Exploring Differences in Older Adult Accelerometer-Measured Sedentary Behavior and Resting Blood Pressure Before and During the COVID-19 Pandemic

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Abstract

Older adults have higher sedentary behavior (SB), lower physical activity, and are particularly susceptible to negative impacts from the COVID-19 pandemic and associated public health restrictions. Pandemic impacts to SB and health, particularly via objective assessment, are not well documented in the literature. Here we described differences in SB, physical activity, and blood pressure (BP) for older adults before and during the pandemic. Baseline thigh-worn activPAL accelerometer and BP measurements from 95 participants enrolled in a SB intervention trial pre-pandemic were compared to 60 enrolled post-pandemic. We used linear regression models adjusted for demographic and health factors to estimate differences in sample means of SB measures and BP. The post-COVID sample was older (age 67 vs. 70), more female (60% vs. 72%), and included more individuals of color (21% vs. 32%). In fully adjusted models, systolic BP was statistically significantly higher in the post-COVID group (6.8, 95% CI: [0.3,13.3]). After adjustment, activPAL-measured and self-reported activity were non-significant but trended towards greater total sitting (0.4 hours [−0.3, 1.1]), fewer daily steps (−270 [−1078, 538]), and greater self-reported TV time (0.4 hours, [-0.3, 1.1]) post-COVID. Future analyses are warranted to better quantify these impacts and guide clinical care and future interventions.

Background

Prior to the onset of the COVID-19 pandemic, older adults age ≥60 had higher sedentary behavior (SB) than younger age groups in the United States and internationally, accumulating an average of 10–14 hours of sitting each day (Copeland et al., 2015, 2017; Harvey et al., 2013; Matthews et al., 2008; Webster et al., 2021). SB is associated with increased risk for numerous chronic health conditions, such as cardiovascular disease and type 2 diabetes (Biswas et al., 2015; Copeland et al., 2017; de Rezende et al., 2014; Knaeps et al., 2018; Taylor et al., 2020). With the onset in March 2020 of the COVID-19 pandemic and associated public health mitigation

measures in the United States, the public faced severe restrictions on indoor public activity, social distancing mandates, and business closures at the federal, state, and local

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level. These measures limited many traditional opportunities for daily physical activity (PA) outside the home. Instead, people were encouraged to engage in PA at home and outdoors. For older adults, particularly those with chronic conditions at the highest risk for contracting and dying from severe COVID-19, adhering to social distancing guidelines was of critical importance to minimize risk (Centers for Disease Control and Prevention, 2021a, 2021b; Washington State Department of Health, 2021), and many older adults experienced fear and anxiety about leaving the home for any reason, including to engage in outdoor PA (Greenwood-Hickman et al., 2021). As a result, pandemic-related restrictions could further increase older adult SB and decrease PA, worsening chronic conditions, mental health, and overall health status (D'Cruz & Banerjee, 2020; Palmer et al., 2020).

There is limited evidence quantifying how SB has changed using objective measurements. In three recent accelerometer-based studies in older adults (sample sizes ranging $N = 18$–165) suggested increases in SB of around 5–30 minutes and decreases of up to 800 steps/day (Browne et al., 2020; Fernández-García et al., 2021). However, these studies used hip-based and wrist-based accelerometers, known to misclassify and underestimate SB (Barreira et al., 2015; Bellettiere et al., 2021; Carlson et al., 2019; Kerr et al., 2013; Marcotte et al., 2020). No published studies yet examine changes in older adult SB using activPAL inclinometers, which are thigh-worn accelerometers that allow valid measurement of posture (sitting vs. standing) in addition to movement to capture sitting behaviors (Kozey-Keadle et al., 2011; Larkin et al., 2016; Lyden et al., 2012).

Changes in PA and SB, as well as pandemic-induced stress (Bellettiere et al., 2021; Browne et al., 2020; Fernández-García et al., 2021; Hamm et al., 2020; Rowlands et al., 2021), could result in increased blood pressure (BP). One large cohort study of working-age adults documented significant increases to both resting systolic and diastolic BP between April and December 2020 (Laffin et al., 2021). However, it is not clear how such findings might translate to the older adult population. Prolonged periods of elevated BP could have long-term downstream consequences, leading to cardiac crisis events if not recognized and controlled as well as increased risk of severe complications from SARS-CoV-2 infection (Salzberger et al., 2021).

Here we leveraged inclinometer-based activity measures and blood pressure from the ongoing Healthy Aging Resources to Thrive (HART) trial's baseline assessments to describe differences in SB, PA, and BP in older adults.

