ABSTRACT

Background: Sedentary behaviour (SB) is negatively associated with cognition and mood. Adults often engage in high levels of SB at work through sitting, which may impact productivity. Consequently, replacing sitting with standing and physical activity (PA) is recommended. However, the associations between sitting, standing and PA at work, and cognition and mood are unknown, this study therefore aimed to explore these relationships. **Methods:** Seventy-five healthy, full-time workers (33 male, [mean±SD] 33.6±10.4 years, 38±7 work hours/week) wore SB (activPAL) and PA (SenseWear Pro) monitors for seven days and recorded their work hours. The day after this monitoring period, participants completed cognitive tests (executive function, attention and working memory) and mood questionnaires (affect, alert, content and calm). Multiple linear regression analyses examined the associations between cognition and mood and the time spent sitting, standing and in each PA intensity during work hours, weekday leisure time and weekends. **Results:** Workplace sitting, standing or PA was not significantly associated with cognition or mood ($p>0.05$). No significant associations were observed between these variables during weekday leisure time or weekends ($p>0.05$). **Conclusions:** In a cohort of healthy workers, workplace sitting, standing and PA are not associated with cognition or mood. Further research in this population is needed examining the influence of workplace behaviours on cognition and mood, as this will contribute to evidence-based workplace guidelines to increase productivity.

INTRODUCTION

The importance of workplace physical inactivity was first demonstrated with the observation that active bus conductors had lower cardiovascular disease incidence compared to 'inactive', or as they would now be classified, sedentary, bus drivers.[1] The workplace has since been identified as a key setting where adults accrue high amounts of sedentary behaviour (SB), defined as any waking behaviour in a sitting, reclining or lying posture.[2] Office workers spend 65–75% of their work hours sitting, typically in prolonged bouts.[3–5] Importantly, a significant proportion of an adults' week is spent at work, thus exposing workers to high levels of sitting. This is clinically relevant since SB is recognised as an independent risk factor for physical and mental health conditions.[6,7] Considering this, recent guidelines suggest replacing workplace sitting with two hours of standing and light-intensity physical activity (PA) could improve employee health and wellbeing, as well as their productivity.[5] However, there is little evidence to support these recommendations.[8,9]

Cognition is related to work performance due to its influence on workers' ability to learn and execute the skills needed to carry out tasks, and has been established as one of the best predictors of work performance across a range of professions.[10] Indeed, cognitive ability is negatively associated with counterproductive work behaviours[11] and employees with greater cognitive capabilities perform more work tasks.[12] Pertinently, associations between cognition and SB have been observed. Cross-sectional and prospective studies in older adults indicate that SB is negatively associated with cognition.[13–15] However, such research excludes the working-age population (18-60 years), an important and potential at risk cohort since some aspects of cognitive performance start declining from the age of 20 years.[16] Indeed, minimal research has explored the impact of SB at work on cognition. Furthermore, a systematic review found inconclusive results from the few studies (n=13) examining interventions to reduce workplace SB and improve cognition.[17]

Mood has also been shown to influence work productivity,[18,19] with workers in a positive mood demonstrating more efficiency and effectiveness in their job roles.[20,21] Furthermore, positive affect is positively related to task performance and negatively related to counterproductive work behaviours, with opposite associations observed for negative affect. [18,19] Mood decreases following up to two weeks of experimentally increasing free-living SB. [22,23] Furthermore, using ecological momentary assessment analyses which allows for real-time assessment during everyday life, time spent in SB was negatively associated with valence and energised arousal.[24] However, whether SB accrued specifically during work hours contributes to these mood disturbances is unknown.

Guidelines to reduce sitting in the workplace recommend progressing towards two hours of standing and light-intensity PA during working hours to improve employee productivity.[5] However, the recommendation of light-intensity PA and standing is based on previous research showing improved blood glucose and insulin concentrations when breaking up prolonged sitting.[25–27] Consequently, whether increasing the time spent in these behaviours can have beneficial effects on factors influencing work productivity, such as cognition and mood, is unknown. Accordingly, this study firstly assessed the relationship between cognition, mood and objectively measured time spent sitting, stepping or standing and in light-, moderate-, and vigorous-intensity PA whilst at work, as well as during weekday leisure time and weekends. Secondly, based on current workplace guidelines,[5] this study assessed whether there was a difference in cognition and mood between individuals who already accumulate two hours of standing and light-intensity PA during their working hours and those who do not. It was hypothesised that greater time spent sitting at work would be associated with lower cognition and mood. Based on current workplace guidelines,[5] it was also hypothesised that standing and light-intensity PA at work would be positively associated with cognition and mood and that those already meeting these guidelines would have higher cognition and mood scores compared to those who do not.

METHODS

Participants

Eighty-four healthy, full-time workers (37 male) volunteered and provided written informed consent prior to commencing the study. Participants were recruited via convenience sample, using advertising emails and posters that were distributed via local business mailing lists. Recruitment and testing took place across a one-year period (November 2016 – November 2017). In order to capture a variation of workplace activity levels (i.e. both those who had high and low sitting time), participants from any workplace were eligible to participate, providing they were employed full-time (minimum of 35 hrs per week). Participants were screened for exclusion criteria including: part-time employment (<35 hrs per week), use of medication, current smoker, body mass index >35 or <18 $kg \cdot m^{-2}$ and diagnosis of cerebrovascular, cardiovascular or metabolic disease. Study procedures were approved by the Liverpool John Moores University Ethics Committee and adhered to the Declaration of Helsinki.

