

## ORIGINAL ARTICLE

# Number of steps and systolic blood pressure: Do work and leisure matter?

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The number of steps per day influences blood pressure and health. However, the association between steps at work and leisure and blood pressure is unknown. Thus, we aimed to investigate the association between the domain-specific number of steps and systolic blood pressure. A thigh-worn accelerometer was used to measure the steps of 694 workers over 1–5 consecutive days, separated into work and leisure domains using a self-reported diary. We linearly regressed steps at work, leisure and total day against systolic blood pressure, adjusting for age, sex, body mass index, smoking, and antihypertensive medication. Additionally, we stratified the analyses on job type (blue-collar or white-collar). The results of this cross-sectional analysis indicated a beneficial association between the number of steps (per 2000-step interval) and systolic blood pressure for the total day ( $-0.5$  mmHg;  $-1.0$  to  $-0.8$ , 95% CI,  $p < 0.05$ ) and work ( $-0.9$  mmHg;  $-1.5$  to  $-0.4$ , 95% CI,  $p < 0.05$ ), but not for leisure ( $+0.1$  mmHg;  $-0.7$  to  $0.9$ , 95% CI,  $p = 0.75$ ). Blue-collar workers took almost twice as many steps at work ( $9143 \pm \text{SD}3837$ ) as white-collar workers ( $5863 \pm \text{SD}3565$ ) and, after stratification on job type, we observed a beneficial association between the number of steps at work and systolic blood pressure among blue-collar workers ( $-1.1$  mmHg;  $-1.7$  to  $-0.4$ , 95% CI,  $p < 0.05$ ), but not for white-collar workers ( $-0.3$  mmHg;  $-1.7$  to  $1.1$ , 95% CI,  $p = 0.7$ ). These findings indicate that the number of steps at work, particularly among blue-collar workers, is beneficially associated with systolic blood pressure. Such findings support the potential of work (re)design to promote walking to improve blood pressure.

## KEYWORDS

accelerometer, domain, gait, health, occupation

## 1 | INTRODUCTION

The World Health Organization's (WHO) 2020 guidelines on physical activity and sedentary behaviors underline the health benefits from being active and the health risks

associated with being overly sedentary.<sup>1</sup> Walking—typically quantified by the number of steps—remains an important and feasible means to meet current physical activity guidelines and increase activity.<sup>2</sup> Walking is an activity accessible to a large proportion of the population all over the world,

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independent of skill level or access to equipment<sup>3</sup> and an activity associated with reduced cardiovascular disease and mortality risk.<sup>4,5</sup>

To date, the majority of research on the association between the number of steps and health has focused on the number of steps *per day* (total steps)<sup>6</sup> omitting information on domain. Domain, in this case, refers to whether activities occur during work or leisure hours.<sup>7</sup> This omission is in spite of evidence indicating large variation in the distribution of activity across domains in adult populations<sup>8</sup> and the evidence of evolving research indicating that associations between physical activity and health can differ depending on domain,<sup>7,9–13</sup> also known as the Physical Activity Paradox.<sup>7,9</sup> For example, walking at work has been shown to produce a higher heart rate than walking during leisure, perhaps indicating extra stimulus at work, which in turn, could explain the negative effect on health.<sup>14</sup> Thus, domain information may be of particular importance when considering adults from different job types, for example, white-collar workers who typically take fewer steps at work<sup>15</sup> and blue-collar workers who can often take a large number of steps at work.<sup>15,16</sup>

Hypertension—defined as high blood pressure of  $\geq 140$  mmHg systolic,  $\geq 90$  mmHg diastolic blood pressure, and/or current use of antihypertensive medication<sup>17</sup>—represents a globally relevant health indicator, prevalent in large portion of the adult population<sup>17</sup> and acting as a leading cause of myocardial infarction and stroke mortality worldwide.<sup>17</sup> Moreover, blood pressure is unlikely to be influenced by the established bidirectional association between physical activity and many other health indicators, such as BMI, making it a more suitable outcome measure for cross-sectional analyses.<sup>6</sup>

We are not aware of any studies, to date, investigating the domain-specific association between the number of steps and blood pressure. Therefore, we aimed to investigate this association among working adults involved in blue-collar and white-collar occupations. Our hypothesis was that the number of steps at work is associated with higher systolic blood pressure (ie, a positive association), while the number of steps at leisure is associated with lower systolic blood pressure (ie, a negative association).

