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Physical activity changes among office workers during the COVID-19 pandemic lockdown and the agreement between objective and subjective physical activity metrics

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ABSTRACT

After the onset of the COVID-19 pandemic, many office workers transitioned to working-from-home (WFH) which altered routine physical activity (PA). To understand how these workers' PA were affected throughout the pandemic, PA data collected in January, April, June, and December 2020 with an activity tracker and a validated survey were analyzed. Between January and December, it was found that step counts during the weekday decreased ($p < 0.01$), weekday heart rate was higher than weekends ($p < 0.01$), activity-tracker and self-reported PA decreased ($p < 0.01$), and sitting time increased ($p < 0.01$). To understand the agreement between the objective and subjective METs, Bland-Altman analyses were completed and demonstrated an acceptable level of agreement. Findings show decreased level of PA amongst WFH office workers and that the activity tracker and survey are reliable methods of recording WFH PA.

1. Introduction

Coronavirus Disease 2019 (COVID-19) was declared a global pandemic on March 11, 2020 by the World Health Organization (World Health Organization, 2020). Responses by governments and workplaces disrupted physical activity (PA) patterns of workers across the globe (Curtis et al., 2021; Lesser and Nienhuis, 2020; Maugeri et al., 2020; Wang et al., 2021). Government-imposed lockdowns and social distancing procedures shifted the work force to a necessary work-from-home (WFH) format for one-third of the working U.S. population, where three-fourths of this population were office workers (Coate, 2021). Before the COVID-19 pandemic, office workers spent most of their working hours physically inactive (Pollard et al., 2022). Moreover, with the increased amount time spent at home, 42.6% of individuals reported an increase in sedentary time (Meyer et al., 2020). Such patterns may be concerning, as long sedentary times and decreased PA of individuals have been associated with the development or decline of detrimental health conditions (Arippa et al., 2022; Chen et al., 2020). With such a large population of the workforce at risk of the effects of reduced PA, and the WFH format likely to continue due to worker preference and reduced operation costs for companies (Dillon et al., 2021; Moens et al., 2021; Xiao et al., 2021), it is important to measure how worker PA has been effected.

To measure and understand the change in PA patterns in WFH populations during COVID-19, studies have used self-reported surveys due to its relative ease of dissemination and accordance with social distancing procedures (Dillon et al., 2021; Fukushima et al., 2021; Lesser and Nienhuis, 2020; Maugeri et al., 2020; Meyer et al., 2020; Sebastião et al., 2021). Recent survey results of 277 individuals reported a reduction of up to 67% in PA (Sebastião et al., 2021) and 42.6% of 3052 participants reported sitting for more than eight hours a day (Meyer et al., 2020). Furthermore, 64.8% of 988 participants reported new physical health issues during the pandemic (Xiao et al., 2021). In addition to customized surveys, the International Physical Activity Questionnaire (IPAQ) is another common tool used to calculate PA. The IPAQ was developed as an international consensus for measuring comparable estimates of PA of adults 18–65 years of age through a week-long analysis of moderate to vigorous PA across domains (i.e., work, travel, domestic, leisure) (Craig et al., 2003). The IPAQ charts PA based on calculated metabolic equivalent (MET), which is the rate of energy expenditure associated with various daily activities compared to sitting down. One recent study that administered the IPAQ found a significantly lower level of PA during COVID-19 than before the pandemic (Maugeri et al., 2020).

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Moreover, PA has been measured using objective metrics from activity trackers. Activity trackers, such as those manufactured by Fitbit Inc., use a triaxial accelerometer and METs/minute to estimate PA (Sjöberg et al., 2021). These devices have been used to measure PA due to their reliability in logging sedentary time and PA (Beagle et al., 2020). Activity tracker based studies found that office workers spend 77% of their working day sedentary, and attained most of their PA after work hours (Thorp et al., 2012). Studies using activity trackers to measure PA during COVID-19 have found that WFH office workers spend 48% of their day engaging in sedentary behavior (Brusaca et al., 2021). Further, individuals spent almost an hour more with combined sleep and time in bed (Curtis et al., 2021).

However, there is a mixed level of agreement, where some PA metrics are more strongly correlated than others, between objective and self-reported PA (Dillon et al., 2021). To find the correlation between the subjective and objective metrics outside of a COVID-19 context, Beagle et al. (2020) compared PA gathered via an activity tracker and self-reported surveys and reported a moderate correlation for vigorous activity but weak correlations for sedentary time, walking, and moderate activity. This study showed participants reported higher activity levels and less sedentary time than outputs from the activity tracker (Beagle et al., 2020). However, the adult population in this study was mostly considered physically active and may not yield the same results in a sedentary occupation. Other studies have found similar results where the two metrics are weakly correlated for walking and moderate labor and strongly correlated for sedentary activities, but they also found that the amount of PA the individual normally experiences in the workplace effects their reporting of PA (Maes et al., 2020). That is, those in occupations with higher PA underestimated their self-reported PA and those whose professions were largely sedentary overestimated self-reported walking (Maes et al., 2020). Yet, these occupations were measured in pre-pandemic conditions which may not be representative of workers who are WFH. Previous work examining the PA of office workers during the COVID-19 pandemic via an activity tracker and survey found acceptable levels of agreement at a group level but poor levels of agreement at an individual level in a WFH setting (Dillon et al., 2021). While this retrospective study is representative of a WFH population, further work can be done to examine how long-term PA trends transformed from before the pandemic began. This mixed level of agreement warrants the need to better understand how these two metrics portray PA.

