

# Drivers of productivity: Being physically active increases yet sedentary bouts and lack of sleep decrease work ability

Marco Giurgiu<sup>1,2</sup>  | Rebecca Nissen<sup>1</sup> | Gerhard Müller<sup>3</sup> | Ulrich W. Ebner-Priemer<sup>1,2</sup> | Markus Reichert<sup>1,2</sup> | Bronwyn Clark<sup>4</sup>

<sup>1</sup>Department of Sports and Sports Science, Mental mHealth Lab, Karlsruhe Institute of Technology (KIT, Karlsruhe, Germany

<sup>2</sup>Department of Psychiatry and Psychotherapy, Central Institute of Mental Health, Medical Faculty Mannheim, Heidelberg University, Heidelberg, Germany

<sup>3</sup>Department of Health Promotion, AOK Baden-Wuerttemberg, Stuttgart, Germany

<sup>4</sup>School of Public Health, The University of Queensland, Brisbane, QL, Australia

## Correspondence

Marco Giurgiu, Karlsruhe Institute of Technology (KIT), Department of Sports and Sports Science, Hertzstr. 16, Karlsruhe 76187, Germany.  
Email: marco.giurgiu@kit.edu

Physical behavior (ie, physical activity, sedentary behavior, and sleep) is a crucial lifestyle factor for preventing and managing diseases across the lifespan. However, less is known about potential work-related psychological and cognitive outcomes such as productivity. The present study examined within-person associations between physical behavior and self-perceived work ability. To investigate the degree to which physical behavior parameters influence self-perceived work ability in everyday life, we conducted an Ambulatory Assessment study in 103 university students over 5 days. Physical behavior was assessed continuously via a multi-sensor system. Self-perceived work ability was assessed repeatedly up to six times per day on smartphones. We employed multilevel modeling to analyze the within-person effects of physical behavior on self-perceived work ability. Physical activity intensity (MET) ( $\beta = 0.15 \pm 0.06$ ,  $t = 2.59$ ,  $p = 0.012$ ) and sit-to-stand transitions ( $\beta = 0.07 \pm 0.03$ ,  $t = 2.44$ ,  $p = 0.015$ ) were positively associated with self-perceived work ability. Sedentary bouts ( $\geq 20$  min) ( $\beta = -0.21 \pm 0.08$ ,  $t = -2.74$ ,  $p = 0.006$ ) and deviation from a recommended sleep duration (ie, 8 h) ( $\beta = -0.1 \pm 0.04$ ,  $t = -2.38$ ,  $p = 0.018$ ) were negatively associated with self-perceived work ability. Exploratory analyses supported the robustness of our findings by comparing various time frames. Total sedentary time and sleep quality were not associated with self-perceived work ability. Regular sleep durations, breaking up sedentary time through sit-to-stand transitions, and higher intensities of physical activity may be important for the regulation of self-perceived work ability in university students' daily lives.

## KEYWORDS

accelerometry, ambulatory assessment, physical behavior, self-perceived work ability

## 1 | INTRODUCTION

It is well recognized that the behaviors people engage in over the whole 24-h cycle (sedentary behavior, activity, and sleep) have health consequences. Sedentary behavior,

defined as any waking behavior characterized by an energy expenditure  $\leq 1.5$  metabolic equivalents (MET), while in a sitting, reclining or lying posture,<sup>1</sup> is negatively associated with several physical and mental health outcomes (eg, cardiovascular diseases, diabetes, cancer, or depression).<sup>2</sup> In

contrast, physical activity has beneficial associations with health and mortality<sup>3</sup> and sleep duration shows bi-directional associations with health, for example, short sleep duration has been associated with mortality.<sup>4</sup> As these behaviors are mutually exclusive, there has been a call for movement studies to take into account all these components of activity within the 24-h cycle.<sup>5</sup>

Physical behaviors also have potential psychological and cognitive outcomes. For example, in office workplaces where high sedentary time has been particularly noted as an issue,<sup>6</sup> researchers have been interested in how increasing standing and movement at work impacts work-related variables. Findings indicate that replacing sitting with standing time through sit-to-stand workstations,<sup>7</sup> reducing total sitting time,<sup>8</sup> and increasing physical activity in sedentary workers<sup>9</sup> improves a broad range of work outcomes including productivity, absenteeism, work limitations, presenteeism, and cognitive function. Additionally, studies have indicated that higher physical activity intensity as well as sleep duration and quality might be associated with occupational outcomes such as productivity and presenteeism.<sup>10</sup> University students are another group prone to engaging in large quantities of sedentary behavior,<sup>11</sup> and there has been recent interest in how students' physical behaviors affect cognitive abilities and productivity.<sup>12</sup> Physical activity has been positively associated with productivity<sup>13</sup> and academic performance.<sup>14</sup> Likewise, sleep quality and duration has been related to academic performance and productivity.<sup>15</sup>

One central concept within the range of productivity parameters of interest is work ability. According to Ilmarinen & Tuomi,<sup>16</sup> work ability can be understood as "how good is the worker at present, in the near future, and how able is he/she to do his/her work with respect to the work demands, health, and mental resources." In simple terms, work ability is the interaction of the workers' resources and his/her work demands. From a theoretical perspective, the concept of work ability is embedded in a so-called "house of work ability" including an interrelationship between conditions inside (eg, functional capacity, professional competence, values) and outside (eg, society, family, social network) the work setting.<sup>16</sup>

Work ability is important as a measure of how workers can cope with the demands of the job and has been shown as a predictor for how long workers will remain at work.<sup>17</sup> Although work ability was originally conceptualized to increase the longevity of an aging work force, it is a crucial concept throughout life, as it has shown associations with individual characteristics, lifestyle, demands at work, risk of sickness absence,<sup>18</sup> long-term disability,<sup>19</sup> and long-term unemployment even in young adults.<sup>20,21</sup> Exploring the association between lifestyle factors such as physical behavior and work ability among university students may inform

interventional and educational programs to prepare the next generation of workers concerning work demands.