## 2 | MATERIALS AND METHODS

The analyzed data were obtained from the Danish Physical ACTivity cohort with Objective measurements (DPHACTO). A full description of this cohort profile and study protocol is published elsewhere.<sup>18,19</sup> A total of 2107 workers from the cleaning, manufacturing, and transport industries in Denmark were invited to participate—of which—1087 were included at baseline. The current analysis includes data from 694 workers (Figure 1). Overall,

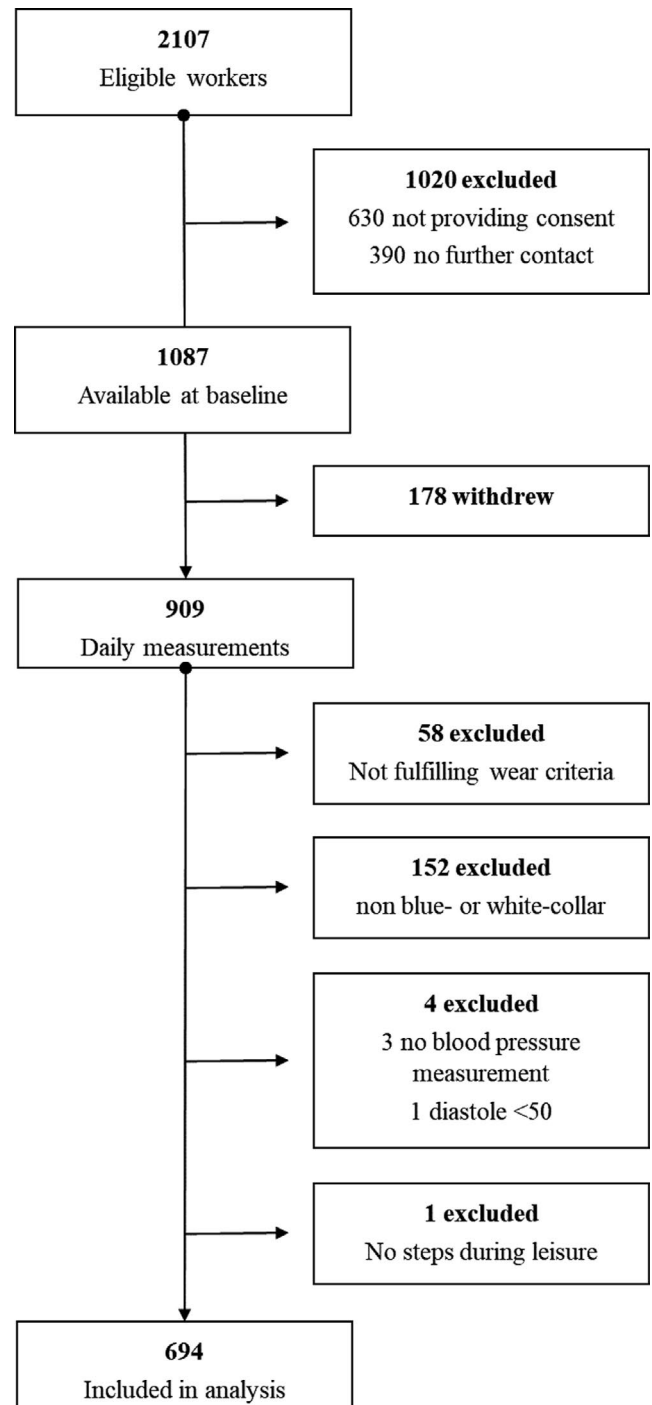


FIGURE 1 The flow of workers

workers completed a health examination with blood pressure measurement.<sup>20</sup> Subsequently, an accelerometer (ActiGraph GT3X+, ActiGraph LLC) was attached to their thigh for measurement of number of steps over consecutive days. Written informed consent was required before participation. Exclusion criteria for participation in device-worn measurements were defined as pregnancy or allergy to adhesive plaster. Data collection was in accordance with the Helsinki Declaration and was approved by the Danish

Data Protection Agency, following evaluation by the local ethics committee (H-2-2012-011).