Understanding how the metrics perform in the scope of COVID-19 could be beneficial for future studies in measuring PA in a similar scenario. A common limitation of most recent works in understanding PA during the pandemic is that they provided snapshots of PA after the onset of the pandemic and WFH, since it is impossible to plan a study for a pandemic. Therefore, these studies are mostly limited to retrospective analyses, which could not account for baseline PA measurements before the pandemic, and consequently may not have the capability of identifying long-term trends over time.

This study analyzed data from a larger prospective office ergonomics study conducted in a government agency in the State of Washington, USA. That study commenced in January 2020 and continued into the pandemic with almost all agency employees WFH. Consequently, the study presented an opportunity to observe the changes in PA in a total WFH setting due to a pandemic induced statewide lockdown, without changes in the protocol. To consider individual perception of PA, a wearable activity tracker was chosen to record participant PA as it is more user friendly (Sjöberg et al., 2021), while the IPAQ-LF was selected due to its ease of dissemination (Craig et al., 2003). The former was considered an unbiased PA metric while the latter was a subjective perception. Therefore, a greater understanding of how these changes in PA were recorded between objective and subjective metrics, and how they agreed with each other, was necessary to determine how worker PA could best be evaluated. The purpose of this study was to 1) examine patterns in PA in WFH office workers throughout the COVID-19 pandemic from January 10, 2020, to December 31, 2020, and 2) investigate the agreement between subjective PA values, via the responses from the International Physical Activity Questionnaire – Long Form (IPAQ-LF), and objective values, via a Fitbit activity tracker. It was hypothesized that PA decreased across all metrics throughout the year 2020. Furthermore, we hypothesized that there was an agreement of PA measures obtained from the two metrics.

2. Methods

2.1. Study population

Participants were initially recruited as part of a larger study. There were 188 state government employees, whose primary jobs were computer-based and mostly desk-bound, enrolled at the beginning of the study. The study protocol was approved by the Washington State Institutional Review Board. Informed consent was obtained with the option to withdraw from the experiment at any time. Participants identified as 76% female, and the mean age of all participants was 44 years (SD = 10.46) (Table 1). The average tenure with the state government was 10.96 (SD = 9.18) years.

2.2. Data collection and analysis

IPAQ-LF surveys were distributed to each participant electronically at four time periods on January 16, 2020, April 6, 2020, May 27, 2020, and December 13, 2020. Participants were asked to complete the survey via SurveyMonkey (Momentive Inc., San Mateo, CA) within two weeks of receiving the invitation. PA from the IPAQ-LF was represented as daily METs/hour. METs are a measure of PA where 1 MET is the equivalent of the amount of energy a person spends sitting down and increases with additional activity level.

Participants were given a Fitbit Charge 2 activity tracker (Fitbit LLC, San Francisco, CA) at the beginning of the study on January 10, 2020. Activity data was logged from the Fitbit for each individual, and data was uploaded directly from the device to data collection service Fitabase (Small Steps Labs LLC, San Diego, CA).

About two weeks before the push of the four designated IPAQ surveys, participants were instructed to wear the device for 30 days. For each individual, activity tracker metrics from seven days prior to the completion of the survey were extracted for analysis. For example, Survey 2 was distributed on April 6, 2020, and if the survey was filled out on April 7, Fitbit data (i.e., heart rate, step count, objective METs) from April 1 – April 7 were used to correlate with the IPAQ-LF metrics (i.e., self-reported METs and sitting time).

At the beginning of this longitudinal study there were 122 participants with recorded Fitbit data and 145 participants who completed the IPAQ-LF. The attrition rate increased as participants withdrew throughout the study and subsequent analyses were performed on the

Table 1
Participant demographics.

	Range (years)	Office Workers (n = 145)
Gender (% female)		76
Age		
	18–24	1
	25–34	31
	35–44	45
	45–54	38
	55–64	29
	65+	1
Tenure		
	1–9	86
	10–19	29
	20–29	22
	30–39	7
	40–49	1

remaining participants at each data collection period (Table 2). Agreement between metric analyses included only those who had recorded data for both the activity tracker and survey. All other metrics were performed on available samples.

Further, heart rate and activity tracker MET data were stratified into either weekdays (i.e., Monday – Friday) or weekends (Saturday-Sunday) (Fig. 1). Weekday data was analyzed for work hours (8:30 a.m.–5:30 p.m.) and outside work hours (5:30 p.m.–12:00 a.m. and 5:30 a.m.–8:30 p.m.) with sleep time removed (12:00 a.m.–5:30 a.m.). Weekends were excluded from this analysis. All other metrics (i.e., self-reported METs, steps, and sitting time) were analyzed based on a single reported value for the day. All analyses were performed on RStudio version 4.1.0 (RStudio, Boston, MA).

2.2.1. Steps

Step counts were also evaluated based on their correlation with PA (Beagle et al., 2020). Daily step counts were logged by the activity tracker and were averaged across all participants for each day.

2.2.2. Heart rate

Participant heart rate was examined due to its correlation with IPAQ based PA (Hansen et al., 2014). Heart rate was logged on daily 1-minute intervals. Data points of zero and over 202 were removed based on the maximum possible heart rate for the youngest possible working age of the study population; 309 total data points were removed. Heart rate data was normalized based on a max-min method (Akanbi et al., 2015) for comparison among individuals (Işler and Kuntalp, 2010). To observe the trend across the year, the minute-based heart rate was averaged to obtain a single average heart rate for each participant during the seven-day period. Participant heart rate was aggregated and averaged for each month.