Engaging in physical activity either during leisure time or in the work setting has shown a beneficial effect on work ability. A scoping review, published by Lusa and colleagues,<sup>9</sup> of randomized control trials ( $N = 25$ ) aimed at increasing physical activity or decreasing sedentary time, showed beneficial effects on work ability. However, none of these studies focused on potential within-person associations between physical behavior and work ability. The relationship between physical behaviors and work engagement is likely to be complex. Employers have expressed concern that workers spending less time sitting and more time active at work may take time away from work tasks thereby reducing work ability.<sup>22</sup> However, the positive aspects of breaking up sitting time and being more physically active on cognitive function by increasing cerebral blood flow and regulating hormonal fluctuations counter that argument.<sup>23</sup> Furthermore, sleep parameters (ie, duration and quality) have been associated with work ability.<sup>10</sup> However, there is only sparse evidence on the association between sedentary behavior and work ability. One study found a slight decrease in work ability in the control group but not in the intervention group who reduced sedentary workplace time.<sup>24</sup> Further research is warranted, taking all daily physical behaviors (comprising sleep, sedentary behavior, and physical activity) into account.<sup>5</sup>

Thus far, the literature has focused on the association between physical behavior and work ability aggregated at the person or group level. To the best of our knowledge, there are currently no studies that have examined a possible within-person association. Studies on work ability in relation to physical behavior typically do not account for the fact that work ability and productivity—as well as the posture and level of activity people engage in—are not static and enduring qualities, but vary across the day and within individuals.<sup>25</sup> To overcome this limitation and to investigate whether physical behavior in everyday life increases or decreases self-perceived work ability, we conducted an ambulatory assessment (AA) study. AA is currently the state-of-the-art methodology for examining the within-person associations between physical behavior and psychological parameters.<sup>26</sup> AA has several advantages, namely assessment in everyday life, in real-time, with device-based methods and repeated measurements with a high sampling frequency, which enables researchers to track dynamic relationships. In our study, we used three accelerometers as a multi-sensor system to assess all components of physical behavior. In addition, we assessed self-perceived work ability repeatedly (approximately 30 times) to enable dynamic within-person analyses.

Based on previous intervention and cross-sectional studies of occupational outcomes,<sup>6–10</sup> we hypothesized that higher sleep quality [1a] would positively predict self-perceived

work ability and a deviation of a recommended sleep duration (ie, sleep duration of 8 h) [1b] would negatively predict self-perceived work ability. Furthermore, we expected that sedentary time [2a] and sedentary bouts [2b] would negatively influence self-perceived work ability. Finally, we expected that increased intensity of physical activity [3a] and an increased number of sit-to-stand transitions [3b] would positively influence self-perceived work ability. Moreover, we conducted explorative analyses on the time course of the effects.

## 2 | MATERIALS AND METHODS

### 2.1 | Participants

One hundred and three university students from various courses of study were recruited between September 2019 and March 2020. Only participants without restrictions to performing their daily activities (ie, those without diseases or injury) were included in the study. Five participants were excluded from the analyses due to compliance reasons, that is, either <30% responses to the e-diary prompts<sup>27</sup> and/or <3 valid days of minimum  $\geq 10$  h per day accelerometer wear time.<sup>28</sup> Thus, the final sample consisted of 98 participants (55.1% female), with a mean age of  $22.1 \pm 2.8$  years and a mean body mass index (BMI) of  $22.3 \pm 2.1$  kg/m<sup>2</sup> (for details see Table 1). All eligible participants received oral and written information regarding the study procedures before written informed consent was obtained. Participants were free to withdraw from the study at any time. The Ethics Committee of the Karlsruhe Institute of Technology (KIT) approved this study.

### 2.2 | Study design and measures

Participants took part in an AA study over five consecutive days (Wednesday to Sunday). During this time frame, participants were instructed to wear accelerometers at distinct positions (ie, attached at wrist, hip, and thigh) continuously for 24 h per day and answer e-diaries on a provided phone. The Move 4 accelerometer (movisens GmbH, Karlsruhe, Germany, movisens.com) captured physical behavior with a range of  $\pm 16$  g and a sampling frequency of 64 Hz. Raw acceleration data were stored on an internal memory card and were processed by a band-pass filter (0.25–11 Hz) to eliminate artifacts. Previous studies have shown that the Move accelerometer is appropriate to assess all aspects of physical behavior.<sup>29–31</sup> To parameterize physical behavior, we calculated various parameters (eg, steps, energy expenditure, sleep/wake time, sedentariness) in 1-minute interval by using the proprietary software DataAnalyzer (version 1.13.7; movisens.com). Based on these parameters and following the terminology of the Sedentary Behavior Research Network (SBRN),<sup>1</sup> each minute of the data file was classified as either sleep, sedentary behavior, or physical activity. In our analyses, we included the following parameters obtained from the activity monitor and e-diary data: (i) sleep quality: participants rated each morning their self-perceived sleep quality [scale 0–100] via e-diary assessment; (ii) deviation of a recommended sleep duration (ie, 8 h): sleep duration of the previous night in h; (iii) sedentary behavior: aggregated sedentary minutes within the time frame of 30 min prior to each e-diary prompt; (iv) sedentary bouts: period of uninterrupted sedentary time ( $\geq 20$  min of uninterrupted sedentary time vs. bouts with at least one sedentary break); (v) physical activity intensity: aggregated metabolic equivalents (MET's) within

**TABLE 1** Participants characteristics ( $n = 98$ )

Variable	n, Mean $\pm$ SD <sup>1</sup>	Minimum	Maximum
Female [%]	$n = 54; 55.1\%$	–	–
Age [yrs.]	$22.12 \pm 2.76$	17	32
BMI [kg/m <sup>2</sup> ]	$22.25 \pm 2.15$	16.33	27.14
Answered e-diary Assessments [per day] <sup>a</sup>	$4.8 \pm 1.0$	1.8	6.2
Self-perceived work ability [0–10] <sup>a</sup>	$6.36 \pm 1.4$	3.12	9.39
Wear Time Accelerometer [h/day] <sup>b</sup>	$22.86 \pm 2.05$	12.55	24
Sedentary time [h/day] <sup>b</sup>	$9.7 \pm 2.2$	2.58	14.99
Sedentary bouts ( $\geq 20$ min) [per day] <sup>b</sup>	$8.24 \pm 2.7$	0	12.8
Sit-Stand transitions [per day] <sup>b</sup>	$32.27 \pm 9.3$	2.2	51
Physical activity duration [h/day] <sup>b</sup>	$6.25 \pm 2.42$	1.53	14.87
Physical activity intensity (MET) [per day] <sup>b</sup>	$2.29 \pm 0.36$	1.64	4.01
Sleep quality [0–100] <sup>b</sup>	$69.71 \pm 13.77$	17.5	100
Sleep duration [h/day] <sup>b</sup>	$7.74 \pm 0.85$	5.69	10.70

<sup>1</sup>standard deviation.

<sup>a</sup>assessed via e-diary, aggregated within participants.

<sup>b</sup>aggregated within participants and days.

the time frame of 30 min prior to each e-diary prompt; and (vi) sit-to-stand transitions: aggregated number of transitions within the time frame of 30 min prior to each e-diary prompt.