## 2.1 | Device-worn measurements of number of steps

The procedure for the accelerometer attachment and signal analysis is described in detail elsewhere.<sup>20</sup> Briefly, the accelerometer was initialized using Actilife software version 5.5 (ActiGraph LLC) and set to sample at a frequency of 30 Hz. The accelerometer was then placed mid-way along the anterior surface of the right thigh and held in place using an adhesive plaster (Opsite Flexifix, Smith & Nephew). Workers were asked to wear the accelerometer 24-h per day over 1–5 days, including at least two working days. Workers were further instructed to remove the device if they experienced any skin irritation or discomfort. A diary was provided to each participant to log work hours and leisure time. After data collection, the diary and ActiGraph device were returned to the research staff.

Accelerometer signals were processed using the Acti4 software developed at the National Research Centre for the Working Environment Copenhagen. Acti4 classifies activity types and postures using a decision tree model based on the inclination and acceleration magnitude.<sup>20</sup> Steps were derived using frequency analysis of acceleration along the longitudinal axis of the thigh, for time intervals classified as walking, running, and stair climbing.<sup>21</sup> These stepping activities are then used to provide a validated measure of the step quantity,<sup>20,21</sup> which can then be classified according to the domain (ie, work and leisure) using participant diary entries.

The mean number of steps across all valid measured days was calculated for 1) total number of steps (ie, steps during awake hours), 2) steps at work, and 3) steps at leisure. A day was considered valid if it comprised at least 10 h of measurement during the awake period. Work or leisure period was considered valid if it comprised at least 4 h of wear time or 75% of average wear time across days.<sup>22</sup>

## 2.2 | Blood pressure measurement

During the health examination, workers were asked to sit on a chair for 15 min with their back supported, arms rested, and legs uncrossed. Thereafter, in a seated position, a cuff was placed on the upper left arm of the participant and resting systolic and diastolic blood pressure were measured using the Omron M6 Comfort (Omron Health Care). Measurements were performed three times at a regular interval of 1–2 min, and the average of systolic blood pressure in millimeters of mercury (mmHg) from the last two measurements was used in the analysis. Physiological outliers were

considered as a diastolic blood pressure value <50 mmHg or >130 mmHg and a systolic blood pressure value <80 mmHg or >240 mmHg.<sup>23</sup> Only systolic blood pressure was included in models as there was a strong positive linear correlation between systolic and diastolic blood pressure in this dataset, similar to previous studies.<sup>24–26</sup>

## 2.3 | Assessment of potential confounders

Age, in years, was based on social registration numbers in Denmark. Sex was determined via a single item “Are you male or female? Yes or No”. Information on job type was determined via a single item “What is your present main occupation? Blue-collar, white-collar, manager, student/trainee, other”. Only those responding “blue-collar” or “white-collar” were included in the present analysis. If considered in terms of the average time at work spent in different physical behaviors, Blue-collar work in the cleaning industry was characterized by a considerable amount of time on feet at work (5.3 h), of which 3.3 h were spent walking.<sup>20</sup> In the transport industry, blue-collar work was typified by a large degree of sedentary behavior (4.6 h) and comparatively little time on feet (2.8 h) or walking (1.8 h).<sup>20</sup> Finally, blue-collar work in manufacturing was typified by moderate quantities sedentary behavior (2.4 h sitting or lying) as well as, stationary standing (2.8 h) and walking time (2.5 h) in comparison with the cleaning and transport groups.<sup>20</sup> Smoking status was obtained using four response categories, which was subsequently collapsed into a dichotomous variable “Do you smoke? Yes (Daily, Occasionally), No (Former, Never)”. Body mass index (BMI,  $\text{kg}\cdot\text{m}^{-2}$ ) was calculated using measured body mass (kg) and height (cm). The use of prescription antihypertensive medicine was assessed using the question “Have you in the last three months been taking prescription medication?” If yes, “What kind of medicine? Antihypertensive? Yes or No”.

## 2.4 | Statistical analysis

R version 4.0.2 (2020-06-22) was used for all statistical analyses. Where appropriate, results were presented as the mean and standard deviation (Mean  $\pm$ 1 SD) and percentages (*N* %). The distribution of stepping data was checked and considered normally distributed. To determine the association between the independent variables, total steps, steps at work and steps at leisure, and the dependent variable, systolic blood pressure, three unadjusted linear regression models were created. Subsequently, adjusted models including smoking status, BMI, sex, and age were created. Both linear and nonlinear models were created, but as nonlinear models did not improve the fit, the linear models were preferred. The

selection of confounders was based on previous research and theoretical assumptions *a priori*.<sup>6</sup>

## 2.5 | Sensitivity analysis

Primary adjusted models were re-run on data stratified according to job type (blue-collar and white-collar). Further for stratification according to the use of antihypertensive medication and smoking (See appendix for results of the latter stratifications).