2.2.3. MET

METs from the activity tracker were logged on minute intervals for each participant throughout the duration of the experiment. METs recorded by the Fitbit were scaled to match those of the IPAQ-LF (i.e., divide Fitbit METs by 10 to remove the scaling factor). METs were then summed for each day and converted from minutes to hour for each participant to generate daily METs/hour.

Participant METs from the IPAQ were calculated according to the IPAQ scoring protocol (*IPAQ Scoring Protocol - International Physical Activity Questionnaire*). The calculated METs were converted from minutes to METs/hour. Outliers were removed if their subjective METs exceeded 200 weekly METs/hour. This was decided based on the maximum PA that can be expected from an individual during a week (Ainsworth et al., 2000). Three outliers were removed.

Missing objective METs and subjective METs that reported zero were removed for data matching. Objective METs from the Fitbit and subjective METs from the IPAQ for each participant were then compared.

2.2.4. Sedentary time

Sitting time as reported in the IPAQ-LF was used to represent subjective sedentary time. Sitting time, in minutes, for the week was obtained and converted to sitting hours a day. Outliers, such as those reporting more than 24 hours of sitting time in a day, were removed.

Table 2
Adherence and completion rates for objective and self-reported survey during study period.

	Objective		Subjective	
Month	*n*	Adherence (%)	*n*	Completion (%)
January	122	82.6	145	100.0
April	122	81.7	111	76.6
June	121	77.0	97	66.9
December	73	84.2	83	57.2

Eight outliers were removed.

2.3. Statistical analysis

Data was separated into four time points based on the dates that participants completed the survey: January, April, June, and December. Data from January was used as the baseline for PA as this was the time before the WFH transition. Non-parametric pairwise Wilcox tests with Bonferroni post-hoc were completed for each metric between the four time points. Furthermore, participant percent changes compared to January were compared for each metric to identify individual trends.

A Bland-Altman analysis was conducted to evaluate agreement between METs obtained from self-reported and objective metrics, as it has been proven as a reliable method of comparing two measurement methods (Myles and Cui, 2007). Additionally, a Pearson correlation test was completed to understand the correlation between the subjective and objective metrics based on previous work comparing continuous metrics (Xiao et al., 2021). Additional Pearson correlation tests were conducted at the individual level to understand how other PA metrics are correlated with MET metrics.

3. Results

Summary of the number of participants and adherence and completion rates for the four time points is shown in Table 2. Objective, Fitbit, adherence rate was calculated based on how often the participants wore the activity tracker throughout the day (i.e., full 24-hours is 100%). Adherence rate for each time period was averaged for each participant and then all participants were averaged to generate the adherence rate. Subjective completion rate was calculated based on how many participants completed the survey with January acting as the baseline.

Average objective and self-reported metrics throughout all four data collection periods are summarized in Table 3. Individual PA changes across all metrics are categorized in Table 4. Individual PA changes were categorized as either increasing or decreasing 0–25%, 25–50%, or 50%+. The majority change was calculated by averaging all the decreases in PA for each row and comparing them against all the increases in PA with the highest total equating in the majority change.

Step count comparisons produced no significant difference in steps between weekdays and weekends ($p > 0.05$); however, a significant interaction between weekday and weekends and months were found, $F(7, 2363) = 5.69$, ($p < 0.01$). Weekday step counts declined by 730 steps from January to April ($p < 0.01$), 897 steps to June ($p < 0.01$), and 1401 to December ($p < 0.01$). No significant differences were found for percent changes ($p > 0.05$).

Normalized heart rate comparisons reveal that participants had 1% lower heart rate during weekdays than weekends ($p < 0.01$). Fig. 2 shows that heart rate was 8% higher during work hours than sleep ($p < 0.01$) and outside work was 7% higher than sleep ($p < 0.01$). No significant differences were found in heart rate between months or for percent changes during work and outside work hours ($p > 0.05$).

Activity-tracker METs comparisons produced no significant differences between weekday and weekend METs/day ($p > 0.05$); however, a significant interaction between weekdays and weekends and months were found, $F(7, 8701) = 5.53$, ($p < 0.01$). Work hours reported 0.12 METs/day more than outside work hours ($p < 0.01$) and 0.47 METs/day more than sleep hours ($p < 0.01$). As seen in Fig. 3A, work hour PA decreased by 0.09 METs/day from January to April ($p < 0.01$), 0.08 METs/day to June ($p < 0.01$), and 0.11 METs/day to December ($p < 0.01$). Work hour PA decreased 6.6% between June and December ($p = 0.05$). Outside work hour PA decreased by 0.06 METs/day from June to April ($p < 0.01$), 0.07 METs/day to June, and 0.09 METs/day to December ($p < 0.01$). No significant percent changes were found for outside work hours ($p > 0.05$) throughout the year.