Study design and procedures

Data collection occurred either at Liverpool John Moores University or at the participants' workplace in a private, quiet room without any external disturbances. Participants completed two test visits. During visit one, participants were fitted with two activity monitors, the activPAL3 and SenseWear Pro to measure SB and PA respectively, and given a wear-time logbook to complete. Following this, participants wore the monitors for the next seven consecutive days and were instructed to maintain their habitual workplace and leisure time behaviours. The second visit occurred between 7.00-9.00 am the day after participants finished wearing the monitors. The time of this visit was selected to prevent daily events potentially influencing participants' cognition and mood. Participants were also instructed to maintain their normal sleep patterns, and diet and caffeine consumption so that the monitoring period represented a typical week for them. Furthermore, this visit always took place the day after a workday (Tuesday-Friday) to ensure that the effects of a weekend, where participants' behaviours may be different to a workday, did not influence cognition and mood outcomes. During this visit participants completed a battery of computer-based cognitive performance tests and two mood questionnaires.

Measurements

Sedentary Behaviour. SB was assessed using the activPAL3 monitor (PAL Technologies, Glasgow, UK), a valid and reliable measure of sedentary time.[28] The activPAL contains a tri-axial accelerometer which responds to gravitational acceleration and acceleration due to segmental movement, enabling the time spent lying, sitting, standing and stepping to be determined.[28,29] For each participant, the activPAL was initialised at a sampling frequency of 20 Hz. The activPAL was waterproofed using a small flexible sleeve to cover the monitor and then secured onto the anterior mid-line of their right upper thigh by the principal researcher using a waterproof medical grade adhesive dressing (Tegaderm). Waterproofing the device permitted participants to wear the monitor continuously for the entire assessment period, which can increase wear time compliance.[30] Additional waterproof dressings and attachment instructions were given to participants in case the monitor became detached during the assessment period to allow for reattachment, or they were advised to contact the principal researcher. Participants were instructed to wear the activPAL monitor continuously over five weekdays and two weekend days (i.e. Saturday and Sunday); as recommended for valid data.[30] Data were downloaded from the monitor using activPAL software (version 7.2.32) and saved in 15 second epochs across 24-hour periods. Data for a day was considered invalid if the monitor was worn < 10 hours, had < 500 steps recorded or any one activity accounted for ≥ 95% of waking wear time.[31] Further validation of data took place by visually inspecting the activPAL event file outputs to corroborate if self-report wake-up and bedtime corresponded with activPAL data. When assessing working hours, it was required that the monitor was worn for >90% of work time. Data were then exported into Excel (Microsoft) for analyses, details of which are provided in Supplementary File 1.

Physical Activity. PA was assessed using the SenseWear Pro 3 (BodyMedia, Inc., Pittsburgh, PA, USA), a multisensory body monitor that is a valid method to assess energy expenditure and in turn PA.[32] Each armband was initialised based on participants' stature, body weight, sex and age. Participants then wore the armband around the upper right arm, in accordance with manufacturer guidelines. Participants were instructed to wear the armband continuously for seven days, only removing for showering or other water-based activities. Data were downloaded from the armband and analysed using SenseWear professional software (version 7.0, BodyMedia, Inc.), which uses algorithms developed by the manufacturer to determine MET values for one minute epochs. For each day, data were considered valid if the monitor was worn ≥10 hours per day and if wear time corresponded with the participant's self-report wear time diary. Based on this criteria, a participant's data were used in analyses if three weekdays and two weekend days were considered valid.[33] These data were then exported to Excel and separated into weekdays and weekends as described in Supplementary File 1. For each day, the time spent in different categories of PA was determined based on recognised

METs values: light-intensity PA 1.5-3.0 METs, moderate-intensity PA 3.1-6.0 METs, and vigorous-intensity PA >6.0 METs.[34] The time spent in moderate-to-vigorous PA (MVPA) was determined by summing the time engaged in moderate- and vigorous-PA. Minute-by-minute data for each category were summed to determine the total time spent in each intensity per day for waking hours and these values were then summed to calculate total PA per day.

Activity Monitoring Analysis. During the activity monitoring period, to delineate between work hours and leisure time activities, participants were given a logbook to record the time they started and finished work each day, as is standard practise.[30] Additionally, participants recorded the time they woke up and went to bed each day to allow for only waking hours to be included in analyses. Participants were provided with written and verbal instructions regarding how to wear the activity monitors and use the logbook. Data from the monitors were only included if both SB and PA data were valid for the same day (i.e. if the participant only wore one of the monitors this day was excluded). For each day, the time spent sitting, standing and stepping and in each intensity of PA were calculated for waking hours, defined using the participants' logbook, and expressed as a percentage of waking hours. Mean values were then determined for each variable to represent a weekday and a weekend day. The same variables were then calculated for work hours, defined using participants' self-report working hours, and expressed as a percentage of total work hours. Total values for the week were calculated using a weighted mean to account for the disproportionate time spent in weekdays compared to weekend days across a week (weekday x 0.71 + weekend x 0.29). Variables for leisure time during the weekday were calculated by subtracting work hours data from weekday data, therefore removing any activity during the time spent at work. ***Cognition.*** All tests were conducted using E-Prime software (Version 2.0 Professional, Psychology Software Tools, Pittsburgh, PA). The E-Prime software was loaded onto a computer and participants completed the tests while seated in a silent room, therefore there were no audible or visual distractions during testing. The cognitive test battery assessed three cognitive components, using three separate tests, with a break permitted between tests. Prior to each test, participants were provided with written on-screen instructions and given the opportunity to ask questions. Participants took between 45-60 minutes to complete the test battery.

