behavioral Medicine*. <https://doi.org/10.1007/s12160-017-9921-1>

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1 RUNNING HEAD: Predicting daily pain and fatigue in older adults

2

3 The Role of Physical Activity and Sedentary Behavior in Predicting Daily Pain and Fatigue

4 in Older Adults: A Diary Study

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Abstract

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Background. Little attention has been paid to within-person daily associations amongst light physical activity (PA), moderate-to-vigorous physical activity (MVPA), and sedentary behavior (SB) with subsequent bodily pain and fatigue. Daily reports of pain and fatigue are less likely to be affected by recall bias and to conflate days of high and low pain/fatigue into one overall score.

Purpose. To examine daily within-person associations between pain, fatigue and physical health and ascertain whether such associations are moderated by individual differences in these variables.

Methods. Participants were 63 community-living older adults (female $n = 43$, mean age = 70.98 years). Questionnaires measured typical levels of PA, SB, bodily pain, fatigue and physical health. Subsequently, on a daily basis over a 1-week period, participants' levels of light PA, MVPA and SB were measured using accelerometers. Participants completed a questionnaire rating their pain and fatigue at the end of each day.

Results. Multilevel modelling revealed positive within-person associations between daily light PA, daily MVPA, and pain, as well as negative within-person associations between daily SB and pain. For individuals with higher typical levels of fatigue, there was a negative association between daily light PA, MVPA and fatigue. For individuals with better levels of physical health, there was also a negative association between daily MVPA and fatigue. For those with higher typical levels of fatigue and better levels of physical health, there was a positive association between daily SB and fatigue. No such interaction effects were found between high levels of typical pain and PA or SB.

Conclusions. Our findings indicate that efforts to promote daily PA in older adults might be more effective for those who report high typical levels of fatigue and physical health, compared to those who report high levels of daily physical pain.

39 *Keywords:* accelerometers, diary studies, physical health, sedentary behavior

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41 According to the United Nations [1], the number of older adults (≥ 60 years) worldwide is
42 expected to increase from 901 million in 2015 to 1.4 billion by 2030. As adults age, they are
43 more likely to experience negative health outcomes (e.g., heart disease, back pain) [2]. For
44 example, evidence shows that many older adults in community settings suffer from bodily
45 pain (63% in men, 91% in women) [3] and fatigue (15% in men, 29% in women) [4]. Bodily
46 pain has been found to be negatively related to walking speed, balance and physical
47 functioning in older women in community settings [5]. With regard to fatigue, positive
48 associations have been reported between this variable and negative health conditions (e.g.,
49 arthritis) in older adults [6].

50 It is well documented that lifestyle factors such as physical activity (PA) and
51 sedentary behavior (SB) can play an important role in determining health-related quality of
52 life in older adults [7]. Evidence shows a positive association between engaging in moderate-
53 to-vigorous PA (MVPA) and improved physical health (e.g., decreased risk of mortality,
54 stroke, type 2 diabetes) [8] and mental health (e.g., fewer depression symptoms) in older
55 adults [9]. In light of recent literature that has identified a high prevalence of light PA in the
56 general public [10], particularly in older adults, research has also examined the role of light
57 PA in improved physical health. Previous studies have reported positive associations between
58 engagement in light PA and the reduction of coronary heart disease in adults and older men
59 [11], as well as fewer depression symptoms in older adults [9].

60 In contrast, spending a large proportion of the day in SB among older adults (age 70-
61 85; men 67.8%, women: 66.3%) [12] can have a negative impact upon health. For example,
62 Stamatakis et al. [13] found that engagement in self-reported SB was associated with a higher
63 cholesterol ratio, BMI, and waist circumference in older adults. Taken together, this evidence
64 indicates that lifestyle factors such as light PA, MVPA and lower SB are important predictors

65 of health. Evidence has also accumulated regarding the role of light PA, MVPA and SB in
66 predicting two important indices of health, namely, bodily pain and fatigue.

67 **Physical Activity, Sedentary Behavior and Bodily Pain**

68 Engagement in self-reported PA has been related to less back pain in older adults [14]. In line
69 with this, PA is recommended as a treatment for chronic pain [15]. Additionally, higher
70 levels of sitting time have been associated with worse bodily pain in community-living older
71 adults [16]. However, the associations between pain and PA are complicated and seem to be
72 influenced by the level at which these associations are investigated. For example, exploration
73 of within-person associations in older adults revealed that daily levels of PA were a
74 significant predictor of higher levels of daily pain in women, even though overall/typical PA
75 was associated with lower levels of pain [17]. In line with this finding, there is also evidence
76 that some older adults who report that activity worsens their pain, also use exercise to manage
77 their pain [18]. Interestingly, the interference of pain with activity was particularly evident in
78 those with severe levels of pain [18], suggesting that typical pain could influence the
79 association between daily pain and daily PA. Within-subject analyses can be used to explore
80 the associations between daily pain and daily PA in more detail, while exploring the
81 moderating influence of typical pain on these associations [17]. In addition, given the
82 negative associations between physical health and pain [19] and between physical health and
83 SB [20], as well as the positive associations between physical health and PA [21], it is also
84 important to examine the moderating influence of physical health in the association between
85 daily PA/SB and daily pain.

86 Daily self-reports are less likely to be affected by recall bias and to conflate days of
87 high and low pain into one overall score of pain. Further, by separating within-person from
88 between-person associations, it is possible to ascertain the degree to which variables correlate
89 with each other within the same individual over time, without such correlations being

90 influenced by between-person differences in the levels of these variables [22]. As noted by
91 Curran, Howard, Bainter, Lane, and McGinley [23], virtually all theories in the psychological
92 sciences postulate joint within- and between-person processes. Omitting either of these two
93 components results in a disjunction between theory and statistical testing. From an applied
94 perspective, understanding true within-person associations over time helps to develop more
95 tailored interventions.

96 **Physical Activity, Sedentary Behavior and Fatigue**

97 Several studies have shown that fatigue is associated with restricted activities [24], lower
98 levels of PA [25,26], and more dependency in activities of daily living [27]. With regard to
99 SB, it has been shown that sedentary adults report higher levels of fatigue compared to active
100 adults [28,29]. There is also evidence that exercise interventions can reduce fatigue in adults
101 aged 55 and older, and that the improvements in fatigue are related to the improvements in
102 PA [26]. Similar to the research on pain, however, the relation between fatigue and PA has
103 been mainly examined at the between-person level. Nevertheless, feelings of fatigue can vary
104 at the within-person (i.e., daily) level [30], and these within-person changes in fatigue are
105 negatively related to changes in PA [31]. Interestingly, levels of typical fatigue have also
106 been negatively related to diurnal PA patterns and physical health (chronic conditions) [32],
107 suggesting that when exploring the associations between fatigue and PA at within-person
108 level, typical levels of fatigue and physical health should be taken into account.