Self-reported METs comparisons revealed that PA decreased by 2.17

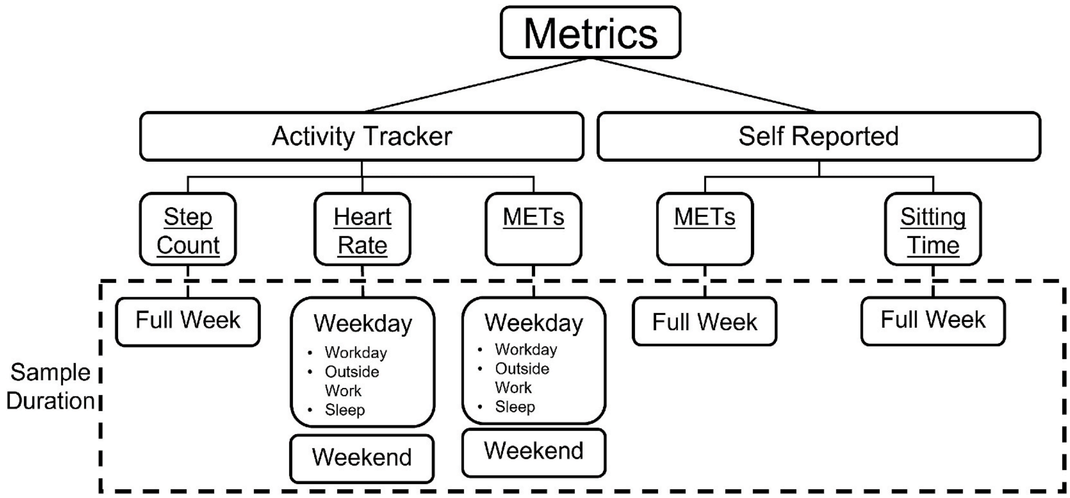

Fig. 1. Physical activity metric organization from January 2020–December 2020.

Table 3
Mean (SD) of objective and subjective metrics.

Metric				Mean (SD)
Activity Tracker	Step Count (Steps)	Full Week		5970 (3892)
	Normalized Heart Rate	Full Week		0.27 (0.07)
		Weekday		0.22 (0.06)
			Work	0.25 (0.04)
			Outside Work	0.24 (0.04)
			Sleep	0.17 (0.05)
		Weekend		0.23 (0.07)
		Full Week		1.35 (0.43)
		Weekday		1.34 (0.40)
			Work	1.51 (0.32)
			Outside Work	1.39 (0.25)
			Sleep	1.03 (0.05)
		Weekend		1.36 (0.48)
Self-report	MET (MET/Hour/Day)			4.86 (4.63)
	Sitting Time (Hours)			7.65 (3.55)

METs/day from January to December ($p < 0.01$) (Fig. 3B). No significant percent changes for self-reported METs were found ($p > 0.05$).

Sitting time comparisons report that sitting time increased by 1.45 hours from January to June ($p = 0.05$) and 1.99 hours to December ($p < 0.01$). No significant differences were found comparing percent changes ($p > 0.05$).

From the Bland-Altman analysis, overall agreement was observed for self-reported and objective METs for each month (Fig. 4). A proportional constant error resulted in a skew across all time points. A bias of 33.55 was found for January (Fig. 4A), a bias of 103.93 for April (Fig. 4B), a bias of 22.50 for June (Fig. 4C), and a bias of 19.41 for December (Fig. 4D), all of which are biased towards self-reported METs. The difference between limits of agreement for January are 140.76, 138.22 for April, 91.77 for June, and 97.37 for December.

Pearson correlation results were categorized as weak ($r \leq 0.3$), moderate ($0.3 \leq r \leq 0.7$), and strong ($r \geq 0.7$) based on established criteria for correlation coefficients (Akoglu, 2018). A Pearson correlation test between self-reported and objective METS resulted in a weak correlation between the two metrics ($p = 0.01$, $r = 0.13$). Individual PA metric correlations with objective and subjective METs are charted in Table 5. Pearson correlations tests for objective METs resulted in a weak negative correlation with sitting time ($p < 0.01$, $r = -0.23$) and strong positive correlation with step count ($p < 0.01$, $r = 0.70$), while subjective METs resulted in a weak negative correlation with sitting time ($p < 0.01$, $r = -0.16$) and positive correlation with step count ($p < 0.01$, $r = 0.25$).

Table 4
Individual PA change of objective and subjective metrics.

Metric	Month (n)	Majority Change	50%+ Decrease	25%–50% Decrease	0%–25% Decrease	0%–25% Increase	25%–50% Increase	50%+ Increase
	Jan.–Apr. (105)	Decrease	0 (0%)	0 (0%)	62 (59%)	41 (39%)	2 (2%)	0 (0%)
Heart Rate	Apr.–Jun. (83)	Decrease	0 (0%)	1 (1%)	42 (51%)	40 (48%)	0 (0%)	0 (0%)
	Jun.–Dec. (47)	Increase	0 (0%)	0 (0%)	19 (40%)	26 (55%)	2 (4%)	0 (0%)
	Jan.–Apr. (107)	Decrease	17 (16%)	31 (29%)	20 (19%)	16 (15%)	10 (9%)	13 (12%)
Step Count	Apr.–Jun. (82)	Increase	8 (10%)	6 (7%)	20 (24%)	24 (29%)	12 (15%)	12 (15%)
	Jun.–Dec. (48)	Decrease	8 (17%)	12 (25%)	14 (29%)	7 (15%)	4 (8%)	3 (6%)
	Jan.–Apr. (107)	Increase	7 (7%)	10 (9%)	34 (32%)	22 (21%)	9 (8%)	25 (23%)
Sitting Time	Apr.–Jun. (74)	Decrease	4 (5%)	6 (8%)	28 (38%)	17 (23%)	13 (18%)	6 (8%)
	Jun.–Dec. (60)	Increase	2 (3%)	2 (3%)	21 (35%)	18 (30%)	10 (17%)	7 (12%)
	Jan.–Apr. (107)	Increase	0 (0%)	2 (2%)	48 (45%)	46 (43%)	11 (10%)	0 (0%)
Activity-Tracker MET	Apr.–Jun. (84)	Decrease	0 (0%)	1 (1%)	55 (66%)	28 (33%)	0 (0%)	0 (0%)
	Jun.–Dec. (52)	Decrease	0 (0%)	2 (4%)	38 (73%)	12 (23%)	0 (0%)	0 (0%)
	Jan.–Apr. (108)	Decrease	30 (28%)	16 (15%)	13 (12%)	17 (16%)	9 (8%)	23 (21%)
Self-reported MET	Apr.–Jun. (83)	Decrease	11 (13%)	14 (17%)	18 (22%)	15 (18%)	1(1%)	24 (29%)
	Jun.–Dec. (53)	Decrease	17 (32%)	9 (17%)	5 (9%)	5 (9%)	2 (4%)	15 (28%)