Participants were loaned a study smartphone (Nokia 6, Nokia Corporation, Espoo, Finland, nokia.com). The smartphone prompted the participants to complete e-diaries up to six times per day via an acoustic, visual, and vibration signal on workdays between 8.00 am and 9.30 pm and on weekend days between 9.30 am and 10 pm. The participants had the opportunity to postpone an e-diary prompt for a maximum of 15 minutes.

To optimize the assessment between physical behavior and momentary experiences, we implemented a mixed-sampling strategy using software movisensXS (version 0.7.47574; xs.movisens.com). In particular, we used accelerometer triggered e-diaries, that is, the thigh sensor analyzed and transferred data on body position and movement acceleration via Bluetooth Low Energy (BLE) to the smartphone in real-time. We implemented both a sedentary triggered algorithm,<sup>32</sup> that is, 30 consecutive minutes in a sitting/lying body position, as well as an activity algorithm,<sup>33</sup> that is, participants were triggered if ten consecutive minutes of 0.22 g movement acceleration intensity were detected. Additionally, to maximize variance, we implemented random prompts at various time points throughout the day. Each trigger condition (sedentary, physical activity, and random) was triggered until two were answered, resulting in a maximum of six e-diary assessments per day. To minimize participant's burden, we implemented so-called time-out phases of 50 min, that is, after an e-diary assessment, there will be no further e-diary assessment for the next 50 min.

To assess momentary self-perceived work ability, we used the following single item from the Work Ability Index (WAI): "Assume that your work ability at its best has a value of 10 points. How many points would you give your current work ability? (0 means that you cannot currently work at all)." This item was presented on electronic smartphone diaries on a visual analog scale (0–10) in German translation.<sup>34</sup> Earlier studies revealed high convergent validity between the used item and the whole WAI.<sup>35,36</sup> To minimize retrospective distortions, we assessed self-perceived work ability multiple times per day in daily life with a cutting-edge approach. Prior to the AA study, participants received an extensive briefing on the use of the devices and completed a paper-pencil survey (including the long version of the WAI [0–49] and basic demographic questions).

### 2.3 | Data preprocessing and statistical analyses

We merged the physical behavior data with momentary experiences by using DataMerger (version 1.8.0; movisens.com). To analyze within-person effects of physical behavior on momentary self-perceived work ability, we conducted

multilevel analyses.<sup>37</sup> We set up a two-level model with repeated measurements (level 1) nested within participants (level 2). First, we estimated the intraclass correlation coefficient (ICC) of the outcome (ie, self-perceived momentary work ability) to indicate the amount of variance on the within- vs. between-person level by calculating unconditional (null-) models. Second, we added the time-variant and time-invariant predictors time [h], time-squared [ $h^2$ ], age [years], sex [female vs. male], day [weekend day vs. weekday], and WAI [0–49] as between-level parameter to our model as covariates. The predictor time of day (squared) was included in the main model to control for potential non-linear (quadratic) time effects. We centered the time-variant level-1 predictors on a personal level. Third, to avoid issues such as multicollinearity or shared variance, we calculated a separate model for each physical behavior parameter (ie, six models adding sleep quality [0–100], sleep duration [deviation of 8 h], sedentary time [0–30 min], sedentary bouts [ $\geq 20$  min], physical activity [MET], and sit-stand transitions [numbers], respectively). Forth, we selected significant predictors from the previous six models to analyze the independence between the main predictors. We specified our models by using restricted maximum likelihood (REML) as the model estimator and unstructured as covariance structure. The equation of the models is presented in the supplementary materials (S1). Model assumptions were checked for multicollinearity and whether the residuals of the models were normally distributed. To compare each predictor's effects, we calculated standardized beta coefficients (stand.  $\beta$ ) following established procedures.<sup>38</sup> To compare the model fit, we used the  $-2\Delta LL$  likelihood ratio test. To calculate the proportion of explained total outcome variance, we used the predicted outcome's squared correlation ( $R^2$ ) with the fixed effects and actual values.<sup>37</sup> Finally, we conducted exploratory analyses of the time courses of the effects of sedentary time, physical activity intensity, and sit-to-stand transitions on self-perceived work ability. For this purpose, we entered varying predictors of different cumulative time frames/aggregation levels (5, 10, 20, 25, 30, 35, 40, 50, 60, 70, 80, 90, and 100 mins) prior to each e-diary entry. All analyses were conducted using SPSS (version 26, IBM). We set the  $\alpha$  level to 0.05 for all analyses.

## 3 | RESULTS

The 98 participants were prompted 3,435 times (ie,  $6.3 \pm 2$  prompts/participant/day on average; Range: 1.8–9.4) across the study period of 5 days. Overall, 67.3% ( $n=2,311$ ) of all prompts were answered, ranging from 30% to 96.9% answered prompts on a participant level. Approximately 31.1% ( $n = 1068$ ) of all prompts occurred at random time points, and 68.9% ( $n= 2,367$ ) were triggered by real-time



algorithms (ie, either remaining in a sitting bout ( $\geq 30$  min) or being active for 10 consecutive min). Participants reported average work ability scores of  $6.36 \pm 1.4$  [scale 0–10]. The aggregated momentary work ability scores significantly correlated with the total WAI ( $r_s = 0.459$ ;  $p < 0.001$ ) on a between-person level, indicating convergent validity. The ICC revealed that 59% ( $\rho I = 0.41$ ) of the variance was due to within-person fluctuations. On average, accelerometers were worn for  $22.86 \pm 2.05$  h/participant/day. Of those times, participants spent on average 9.7 h/day in sedentary behavior, 7.7 h/day while sleeping with self-reported quality of 69.71 [scale 0–100], and 6.25 h/d while in an upright posture with an average movement intensity of 2.29 MET. The categorization of sedentary time into bouts shows that 51.7% of all bouts were short bouts ( $\leq 5$  min), 28.3% were short-to-moderate bouts (5–19 min), 11.1% were moderate-to-long bouts (20–39 min), and 8.9% long bouts ( $\geq 40$  min).