Regression results were presented as the coefficients ( $\beta$ ), the upper and lower confidence intervals (95% CI) and *p*-value (threshold for statistical significance set at  $p < 0.05$ ). Residuals from each model were assessed for deviation from normality, and correlation between predictors was used to assess multicollinearity issues.

## 3 | RESULTS

A total of 694 eligible workers were included in the analysis (Figure 1). Including 560 blue-collar and 134 white-collar workers (Table 1). Mean systolic and diastolic blood pressure were  $134 \pm 15$  mmHg and  $84 \pm 10$  mmHg, respectively. The average total steps were  $13187 \pm 4728$ , consisting of  $8511 \pm 4004$  steps at work and  $5490 \pm 2593$  steps at leisure. The average number of days measured was  $2.8 \pm 1.0$ , consisting on average of  $7.6 \pm 1.3$  h measured at work per day and  $13.7 \pm 2.4$  h measured at leisure per day.

**TABLE 1** Descriptive data for the study population of 694 workers, of which 560 were blue-collar workers and 134 were white-collar workers

		Total	Blue-collar	White-collar
	<i>n</i>	Mean ( $\pm 1$ SD) or Mean (%)		
Age (years)	694	45 (9.6)	45 (9.6)	47 (9.1)
Sex				
Male	694	366 (52.7%)	302 (53.9%)	64 (47.8%)
Female		328 (47.3%)	258 (46.1%)	70 (52.5%)
BMI ( $\text{kg}\cdot\text{m}^{-2}$ )	681	27.3 (4.8)	27.4 (4.9)	26.9 (4.5)
Smoking status				
Current smoker	690	196 (28.2%)	173 (30.9%)	23 (17.2%)
Non-smoker		494 (71.2%)	384 (68.6%)	110 (82.1%)
Prescribed antihypertensive medication	692	95 (Y); 597 (N)	77 (Y); 482 (N)	18 (Y); 115 (N)
Blood pressure				
Systolic	694	133.9 (14.6)	133.5 (14.7)	135.5 (14.2)
Diastolic		83.7 (10.2)	83.6 (10.2)	84.2 (10.0)
Steps				
Total	694	13 187 (4728)	13 820 (4644)	10 546 (4139)
At work		8511 (4004)	9143 (3837)	5863 (3565)
At leisure		5490 (2593)	5538 (2628)	5292 (2437)

Note: Values are presented as mean values  $\pm 1$  standard deviation (SD) or percentage (%) for count variables.

Estimates for unadjusted and adjusted models for the association between total steps, steps at work, and steps at leisure, and systolic blood pressure are presented in Table 2. For adjusted models, the direction of the association appeared negative as illustrated by Figure 2.

As shown in Table 2, a higher total number of steps was associated with a lower systolic blood pressure ( $-0.5$  mmHg per 2000-step interval;  $-1.0$  to  $-0.08$ , 95%CI,  $p = 0.02$ ). Furthermore, a higher number of steps at work was also associated with lower systolic blood pressure ( $-0.9$  mmHg per 2000-step interval;  $-1.4$  to  $-0.4$ , 95%CI,  $p = 0.0006$ ). However at leisure, no clear association was observed between number of steps and systolic blood pressure ( $+0.1$  mmHg per 2000-step interval;  $-0.7$  to  $0.9$ , 95%CI,  $p = 0.75$ ).

## 3.1 | Sensitivity analysis

The association was further investigated within job types (Table 2). Among blue-collar workers, a higher total number of steps was negatively associated with a lower systolic blood pressure, although not statistically significant ( $-0.5$  mmHg per 2000-step interval;  $-1.0$  to  $0.0$ , 95%CI,  $p = 0.05$ ). At work among blue-collar workers, a higher number of steps was significantly associated with a lower systolic blood pressure ( $-1.1$  mmHg per 2000-step interval;  $-1.7$  to  $-0.4$ , 95% CI,  $p = 0.0009$ ), whereas no clear association was found within the leisure domain ( $+0.3$  mmHg per 2000-step interval;  $-0.6$  to  $1.2$ , 95% CI,  $p = 0.50$ ).