Executive function was assessed using the Stroop Colour-Word test[35] which generated an interference score based on the reaction times (RT) from three tasks: the Word Task, the Colour Task and the Colour-Word Task. For each task, participants were instructed to name the ink colour of the displayed text by pressing the keyboard letter that corresponded to that colour. In the Word Task the words ‘red’, ‘blue’, ‘yellow’ or ‘green’ were presented in a congruous ink colour. In the Colour Task a series of four letter X’s were presented in either red, blue, yellow or green ink. In the Colour-Word Task the names of these four colours were presented in an incongruent ink colour. For each task, the percentage of correct responses was determined and the mean RT for correct responses calculated. An interference score was calculated by subtracting the mean time needed to complete the Colour and Word tasks from the time needed to complete the Colour-Word task (Interference = Colour-Word task – [(Word task + Colour task) / 2].[36]

Attention was assessed using the Attention Network Task (ANT) which examined three attentional networks: alerting, orienting and executive control.[37] A central arrow was displayed on screen and participants were required to indicate the direction (left or right) of this arrow by clicking with the computer mouse in the corresponding direction. The central arrow was flanked by one of three types of flankers: two arrows each side pointing in the same direction as the central arrow (congruent condition), two arrows each side pointing in the opposite direction of the central arrow (incongruent condition), or two straight lines each side of the central arrow (neutral condition). Prior to the presentation of the arrow, participants were shown one of four cue (*) types: a central cue, a double cue, a spatial cue, or no cue. The central and double cues indicated that the arrow would be presented soon, while the spatial cue additionally provided an indication of where the arrow would be presented. The no cue provided none of this information. The efficiency of these networks was assessed by determining how alerting cues, spatial cues and flankers influenced RT to respond to the arrow. Mean RT for correct trials was calculated as a function of a cue or flanker condition to form a RT score for each network.[37]

Working memory was assessed using the N-Back Task[38] which calculated the response accuracy to identify whether a presented letter was the same as that presented one (one-back), two (two-back) or three (three-back) times prior in a letter sequence. Typically, as the working memory demand increases in each condition, so in turn does the number of errors. For all conditions a series of letters were consecutively presented on the screen and participants had to respond whether this letter was a target or a non-target. Participants logged their response by clicking with the computer mouse either left for a target letter or right for a non-target letter.

Mood. Mood was assessed using two questionnaires: The Positive and Negative Affect Schedule (PANAS)[39] and the Bond-Lader Mood Rating Scale.[40] The PANAS required participants to respond using a 5-item Likert scale ranging from 1 (very slightly or not all all) to 5 (extremely) the extent to which they felt 10 positive and 10 negative states. Values were then totalled to give separate positive and negative affect scores ranging from 10-50. The Bond-Lader Mood Rating Scale included 12 visual analogue scales featuring bipolar end-points for different mood dimensions: Alert-Drowsy, Calm-Excited, Strong-Feeble, Clear Headed-Muzzy, Well Coordinated-Clumsy, Energetic-Lethargic, Contented-Discontented, Tranquil-Troubled, Quick Witted-Mentally Slow, Relaxed-Tense, Attentive-Dreamy, Proficient-Incompetent, Happy-Sad, Amicable-Antagonistic, Interested-Bored, and Gregarious-Withdrawn. These scales were combined to form three mood factors: alert, calm and content;

with each mood factor calculated as an average of the scores from the relevant mood scales.[40] For both questionnaires, participants were asked to respond based on their mood over the past few days.

Statistical analyses

Data were analysed using statistical software (SPSS Version 25.0, IBM Corporation, Somers, NY, USA). Results are presented as means ± standard deviation (SD). Multiple linear regression analysis was used to examine the independent associations between cognition and mood and the time spent sitting, standing, stepping and in each PA intensity during work hours, weekday leisure time and weekends. All models run were adjusted for age and sex. Cognition and mood data were standardised using z-scores transformations. Linear transformations of 5% were applied to sitting, standing, stepping and PA data to adjust the interpretation of coefficients from a 1% to 5% change in each domain. Results of the multiple linear regression analyses are presented as the unstandardised coefficient with 95% confidence intervals (CI). P-values were adjusted for multiple comparisons using a false discovery rate (FDR). To assess for differences in cognition and mood based on meeting current workplace activity guidelines, data were split into two groups: individuals who accumulated two hours of standing and light-intensity PA during their working hours, and those who did not. Differences between groups were assessed using a one-way ANCOVA, with age and sex as covariates. Significance was accepted as $p<0.05$.

RESULTS

From the originally recruited sample size of 84, 75 participants (33 male) completed the study and were included in analyses. Nine participants were excluded due to invalid activity monitor wear time. Participants were a mean age of 33.6±10.4 years, with a body mass of 71.8±14.2 kg, stature of 169.3±9.4 cm and a body mass index of 25.0±3.8 kg·m^{-2}. Full descriptive characteristics are shown in Table 1. Participants were employed across 12 different workplaces, representing nine sectors. Mean time spent sitting, standing, stepping and in each PA intensity during work hours, weekday leisure time, weekends and per week are shown in Table 2. Mean scores for all cognition and mood outcomes are shown in Supplementary Table 1.

Sitting, standing and stepping

Multiple linear regression analyses between the time spent sitting, standing and stepping in each domain (work hours, weekday leisure time and weekends) and all cognition outcomes are shown in Table 3 and all mood outcomes are shown in Table 4. Weekday leisure time sitting was positively associated with executive control score (β=0.292, p=0.033), indicating longer RTs with increased time spent sitting. Negative associations were observed between weekday leisure standing and one back accuracy (β=-0.289, p=0.040) and work hours standing and three back accuracy (β=-0.290, p= 0.021). Stepping during weekday leisure time was positively associated with orienting network score (β=0.303, p=0.024), indicating longer RTs with increased time spent stepping, and with the calm mood state (β=0.292, p=0.046). All significant outcomes returned to the null once FDR corrections were applied (p>0.05).