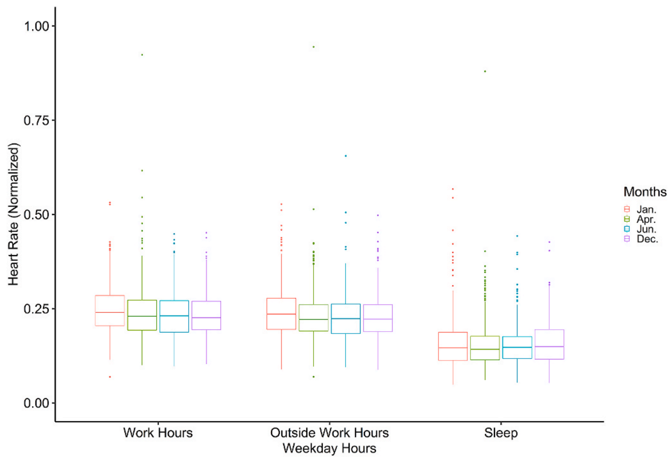

Fig. 2. Normalized heart rates of study participants in 2020. Jan. (n = 117), Apr. (n = 99), Jun. (n = 85), Dec. (n = 52).

4. Discussion

This study investigated the changes of PA, through self-reported and objective metrics, during the WFH transition during the COVID-19 pandemic. Analysis of both metrics point towards a decrease in PA from the beginning of the year before COVID-19 and PA at the end of the 2020 year, which could be due to the drastic lifestyle changes that resulted from the pandemic. This decrease in PA was expected as other studies witnessed similar behaviors in workers as they transitioned to a WFH format beginning in March and spent longer times at home (Curtis et al., 2021). However, even after the transition, weekends had higher indicators of increased PA than weekdays which is similar to findings of other works investigating office worker PA (Parry and Straker, 2013).

Step count did not significantly differ between weekdays and weekends, however, there was a consistent decline in step count throughout the year. This change was expected as individuals were likely more confined to their homes during government imposed lockdowns and naturally sit longer while WFH (Widar et al., 2021). A lack of significant percent changes may reflect individual habits as those who were inactive before the pandemic showed a decrease in PA while those with active habits before the pandemic had an increase in PA (Lesser and Nienhuis, 2020; Meyer et al., 2020). Alternatively, the lack of a significant change may further emphasize the relation between office work PA and WFH PA since both locations require a large amount of sitting time and previous work found no change in walking when comparing before WFH to after (Aegerter et al., 2021).

Although heart rate was found to be lower during weekends when compared to weekdays, there was no significant change throughout the year (Fig. 2). This lack of a significant change can be attributed to the fact that workers who WFH tend to have a more stable heart rate than those in an office (Widar et al., 2021). Furthermore, the minimal differences found between the four time points could be due to the 24-hour duration that was examined which included participant sleep time. With such a large time range, and an average increase of 34 min of sleep during the COVID-19 pandemic (Hallman et al., 2021), it may be difficult for moderate to vigorous physical activities to influence heart rate. Further, since heart rate data was normalized for comparative purposes, granular changes that may contribute to any differences may have been dampened. Additionally, as participants were examined as a whole to evaluate the overall change in PA across office workers, it would take a larger proportion of individuals to engage in higher levels of PA to produce any major differences. This can be seen when examining heart rate at the individual level where about half of the participants experienced a decrease in heart rate while the other half experienced an increase (Table 4). With no difference between pre-COVID-19 office work and WFH months, this could suggest that, during the pandemic lockdown, WFH PA was similar to PA experienced working in the office in this region.