109 **Purpose of the Study**

110 Our aim was to examine the relation between daily (over a 7-day period) light PA, MVPA,
111 and SB, and subsequent bodily pain and fatigue. We also investigated whether such
112 associations were moderated by individuals' typical levels of bodily pain, fatigue and
113 physical health. This is the first attempt to examine within-and between person associations
114 of light PA, MVPA and SB with subsequent bodily pain and fatigue in older adults. It was

115 hypothesized that daily light PA and MVPA would predict lower levels of daily pain,
116 whereas daily SB would predict higher levels of pain, but only for those with low levels of
117 typical pain and high levels of physical health. In addition, it was hypothesized that daily
118 light PA and MVPA would predict lower levels of fatigue, whereas daily SB would predict
119 higher levels of fatigue, but only for those with low levels of typical fatigue and high levels
120 of physical health.

121 **Method**

122 **Participants**

123 Older community-dwelling adults ($n = 67$) in the UK were recruited. Inclusion criteria were
124 that participants did not use a walker or a wheelchair and were above the age of 60 years.
125 Simulation studies (e.g., McNeish & Stapleton; Maas & Hox) [33,34] indicate that $N > 50$ at
126 level 2 (participants in our case) of a multilevel model, provides adequate power for variance,
127 standard error and fixed effects estimates. A list of contacts was provided to the researchers
128 from a database of about 1000 volunteers who were registered with a UK university as
129 potential participants for studies on ageing-related topics. Participants were sent invitation
130 letters and/or emails. In total, 63 participants ($n = 63$, $M_{\text{age}} = 70.98$, $SD = 6.92$, female =
131 68.3%) were included in the analysis, after four participants were excluded (not sufficient
132 accelerometer wear time = 2, using a walker = 2) from the analysis. As can be seen in Table 1,
133 the participants had an average body mass index (BMI; kg/m^2) of 25.14 ($SD = 3.47$), were
134 well educated (highest degree obtained = a post-graduate degree; 28.6%), and had a
135 comfortable income (£20,000-£35,000 = 34.9%). The participants were mostly white and
136 British (79.4%) and more than one-third of the participants were co-habiting (65.1%) with
137 their partner. Many participants (57.1%) reported having been diagnosed with a
138 cardiovascular condition.

139 **Procedures**

140 Ethical approval for this study was granted by the Ethical Review Committee at a UK
141 university. An introductory session about the study took place in an initial session in a lab or
142 in a convenient place for the participant. The participants signed written consent forms. Their
143 weight and height were then measured to calculate BMI (kg/m^2) using a portable scale
144 (TANITA BC-545N). Two participants refused to be measured, and their self-reported
145 weight and height were recorded. At the beginning of the study, a set of questionnaires was
146 distributed to the participants, to provide pre-diary typical measures of the study variables,
147 including demographics. Further, either a palmtop computer (Scroll Pocket Tablet PC) or a
148 smartphone (ZTE Blade Q Mini Android Smartphone), depending on equipment availability,
149 was given to the participants for the daily assessments. The devices were programmed to
150 prompt a set of daily questions between 4 pm and 9 pm every day on a random basis. The
151 devices had touch-screens which participants had to tap to record an answer. If the
152 participants did not respond to the first alarm, a second alarm was provided 2 minutes later. If
153 there were no answers, the question was treated as missing ($n= 45$). Answers that were
154 outside of the alarm range due to system errors were treated as missing ($n= 1$). The answers
155 were stored within each participant's device. At the end of the data collection, research staff
156 downloaded the answers from the devices to a lab-based desktop computer. In addition to the
157 touchscreen devices, an accelerometer was distributed to the participants to wear over seven
158 days during waking hours. Participants were instructed to wear the monitor on their right hip,
159 to avoid wearing the accelerometer during any water activities, and to record in a diary each
160 time point when they started and stopped wearing the accelerometer.

161 **Measures**

162 *Demographics*

163 We asked participants to tick whether they were diagnosed with any cardiovascular disease
164 over the past 12 months. We assessed the occurrence (*have* = 1, *do not have* = 0) of high

165 cholesterol, heart disease, vascular disease, high blood pressure and circulatory problems. In
166 addition, gender (*male* = 0, *female* = 1) and marital status (*living alone* = 0, *living with*
167 *someone else* = 1) were coded.

168 ***Typical and daily bodily pain***

169 For typical pain, participants were asked to complete the two pain items from the RAND 36-
170 Item Health Survey [35] [i.e., “How much bodily pain have you had during the past 4 weeks?”
171 ranging from 1 (*none*) to 6 (*very severe*), and “During the past 4 weeks, how much did pain
172 interfere with your normal work (including both work outside the home and housework)?”,
173 ranging from 1 (*not at all*) to 5 (*extremely*)]. The coefficient alpha (α) was 0.78 in a previous
174 study [35] and $\alpha = 0.79$ in the present study. Items were averaged for our analysis. To
175 measure daily bodily pain, we asked one item: “How much bodily pain do you have right
176 now?”, and responses were rated on a 1 (*no pain*) to 4 (*severe pain*) scale.

177 ***Typical and daily fatigue***

178 The Multi-Dimensional Fatigue Index (MFI-20) [36] was utilized to assess fatigue over the
179 previous 4 weeks with a total of 20 items. The scale tapped five dimensions of fatigue:
180 general fatigue (e.g., “I feel tired”), physical fatigue (e.g., “Physically, I feel able to only do a
181 little”), reduced activity (e.g., “I think I do very little in a day), mental fatigue (e.g., “My
182 thoughts easily wander”), and reduced motivation (e.g., “I don’t feel like doing anything).
183 Answers were rated on a 5-point scale from 1 (*yes, that is true*) to 5 (*no, that is not true*).
184 Good internal reliability coefficients were found in a previous study (α range: 0.75-0.94) [36]
185 and in the present study (α range: 0.67-0.83). Subscales were summed to calculate a total
186 fatigue score. To assess daily fatigue, one item (“How much fatigue do you feel right now?”)
187 was chosen from the MFI and was answered at each beep. Participants provided a rating from
188 1 (*no fatigue*) to 4 (*severe fatigue*).