Physical activity intensity

Multiple linear regression analyses between the time spent sitting, standing and stepping in each domain (work hours, weekday leisure time and weekends) and all cognition outcomes are shown in Table 5 and all mood outcomes are shown in Table 6. Negative associations were observed between work hours moderate-intensity PA (β=-0.310, p=0.042) and MVPA (β=-0.317, p=0.037) and executive function, indicating shorter RTs with increased time spent in these intensities of PA. Work hours moderate-intensity PA (β=0.327, p=0.044) and MVPA (β=0.319, p=0.049) were positively associated with the content mood state. Negative associations were also observed between weekday leisure time moderate-intensity PA (β=-0.341, p=0.024) and MVPA (β=-0.335, p=0.03) and executive control score, indicating shorter RTs with increased time spent in these intensities of PA. Weekday leisure time moderate-intensity PA (β=0.352, p=0.027) and MVPA (β=0.373, p=0.024) were positively associated with the calm mood state. Weekend vigorous-intensity PA was positively associated with the alert mood state (β=0.322, p=0.049). All significant outcomes returned to the null once FDR corrections were applied (p>0.05).

Workplace guidelines

Fifty-five participants (73.3%) achieved the current workplace guidelines of at least two hours of standing or light-intensity PA during work hours; whilst twenty participants (26.7%) did not. Mean scores for all cognition and mood outcomes for each group are shown in Table 7. No significant differences were observed for any cognition or mood outcomes between the groups (p>0.05).

DISCUSSION

This study assessed whether sitting at work is associated with cognition and mood. A less sedentary workplace has been suggested to be more productive,[5] and cognition and mood likely play a role in employee productivity. In contrast to this, we found no independent association between the time spent sitting at work and aspects of cognition and mood once controls for multiple comparisons were applied. Additionally, we found that neither standing nor any intensity of PA during work hours were associated with cognition or mood. Furthermore, this study explored whether cognition and mood differed between individuals who accumulate two hours of standing and light-intensity PA during their working hours, in line with current guidelines,[5] and those who do not. However, no differences between groups were observed for any cognition or mood outcomes. Collectively these findings suggest that further research is needed to explore the impact of workplace sitting and PA on aspects of cognition and mood in healthy, working-age adults. Together, this information will contribute to evidence-based guidelines on workplace behaviours to increase productivity.

The finding that sitting at work was not associated with cognition contrasts previous research showing relationships between SB and cognition.[13–15] However, these previous studies have assessed older populations who experience an accelerated rate of age-related cognitive decline compared to younger adults,[16] and in this study we have assessed young, working-age adults, with a mean age of 33 years. Consequently, this may indicate sitting has minimal impact on cognition for younger adults. Indeed, experimental studies assessing young, healthy adults have observed no impairment in cognition following an acute prolonged sitting period[41,42] or following a one-week free-living SB intervention.[43] Additionally, it has been suggested that participants' regular PA may offset the effects of sitting on cognition.[17] Indeed, in adults that met PA guidelines, one-week of experimentally increased free-living SB did not negatively affect mood.[43] Furthermore, the cognitive engagement of the activities that participants engage in whilst at work, in addition to their PA and SB levels, may impact cognition.[17] Such factors were not assessed or controlled for in this study, which may contribute to our findings.

The time spent sitting at work was not associated with aspects of mood, which contrasts previous research showing negative associations between sitting and valence and energised arousal.[24] However, this previous work used ecological momentary assessment analyses, which allowed for the real-time assessment of mood directly following a prolonged sitting period. In our study, we asked participants to recall their mood over the past few days, consequently, alongside recall bias, a combination of daily events over this time period may have altered mood state above that which sitting could influence. Indeed, mood is known to transiently change throughout the day owing to daily stressors[44] and responses can persist for hours following an event.[45] Consequently, to fully understand the influence of work hours sitting on mood, assessments of mood should be determined at the start and immediately at the end of a working day; which future research should consider.

In addition to workplace sitting, this study also assessed whether the time spent standing and engaging in any intensity of PA were associated with cognition and mood. Importantly, we found no associations between the time spent in any of these behaviours and mood or cognition. These findings support previous research stating inconclusive results from studies examining the effect on cognition of PA interventions to reduce workplace sitting time.[17] Furthermore, no differences in cognition were observed between individuals who attained current workplace guidelines of two hours of standing and light-intensity PA[5] and those that did not. Taken together, this may indicate that PA during work hours is not sufficient to alter cognition and longitudinal studies are needed to explore this further. Collectively, our data does not align with current workplace activity guidelines[5] and may indicate that recommending standing and light-intensity PA will not elicit improvements in workers' mood and cognition, and their subsequent productivity. Furthermore, our findings support previous criticisms regarding the lack of evidence to support these recommendations.[8,9] This indicates that more research is required in the area of workplace activity before guidelines regarding the duration and type of PA can be prescribed.

In addition to the workplace, this study examined the time spent sitting, standing, stepping and in each PA intensity during weekday leisure time and weekends to explore if results differed depending on the domain assessed. As observed for work hours, in each of these domains, the time spent engaging in any of these behaviours was not significantly associated with cognition and mood. The lack of association between mood and PA may be surprising owing to the frequently cited benefits of PA on mood state.[46] However, the effect of PA on mood is attenuated when individuals' mood scores are higher.[47] Consequently, in our sample of healthy adults, the association between PA and mood may be small owing to their higher overall mood. Furthermore, the duration and modality of PA are factors that can influence mood[46] and we were not able to explore the type of PA nor the duration of the PA bouts that individuals completed. The lack of association between PA and cognition may be surprising given the benefits of PA for the maintenance of cognition.[48,49] However, the majority of research in this area has examined children and older adults, with little focus on young and middle-age adults,[49] which is the age range included in this study. Thus, whether PA is associated with cognition in young and middle-aged healthy adults is less clear.