Interestingly, subjective METs significantly decreased from January to December while objective METS significantly decreased from throughout the year (Fig. 3). There were also no significant percent changes for self-reported METs but there were for objective METs during work hours. However, it would be expected for the two metrics to align in their findings since they reported over the same time frame. This suggests that external factors could have influenced the reported PA. Objective measurements via activity trackers tend to report PA more consistently given they have identical sensors, and as a result, have smaller variabilities. However, because the activity tracker constantly records PA, it may be recording data even when the user is not wearing the device which could influence the results. This is especially true for objective METs as analysis of the data shows a 99% adherence rate, when calculated the same way as Table 1, even when other PA metrics were not recording data. However, because it cannot be said for certain if the participants were missing data due to not wearing the device, or because the device was not recording activity correctly, the data was left unaltered. This possible inclusion of inactivity could influence the findings of objective METs, but since the METs resulted in similar PA across participants, results may not have been affected much if at all. Comparatively, self-reported metrics are inherently susceptible to factors that could influence reported PA such as the duration and frequency participants normally engage in PA (Durante and Ainsworth, 1996). Additionally, the type of activity affects participant reporting as individuals are able to recall longer durations of time the longer they spent sitting (Dillon et al., 2021). Further, the instructions for the IPAQ can be

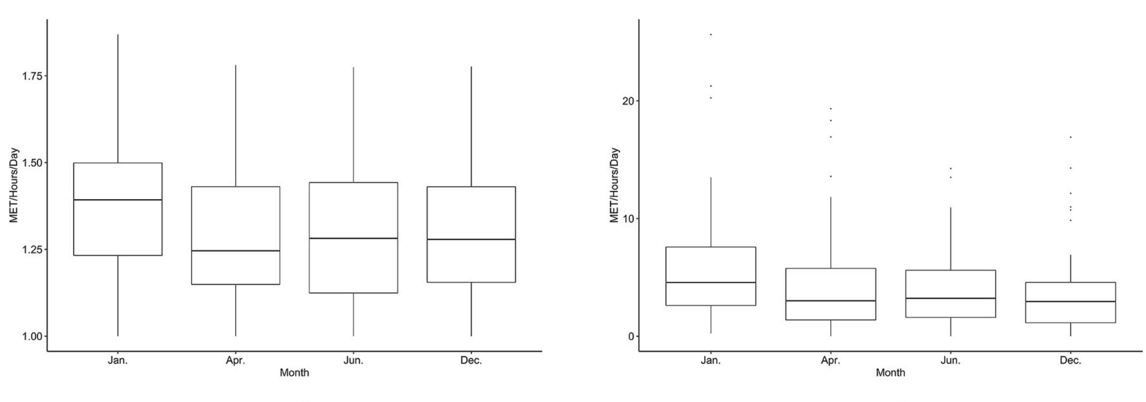

Fig. 3. Average Participant MET/Hours/Day at four time points in 2020: A) Activity-tracker METs, B) Self-reported METs. Jan. (n = 119), Apr. (n = 99), Jun. (n = 91), Dec. (n = 56).