189 ***Daily physical activity and sedentary behavior***

190 Accelerometers were used to monitor PA and SB levels (model GT3X+ was worn by 47
191 participants and model WGT3X-BT was worn by 16 participants). The two models have been
192 shown to produce very similar results [37], and this was also the case in our study according
193 to the results of one-way MANOVA (Pillai's trace = 0.01, $F(3, 59) = 0.19$, $p = .91$, follow-
194 up univariate ANOVAs: SB: $F(1, 61) = 0.19$, $p = .67$, light PA: $F(1, 61) = 0.00$, $p = .98$, and
195 MVPA: $F(1, 61) = 0.1$, $p = .76$). Hence, in our analysis we combined the data from the two
196 types of accelerometers. Participants who wore the accelerometer a minimum of 10 hours a
197 day for 5 days, including 1 weekend day over 7 days, were included in the analysis Data were
198 extracted using the ActiGraph software. The researcher programmed the monitor to
199 accumulate movement data every 60 seconds. Non-wear time was classified as 90 minutes of
200 consecutive non-activity counts (< 100 counts) with 2 minutes of tolerance allowance
201 [38].Based on the diary the participants recorded, we set a time filter to standardize wearing
202 time (7:30 am to 10:30 pm). For the purposes of our analysis, for each day and for each
203 participant, we utilized the movement data accumulated from the morning until the time they
204 answered the daily questions on bodily pain and fatigue. Hence, in our analysis daily PA and
205 SB were used as predictors of daily bodily pain and fatigue.

206 Counts per minute were processed to categorize the thresholds of activities [i.e., SB:
207 0-99 counts per minute (cpm) [12] light PA: 100-2019 cpm, moderate PA: 2,020-5,998 cpm,
208 and vigorous PA: $\geq 5,999$ cpm [39]. Moderate and vigorous intensities were summed to
209 represent MVPA. Finally, each activity category (light PA, MVPA, and SB) was divided by
210 the total wear days and then multiplied by 100 to represent the proportion of each activity
211 category, in order to reduce inter-participant variability [10,40]. These proportion scores were
212 used in the main analysis.

213 ***Typical health status***

214 The RAND 36-Item Health Survey was administered to measure physical health [35].
215 Participants were told: “The following questions are about activities you might do during a
216 typical day. During the past 4 weeks, has your health limited you in these activities? If so,
217 how much?” Rating scales varied depending on items (e.g., carrying groceries). Higher scores
218 on the four subscales represented better physical health [35]. Good internal consistency
219 coefficients have been found in adults (mean age = 30.54, $\alpha = 0.89$) [41], and this was also
220 the case in the current study ($\alpha = 0.75$).

221 *Typical physical activity*

222 Typical PA was assessed using the Physical Activity Scale for the Elderly (PASE) [42]. In
223 total, 18 items were rated using 4-point scales (hours/week) (e.g., “How much time was spent
224 on the activity over the last 7 days?”) and yes/no questions (e.g., “Have you performed ‘light
225 housework’ over the last 7 days?”). The items captured 7 dimensions of PA (e.g., walking,
226 light sport/recreation). Items were multiplied by the number of hours the participants spent
227 and were weighted and summed to obtain an overall score of PA [43]. People with higher
228 scores were more physically active. Acceptable Cronbach’s alpha for reliability was 0.73 in a
229 previous study with older adults [44], but somewhat lower in our study ($\alpha = .56$).

230 *Typical sedentary behavior*

231 Typical sedentary time was assessed with seven items from the Measure of Older adults’
232 Sedentary Time (MOST) [45]. The survey asked the participants to record their total
233 sedentary time (hours and minutes) over the previous seven days (e.g., watching television).
234 Items were summed with higher scores representing higher levels of SB. Test-retest
235 reliability was found to be acceptable (Intra-class correlation coefficient = 0.52, 95%
236 confidence interval = 0.27-0.70) in older adults [45]. The Cronbach’s alpha coefficient is not
237 applicable for this scale.

238 **Data Analysis**

239 Linear mixed models (IBM SPSS, version 22) were tested to examine within- and between-
240 person associations between light PA, MVPA, and SB with bodily pain and fatigue. We ran
241 four models in total. In the first two, light PA and MVPA predicted bodily pain and fatigue
242 respectively, and in the other two models SB predicted pain and fatigue respectively. Within-
243 person predictors (level 1; daily light PA, daily MVPA, and daily SB) were person-mean
244 centered. At level 2, the average of daily light PA, daily MVPA and daily SB over the 7 days
245 were entered as predictors. By including the predictor average scores over the 7-day period at
246 level 2, the level 1 within-person associations were not conflated by between-person
247 differences [22]. In addition, we tested the cross-level interactions between each of the level 1
248 predictors with typical pain (when predicting daily pain), with typical fatigue (when
249 predicting daily fatigue), and with physical health (when predicting daily pain and fatigue).
250 BMI, age, presence/absence of cardiovascular disease, gender and co-habiting were also
251 entered at level 2 as covariates. Level 2 predictors were uncentered [46]. All level 1 and 2
252 predictors, apart from the categorical ones, were converted into Z scores to obtain β
253 coefficients from the analysis. R_1^2 was estimated as an effect size, representing the amount of
254 variance at level 1 explained by the predictors, compared to the variance explained by a
255 model with only the intercept [47].

256 **Results**

257 Participants completed 341 (77.3%) out of 441 (over seven days) daily questions on bodily
258 pain and fatigue. The percentage of missing cases for the pre-diary survey was around 3.2%.
259 The skewness scores for the dependent variables of bodily pain (1.89) and fatigue (0.93) were
260 within an acceptable range (skewness ± 2) [48]. Daily light PA and SB were highly correlated
261 ($r = -0.83$, $p < 0.01$) as is often the case in the literature; hence, separate models for light PA
262 and SB were run.

263 Table 2 shows that the participants wore accelerometers for almost 10 hours (594.13
264 minutes) before they answered the daily questions. The participants spent most of their time
265 in SB (58.58%) and light PA (35.80%), with a lower proportion of MVPA (5.62%).
266 According to R_1^2 , models 1 and 2 (Table 3) predicted 52.8% (bodily pain) and 21.0% (fatigue)
267 of the variance at level 1. Also, models 3 and 4 (Table 4) accounted for 54.8% (bodily pain)
268 and 19.1% (fatigue) of the variance.