Domain of steps	Type of model	$\beta$ Coefficient	95% CI		<i>p</i> -value
			Lower	Higher	
Total	Unadjusted	-0.7	-1.2	-0.3	<0.05
	Adjusted	-0.5	-1.0	-0.08	0.02
At work	Unadjusted	-0.9	-1.5	-0.4	<0.05
	Adjusted	-0.9	-1.5	-0.4	<0.05
At leisure	Unadjusted	-0.6	-1.4	0.2	0.2
	Adjusted	0.1	-0.7	0.9	0.8
Blue-collar					
Total	Adjusted	-0.5	-1.0	-0.0	0.05
At work	Adjusted	-1.1	-1.7	-0.4	<0.05
At leisure	Adjusted	0.3	-0.6	1.2	0.5
White-collar					
Total	Adjusted	-0.3	-1.4	0.9	0.6
At work	Adjusted	-0.3	-1.7	1.1	0.7
At leisure	Adjusted	-0.7	-2.8	1.4	0.5

Note: Analysis was conducted on the data from 694 workers, of which 560 blue-collar workers and 134 white-collar workers.  $\beta$  coefficients and confidence interval values are presented per 2000-step interval.

Unadjusted models included only the dependent and independent variables. Adjusted models also included smoking status, BMI, sex, and age.

Among white-collar workers, we observed only small tendencies of non-significant beneficial association between the number of steps and systolic blood pressure; neither number of steps in total (-0.3 mmHg per 2000-step interval; -1.4 to 0.9, 95%CI,  $p = 0.60$ ), at work (-0.3 mmHg per 2000-step interval; -1.7 to 1.1, 95%CI,  $p = 0.68$ ) nor at leisure (-0.7 mmHg per 2000-step interval; -2.8 to 1.4, 95%CI,  $p = 0.49$ ).

## 4 | DISCUSSION

The aim of this study was to investigate the association between the domain-specific number of steps and blood pressure. We found a beneficial association between the number of steps and systolic blood pressure for total steps and steps at work, but not for steps at leisure. Further, we observed a beneficial association between number of steps at work and systolic blood pressure among blue-collar workers, but no clear beneficial association at work for white-collar workers.