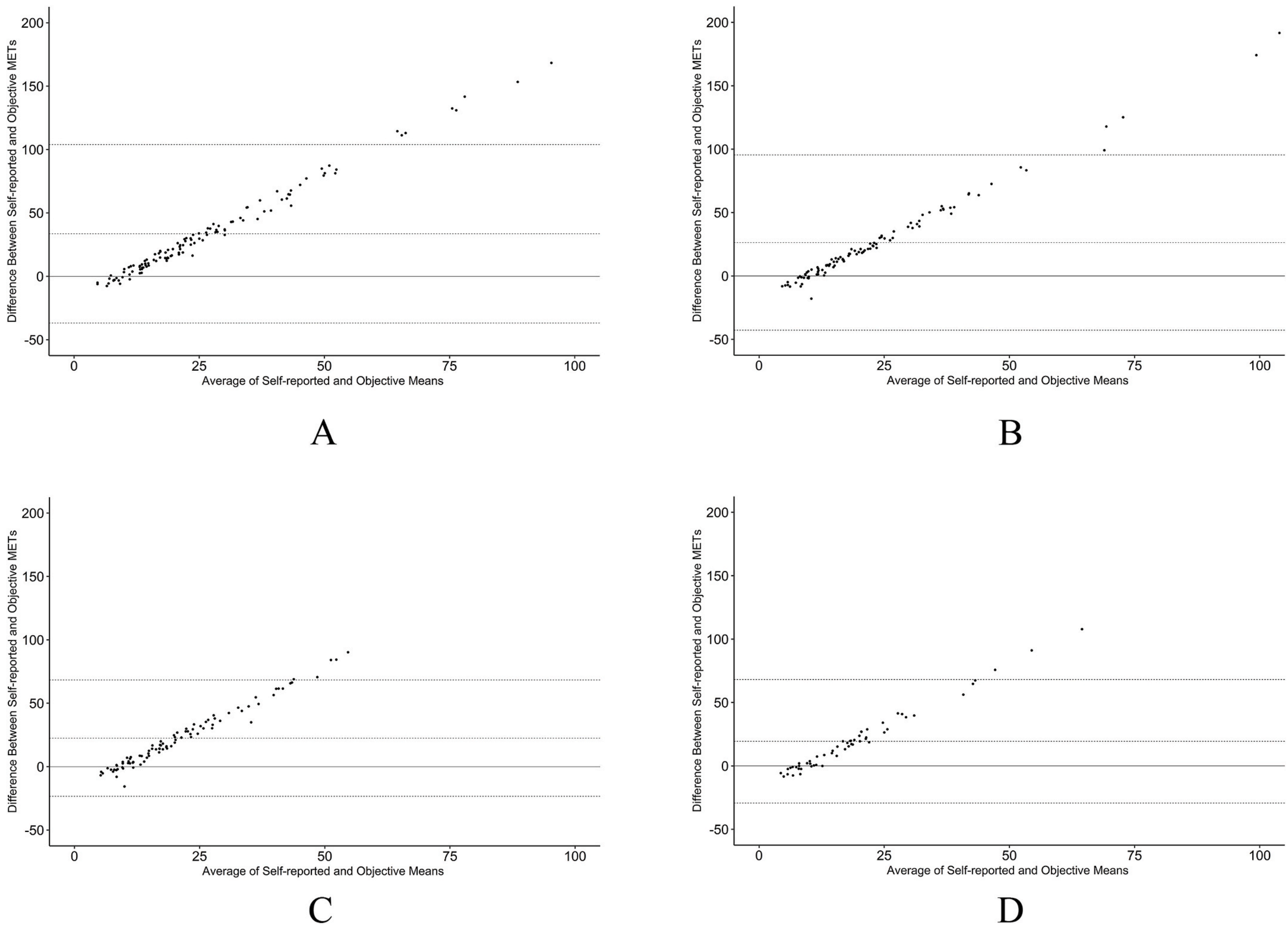

Fig. 4. (A) Jan. Bland-Altman Analysis: upper level of agreement = 103.93, lower level of agreement = −36.83, n = 119. (B) Apr. Bland-Altman Analysis: upper level of agreement = 95.48, lower level of agreement = −42.74, n = 99. (C) Jun. Bland-Altman Analysis: upper level of agreement = 68.39, lower level of agreement = −23.38, n = 91. (D) Dec. Bland-Altman Analysis: upper level of agreement = 68.10, lower level of agreement = −29.27, n = 56.

Table 5
Pearson correlation between individual MET metrics.

Metric Comparison	Objective MET		Subjective MET	
	r	*p*-value	r	*p*-value
Heart Rate	-0.08	0.15	0.08	0.18
Step Count	0.70	<0.01	0.25	<0.01
Sitting Time	-0.23	<0.01	-0.16	<0.01

unclear and confusing to those who are unfamiliar with the PA distinctions it asks the user to recall which could lead to unintentional misreporting (Lavelle et al., 2020). Additionally, participants might have unintentionally misreported their PA because they perceived a change in their own PA that may or may not have been present. This perception in decreased PA was apparent at the individual level (Table 4) as it was the only metric to report a decrease across all time comparisons. Finally, the largest variation in METs across both metrics was found in April which could be due to individuals becoming more active more sporadically during the early months of WFH, as they became accustomed to the WFH format.

An increase in sitting time from January to December show that workers spent around 8.58 hours sitting during December which is more than the typical 6.6 hours of sedentary time office workers engage in (Thorp et al., 2012). However, this increased sitting time correlates with expected behaviors of WFH and previous work that also found individuals experienced an increase in sedentary time (Brusaca et al., 2021). This is likely because people did not have the opportunity to engage in PA that they may have gotten from commuting, visiting gyms, or recreational areas that may have been closed due to the pandemic lockdown orders (Lesser and Nienhuis, 2020). Further, without the need to commute to work, individuals spent more time in bed before shifting over to their at home workstation (Curtis et al., 2021). However, at the individual level (Table 4) participants showed a decrease in sitting time during April and June which could be an indicator of change in activity due to adjusting to WFH or individuals being more active in warmer weather.

The agreement between self-reported and objective METs (Fig. 4) were similar to previous literature (Dillon et al., 2021). However, it should be noted that the two metrics were only weakly correlated. This disconnect was expected since similar studies have found a weak correlation between the IPAQ and objective measurements (Lavelle et al., 2020). Previous work also resulted in similar findings – that the two metrics can be adequately compared for sedentary behaviors but have a lower correlation for active behaviors (Beagle et al., 2020; Maes et al., 2020). The bias towards the self-reported metric suggests that the IPAQ-LF METs were overreported when compared to the Fitbit METs. This again could be due to the subjective nature of surveys that could be influenced by sedentary time, survey fatigue, or survey understanding (Dillon et al., 2021; Lavelle et al., 2020; Prince et al., 2020). The weak correlation between the two metrics could be due to limitations of self-reported and objective metrics. Though subjective metrics were a safe way to measure PA during COVID-19, self-reported PA via surveys can be susceptible to biased results (Helmerhorst et al., 2012). This could be especially true during this particular period as there was an increase in reported mental health issues during the COVID-19 pandemic (Lesser and Nienhuis, 2020), and perceived competence has been shown to be correlated with PA (Teixeira et al., 2012). Further, multiple outliers in the subjective data were removed due to the reporting of obviously unreasonable PA that indicate how easy it is for data to be potentially misreported – especially those with higher than normal values but not great enough to qualify as outliers. Additionally, objective metrics from activity trackers are limited by the possibility of misreporting information depending on the sensitivity of the tracker, especially when measuring energy expenditure (Prince et al., 2020). Further, depending on the demographic of the office workers, the study population could have affected the results, as it has been found that men are more likely to overreport PA than women (Hansen et al., 2014). Additionally, inconsistencies in the data reporting such as participants forgetting to wear their activity tracker or interpreting the survey instructions differently could have further extended this gap in reported PA.

However, correlations amongst the MET and other PA metrics at the individual level (Table 5) echo previous findings where objective metrics are more strongly correlated to PA related metrics (i.e., body mass index) than subjective metrics, and PA is more strongly correlated to both than sedentary activity (Beagle et al., 2020). Although these metrics may not be considered a "gold standard", they still capture similar observations of PA. This suggests that they may be reliable in the instance where a gold standard measure may not be practical due to costs or usability limitations.