269 **Daily light PA, MVPA, and daily SB Predicting Bodily Pain**

270 Table 3 shows the standardized coefficients (β) and standard errors for level 1 and level 2
271 predictors of bodily pain. Engagement in daily light PA ($\beta= 0.151, p= 0.009$), daily MVPA
272 ($\beta= 0.110, p= 0.023$), and higher levels of typical pain ($\beta= 0.543, p<0.001$) positively
273 predicted bodily pain experienced at the daily level. No other significant associations were
274 found. Typical bodily pain and physical health did not significantly moderate the associations
275 between daily light PA, MVPA, and bodily pain. Table 4 shows that typical pain ($\beta= 0.515,$
276 $p<0.001$) and daily SB ($\beta= -0.182, p= 0.003$) over the 7 days predicted bodily pain at the
277 daily level. No other associations were significant.

278 **Daily light PA, MVPA, and SB Predicting Fatigue**

279 Table 3 depicts that daily light PA and MVPA did not significantly predict fatigue. However,
280 a number of significant interactions emerged. Those interactions were further probed via
281 simple slope analyses, for which we report unstandardized coefficients. Specifically, for
282 individuals with lower levels of typical fatigue, there was a positive association between daily
283 light PA and daily fatigue ($B = 3.28, p< 0.001$), whereas for those with higher levels of
284 typical fatigue, this association was negative ($B = -3.22, p= 0.001$). For those with lower
285 levels of typical fatigue, there was also a positive association between daily MVPA and daily
286 fatigue ($B = 3.49, p< 0.001$), whereas for those with higher levels of typical fatigue, this
287 association was negative ($B = -3.41, p< 0.001$). For individuals with lower typical levels of

288 physical health, there was a positive association between daily MVPA and fatigue ($B = 2.93$,
289 $p = 0.027$), whereas for those with higher levels of typical physical health, this association
290 was negative ($B = -2.85$, $p = 0.034$). Typical levels of physical health did not significantly
291 interact with light PA to predict daily fatigue. With regard to main effects, typical fatigue ($\beta =$
292 0.263 , $p = 0.031$) and cardiovascular disorder ($\beta = 0.483$, $p = 0.014$) were also significantly
293 associated with daily fatigue.

294 Simple slope analyses were also conducted to probe significant interactions in Table 4.
295 Specifically, for individuals with lower typical levels of fatigue, there was a negative
296 association between daily SB and fatigue ($B = -4.612$, $p < 0.000$), whereas for those with
297 higher levels of typical fatigue, this association was positive ($B = 4.513$, $p < 0.000$). For
298 individuals with lower typical levels of physical health, there was a negative association
299 between daily SB and fatigue ($B = -3.779$, $p = 0.019$), whereas for those with higher levels of
300 typical physical health, this association was positive ($B = 3.680$, $p = 0.022$). With regard to
301 main effects, typical fatigue ($\beta = 0.274$, $p = 0.026$) and the presence of cardiovascular diseases
302 ($\beta = 0.489$, $p = 0.013$) also predicted daily fatigue.

303

Discussion

304 In this study we examined daily associations between objectively-assessed light PA, MVPA,
305 and SB, and subsequent bodily pain and fatigue in a sample of older adults. Further, we
306 explored whether these within-person associations were moderated by between-person
307 differences in typical bodily pain, fatigue and physical health.

Predictors of Bodily Pain

309 We expected that daily light PA and MVPA (and SB) would be negative (positive) predictors
310 of daily pain, but only for those with low levels of typical pain and better levels of health.
311 Contrary to our hypothesis, the within-person associations of daily light PA and MVPA with
312 daily bodily pain were positive, in that more engagement in daily light PA and MVPA

313 predicted more subsequent bodily pain. However, this finding is in line with a previous study
314 in which a positive within-person association was found between PA and pain in a sample of
315 older adults [17]. With respect to daily SB and bodily pain, the analysis showed that more
316 engagement in daily SB was associated with less subsequent bodily pain in older adults. This
317 finding is aligned with our results pertaining to PA and pain.

318 Even though engagement in PA might predict higher levels of bodily pain in the short
319 term in older adults, it is well established that regular PA can maintain and improve health in
320 older adults [49,50]. In fact, there are studies showing a negative as opposed to a positive
321 association between PA and pain (e.g., Cecchi et al. [14]). Given these apparently
322 inconsistent findings regarding the associations between PA and pain, more research is
323 needed to explore the temporal effects of PA on pain in more detail. Future studies may need
324 to utilize more frequent measurement points (e.g., hourly). Given some reports that feelings
325 of pain can fluctuate throughout the day [50], it is possible that PA/SB might predict pain in
326 different ways depending on the time of the day. It would also be interesting to explore the
327 impact of the type of activity on the associations between PA and pain. For example, lifting
328 heavy objects and gardening could have differential effects on the relationship between pain
329 and PA.

330 Finally, typical physical health did not moderate the associations between pain and
331 PA or SB. It should be acknowledged though that the overall perceived physical health of the
332 participants was good (i.e. 81 out of 100). Therefore, in order to explore this hypothesis in the
333 future it is important to include a sample with a greater variation in perceived physical health.

334 **Predictors of Fatigue**

335 We expected that daily light PA and MVPA (and SB) would be negative (positive) predictors
336 of daily fatigue, but only for those with low levels of typical fatigue and better levels of
337 physical health. The results partially supported our hypotheses. There were no significant

338 within- and between-person associations between light PA, MVPA, SB and subsequent
339 fatigue. Other studies have generally reported modest negative associations between fatigue
340 and PA [25,51]. Such modest and/or non-significant associations could be due to the
341 possibility that the relations between PA, SB and fatigue are dependent on individuals' levels
342 of health and their general levels of fatigue.

343 Better typical levels of physical health moderated the association between daily
344 MVPA and fatigue, and between SB and fatigue. As hypothesized, those who engaged in
345 more MVPA and less SB reported less fatigue, but this was the case only for individuals with
346 better perceived health. In contrast, for those with worse perceived health, engagement in
347 more MVPA and less SB was detrimental as it resulted in more daily fatigue. Interestingly,
348 physical health did not moderate the association between light PA and fatigue. These findings
349 suggest that intensive forms of PA should be reserved for those in better physical health,
350 while those in lower physical health should initially be prescribed light PA. Given that
351 physical health did not influence the associations between light PA and fatigue, perhaps light
352 PA would be the most suitable type of PA to start an intervention to reduce fatigue for older
353 adults. Increasing light PA might not only benefit levels of fatigue and physical health, but it
354 is also a feasible target for older adults who are not active.