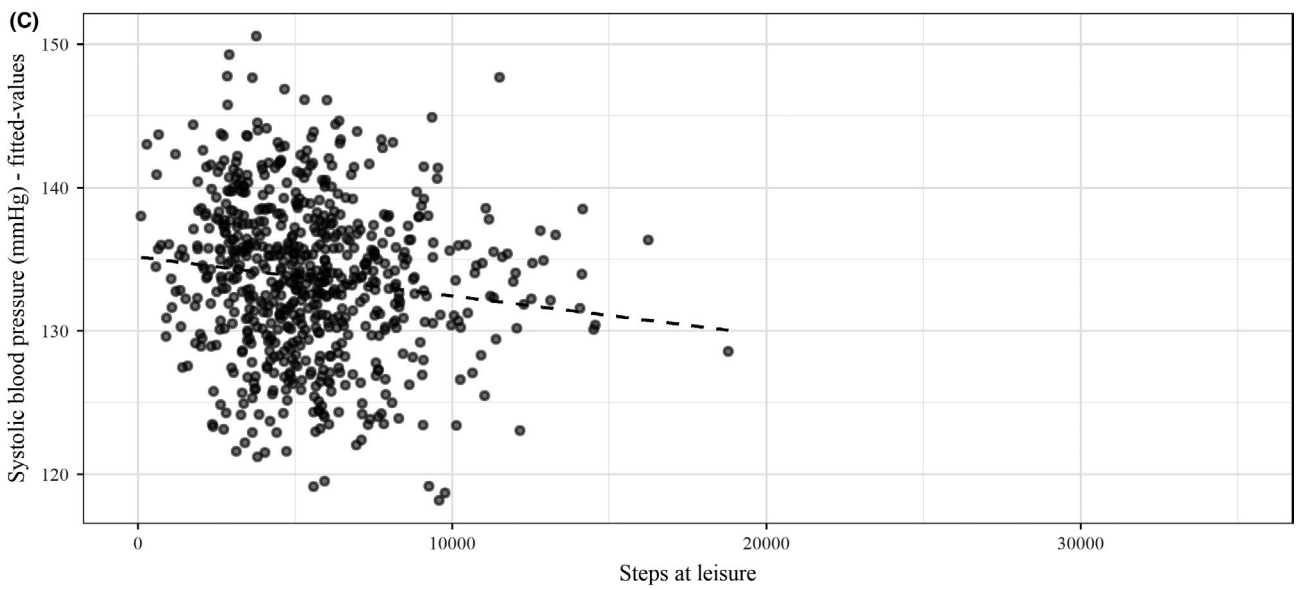
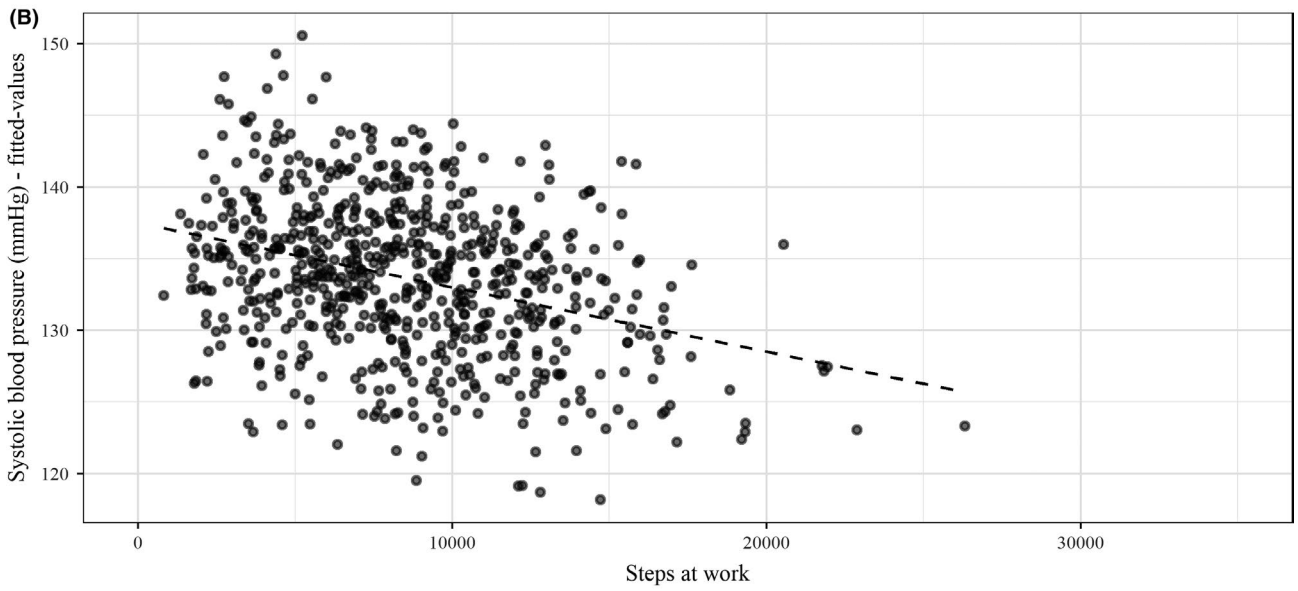
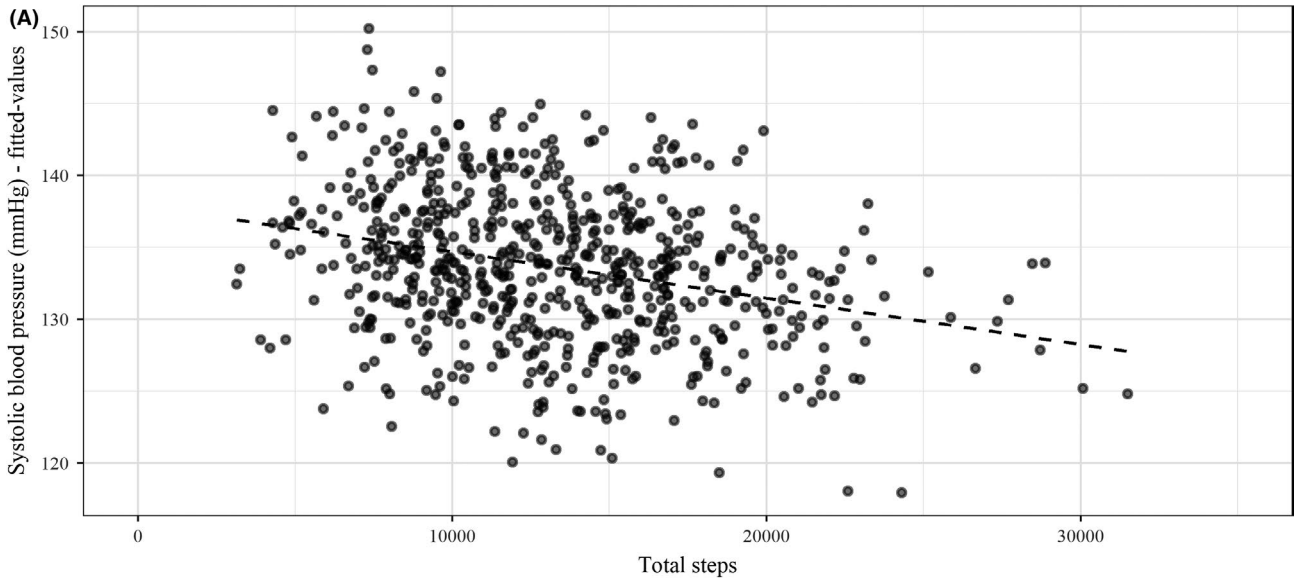
Our main finding was a beneficial association between the number of steps and systolic blood pressure for the total number of steps, and steps at work, but not for steps at leisure. A beneficial association between the number of steps and systolic blood pressure is in line with previous studies,<sup>27,28</sup> and not novel. However, the finding of a beneficial association between the number of steps at work and systolic blood pressure is novel and in contrast to our hypothesis. This hypothesis was based on the findings of research into the physical