### 3.1 | Effects of physical behavior on self-perceived work ability

In the first model, we included only the covariates: sex, age, BMI, weekday, time, time-squared, and WAI. Across all eight models, we found stable significant effects for the predictors sex (stand.  $\beta = -0.15$ ,  $t = -2.31$ ,  $p = 0.023$ ) and WAI (stand.  $\beta = 0.32$ ,  $t = 5.3$ ,  $P = <0.001$ ). In comparison with males, females reported significantly less work ability by 0.62 units [scale 0–10]. Further, one unit's increase of the WAI score [scale 0–49] was significantly associated with higher momentary self-perceived work ability rating of 0.15 units. The day of week was significantly associated with self-reported work ability in model 1 (stand.  $\beta = -0.04$ ,  $t = 2.32$ ,  $p = 0.02$ ), that is, compared to weekday, participants reported less work ability on weekend days by 0.15 units. However, the association was not significant across all models, thus indicating it was not a stable effect. We found that time (stand.  $\beta = 0.25$ ,  $t = 3.65$ ,  $p < 0.001$ ) and time-squared (stand.  $\beta = -0.34$ ,  $t = -5.38$ ,  $p < 0.001$ ) significantly influenced work ability in both positive and negative directions. In practice, the reported level of work ability followed a reverse u-shaped trajectory, that is, an increasing level until approximately 1 pm, followed by a subsequent decrease until the end of the day. Moreover, time of the day showed significant random effects ( $p < 0.001$ ). In other words, the effects of time of day on self-perceived work ability varied significantly between participants, that is, participants showed different within-person effects of time of day on self-perceived work ability. None of the time-invariant predictors age (stand.  $\beta = -0.02$ ,  $t = 0.25$ ,  $p = 0.8$ ) and BMI (stand.  $\beta = -0.06$ ,  $t = -0.9$ ,  $p = 0.37$ ) influenced self-reported work ability.

Sleep. In models 2 and 3, we added the predictors of sleep quality and sleep duration to model 1, respectively. The model fit of the outcome self-perceived work ability improved by adding sleep quality  $-2\Delta LL(4) = 1525.4$ ;  $p < 0.001$ ) but not by adding sleep duration  $-2\Delta LL(1) = 1.4$ ;  $p = 0.24$ ). In contrast to our expectations, we found no significant associations between sleep quality and self-perceived work ability (stand.  $\beta = 0.01$ ,  $t = 0.22$ ,  $p = 0.82$ ). However, the results revealed a significant random effect of sleep quality ( $p = 0.004$ ). In other words, the effects of sleep quality on self-perceived work ability varied significantly between participants, that is, participants did show different within-person effects of sleep quality on self-perceived work ability. As hypothesized (hypothesis 1b), deviation from regular sleep duration of 8 h (stand.  $\beta = -0.04$ ,  $t = -2.43$ ,  $p = 0.015$ ) negatively predicted self-perceived work ability. In practice, a deviation from recommended sleep duration (ie, sleep duration of 8 h) of  $\pm 1$  h reduced self-reported work ability by 0.1 units. The effect was stable when adding further physical behavior predictors (model 8), thus indicating statistical independence.

Sedentary behavior. In models 4 and 5, we added the predictors of sedentary time and sedentary bouts to model 1, respectively. The model fit of the outcome self-perceived work ability reduced significantly in model 4 ( $-2\Delta LL(1) = 9.4$ ;  $p = 0.0022$ ) and improved significantly in model 5 ( $-2\Delta LL(1) = 51.7$ ;  $p < 0.001$ ). Sedentary time during 30 min prior to the e-diary prompt did not significantly predict self-perceived work ability (stand.  $\beta = -0.01$ ,  $t = 0.47$ ,  $p = 0.64$ ). Thus, hypothesis 2a was not verified. However, sedentary bouts ( $\geq 20$  min) negatively influenced self-perceived work ability (stand.  $\beta = -0.04$ ,  $t = -2.72$ ,  $p = 0.007$ ) compared with interrupted bouts, that is, being sedentary for 20 min or longer without interruption was associated with lower prospective work ability. The negative effect of sedentary bouts was not stable when adding additional physical behavior parameters (model 8), indicating interrelatedness between sleep, physical activity, and sedentary behavior.

Physical activity. In models 6 and 7, we added the predictors of physical activity intensity and numbers of sit-to-stand transitions to model 1, respectively. The model fit of the outcome self-perceived work ability improved significantly in both models (ie, model 6:  $-2\Delta LL(4) = 759.8$ ;  $p < 0.001$ ; model 5:  $-2\Delta LL(1) = 115.5$ ;  $p < 0.001$ ). As hypothesized (hypotheses 3a and 3b), physical activity intensity (stand.  $\beta = 0.06$ ,  $t = 2.75$ ,  $p = 0.008$ ) and the number of sit-and-stand transitions (stand.  $\beta = 0.04$ ,  $t = 2.37$ ,  $p = 0.018$ ) positively predicted self-perceived work ability. In practice, increasing intensity by 1 MET and increasing number of sit-to-stand transitions by 1 transition during 30 minutes prior to the e-diary improved work ability by 0.15 and 0.07 units. Moreover, physical activity intensity showed significant random effects ( $p = 0.025$ ). In other words, the effects of physical activity intensity on self-perceived work ability vary significantly

TABLE 2 Multilevel model analyses to predict self-perceived work ability: fixed and random effects