355 Contrary to our hypothesis, the expected negative (positive) association between daily
356 light PA (SB) and subsequent daily fatigue were evident only for those individuals with high
357 (as opposed to low) typical fatigue levels. The current findings suggest that those with higher
358 typical levels of fatigue might benefit more in terms of their daily fatigue levels from moving
359 more and sitting less than those with lower levels of typical fatigue. Even though exercise
360 interventions have been shown to reduce the levels of fatigue [52], even in clinical
361 populations with high levels of fatigue such rheumatoid arthritis [53] and multiple sclerosis
362 [54], to our knowledge little attention has been paid to the moderating role of typical levels of

363 fatigue on these benefits. Therefore, the possibility that those with higher levels of typical
364 fatigue might benefit more from being physically active in terms of their daily fatigue should
365 be investigated in future intervention studies. Our findings also highlight the need to focus
366 PA-promoting interventions in older adults on individuals who report high levels of fatigue
367 and perhaps experience chronic fatigue. Given that higher levels of light PA were associated
368 with lower levels of fatigue in those with higher levels of typical fatigue, perhaps PA-
369 promoting interventions for this particular population should focus on light PA. As
370 mentioned above, this is likely to be a feasible target for people who are not physically active,
371 and such type of activity can help to increased overall health [55,56].

372 **Limitations and Future Research Directions**

373 We must acknowledge some limitations of the present study. The standardized coefficients
374 associated with the main effects of daily SB, light PA and MVPA were small. However, such
375 effects are in line with our research in the pain and fatigue literatures utilizing objective
376 assessments of PA [25,51]. Given that our participants were generally inactive, 1 SD
377 increases in daily SB, light PA and MVPA represent substantial deviations from the sample's
378 mean scores on those variables. It should be also considered that objective PA and self-
379 reported pain and fatigue do not share common method variance, as is the case with self-
380 reported PA. Another limitation of the study is that due to its short duration (7 days), we do
381 not know the extent to which our findings would generalize over a longer period of time (e.g.,
382 two or three months). A measurement burst approach [57] in which diaries are administered
383 on multiple occasions (e.g., 3 weeks over a year) would allow for a test of seasonal effects
384 (e.g., due to the weather). Assessing multiple activities and rates of fatigue and pain
385 throughout the same day can also offer a more comprehensive understanding of the dynamic
386 nature of the relations between these two variables, PA and SB. In addition, objectively-
387 assessed PA cannot readily differentiate between different modes of activity (e.g., lifting

388 heavy objects vs. playing with children) which can predict variations in perceptions of pain
389 and fatigue. Another limitation of the study was that the sample was rather ethnically
390 homogenous, relatively educated, relatively healthy (e.g., low bodily pain and fatigue scores),
391 quite wealthy, and thus not wholly representative of the general population of older adults in
392 the UK. Future studies should aim to recruit older adults from more diverse backgrounds.
393 Further, another limitation was that we used self-reported measures of health. In future
394 investigations, it might be informative to replicate our study using objective assessments of
395 physical health (e.g., field- based tests of gait speed or hand grip strength).
396 Notwithstanding the limitations above, this study has several strengths. This is the first study
397 to examine within-person associations between light PA, MVPA, SB and subsequent daily
398 pain and fatigue in older adults. We were able to establish support for such within-person
399 associations which were not confounded by individual differences in PA and SB. In addition,
400 advancing past research, we specifically measured light PA because in older adults a high
401 proportion of time is spent engaging in this type of PA [10,58]. Indeed, we found that
402 engagement in daily light PA represented 35.80% of the daily activity up to the measurement
403 of pain and fatigue, a much higher percentage than that for MVPA (5.62%). We measured
404 levels of PA and SB both objectively and via self-reports. In contrast, most of the previous
405 studies have only used self-reports of PA and/or SB in predicting bodily pain and fatigue. By
406 using smart devices for EMA, we were able to obtain real-time reports of pain and fatigue.
407 Future studies in this field could build on our findings to develop targeted PA interventions
408 for individuals with varying levels of fatigue and pain. Such interventions could use modern
409 technology (e.g., smartphones) to target beliefs, barriers and benefits of being more
410 physically active and less sedentary.

411

References

- 412 1. United Nations. *World Population Ageing 2015.*; 2015.
413 <http://www.un.org/en/development/desa/population/publications/pdf/ageing/WPA2015>
414 [_Report.pdf](#).
- 415 2. World Health Organization. 10 facts on ageing and health.
416 <http://www.who.int/features/factfiles/ageing/en/>. Published 2016.
- 417 3. Bergh I, Steen G, Waern M, et al. Pain and its relation to cognitive function and
418 depressive symptoms: A Swedish population study of 70-year-old men and women. *J*
419 *Pain Symptom Manage*. 2003;26(4):903-912. doi:10.1016/S0885-3924(03)00329-4.
- 420 4. Vestergaard S, Nayfield SG, Patel K V, et al. Fatigue in a Representative Population of
421 Older Persons and Its Association With Functional Impairment, Functional Limitation,
422 and Disability. *Journals Gerontol*. 2009;64A(1):76-82. doi:10.1093/gerona/gln017.
- 423 5. Sampaio RAC, Sewo Sampaio PY, Uchida MC, et al. Walking speed and balance
424 performance are associated with Short-Form 8 bodily pain domain in Brazilian older
425 female. *J Clin Gerontol Geriatr*. 2015;6(3):89-94. doi:10.1016/j.jcgg.2015.02.005.
- 426 6. Williamson RJ, Purcell S, Sterne A, et al. The relationship of fatigue to mental and
427 physical health in a community sample. *Soc Psychiatry Psychiatr Epidemiol*.
428 2005;40(2):126-132. doi:10.1007/s00127-005-0858-5.
- 429 7. Vogel T, Brechat P -h., Leprêtre P -m., et al. Health benefits of physical activity in
430 older patients: a review. *Int J Clin Pract*. 2009;63(2):303-320.
431 doi:<http://dx.doi.org/10.1111/j.1742-1241.2008.01957.x>.
- 432 8. World Health Organization. Global Strategy on Diet, Physical Activity and Health-