Limitations. This study is strengthened by the objective assessment of sitting, standing, stepping and PA over an entire week which provided a complete picture of our participants' habitual activity levels across various time domains. Nonetheless, we only assessed a small number of cognitive domains and mood states that could influence workers' productivity; others may be associated with sitting and PA and should be explored. For example, The National Institutes of Health have identified executive function, episodic memory, language, processing speed, working memory, and attention as the cognition subdomains most important for health and success in work;[50] all of which were not assessed in our study. Additionally, we did not control for factors such as sleep, stress, caffeine and diet, which are important determinants of cognition and mood. Furthermore, the weekday on which cognition and mood assessments took place was not controlled between individuals, and changes in mood across the week are suggested.[51]

The influence of the number or the length of breaks from sitting on cognition and mood were not considered, factors which are known to have an important effect on cardiometabolic health markers.[52] Some participants were employed in the same workplace which may increase the homogeneity of our data, owing to similar work hour behaviour patterns. Nonetheless, our sample appears representative of the typical English workers since weekday sitting (61.0%), standing (26.1%) and stepping (13.0%) time was similar to that previously reported by Smith et al.[53] in English workers (weekday sitting 66.2%, standing 23.3% and stepping 10.5%). Finally, whilst our study found no significant associations between workplace activity and cognition and mood, fully powered studies are needed to confirm or refute these findings.

CONCLUSION

This study demonstrates that in young, healthy workers, sitting during work hours is not associated with cognition or mood, factors that can influence work productivity. In contrast to guidelines advising increasing standing and light-intensity PA at work to improve productivity, these behaviours were not associated with cognition or mood. Additionally, meeting the recommendation of two hours of standing and light-intensity PA during working hours did not result in higher levels of cognition or mood. Further research is therefore needed to determine the influence of workplace sitting and PA on cognition and mood to provide evidence-based guidelines on workplace behaviours to increase productivity. Additionally, the influence of sitting during work hours on other domains of cognition and mood and over a long-term follow up should be explored.

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AUTHOR CONTRIBUTIONS

SC, NH, DT, and RD contributed to the conception and design of the study. SC completed all data collection and analyses. SC and AT statistically analysed data. SC and AT interpreted the data. SC drafted the initial manuscript. All authors contributed to the critical revision of the manuscript, approve the final submission and take responsibility for the integrity of the data and the accuracy of the data analysis.

COMPETING INTERESTS

RD is employed by Unilever, which has commercial interests in Food, Home and Personal Care products. All other authors declare that they have no competing interests.

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List of Tables

Table 1: Participant descriptive characteristics (n=75, 33 male)

	Mean±SD or n of group
Age (years)	33.6±10.4
Body Mass (kg)	71.8±14.2
Stature (cm)	169.3±9.4
Body Mass Index ($kg{\cdot}m^{-2}$)	25.0±3.8
Ethnic Group	
White British	69
Asian	5
Caribbean or Black	1
Marital Status	
Single	45
Married	29
Divorced	1
Tertiary Level of Education	75
Job Category	
Administration	22
Research and Development	21
Education	8
Managerial	6
Computing	5
Human Resources	4
Commercial	4
Legal/Finance	3
Sport/Leisure	2
Work Hours (per week)	38±7
Work Hours (per day)	8±1

Table 2: Time spent engaging in objectively measured sitting, standing, stepping and physical activity (PA) intensities during work hours, weekday leisure time, weekends and per week (n=75, mean±SD).

	Time	**% of Waking Wear Time**
Work Hours		
Sitting Time (minutes)	322.9±86.0	66.2±14.4
Standing Time (minutes)	115.9±62.5	22.9±10.9
Stepping Time (minutes)	54.7±36.6	10.9±6.5
Light-Intensity PA (minutes)	142.2±59.3	28.7±10.9
Moderate-Intensity PA (minutes)	40.9±35.2	8.2±6.3
Vigorous-Intensity PA (minutes)	1.8±3.5	0.4±0.7
MVPA (minutes)	42.7±36.0	8.6±6.4
Total PA (minutes)	184.9±80.0	37.3±13.9
Weekday Leisure Time		
Sitting Time (minutes)	262.0±75.1	55.8±10.9
Standing Time (minutes)	135.8±43.6	29.2±8.1
Stepping Time (minutes)	69.9±26.9	15.0±5.1
Light-Intensity PA (minutes)	146.4±58.2	34.3±10.1
Moderate-Intensity PA (minutes)	53.7±33.3	12.9±7.6
Vigorous-Intensity PA (minutes)	8.0±9.2	1.9±2.3
MVPA (minutes)	61.7±37.6	14.8±8.6
Total PA (minutes)	208.1±72.0	49.1±12.4
Weekends		
Sitting Time (minutes)	500.8±125.3	56.2±14.5
Standing Time (minutes)	272.6±99.9	30.2±10.6
Stepping Time (minutes)	123.1±54.1	13.6±5.5
Light-Intensity PA (minutes)	304.2±106.3	36.7±11.8
Moderate-Intensity PA (minutes)	90.0±66.0	11.0±8.2
Vigorous-Intensity PA (minutes)	8.0±13.9	0.9±1.6
MVPA (minutes)	98.0±72.9	11.9±8.9
Total PA (minutes)	402.2±132.9	48.6±14.2
Whole Week		
Sitting Time (minutes)	556.2±88.3	59.7±9.4
Standing Time (minutes)	255.6±72.5	27.2±7.1
Stepping Time (minutes)	123.7±43.0	13.2±4.3
Light-Intensity PA (minutes)	283.0±87.4	32.8±8.0
Moderate-Intensity PA (minutes)	90.3±54.4	10.5±6.1
Vigorous-Intensity PA (minutes)	9.0±10.0	1.0±1.1
MVPA (minutes)	99.3±59.5	11.5±6.5
Total PA (minutes)	387.5±108.6	44.4±10.7

PA- physical activity; MVPA- moderate-to-vigorous physical activity.