	Covariate model		Sleep models		Sedentary behavior models			Physical activity models		Physical behavior model
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8		
	b (SE) <sup>1</sup>	b (SE)	b (SE)	b (SE)	b (SE)	b (SE)	b (SE)	b (SE)	b (SE)	
Fixed effects										
Intercept, $\beta_{00}$	1.94 (2.02)	1.66 (2.29)	1.95 (2.01)	1.93 (2.02)	2.16 (2.01)	2.25 (2.04)	1.98 (2.04)	2.28 (2.05)		
Sex <sup>a</sup> , $\beta_{01}$	-0.63 (0.27)*	-0.6 (0.29)*	-0.66 (0.27)*	-0.62 (0.27)*	-0.65 (0.27)*	-0.69 (0.27)*	-0.63 (0.27)*	-0.69 (0.27)*		
Age, $\beta_{02}$	-0.01 (0.05)	-0.01 (0.05)	-0.01 (0.05)	-0.01 (0.05)	-0.02 (0.05)	-0.03 (0.05)	-0.01 (0.05)	-0.03 (0.05)		
BMI, $\beta_{03}$	-0.06 (0.06)	-0.04 (0.07)	-0.06 (0.06)	-0.06 (0.06)	-0.06 (0.06)	-0.05 (0.06)	-0.06 (0.06)	-0.05 (0.06)		
WAI, $\beta_{04}$	0.15 (0.03)**	0.15 (0.03)**	0.15 (0.03)**	0.15 (0.03)**	0.15 (0.03)**	0.15 (0.03)**	0.15 (0.03)**	0.15 (0.03)**		
Sleep quality, $\beta_{10}$	-	0.001 (0.003)	-	-	-	-	-	-		
Sleep duration, $\beta_{10}$	-	-	-0.1 (0.04)*	-	-	-	-	-	-0.12 (0.04)**	
Sedentary time, $\beta_{10}$	-	-	-	-0.002 (0.003)	-	-	-	-	-	
Sedentary bouts <sup>b</sup> , $\beta_{10}$	-	-	-	-	-0.21 (0.08)**	-	-	-	-0.04 (0.1)	
Physical activity intensity, $\beta_{10}$	-	-	-	-	-	0.15 (0.06)**	-	-	0.12 (0.06)	
Sit-to-Stand transitions, $\beta_{10}$	-	-	-	-	-	-	0.07 (0.03)*	-	0.04 (0.04)	
Time of day, $\beta_{20}$	0.13 (0.04)**	0.14 (0.04)**	0.13 (0.04)**	0.13 (0.04)**	0.12 (0.04)**	0.08 (0.04)*	0.12 (0.04)**	0.07 (0.04)*		
Time of day squared, $\beta_{30}$	-0.01 (0.002)**	-0.013 (0.002)**	-0.01 (0.002)**	-0.01 (0.002)**	-0.01 (0.002)**	-0.01 (0.002)**	-0.01 (0.002)**	-0.01 (0.002)**		
Weekend day, $\beta_{40}$	-0.16 (0.07)*	-0.1 (0.08)	-0.13 (0.07)*	-0.16 (0.07)*	-0.16 (0.07)*	-0.13 (0.07)	-0.15 (0.07)*	-0.09 (0.07)		
Random effects										
Intercept, $u_0$	1.64 (0.3)**	1.73 (0.33)**	1.65 (0.3)**	1.64 (0.3)**	1.63 (0.3)**	1.58 (0.3)**	1.69 (0.31)**	1.64 (0.31)**		
Time of day, $u_2$	0.02 (0.02)**	0.02 (0.003)**	0.02 (0.004)**	0.02 (0.003)**	0.02 (0.003)**	0.02 (0.003)**	0.02 (0.003)**	0.02 (0.003)**		
Intercept and time	-0.08 (0.03)**	-0.08 (0.03)**	-0.08 (0.03)**	-0.08 (0.03)**	-0.08 (0.03)**	-0.07 (0.03)**	-0.08 (0.03)**	-0.07 (0.03)**		
Sleep quality, $u_3$	-	0.0004 (0.0001)**	-	-	-	-	-	-		
Intercept and sleep quality	-	0.001 (0.005)	-	-	-	-	-	-		
Sleep quality and time	-	0.001 (0.001)	-	-	-	-	-	-		
Physical activity intensity (PAI), $u_3$	-	-	-	-	-	0.1 (0.04)*	-	0.09 (0.04)*		
Intercept and PAI	-	-	-	-	-	-0.24 (0.08)**	-	-0.25 (0.08)**		
PAI and time	-	-	-	-	-	0.04 (0.01)**	-	0.04 (0.01)**		
Residual, $\tau$	2.2 (0.07)**	1.89 (0.07)**	2.2 (0.07)**	2.2 (0.07)**	2.16 (0.07)**	2.14 (0.07)**	2.19 (0.07)**	2.11 (0.07)**		

<sup>1</sup>Unstandardized estimates and standard errors.<sup>a</sup>compared to males.<sup>b</sup>compared to interrupted sedentary bouts.<sup>c</sup>compared to weekday.\* $p < 0.05$ ; \*\* $p < 0.01$ .

between participants, that is, participants showed different within-person effects of physical activity intensity on self-perceived work ability. The positive effects of physical activity intensity and sit-to-stand transitions were not stable when adding additional physical behavior parameters (model 8), indicating interrelatedness between sleep, physical activity, and sedentary behavior. All predictors explained 12.43% of the total outcome variance cumulatively.

**Physical behavior.** In the final model 8, only the main predictor of deviation from a recommended sleep duration (ie, sleep duration of 8 h) ( $p = 0.008$ ) and the covariates time-squared ( $p = 0.001$ ), WAI ( $p < 0.001$ ), and sex ( $p = 0.014$ ) remained significant. According to Arend and Schäfer's<sup>39</sup> rules of thumb for minimum detectable effect sizes, our data allow the detection of medium effects for within-person associations. Table 2

### 3.2 | Effects of physical behavior over time

To test our main hypotheses [2–3], we used 30-min segments of physical activity and sedentary behavior prior to each e-diary assessment. Since empirical evidence is lacking on the potential temporal associations between physical behavior and work ability, we computed a series of additional exploratory multilevel models across the smaller (5, 10, 15, 20 min) and graded (40–250 min) time frames.

**Physical activity.** Physical activity intensity prediction of self-perceived work ability (green line) was stable across distinct time frames. The standardized  $\beta$ 's were positive and significant, ranging from 0.063 (time frame: 25 min) to 0.116 (time frame: 200 min). Moreover, sit-to-stand transitions prediction of self-perceived work ability (orange line) was stable in all models except the models with the shorter timeframes (ie, 5, 10, and 25 min). The standardized  $\beta$ 's were positive and significant, ranging from 0.032 (time frame: 15 min) to 0.1 (time frame: 150 min). Interestingly, the positive effect of sit-to-stand transitions increased while focusing on graded time frames.

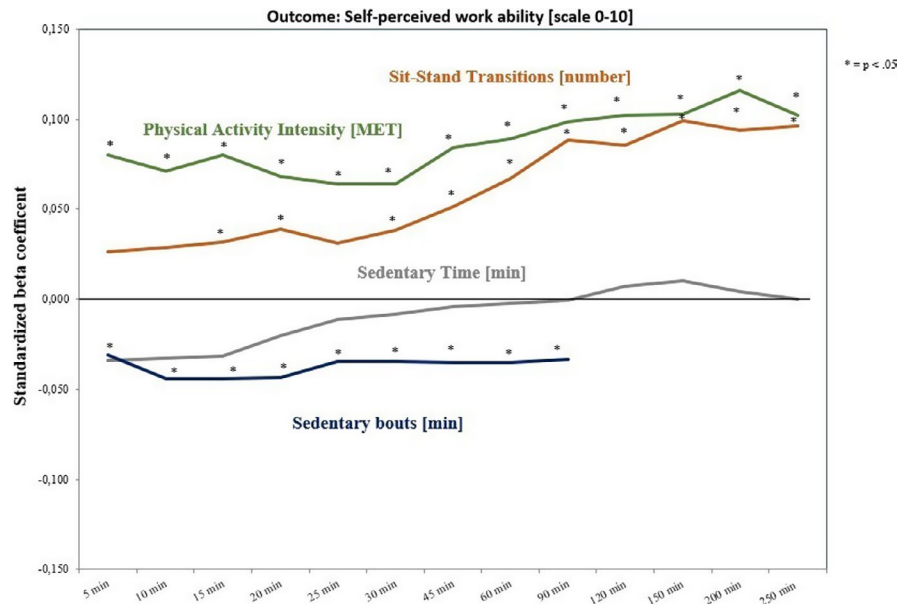
**Sedentary behavior.** We found in eight of nine models a significant negative effect of sedentary bouts on self-perceived work ability (blue line) with standardized  $\beta$ 's ranging from  $-0.044$  (time frame: 10 min) to  $-0.033$  (time frame: 90 min). Since the observed occasions of uninterrupted sedentary time  $\geq 90$  min was too low, we did not calculate the graded (120–250) time frame models. In contrast, sedentary time prediction of self-perceived work ability (gray line) showed significance in only one model, that is, the shortest time frame of 5 min (standardized  $\beta$ :  $-0.033$ ). Therefore, our previously presented results (hypothesis 2–3) are robust across different time frames and were not an artifact of a selected time frame (eg, 30 min). Figure 1.