- 433 Physical Activity and Older Adults.
434 http://www.who.int/dietphysicalactivity/factsheet_olderadults/en/. Published 2016.
- 435 9. Loprinzi PD. Objectively measured light and moderate-to-vigorous physical activity is
436 associated with lower depression levels among older US adults. *Aging Ment Health*.
437 2013;17(7):801-805. doi:10.1080/13607863.2013.801066.
- 438 10. Owen N, Sparling PB, Healy GN, et al. Sedentary Behavior: Emerging Evidence for a
439 New Health Risk. *Mayo Clin Proc*. 2010;85(12):1138-1141.
440 doi:10.4065/mcp.2010.0444.
- 441 11. Sesso HD, Paffenbarger RS, Lee I-M. Physical Activity and Coronary Heart Disease in
442 Men : The Harvard Alumni Health Study. *Circulation*. 2000;102(9):975-980.
443 doi:10.1161/01.CIR.102.9.975.
- 444 12. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary
445 behaviors in the United States, 2003-2004. *Am J Epidemiol*. 2008;167(7):875-881.
446 doi:<http://dx.doi.org/10.1093/aje/kwm390>.
- 447 13. Stamatakis E, Davis M, Stathi A, Hamer M. Associations between multiple indicators
448 of objectively-measured and self-reported sedentary behaviour and cardiometabolic
449 risk in older adults. *Prev Med (Baltim)*. 2012;54(1):82-87.
450 doi:10.1016/j.ypmed.2011.10.009.
- 451 14. Cecchi F, Debolini P, Lova RM, et al. Epidemiology of back pain in a representative
452 cohort of Italian persons 65 years of age and older: the InCHIANTI study. *Spine (Phila
453 Pa 1976)*. 2006;31(10):1149-1155. doi:10.1097/01.brs.0000216606.24142.e1.
- 454 15. Connelly P. Guidance on the management of pain in older people. *Age Ageing*.
455 2013;42:i1-i57. doi:10.1093/ageing/afs200.

- 456 16. Balboa-Castillo T, León-Muñoz LM, Graciani A, Rodríguez-Artalejo F, Guallar-
457 Castellón P. Longitudinal association of physical activity and sedentary behavior
458 during leisure time with health-related quality of life in community-dwelling older
459 adults. *Health Qual Life Outcomes*. 2011;9(1):47. doi:10.1186/1477-7525-9-47.
- 460 17. Ho A, Ashe MC, DeLongis A, Graf P, Khan KM, Hoppmann CA. Gender Differences
461 in Pain-Physical Activity Linkages among Older Adults: Lessons Learned from Daily
462 Life Approaches. *Pain Res Manag*. 2016;9. doi:10.1155/2016/1931590.
- 463 18. Brown ST, Kirkpatrick MK, Swanson MS, McKenzie IL. Pain Experience of the
464 Elderly. *Pain Manag Nurs*. 2011;12(4):190-196. doi:10.1016/j.pmn.2010.05.004.
- 465 19. Reyes-Gibby CC, Aday L, Cleeland C. Impact of pain on self-rated health in the
466 community-dwelling older adults. *Pain*. 2002;95(1):75-82. doi:10.1016/S0304-
467 3959(01)00375-X.
- 468 20. Rezende LFM de, Rodrigues Lopes M, Rey-López JP, Matsudo VKR, Luiz O do C.
469 Sedentary Behavior and Health Outcomes: An Overview of Systematic Reviews.
470 Lucia A, ed. *PLoS One*. 2014;9(8):e105620. doi:10.1371/journal.pone.0105620.
- 471 21. Haider S, Luger E, Kapan A, et al. Associations between daily physical activity,
472 handgrip strength, muscle mass, physical performance and quality of life in prefrail
473 and frail community-dwelling older adults. *Qual Life Res*. 2016;25(12):3129-3138.
474 doi:10.1007/s11136-016-1349-8.
- 475 22. Raudenbush SW, Bryk AS. *Hierarchical Linear Models: Applications and Data*
476 *Analysis Methods*. Vol 2nd.; 2002.
- 477 23. Curran PJ, Howard AL, Bainter SA, Lane ST, McGinley JS. The separation of
478 between-person and within-person components of individual change over time: A

- 479 latent curve model with structured residuals. *J Consult Clin Psychol*. 2014;82(5):879-
480 894. doi:10.1037/a0035297.
- 481 24. Gill TM, Desai MM, Gahbauer EA, Holford TR, Williams CS. Restricted Activity
482 among Community-Living Older Persons: Incidence, Precipitants, and Health Care
483 Utilization. *Ann Intern Med*. 2001;135(5):313. doi:10.7326/0003-4819-135-5-
484 200109040-00007.
- 485 25. Egerton T, Chastin SFM, Stensvold D, Helbostad JL. Fatigue May Contribute to
486 Reduced Physical Activity Among Older People: An Observational Study. *Journals*
487 *Gerontol Ser A Biol Sci Med Sci*. 2016;71(5):670-676. doi:10.1093/gerona/glv150.
- 488 26. Nicklas BJ, Beavers DP, Mihalko SL, Miller GD, Loeser RF, Messier SP. Relationship
489 of Objectively-Measured Habitual Physical Activity to Chronic Inflammation and
490 Fatigue in Middle-Aged and Older Adults. *Journals Gerontol Ser A Biol Sci Med Sci*.
491 2016;71(11):1437-1443. doi:10.1093/gerona/glw131.
- 492 27. Moreh E, Jacobs JM, Stessman J. Fatigue, function, and mortality in older adults. *J*
493 *Gerontol A Biol Sci Med Sci*. 2010;65(8):887-895. doi:10.1093/gerona/glq064.
- 494 28. Ellingson LD, Kuffel AE, Vack NJ, Cook DB. Active and sedentary behaviors
495 influence feelings of energy and fatigue in women. *Med Sci Sports Exerc*.
496 2014;46(1):192-200. doi:10.1249/MSS.0b013e3182a036ab.
- 497 29. Wennberg P, Boraxbekk C-J, Wheeler M, et al. Acute effects of breaking up prolonged
498 sitting on fatigue and cognition: a pilot study. *BMJ Open*. 2016;6(2):e009630.
499 doi:10.1136/bmjopen-2015-009630.
- 500 30. Ravesloot C, Ward B, Hargrove T, et al. Why stay home? Temporal association of
501 pain, fatigue and depression with being at home. 2016;9(2):218-225.

502 doi:10.1016/j.dhjo.2015.10.010.

503 31. Murphy SL, Kratz AL, Williams DA, Geisser ME. The association between symptoms,
504 pain coping strategies, and physical activity among people with symptomatic knee and
505 hip osteoarthritis. *Front Psychol.* 2012;3(SEP).