Table 3: Associations between executive function, attention and working memory (z-score) and the time spent sitting, standing and stepping during work hours, weekday leisure time and weekends.

	Cognition (z-scores)													
	Executive Function		**Alerting Network**		**Orienting Network**		**Executive Control**		**One-Back**		**Two-Back**		**Three-Back**	
	Unstandardised coefficient (95% CI)	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***
Sitting														
Work Hours	0.061 (-0.026, 0.147)	0.165	0.053 (-0.032, 0.137)	0.217	-0.026 (-0.114, 0.062)	0.553	-0.035 (-0.121, 0.051)	0.418	-0.003 (-0.089, 0.083)	0.938	-0.004 (-0.093, 0.084)	0.921	0.082 (-0.006, 0.169)	0.066
Weekday Leisure	-0.053 (-0.176, 0.070)	0.395	-0.062 (-0.182, 0.059)	0.311	-0.092 (-0.217, 0.034)	0.149	0.134 (0.011, 0.256)	0.033	0.110 (-0.015, 0.234)	0.083	-0.001 (-0.128, 0.126)	0.987	-0.053 (-0.178, 0.073)	0.407
Weekend	0.041 (-0.051, 0.133)	0.380	0.012 (-0.078, 0.102)	0.796	0.040 (-0.053, 0.134)	0.393	-0.004 (-0.096, 0.087)	0.923	-0.056 (-0.148, 0.036)	0.226	0.020 (-0.074, 0.114)	0.669	-0.001 (-0.094, 0.093)	0.991
Standing														
Work Hours	-0.108 (-0.221, 0.005)	0.061	-0.092 (-0.204, 0.020)	0.107	-0.007 (-0.126, 0.112)	0.911	0.069 (-0.046, 0.184)	0.233	0.008 (-0.106, 0.121)	0.895	0.006 (-0.112, 0.124)	0.922	-0.136 (-0.251, -0.022)	0.021
Weekday Leisure	0.099 (-0.071, 0.268)	0.248	0.065 (-0.103, 0.232)	0.445	0.054 (-0.125, 0.232)	0.550	-0.159 (-0.331, 0.014)	0.070	-0.179 (-0.350, -0.008)	0.040	0.011 (-0.166, 0.189)	0.900	0.052 (-0.121, 0.225)	0.551
Weekend	-0.085 (-0.212, 0.042)	0.185	-0.022 (-0.148, 0.103)	0.724	-0.042 (-0.175, 0.092)	0.535	0.009 (-0.120, 0.138)	0.887	0.107 (-0.021, 0.234)	0.099	-0.022 (-0.155, 0.110)	0.740	0.018 (-0.111, 0.147)	0.785
Stepping														
Work Hours	-0.009 (-0.208, 0.190)	0.931	-0.019 (-0.210, 0.173)	0.847	0.141 (-0.049, 0.331)	0.142	0.011 (-0.185, 0.207)	0.910	0.017 (-0.181, 0.216)	0.861	0.013 (-0.186, 0.212)	0.896	-0.029 (-0.230, 0.173)	0.776
Weekday Leisure	0.036 (-0.240, 0.311)	0.797	0.146 (-0.119, 0.411)	0.276	0.304 (-0.042, 0.566)	0.024	-0.243 (-0.514, 0.029)	0.079	-0.087 (-0.364, 0.190)	0.532	-0.014 (-0.292, 0.263)	0.917	0.141 (-0.139, 0.422)	0.318
Weekend	0.016 (-0.234, 0.265)	0.901	0.011 (-0.230, 0.251)	0.929	-0.126 (-0.364, 0.112)	0.295	-0.011 (-0.257, 0.234)	0.926	0.017 (-0.233, 0.266)	0.893	-0.071 (-0.321, 0.179)	0.572	-0.052 (-0.305, 0.201)	0.683

*Statistical significance defined as false discovery rate (FDR) < 0.25.

Table 4: Associations between mood (z-score) and the time spent sitting, standing and stepping during work hours, weekday leisure time and weekends.

	Mood (z-scores)									
	Positive Affect		**Negative Affect**		**Alert**		**Calm**		**Content**	
	Unstandardised coefficient (95% CI)	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***
Sitting										
Work Hours	-0.039 (-0.124, 0.047)	0.374	-0.007 (-0.096, 0.082)	0.878	-0.014 (-0.144, 0.087)	0.785	-0.049 (-0.141, 0.043)	0.286	-0.056 (-0.151, 0.038)	0.237
Weekday Leisure	0.003 (-0.119, 0.126)	0.957	-0.036 (-0.163, 0.091)	0.574	0.007 (-0.135, 0.150)	0.917	-0.099 (-0.229, 0.032)	0.136	-0.013 (-0.147, 0.122)	0.851
Weekend	-0.037 (-0.128, 0.055)	0.426	0.048 (-0.046, 0.143)	0.312	-0.038 (-0.152, 0.076)	0.508	0.025 (-0.080, 0.130)	0.637	-0.100 (-0.208, 0.008)	0.068
Standing										
Work Hours	0.029 (-0.086, 0.143)	0.621	0.045 (-0.073, 0.163)	0.448	-0.032 (-0.177, 0.113)	0.658	0.066 (-0.071, 0.202)	0.336	0.020 (-0.121, 0.160)	0.780
Weekday Leisure	-0.044 (-0.215, 0.128)	0.614	0.063 (-0.114, 0.239)	0.481	-0.028 (-0.224, 0.167)	0.773	0.073 (-0.111, 0.256)	0.428	-0.025 (-0.214, 0.164)	0.791
Weekend	0.065 (-0.063, 0.194)	0.315	-0.066 (-0.198, 0.066)	0.324	0.074 (-0.097, 0.244)	0.390	-0.033 (-0.193, 0.128)	0.685	0.162 (-0.002, 0.327)	0.053
Stepping										
Work Hours	0.108 (-0.085, 0.301)	0.269	-0.090 (-0.290, 0.110)	0.374	0.123 (-0.084, 0.330)	0.239	0.054 (-0.136, 0.243)	0.571	0.181 (-0.014, 0.377)	0.068
Weekday Leisure	0.070 (-0.197, 0.337)	0.602	0.029 (-0.248, 0.306)	0.837	0.025 (-0.298, 0.348)	0.877	0.301 (0.005, 0.596)	0.046	0.087 (-0.218, 0.392)	0.569
Weekend	0.020 (-0.222, 0.263)	0.867	-0.100 (-0.351, 0.152)	0.431	0.010 (-0.265, 0.285)	0.940	-0.039 (-0.290, 0.213)	0.758	0.150 (-0.110, 0.409)	0.251