## 4 | DISCUSSION

Using cutting-edge ambulatory assessment procedures, we here provide the first ecologically valid associations for positive within-person effects of physical activity intensity and sit-to-stand transitions, as well as adverse effects of sedentary bouts ( $\geq 30$  min) and deviation from a recommended sleep duration (ie, 8 h) on self-perceived work ability. Contrary to our hypotheses, we found no effects of total sedentary time and sleep quality on self-perceived work ability. These within-person findings are of tremendous value to guide future research and, importantly, if replicated, to inform intervention approaches since they unravel momentary real-life drivers of work ability. Put simply, they inform changes workers can make in their everyday life to increase work ability in subsequent periods.

Our findings that higher intensities of physical activity and a higher number of sit-to-stand transitions were positively associated with self-perceived work ability are in line with previous intervention studies,<sup>7,8</sup> which have shown that multi-component interventions (including organizational, environmental, and individual components) targeting increased activity and regular breaks in sedentary time result in productivity gain. Several psychophysiological mechanisms are reasonable to explain the findings. Sit-to-stand transitions and physical activities with higher intensities (eg, walking instead of standing) can promote blood flow,<sup>40</sup> which may lead to an increase of self-perceived work ability. Moreover, there is some evidence that regular physical activity through the workday (eg, using sit-to-stand workstations or integrating regular walking breaks) may reduce musculoskeletal pain<sup>41</sup> and thus lead to a long-term work ability gain. However, it is also likely that the effects of physical activity and sedentary behavior on work ability might be explained through components of well-being. The literature provides strong evidence that both waking behaviors (ie, sedentary behavior and physical activity) are associated with several psychological constructs such as stress or mood.<sup>42</sup> Our study revealed that prolonged sedentary bouts ( $\geq 20$  min) were negatively related to self-perceived work ability. Since an earlier study has found that sedentary bouts were negatively associated with feelings of energy,<sup>26</sup> it might be possible that a less energized state may also affect self-perceived work ability. Thus, further studies are needed to gather more in-depth insights into potential mediation between sedentary behavior, energetic arousal, and work ability.

There is broad evidence that insufficient sleep is associated with adverse mental and physical health conditions.<sup>10</sup> We found that a deviation from a recommended sleep duration of 8 h<sup>43</sup> was negatively associated with self-perceived work ability. In accordance with the present results, previous studies have shown that workers who sleep less than 6 h per



**FIGURE 1** Effects of sedentary time, sedentary bouts, physical activity, and sit-stand transitions on self-perceived work ability averaged within different time frames. The *x*-axis depicts the temporal aggregation level of sedentary time, sedentary bouts, physical activity, and sit-stand transitions in minutes, intensity level, or numbers prior to each e-diary prompt. For example, the value "30" represents the average sedentary time and the average acceleration aggregated within the 30 min prior to each e-diary prompt. The *Y*-axis depicts the standardized  $\beta$ s from the multilevel models for sedentary time, physical activity intensity, and sit-to-stand transitions to predict self-perceived work ability

day reported higher productivity loss than workers who sleep between 7 and 9 h.<sup>44</sup> Future studies are needed to explore the potential mechanisms between irregular sleep duration and self-perceived work ability. Contrary to expectations and existing findings,<sup>45</sup> sleep quality was not associated with self-perceived work ability. One possible reason for this null finding might be the assessment item. We used a single item to assess sleep quality, which might not be sensitive enough to detect changes in such a complex construct. A solution for future AA studies might be to add further sleep quality questions, for example, sleep latency or awakenings during the night.<sup>5</sup>

One advantage of using ecological momentary assessment measures in conjunction with 24-h monitoring is the ability to explore the time course of the relationship between variables. Our exploratory analyses on the time course of the effects of physical behaviors on work ability revealed some potential future applications. The findings suggest that physical activity intensity and more frequent sit-to-stand transitions may have longer-lasting benefits because the size of effect increased in graded time frame analyses. It should be noted that the level of activity the students displayed was largely at a level considered "light" (average 2.29 MET) in the activity continuum and such a level may be feasible to introduce into work and study environments. Moreover, we found that self-perceived work ability followed a u-shape trajectory in terms of fluctuating over the day. In particular, the level of self-perceived work ability increased until approximately 1 pm, followed by a

subsequent decrease until the end of the day. This may inform future intervention studies to consider the potential diurnal effects as well as encouraging students to restructure their work in line with a diurnal trajectory. These findings need to be confirmed in other samples, such as workers and in interventional studies.

After adding different physical behavior parameters in one single model, findings for most predictors lost significance. Only the deviation from a recommended sleep duration of 8 h remained statistically significant. It is difficult to explain this result, but it is possible that compared to physical activity and sedentary behavior, sleep duration may have the most decisive impact on self-perceived work ability. However, other explanations might be possible. Given the natural co-dependency between those behaviors, shared variance may result in a null finding. In particular, time spent in physical activity, sedentary behavior, and sleep can be added up to a finite sum of, for example, 24 h, 1440 min, or 100%.<sup>5</sup> This co-dependency lends itself to analyzing the interrelatedness of behaviors in a relative manner instead of individual entities. Over the last few years, compositional data analyses (CoDA) have become a popular statistical approach in occupational research.<sup>46</sup> However, we are not aware that any published study has integrated the CoDA-approach in multilevel analyses. Thus, given the detected natural co-dependency between physical behaviors on the effect of self-perceived work ability, future research endeavors might explore using the CoDA-approach for within-person analyses.