**TABLE 2** Adjusted and unadjusted estimates and 95% confidence intervals (CI) for the association between number of total steps and steps within domains and systolic blood pressure

activity paradox,<sup>7</sup> where six general mechanisms have been proposed to explain this paradox,<sup>29</sup> including an insufficient dose, elevated 24-h heart rate, heavy lifting and static postures, insufficient recovery time, low work task control, and increased inflammation levels.<sup>29</sup> However, the general mechanism or pathway resulting in the paradox is likely to depend on the health outcome and physical activity type. The number of steps is thought to account for both light and moderate-intensity physical activity types.<sup>6</sup> Thus, in the current study sample, steps at work may therefore constitute sufficiently dynamic whole-body movement that beneficially affects blood pressure, in contrast to movements with a high intensity that occur at work.<sup>29</sup>

We did not find any clear beneficial association between number of steps at leisure and systolic blood pressure. Previous research indicates a beneficial and protective effect of leisure-time physical activity on health.<sup>30</sup> In the current study, the number of steps at leisure was quite low ( $5490 \pm 2593$ ), which if considered in isolation, indicates a rather sedentary period that may not be sufficient to have a protective effect on blood pressure. Previous research on the number of steps and health seldom considers job types that accrue a high number of steps at work, instead of focusing on white-collar workers in high-income countries—considering leisure time or total time in isolation from time at work. Our stratification on job type illustrates why this approach may be flawed.

We observed a beneficial association between number of steps at work and systolic blood pressure among blue-collar workers, but no clear beneficial association at work



**FIGURE 2** Fitted values from adjusted models representing the association between: Daily steps (A), steps at work (B), steps at leisure (C), and systolic blood pressure. Adjusted models included smoking status, BMI, sex, and age. Analysis was conducted on the data from 694 workers, of which 560 blue-collar workers and 134 white-collar workers. The dashed line indicates the direction of association. The color gradient indicates the density of data points, where light gray is the least dense and black is the densest

for white-collar workers. A simple explanation for this new finding may be that blue-collar workers accrued a sufficient number of steps at work to have a beneficial effect on blood pressure, whereas white-collar workers did not. In the current dataset, blue-collar workers took practically twice the number of steps at work than white-collar workers. This finding was possible only through the inclusion of domain and job type information and, thus, serves to highlight the importance of this information. For example, if our analysis did not include domain or job type information, we would likely conclude that the total number of daily steps is important for blood pressure, without providing any recognition as to where these steps occur for a large proportion of working-age adults.