*Statistical significance defined as false discovery rate (FDR) < 0.25.

Table 5: Associations between executive function, attention and working memory (z-score) and the time spent in each physical activity (PA) intensity during work hours, weekday leisure time and weekends.

	Cognition (z-scores)														
	Executive Function		**Alerting Network**		**Orienting Network**		**Executive Control**		**One-Back**		**Two-Back**		**Three-Back**	
	Unstandardised coefficient (95% CI)	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***	**Unstandardised coefficient (95% CI)**	**p-value***
Light-Intensity PA														
Work Hours	-0.088 (-0.199, 0.023)	0.117	0.00 (-0.116, 0.116)	1.000	-0.006 (-0.119, 0.107)	0.914	-0.007 (-0.101, 0.088)	0.891	0.079 (-0.036, 0.193)	0.174	0.069 (-0.045, 0.184)	0.231	0.015 (-0.088, 0.119)	0.768
Weekday Leisure	0.042 (-0.108, 0.193)	0.575	-0.060 (-0.218, 0.097)	0.445	0.002 (-0.151, 0.156)	0.976	0.000 (-0.128, 0.129)	0.999	-0.058 (-0.212, 0.096)	0.458	-0.050 (-0.205, 0.105)	0.522	-0.079 (-0.219, 0.060)	0.261
Weekend	-0.058 (-0.184, 0.067)	0.355	0.051 (-0.080, 0.182)	0.436	-0.062 (-0.190, 0.066)	0.336	0.021 (-0.086, 0.128)	0.691	0.075 (-0.054, 0.203)	0.249	-0.068 (-0.196, 0.061)	0.297	0.033 (-0.084, 0.642)	0.576
Moderate-Intensity PA														
Work Hours	-0.248 (-0.486, -0.009)	0.042	0.013 (-0.233, 0.260)	0.914	0.110 (-0.135, 0.355)	0.374	-0.027 (-0.216, 0.161)	0.774	-0.038 (-0.285, 0.210)	0.763	0.010 (-0.244, 0.264)	0.935	-0.128 (-0.350, 0.095)	0.256
Weekday Leisure	0.149 (-0.049, 0.347)	0.138	0.034 (-0.171, 0.239)	0.739	0.009 (-0.195, 0.212)	0.932	-0.181 (-0.338, -0.025)	0.024	0.021 (-0.185, 0.226)	0.842	0.048 (-0.163, 0.259)	0.650	0.111 (-0.074, 0.295)	0.237
Weekend	0.029 (-0.148, 0.206)	0.746	0.118 (-0.065, 0.301)	0.203	0.022 (-0.159, 0.204)	0.806	-0.032 (-0.172, 0.108)	0.651	0.126 (-0.058, 0.310)	0.175	0.028 (-0.161, 0.217)	0.767	0.016 (-0.149, 0.181)	0.848
Vigorous-Intensity PA														
Work Hours	-0.696 (-2.404, 1.013)	0.419	-0.120 (-1.860, 1.620)	0.891	-1.020 (-2.718, 0.678)	0.234	-0.067 (-1.475, 1.340)	0.924	-0.543 (-2.288, 1.203)	0.536	0.311 (-1.444, 2.066)	0.725	-1.075 (-2.593, 0.443)	0.162
Weekday Leisure	0.109 (-0.537, 0.755)	0.736	0.234 (-0.424, 0.892)	0.480	0.233 (-0.409, 0.875)	0.472	-0.205 (-0.737, 0.327)	0.444	0.233 (-0.428, 0.895)	0.483	0.103 (-0.562, 0.768)	0.758	0.515 (-0.060, 1.090)	0.078
Weekend	-0.104 (-0.963, 0.755)	0.809	-0.513 (-1.388, 0.362)	0.246	0.135 (-0.718, 0.989)	0.752	-0.263 (-0.970, 0.445)	0.461	-0.186 (-1.063, 0.692)	0.674	0.352 (-0.530, 1.235)	0.428	-0.410 (-1.173, 0.353)	0.287
MVPA														
Work Hours	-0.247 (-0.480, -0.015)	0.037	0.033 (-0.210, 0.275)	0.788	0.081 (-0.159, 0.320)	0.504	-0.027 (-0.211, 0.158)	0.772	-0.035 (-0.278, 0.207)	0.771	0.005 (-0.242, 0.253)	0.965	-0.150 (-0.365, 0.065)	0.167
Weekday Leisure	0.138 (-0.042, 0.318)	0.131	0.028 (-0.160, 0.217)	0.764	0.020 (-0.166, 0.205)	0.833	-0.158 (-0.301, -0.014)	0.031	0.026 (-0.162, 0.214)	0.784	0.049 (-0.143, 0.241)	0.608	0.133 (-0.034, 0.300)	0.117
Weekend	0.015 (-0.147, 0.177)	0.852	0.078 (-0.091, 0.248)	0.357	0.028 (-0.139, 0.195)	0.740	-0.031 (-0.159, 0.098)	0.634	0.098 (-0.071, 0.267)	0.250	0.033 (-0.140, 0.205)	0.705	-0.005 (-0.155, 0.145)	0.942

*Statistical significance defined as false discovery rate (FDR) < 0.25. PA- physical activity; MVPA- moderate-to-vigorous physical activity.