Several limitations of our work merit further discussion. First, we included university students as our target group, and thus, our results may have limited generalization to other populations such as white- or blue-collar workers. However, given the high variability of students' work time and tasks as well as a high variability of performed physical behaviors, they might be of particular interest to explore possible within-person associations between physical behaviors and self-perceived work ability in terms of maximizing outcome and predictor variance. Second, we cannot exclude residual confounders (eg, everyday life factors that affect productivity, such as social or nutritional behaviors, or drug consumption such as caffeine and alcohol). Third, we analyzed data from an observational study, which show an exact chronological order (eg, the sedentary time prior to an e-diary assessment). However, chronology comprises only one aspect of causality.<sup>47</sup> Thus, additional studies are needed to underpin a causal hypothesis, for example, to induce sit-to-stand transitions in daily life experimentally.<sup>48</sup> Fourth, we used a single-item measure to capture within-person associations between self-perceived work ability and physical behaviors. Although our data, as well as the literature,<sup>35,36</sup> provide evidence for convergent validity on a between-person level, the within-person reliability remains unclear. Future research endeavors should test the within-person reliability of the momentary self-perceived work ability measure with at least three items.<sup>49</sup> Fifth, we assessed work ability from a self-perceived perspective. In future studies, objective measures of work-related variables (eg, working memory) should be considered to confirm the relationships between physical behaviors and productivity more broadly.

#### 4.1 | Perspective

Using an innovative study design, we found within-person associations between physical behaviors and self-perceived work ability among university students. In particular, physical activity intensity and the number of sit-to-stand transitions were positively associated with self-perceived work ability, whereas sedentary bouts ( $\geq 30$  min uninterrupted) and deviation from a recommended sleep duration (ie, 8 h) were negatively associated with self-perceived work ability. These findings may inform future studies to consider both within-person and between-person level data collection and analyses in occupational groups. They also suggest value in further examination of the time course of the beneficial and negative outcomes of various physical behaviors.

#### ACKNOWLEDGEMENTS

The authors would like to thank all participants contributing to the study.

#### DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

#### ORCID

Marco Giurgiu  <https://orcid.org/0000-0001-6684-3463>

#### REFERENCES

1. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act*. 2017;14(1):75.
2. Saunders TJ, McIsaac T, Douillette K, Gaulton N, Hunter S, Rhodes RE. Sedentary behaviour and health in adults: an overview of systematic reviews. *Appl Physiol Nutr Metab*. 2020;45(10):S197-S217.
3. Woodcock J, Franco OH, Orsini N, Roberts I. Non-vigorous physical activity and all-cause mortality: systematic review and meta-analysis of cohort studies. *Int J Epidemiol*. 2011;40(1):121-138.
4. Itani O, Jike M, Watanabe N, Kaneita Y. Short sleep duration and health outcomes: a systematic review, meta-analysis, and meta-regression. *Sleep Med*. 2017;32:246-256.
5. Rosenberger ME, Fulton JE, Buman MP, et al. The 24-hour activity cycle: a new paradigm for physical activity. *Med Sci Sports Exerc*. 2019;51(3):454-464.
6. Thorp AA, Healy GN, Winkler E, et al. Prolonged sedentary time and physical activity in workplace and non-work contexts: a cross-sectional study of office, customer service and call centre employees. *Int J Behav Nutr Phys Act*. 2012;9:128.
7. Peterman JE, Healy GN, Winkler EA, et al. A cluster randomized controlled trial to reduce office workers' sitting time: effect on productivity outcomes. *Scand J Work Environ Health*. 2019;45(5):483-492.
8. Edwardson CL, Yates T, Biddle SJH, et al. Effectiveness of the stand more at (SMARt) work intervention: cluster randomised controlled trial. *BMJ*. 2018;363:k3870.
9. Lusa S, Punakallio A, Mänttari S, et al. Interventions to promote work ability by increasing sedentary workers' physical activity at workplaces - a scoping review. *Appl Ergon*. 2020;82:102962.
10. Ishibashi Y, Shimura A. Association between work productivity and sleep health: a cross-sectional study in Japan. *Sleep Health*. 2020;6(3):270-276. <https://doi.org/10.1016/j.sleh.2020.02.016>
11. Castro O, Bennie J, Vergeer I, Bosselut G, Biddle SJH. How sedentary are university students? A systematic review and meta-analysis. *Prev Sci*. 2020;21(3):332-343.
12. Castro O, Vergeer I, Bennie J, Cagas J, Biddle SJH. Using the behavior change wheel to understand university students' prolonged sitting time and identify potential intervention strategies. *Int J Behav Med*. 2021;28(3):360-371. <https://doi.org/10.1007/s12529-020-09926-0>
13. Nowak PF, Bożek A, Blukacz M. Physical activity, sedentary behavior, and quality of life among university students. *Biomed Res Int*. 2019; ;2019:1-10.
14. Haverkamp BF, Wiersma R, Vertessen K, van Ewijk H, Oosterlaan J, Hartman E. Effects of physical activity interventions on cognitive outcomes and academic performance in adolescents and young adults: A meta-analysis. *J Sports Sci*. 2020;38(23):2637-2660. <https://doi.org/10.1080/02640414.2020.1794763>