Our study contains particular strengths and limitations that warrant consideration. A main strength of our study is the valid measure of number of steps under free-living conditions and the information on domain allowing domain-specific analyses. It was also conducted in large a sample ( $n = 694$ ) with a large range in the number of steps and workers employed in different job types. A primary limitation is the cross-sectional design limiting the ability to determine causality. We hope to have mitigated this limitation somewhat by using systolic blood pressure as a health outcome, since it is less likely to be affected by the bidirectional nature of the association between the number of steps and many other health outcomes. In addition, we did not include the information of non-working days, which does not facilitate the investigation of activities on these days and their influence. A further limitation of the current analysis is the omission of cadence to quantify intensity in addition to the number of steps taken. However, findings of recent research emphasizes that the number of steps taken is more strongly associated with health and not the intensity.<sup>5,31</sup> Nevertheless, further research should be conducted to explore the association between stepping cadence and health, as the evidence is still lacking.<sup>6</sup>

Finally, it must also be highlighted, however, that due to the relatively low sample size of white-collar workers included in the analyses ( $n = 134$ ) there is the possibility of a low statistical power, which may explain the lack of any clear association. Further, because the general health of white-collar workers was better than that of blue-collar workers,<sup>20</sup> caution should be taken extrapolating our findings among blue-collar workers to white-collar workers, as the extent of the effect of increasing the dose of steps may not be the same.

In summary, our results indicate that the number of steps at work is beneficially associated with systolic blood

pressure, particularly among those involved in blue-collar work. This association was observed among a sample of blue-collar workers, pertaining to three different industry groups, and with a broad range of physical work demands.<sup>20</sup> Although further research is obviously required to confirm our findings, the current results highlight the importance of information on domain and job type, and support the potential of work (re)design to promote walking and improve blood pressure.

## 5 | PERSPECTIVES

The implication of the current findings, if causality can be proven, is that the number of steps at work is extremely important for health—as there is good evidence documenting the health benefits of blood pressure reduction.<sup>32</sup> These findings could influence the organization of work to include more steps, particularly for white-collar workers being sedentary both at work and at leisure. However, more research is required to determine the dose needed for a beneficial effect on blood pressure among this group. In the case of blue-collar workers, stepping could be incorporated to counter the effect of work activities considered to elevate 24-h blood pressure (eg, heavy lifting).<sup>33</sup> Essentially, we suspect that the effect of number of steps may differ between white-collar and blue-collar job groups. Therefore, further research should explore the association between steps and blood pressure among white-collar and blue-collar workers. The findings of such research could allow activity at work could be reframed as health promoting<sup>34</sup>; however, further observational and interventional research is required on precisely how this can be achieved.

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## CONFLICT OF INTEREST


The authors declare that they have no conflicts of interest.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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## APPENDIX

Stepping category	Type of model	B	95% CI		p-value
Yes (n = 77)					
Total	Adjusted	-1.5	-3.1	0.08	0.06
At work	Adjusted	-0.4	-2.4	1.6	0.70
At leisure	Adjusted	-2.7	-5.8	0.4	0.09
No (n = 482)					
Total	Adjusted	-0.4	-1.0	0.1	0.10
At work	Adjusted	-1.1	-1.7	-0.5	<0.05
At leisure	Adjusted	0.6	-0.3	1.5	0.20

**TABLE A1** The association between number of steps and systolic blood pressure among blue-collar stratified by the use of antihypertensive medication (Yes or No)

Stepping category	Type of model	B	95% CI		p-value
Current smoker (n = 173)					
Total	Adjusted	-0.9	-1.8	0.03	0.06
At work	Adjusted	-1.4	-2.4	-0.3	<0.05
At leisure	Adjusted	-0.6	-2.2	1.1	0.5
Non-smoker (n = 384)					
Total	Adjusted	-0.4	-1.0	0.3	0.2
At work	Adjusted	-0.9	-1.7	-0.2	<0.05
At leisure	Adjusted	0.7	-0.4	1.8	0.2

**TABLE A2** The association between number of steps and systolic blood pressure among blue-collar stratified by smoking status (Current smoker or non-smoker)