Table 6: Associations between mood (z-score) and the time spent in each physical activity (PA) intensity during work hours, weekday leisure time and weekends.

	Mood (z-scores)									
	Positive Affect		Negative Affect		Alert		Calm		Content	
	Unstandardised coefficient (95% CI)	p-value*	Unstandardised coefficient (95% CI)	p-value*	Unstandardised coefficient (95% CI)	p-value*	Unstandardised coefficient (95% CI)	p-value*	Unstandardised coefficient (95% CI)	p-value*
Light-Intensity PA										
Work Hours	-0.028 (-0.143, 0.086)	0.622	-0.034 (-0.150, 0.083)	0.566	-0.037 (-0.163, 0.089)	0.558	-0.047 (-0.169, 0.075)	0.445	-0.018 (-0.146, 0.109)	0.772
Weekday Leisure	-0.050 (-0.205, 0.105)	0.521	0.001 (-0.157, 0.159)	0.989	0.039 (-0.134, 0.212)	0.651	-0.030 (-0.198, 0.138)	0.721	0.040 (-0.135, 0.215)	0.647
Weekend	-0.004 (-0.133, 0.125)	0.949	-0.022 (-0.153, 0.109)	0.739	-0.008 (-0.167, 0.150)	0.915	-0.083 (-0.236, 0.071)	0.283	0.044 (-0.116, 0.204)	0.583
Moderate-Intensity PA										
Work Hours	0.199 (-0.046, 0.443)	0.109	-0.120 (-0.363, 0.123)	0.328	0.148 (-0.100, 0.396)	0.235	0.087 (-0.143, 0.316)	0.450	0.238 (0.007, 0.469)	0.044
Weekday Leisure	0.001 (-0.202, 0.204)	0.994	0.064 (-0.138, 0.266)	0.530	0.010 (-0.208, 0.228)	0.925	0.229 (0.027, 0.431)	0.027	0.059 (-0.145, 0.262)	0.564
Weekend	-0.043 (-0.225, 0.139)	0.638	-0.152 (-0.333, 0.028)	0.097	0.051 (-0.137, 0.240)	0.587	0.019 (-0.156, 0.193)	0.831	0.084 (-0.091, 0.260)	0.339
Vigorous-Intensity PA										
Work Hours	0.130 (-1.612, 1.871)	0.882	-0.383 (-2.141, 1.375)	0.664	1.812 (-1.354, 4.977)	0.255	-0.534 (-3.853, 2.785)	0.747	0.962 (-2.355, 4.280)	0.562
Weekday Leisure	0.019 (-0.639, 0.678)	0.953	-0.092 (-0.756, 0.573)	0.784	-0.179 (-0.911, 0.554)	0.625	0.480 (-0.288, 1.247)	0.215	0.319 (-0.449, 1.086)	0.408
Weekend	0.137 (-0.738, 1.013)	0.755	-0.020 (-0.904, 0.864)	0.963	0.888 (0.004, 1.771)	0.049	-0.085 (-1.011, 0.842)	0.855	0.168 (-0.758, 1.095)	0.716
MVPA										
Work Hours	0.191 (-0.048, 0.430)	0.115	-0.113 (-0.333, 0.107)	0.310	0.138 (-0.103, 0.379)	0.256	0.073 (-0.152, 0.298)	0.518	0.226 (0.001, 0.452)	0.049
Weekday Leisure	-0.006 (-0.191, 0.179)	0.949	0.151 (-0.459, 0.762)	0.622	0.008 (-0.193, 0.209)	0.937	0.218 (0.031, 0.405)	0.024	0.067 (-0.121, 0.254)	0.478
Weekend	-0.029 (-0.195, 0.138)	0.731	-0.118 (-0.276, 0.041)	0.143	0.072 (-0.099, 0.243)	0.400	0.007 (-0.152, 0.167)	0.927	0.074 (-0.086, 0.234)	0.354

* Statistical significance defined as false discovery rate (FDR) < 0.25. PA- physical activity; MVPA- moderate-to-vigorous physical activity.

Table 7: Mean scores for all cognition (executive function, attention and working memory) and mood (positive and negative affect, alert, calm, content) outcomes split based on individuals who accumulated two hours of standing and light-intensity PA during their working hours (Achieved Guidelines, n=55) and those who did not (Did Not Achieve Guidelines, n=20) (mean±SD).

	Achieved Guidelines	**Did Not Achieve Guidelines**	**p-value**
Executive Function			
Interference Score (ms)	150±110	203±141	0.087
Attention			
Alerting Network (ms)	15±20	20±24	0.453
Orientating Network (ms)	17±23	13±22	0.593
Executive Control (ms)	68±35	68±24	0.957
Working Memory			
One Back Accuracy (%)	91.8±7.3	92.0±8.2	0.969
Two Back Accuracy (%)	90.4±10.3	84.0±22.1	0.099
Three Back Accuracy (%)	74.9±20.7	81.3±10.4	0.139
Mood			
Positive Affect	34.3±6.5	30.6±7.6	0.052
Negative Affect	16.2±5.7	15.6±5.4	0.667
Alert	68.0±16.6	61.4±16.6	0.237
Calm	52.1±11.5	48.1±14.0	0.283
Content	69.1±16.7	61.1±17.5	0.126