Limitations of this study include the sample population and the unpredictable nature of the pandemic environment the study took place during. The participants of this study were all office workers from the northwest region of the country which may not be representative of other worker or demographic populations. Of course, the COVID-19 pandemic was likely the largest influencing factor of this study. The pandemic led to the implementation of new safety protocols and quarantine lockdowns that may have affected participant PA in ways that may not be truly representative of their normal PA. However, this limitation may prove to be an important strength as it provides insight into a rare phenomenon that may help future researchers better understand how a pandemic affects society and consequently how to better prepare or adapt. Like many employers that made the sudden shift to WFH, best practices and ergonomic training were overlooked for the health of employees which may have exacerbated any PA changes (McAllister et al., 2022). Further, as this was a secondary study, details about individual home offices were not gathered or if the state agency provided additional ergonomic equipment support during this transition that could have affected participants. Consequently, potential confounders such as office equipment, and even prior health status, may not have been taken into account for this analysis. However, many workers began WFH for the first time during the COVID-19 pandemic and may not have had adequate home office environments (Fukushima et al., 2021; Xiao et al., 2021). As a result, related confounders could potentially be counteracted if most of the workers had similar improper WFH environments. Still, future works may benefit from considering WFH environment components that could influence results. The age of the population could have also influenced the results since it was found that older adults were more active than younger adults (Meyer et al., 2020). Further, a large extent of this study was conducted through a WFH format which allows for a greater flexibility in the opportunities, or lack thereof, for PA. This variability may lead to deviations in normal PA patterns than what would be expected from a typical officer worker population. Additionally, self-reported PA was only gathered from the past week from when the IPAQ-LF was distributed which only offers a snapshot of participant PA. Individual PA could have also been affected by weather patterns during measurement periods. The data could also be influenced by the natural seasonal changes throughout the year that would dictate the participant's level of PA (i.e., less PA in colder months than warmer months) (Turrisi et al., 2021). Finally, the loss of participants throughout the study could have had an effect on the results by narrowing the scope of PA patterns in the study population of interest. The additional distress caused by the pandemic may have encouraged participants to dropout (Rossi et al., 2020). However, IRB protocol allows participants to withdraw at any time without disclosing a reason. As a result, it is unlikely that total adherence can be enforced in any human subject study as participant attrition has been found in similar studies (Dillon et al., 2021). The loss of participants during longitudinal studies are a common occurrence as most longitudinal studies have an attrition rate of 30%–70% (Goodman and Blum, 1996; Gustavson et al., 2012; Tambs et al., 2009). However, the participant retention rate in this study falls well within those bounds. There is no evidence of selective dropout, and any bias should be mitigated by a relatively stable demographic representation of participants throughout the study (Appendix A). Finally, due to the limited number of participants in the study, an in depth analysis of all possible covariates were not conducted as that was not the focus of this study. However, potential confounders were considered and appropriately investigated. It was found that age ranges (25–34) [$r = -0.97$], (35–44) [$r = -0.98$], (45–54) [$r = -0.97$], and (55–64) [$r = -0.98$] had the largest influence on self-reported METs/day. This is likely because this was the most represented age of office workers in this study (i.e., 44 years). With the mean age of office and administrative support occupations at 42.1 years according to the United States Bureau of Labor and Statistics, this study offers results that may be generalizable to the larger population of office workers (*Employed Persons by Detailed Occupation and Age*, 2022).

5. Conclusion

As the COVID-19 pandemic influenced statewide lockdowns, office workers in areas adopting similar pandemic responses were suddenly transitioned to a WFH format under the safety guidance of government agencies. This study quantified such disruptive changes in individuals' PA. It was found participants ultimately experienced a reduced amount of PA. The largest distinctions were found when comparing PA at the beginning of the year before the pandemic and the succeeding months after. Evaluation of PA between the two metrics via a Bland-Altman analysis resulted in an acceptable level of agreement, although the two metrics were only weakly correlated. This suggests that both metrics should be taken into consideration to get a fuller understanding of individual PA. These findings promote the idea that a decrease in PA can be expected in workers who WFH. With the recommended PA for adults being 500 METs a week (*Physical Activity Guidelines for Americans, 2nd edition, 2018*), WFH PA is important to understand as the pandemic continues to influence the working landscape. Consequently, interventions may be necessary to negate any harmful effects that could come with a sedentary lifestyle. As the WFH format is likely to continue (Moens et al., 2021), using wearables such as the Fitbit to track PA will help individuals recognize their level of PA and make the appropriate accommodations. Understanding the PA of office workers who WFH will also help organizations initiate appropriate healthy behavioral changes to promote a better working lifestyle for their employees.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Participant demographics for each month.

Month	Metric	Gender %Female	Age M (SD)	Experience Range M (SD)
Jan	Objective	74.79	44.24 (10.14)	11.24 (9.15)
	Subjective	66.36	44.01 (11.03)	12.21 (10.03)
Apr	Objective	74.26	44.55 (10.04)	12.02 (9.53)
	Subjective	72	44.84	13.01 (10.34)
Jun	Objective	77.65	44.8 (10.26)	11.66 (9.24)
	Subjective	73.13	44.4 (10.99)	12.54 (10.09)
Dec	Objective	70.37	46.24 (10.47)	13.37 (10.58)
	Subjective	73.21	46 (11.04)	14.3 (10.65)

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