506 32. Egerton T, Helbostad JL, Stensvold D, Chastin SFM. Fatigue Alters the Pattern of
507 Physical Activity Behavior in Older Adults: Observational Analysis of Data from the
508 Generation 100 Study. *J Aging Phys Act.* 2016;24(4):633-641. doi:10.1123/japa.2015-
509 0237.

510 33. McNeish DM, Stapleton LM. The Effect of Small Sample Size on Two-Level Model
511 Estimates: A Review and Illustration. *Educ Psychol Rev.* 2016;28(2):295-314.
512 doi:10.1007/s10648-014-9287-x.

513 34. Maas CJM, Hox JJ. Sufficient Sample Sizes for Multilevel Modeling. *Methodology.*
514 2005;1(3):86-92. doi:10.1027/1614-2241.1.3.86.

515 35. Hays RD, Sherbourne CD, Mazel RM. The rand 36-item health survey 1.0. *Health*
516 *Econ.* 1993;2(3):217-227. doi:10.1002/hec.4730020305.

517 36. Smets EMA, Garssen B, Bonke B, De M, Haes JCJ. The multidimensional Fatigue
518 Inventory (MFI) psychometric qualities of an instrument to assess fatigue. *J*
519 *Psychosom Res.* 1995;39(3 SRC):315-325. doi:http://dx.doi.org/10.1016/0022-
520 3999(94)00125-o.

521 37. Miller J. Cross-Generation Accuracy. 2015. [http://actigraphcorp.com/wp-](http://actigraphcorp.com/wp-content/uploads/2015/04/cross-generation-accuracy.pdf)
522 [content/uploads/2015/04/cross-generation-accuracy.pdf](http://actigraphcorp.com/wp-content/uploads/2015/04/cross-generation-accuracy.pdf).

523 38. Choi L, Ward SC, Schnelle JF, Buchowski MS. Assessment of wear/nonwear time

- 524 classification algorithms for triaxial accelerometer. *Med Sci Sports Exerc.*
525 2012;44(10):2009-2016. doi:http://dx.doi.org/10.1249/mss.0b013e318258cb36.
- 526 39. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical
527 activity in the United States measured by accelerometer. *Med Sci Sports Exerc.*
528 2008;40(1):181-188. doi:10.1249/mss.0b013e31815a51b3.
- 529 40. Bélanger M, Townsend N, Foster C. Age-related differences in physical activity
530 profiles of English adults. *Prev Med (Baltim).* 2011;52(3):247-249.
531 doi:10.1016/j.ypmed.2011.02.008.
- 532 41. Padden DL, Connors RA, Agazio JG. Stress, coping, and well-being in military
533 spouses during deployment separation. *West J Nurs Res.* 2011;33(2):247-267.
534 doi:10.1177/0193945910371319.
- 535 42. Washburn RA, McAuley E, Katula J, Mihalko SL, Boileau RA. The physical activity
536 scale for the elderly (PASE): evidence for validity. *J Clin Epidemiol.* 1999;52(7):643-
537 651. doi:10.1016/S0895-4356(99)00049-9.
- 538 43. Washburn RA, Smith KW, Jette AM, Janney CA. The physical activity scale for the
539 elderly (PASE): Development and evaluation. *J Clin Epidemiol.* 1993;46(2):153-162.
540 doi:10.1016/0895-4356(93)90053-4.
- 541 44. Loland N. Reliability of the physical activity scale for the elderly (PASE). *Eur J Sport*
542 *Sci.* 2002;2(5):1-12. doi:10.1080/17461390200072504.
- 543 45. Gardiner PA, Clark BK, Healy GN, Eakin EG, Winkler EAH, Owen N. Measuring
544 older adults' sedentary time: reliability, validity, and responsiveness. *Med Sci Sports*
545 *Exerc.* 2011;43(11):2127-2133. doi:10.1249/MSS.0b013e31821b94f7.

- 546 46. Bolger N, Laurenceau J. *Intensive Longitudinal Methods*. New York: Guilford Press;
547 2013.
- 548 47. Hox J, Moerbeek M, Schoot R van de. *Multilevel Analysis: Techniques and*
549 *Applications*. 2nd ed. New York: Routledge; 2010.
- 550 48. Gravetter F, Wallnau L. *Statistics for the Behavioral Sciences.*; 2016.
- 551 49. World Health Organization. *Global Recommendations on Physical Activity for Health.*;
552 2011.
- 553 50. Focht B, Ewing V, Gauvin L, Rejeski W. The unique and transient impact of acute
554 exercise on pain perception in older, overweight, or obese adults with knee
555 osteoarthritis. *Ann Behav Med*. 2002;24(3):201-210.
- 556 51. Mahieu MA, Ahn GE, Chmiel JS, et al. Fatigue, patient reported outcomes, and
557 objective measurement of physical activity in systemic lupus erythematosus. *Lupus*.
558 2016;25(11):1190-1199. doi:10.1177/0961203316631632.
- 559 52. Puetz TW, O'Connor PJ, Dishman RK. Effects of chronic exercise on feelings of
560 energy and fatigue: A quantitative synthesis. *Psychol Bull*. 2006;132(6):866-876.
561 doi:10.1037/0033-2909.132.6.866.
- 562 53. Rongen-van Dartel SAA, Repping-Wuts H, Flendrie M, et al. Effect of Aerobic
563 Exercise Training on Fatigue in Rheumatoid Arthritis: A Meta-Analysis. *Arthritis*
564 *Care Res (Hoboken)*. 2015;67(8):1054-1062. doi:10.1002/acr.22561.
- 565 54. Pilutti LA, Greenlee TA, Motl RW, Nickrent MS, Petruzzello SJ. Effects of Exercise
566 Training on Fatigue in Multiple Sclerosis. *Psychosom Med*. 2013;75(6):575-580.
567 doi:10.1097/PSY.0b013e31829b4525.