15. El Ansari W, Stock C. Is the health and wellbeing of university students associated with their academic performance? Cross sectional findings from the United Kingdom. *Int J Environ Res Public Health*. 2010;7(2):509-527.
16. Ilmarinen J, Past TK. Present and future of work ability. In: *Proceedings of the 1st International Symposium on Work Ability*. Tampere (Finland): Finnish Institute of Occupational Health; 2014:1-25.
17. Tuomi K, Ilmarinen J, Seitsamo J, et al. Summary of the Finnish research project (1981–1992) to promote the health and work ability of aging workers. *Scand J Work Environ Health*. 1997;23(Suppl 1):66-71.
18. Reeuwijk KG, Robroek SJW, Niessen MAJ, Kraaijenhagen RA, Vergouwe Y, Burdorf A. The prognostic value of the work ability index for sickness absence among office workers. *PLoS ONE*. 2015;10(5):e0126969.
19. Kinnunen U, Nätti J. Work ability score and future work ability as predictors of register-based disability pension and long-term sickness absence: a three-year follow-up study. *Scand J Public Health*. 2018;46(3):321-330.
20. van den Berg TIJ, Elders LAM, de Zwart BCH, Burdorf A. The effects of work-related and individual factors on the Work Ability Index: a systematic review. *Occup Environ Med*. 2009;66(4):211-220.
21. Lappalainen K, Manninen P, Räsänen K. Association among sociodemographic factors, work ability, health behavior, and mental health status for young people after prolonged unemployment. *Workplace Health Saf*. 2017;65(2):65-73.
22. Gilson ND, Burton NW, van Uffelen JGZ, Brown WJ. Occupational sitting time: employees' perceptions of health risks and intervention strategies. *Health Promot J Austr*. 2011;22(1):38-43.
23. Chandrasekaran B, Pesola AJ, Rao CR, Arumugam A. Does breaking up prolonged sitting improve cognitive functions in sedentary adults? A mapping review and hypothesis formulation on the potential physiological mechanisms. *BMC Musculoskelet Disord*. 2021;22(1):274.
24. Tobin R, Leavy J, Jancey J. Uprising: an examination of sit-stand workstations, mental health and work ability in sedentary office workers, Western Australia. *Work*. 2016;55(2):359-371.
25. Pedersen ESL, Danquah IH, Petersen CB, Tolstrup JS. Intra-individual variability in day-to-day and month-to-month measurements of physical activity and sedentary behaviour at work and in leisure-time among Danish adults. *BMC Public Health*. 2016;16(1):1222.
26. Giurgiu M, Koch ED, Ottenbacher J, Plotnikoff RC, Ebner-Priemer UW, Reichert M. Sedentary behavior in everyday life relates negatively to mood: an ambulatory assessment study. *Scand J Med Sci Sports*. 2019;29(9):1340-1351.
27. Delespaul PAEG. *Assessing schizophrenia in daily life: the experience sampling method*. Maastricht: Datawys/Universitaire Pers Maastricht; 1995.
28. Migueles JH, Cadenas-Sanchez C, Ekelund U, et al. Accelerometer data collection and processing criteria to assess physical activity and other outcomes: a systematic review and practical considerations. *Sports Med*. 2017;47(9):1821-1845.
29. Barouni A, Ottenbacher J, Schneider J, et al. Ambulatory sleep scoring using accelerometers-distinguishing between nonwear and sleep/wake states. *PeerJ*. 2020;8:e8284. <https://doi.org/10.7717/peerj.8284>
30. Anastasopoulou P, Tubic M, Schmidt S, Neumann R, Woll A, Härtel S. Validation and comparison of two methods to assess human energy expenditure during free-living activities. *PLoS ONE*. 2014;9(2):e90606. <https://doi.org/10.1371/journal.pone.0090606>
31. Giurgiu M, Bussmann JBJ, Hill H, et al. Validating accelerometers for the assessment of body position and sedentary behaviour. *Journal for the Measurement of Physical Behaviour*. 2020;3(3):253-263.
32. Giurgiu M, Niermann C, Ebner-Priemer U, Kanning M. Accuracy of sedentary behavior-triggered ecological momentary assessment for collecting contextual information: development and feasibility study. *JMIR Mhealth Uhealth*. 2020;8(9):e17852. <https://doi.org/10.2196/17852>.
33. Ebner-Priemer UW, Koudela S, Mutz G, Kanning M. Interactive multimodal ambulatory monitoring to investigate the association between physical activity and affect. *Front. Psychol*. 2013;3:596.
34. Hasselhorn HM, Freude G. *Der Work-ability-Index: Ein Leitfaden*. Bremerhaven: Wirtschaftsverl. NW, Verlag für Neue Wiss; 2007.
35. El Fassi M, Bocquet V, Majery N, Lair ML, Couffignal S, Mairiaux P. Work ability assessment in a worker population: comparison and determinants of Work Ability Index and Work Ability score. *BMC Public Health*. 2013;13(1):305.
36. Vänni K, Virtanen P, Luukkaala T, Nygård C-H. Relationship between perceived work ability and productivity loss. *Int J Occup Saf Ergon*. 2012;18(3):299-309.
37. Hoffman L. *Longitudinal analysis: Modeling within-person fluctuation and change*. New York: Routledge; 2015:340-341.
38. Hox JJ. *Multilevel analysis*, 2nd edn. New York: Routledge; 2010:392.
39. Arend MG, Schäfer T. Statistical power in two-level models: A tutorial based on Monte Carlo simulation. *Psychol Methods*. 2019;24(1):1-19.
40. Healy GN, Matthews CE, Dunstan DW, Winkler EAH, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003–06. *Eur Heart J*. 2011;32(5):590-597.
41. Dutta N, Walton T, Pereira MA. Experience of switching from a traditional sitting workstation to a sit-stand workstation in sedentary office workers. *Work*. 2015;52(1):83-89.
42. Biddle SJH. Physical activity and mental health: evidence is growing. *World Psychiatry*. 2016;15(2):175-176.
43. National Sleep Foundation. Sleep in America Poll. <https://www.sleepfoundation.org/sites/default/files/inline-files/2002SleepInAmericaPoll.pdf>. Accessed December, 22.
44. Hafner M, Stepanek M, Taylor J, Troxel WM, van Stolk C. Why sleep matters-the economic costs of insufficient sleep: a cross-country comparative analysis. *Rand Health Q*. 2017;6(4):11.
45. Marklund S, Mienna CS, Wahlström J, Englund E, Wiesinger B. Work ability and productivity among dentists: associations with musculoskeletal pain, stress, and sleep. *Int Arch Occup Environ Health*. 2020;93(2):271-278.
46. Gupta N, Rasmussen CL, Holtermann A, Mathiassen SE. Time-based data in occupational studies: the whys, the hows, and some remaining challenges in compositional data analysis (CoDA). *Ann Work Expo Health*. 2020;64(8):778-785.
47. Susser M. What is a cause and how do we know one? A grammar for pragmatic epidemiology. *Am J Epidemiol*. 1991;133(7):635-648.
48. Myin-Germeys I, Klippel A, Steinhart H, Reininghaus U. Ecological momentary interventions in psychiatry. *Curr Opin Psychiatry*. 2016;29(4):258-263.

49. Geldhof GJ, Preacher KJ, Zyphur MJ. Reliability estimation in a multilevel confirmatory factor analysis framework. *Psychol Methods*. 2014;19(1):72-91.

### SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

**How to cite this article:** Giurgiu M, Nissen R, Müller G, Ebner-Priemer UW, Reichert M, Clark B. Drivers of productivity: Being physically active increases yet sedentary bouts and lack of sleep decrease work ability. *Scand J Med Sci Sports*. 2021;00:1–11. <https://doi.org/10.1111/sms.14005>