- 568 55. Manns PJ, Dunstan DW, Owen N, et al. Addressing the nonexercise part of the activity
569 continuum: a more realistic and achievable approach to activity programming for
570 adults with mobility disability? *Phys Ther.* 2012;92(4):614-625.
571 doi:10.2522/ptj.20110284.
- 572 56. Matthews CE, Moore SC, Sampson J, et al. Mortality Benefits for Replacing Sitting
573 Time with Different Physical Activities. *Med Sci Sports Exerc.* 2015;47(9):1833-1840.
574 doi:10.1249/MSS.0000000000000621.
- 575 57. Sliwinski MJ. Measurement-Burst Designs for Social Health Research. *Soc Personal*
576 *Psychol Compass.* 2008;2(1):245-261. doi:10.1111/j.1751-9004.2007.00043.x.
- 577 58. Gando Y, Yamamoto K, Murakami H, et al. Longer Time Spent in Light Physical
578 Activity Is Associated With Reduced Arterial Stiffness in Older Adults. *Hypertension.*
579 2010;56(3):540-546. doi:10.1161/HYPERTENSIONAHA.110.156331.
- 580

581 Table 1

582 *Participant Characteristics*

Variable	
Sex, <i>n</i> (%)	63; female = 43 (68.3)
Age, mean (SD)	70.98 (6.92)
Education completed, <i>n</i> (%)	Missing 4 (6.3)
Primary	7 (11.1)
Secondary	10 (15.9)
Higher	15 (23.8)
Post graduate	18 (28.6)
Other	9 (14.3)
Annual income, <i>n</i> (%)	
Below £20,000	22 (34.9)
£20,000 -35,000	22 (34.9)
£35,000 – 45,000	11 (17.5)
Above 45,000	8 (12.7)
Ethnicity, <i>n</i> (%)	
White British	50 (79.37)
Other White	2 (3.17)
Black Caribbean	1 (1.59)
Indian	7 (11.11)
Other	3 (4.76)
BMI (kg/m ²), mean (SD)	25.14 (3.47)
Cardiovascular disorder (%)	0 = have (57.1), 1 = do not have (42.9)
Cohabiting with partner (%)	0 = no (34.9), 1 = yes (65.1)

583

584 Table 2

585 *Descriptive Statistics and Intraclass Correlation Coefficients for Study Variables*

	<i>M</i>	<i>SD</i>	<i>ICC</i>	<i>Min</i>	<i>Max</i>
1. Daily accelerometer wear time (min/day)	594.13	115.27	-	-	-
2. Daily SB (% waking time)	58.58	13.44	0.93	-	-
3. Person-mean SB (%)	59.15	10.70	-	-	-
3. Daily light PA (% waking time)	35.80	11.61	0.90	-	-
4. Person-mean light PA (%)	35.43	8.79	-	-	-
5. Daily MVPA (% waking time)	5.62	5.92	0.78	-	-
6. Person-mean MVPA (%)	5.42	3.72	-	-	-
7. Daily bodily pain (scale range = 1-4)	1.24	0.47	0.87	1	4
8. Daily fatigue (scale range = 1-4)	1.59	0.71	0.87	1	4
9. Typical physical health (scale range = 0-100)	80.95	17.59	-	21.67	100
10. Typical PA	140.57	58.11	-	43.21	330
11. Typical SB (min/day)	470.37	216.20	-	570	8,340
11. Typical pain (scale range = 1-5.5)	1.79	0.83	-	1	4.50
12. Typical fatigue (scale range = 20-100)	39.21	13.57	-	20	81
14. BMI (kg/m ²)	25.14	3.44	-	-	-
15. Age (years)	70.98	6.87	-	-	-

586

587 *Note.* Unstandardized estimates were used to calculate descriptive statistics.

Predictor Variable	Parameter Estimate (SE)	
	Model 1 bodily pain	Model 2 fatigue
Fixed Effects	β (SE)	β (SE)
Intercept	-0.136 (0.285)	-0.437 (0.309)
Daily light PA	0.151** (0.058)	0.029 (0.061)
Person-mean light PA	-0.064 (0.136)	0.080 (0.144)
Daily MVPA	0.110* (0.048)	0.044 (0.053)
Person-mean MVPA	-0.202 (0.156)	-0.005 (0.171)
Daily light PA x typical bodily pain	0.100 (0.075)	-
Daily MVPA x typical bodily pain	-0.090 (0.051)	-
Daily light PA x typical fatigue	-	-0.240** (0.072)
Daily MVPA x typical fatigue	-	-0.254*** (0.061)
Daily light PA x typical physical health	-0.014 (0.074)	-0.154 (0.084)
Daily MVPA x typical physical health	-0.030 (0.058)	-0.164* (0.076)
Typical PA	0.012 (0.083)	-0.122 (0.091)
Typical pain	0.543*** (0.113)	-
Typical fatigue	-	0.263* (0.119)
Typical physical health	-0.070 (0.105)	0.006 (0.131)
BMI	-0.097 (0.089)	0.151 (0.097)
Age	-0.155 (0.102)	0.132 (0.113)
Cardiovascular disease	0.040 (0.178)	0.483* (0.190)
Gender	0.063 (0.240)	0.308 (0.248)
Cohabiting	0.139 (0.193)	-0.076 (0.211)
Random Effects		

Intercept	0.283*** (0.079)	0.369*** (0.093)
Residual (AR1 diagonal)	0.434*** (0.041)	0.492*** (0.043)
-2 restricted log likelihood	798.796	857.948
Akaike information criterion	804.796	863.948
R_1^2	0.528	0.210

590

591 *Note.* * $p < .05$, ** $p < .01$, *** $p < .000$.

593 *Multilevel Modelling Coefficients of SB Predicting Daily Pain and Fatigue*

Predictor Variable	Parameter Estimate (SE)	
	Model 3 bodily pain	Model 4 fatigue
Fixed Effects	β (SE)	β (SE)
Intercept	-0.121 (0.281)	-0.373 (0.315)
Daily SB	-0.182** (0.061)	-0.050 (0.065)
Person-mean SB	0.171 (0.130)	-0.047 (0.143)
Daily SB x typical bodily pain	-0.015 (0.076)	-
Daily SB x typical fatigue	-	0.336*** (0.080)
Daily SB x typical physical health	0.052 (0.077)	0.212* (0.096)
Typical sedentary time	-0.102 (0.086)	-0.035 (0.096)
Typical pain	0.515*** (0.109)	-
Typical fatigue	-	0.274* (0.120)
Typical physical health	-0.063 (0.102)	0.009 (0.133)
BMI	-0.064 (0.084)	0.142 (0.094)
Age	-0.128 (0.095)	0.136 (0.107)
Cardiovascular disease	0.029 (0.174)	0.489* (0.191)
Gender	0.110 (0.229)	0.299 (0.246)
Cohabiting	0.083 (0.196)	-0.174 (0.221)
Random Effects		
Intercept	0.271*** (0.075)	0.378*** (0.093)
Residual (AR1 diagonal)	0.436*** (0.040)	0.494*** (0.043)
-2 restricted log likelihood	789.974	850.538
Akaike information criterion	795.974	856.538
R_1^2	0.548	0.191

594 *Note.* * $p < .05$, ** $p < .01$, *** $p < .0$