Methods

Setting

The study was conducted at Kaiser Permanente Washington Health Research Institute in Seattle, Washington (WA). Data were obtained from the baseline measurements of the HART trial, which began in February 2019 and is ongoing. HART trial recruitment prior to the COVID-19 pandemic (pre-COVID) spanned 2/19/2019–3/4/2020 when it was paused due to the pandemic's onset. Effective early-March 2020, Washington State began implementing state-mandated restrictions and business closures and encouraging residents to stay at home, limit social gatherings, and maintain physical distance when in public spaces (Washington State Department of Health, 2021). Enrollment after onset of the COVID-19 pandemic (post-COVID) resumed 10/2/2020 and is ongoing. For this study, we include only participants enrolled through 4/19/2021, by which point widespread vaccination for older adults had occurred in Washington State and was likely to change individual behaviors related to control of the pandemic, including PA behavior. All research activities were reviewed and approved by the Kaiser Permanente Washington Institutional Review Board (#1315055). Additional detail on the parent trial can be found at ClinicalTrials.gov (NCT03739762).

Brief Overview of the Parent Trial

HART is a randomized controlled trial that aims to reduce sitting time in older adults with a body mass index (BMI) of 30 kg/m^{2} or above. Full details of the trial's original and revised COVID-19 protocol were described previously (Rosenberg et al., 2021). Primary outcomes of interest are thigh-worn activPAL SB metrics and blood pressure measured at 6 months follow-up. Participants ($N = 284$; recruitment ongoing) were recruited from Kaiser Permanente Washington membership panels.

Eligibility criteria included: age 60–89; BMI of 30–50 kg/m^{2}; self-report of ≥6 hours daily sitting; ability to stand from a seated position without assistance and walk one block; English fluency; continuous enrollment within Kaiser Permanente Washington in the prior 12 months; and no indications in their medical record of long-term nursing, palliative, or hospice care or a diagnosis of cancer, deafness/significant hearing loss, dementia, or a serious mental health disorder in the prior 24 months. Eligible participants who provided full written consent and successfully completed baseline study measurements were randomized to receive a sitting reduction intervention or a healthy living-focused attention control condition for 6 months.

In response to the SARS-CoV-2 pandemic, all in-person participant contact was halted as of March 4, 2020, at which time we had enrolled 100 participants. Subsequently, several protocol changes were made to accommodate remote implementation of the trial (Figure 1). Revised recruitment and measurement protocols were implemented in September 2020. Post-COVID participants completed all baseline measurements by phone and mail rather than coming into the research clinic. Measurement assessors mailed standard commercial devices to obtain blood pressure, weight, and

Figure 1. Summary comparison of key recruitment and measurement protocol changes between pre- and post-COVID period. *Note. Data collection methods presented in this table represent baseline data only.* [a]ActivPAL devices were mailed to participants and returned during in-person visits pre-COVID-19. Devices were mailed out to participants and returned by mail post-COVID-19. [b] Varied Omron models were mailed to participants post-COVID-19 due to limited availability

waist circumference remotely by phone, rather than using standardized devices in the research clinic. Secondly, because participation and study measurements were no longer dependent on attending in-person study visits in downtown Seattle, WA, the geographic recruitment area was expanded from the greater King County, WA region to the entirety of Washington State to foster increased sample diversity.

Sedentary Behavior & Physical Activity Measurement

Daily waking sitting time, sitting patterns and PA outcomes of interest were measured by the activPAL3 micro device (PAL Technologies Ltd, Glasgow, UK) at the baseline timepoint of the HART trial (i.e., prior to any intervention activity). The activPAL is feasible in older adult studies, (Grant et al., 2008; Lewis et al., 2016; Rosenberg et al., 2015) is sensitive to change, (Kozey-Keadle et al., 2012; Rosenberg et al., 2015) and has high validity compared to direct observation (Kozey-Keadle et al., 2011; Larkin et al., 2016; Lyden et al., 2012). The same activPAL protocols were employed pre- and post-COVID, with the exception that devices were provided via mail with a follow-up phone call from study staff to review adherence in post-COVID sample. Participants adhered the device to the front center thigh with a waterproof medical adhesive (Tegaderm[TM]) and were instructed to wear the device 24 hours/day for 7 days. Participants tracked their sleep time and whether they removed the device for any reason each day they wore the device using study-provided paper logs. After completing the 7-day wear, participants returned the activPAL device to the study, and data were downloaded and processed using proprietary activPAL software and programs developed for the R statistical software package, which removed self-report sleep time from the data to calculate waking hours spent sitting. As documented in prior studies and similar to standard procedures for accelerometer processing, data are considered valid if wear time is greater than 10 hours per day with a minimum of four valid days of data for each assessment period (Donaldson et al., 2016; Matthews et al., 2012; Migueles et al., 2017; Rosenberg et al., 2018; Ward et al., 2005).

Self-reported measures of TV-viewing and computer time were assessed via self-report survey at the baseline measurement visit using the AusDiab3 questionnaire (Clark et al., 2015). Participants responded to the following question, "*How much time in total did you spend sitting or lying down while [watching television or videos or DVDs/using the computer or internet]?*", separately for the last weekday and weekend day to capture differing patterns of activity for older adults across the week (Marshall et al., 2015). To minimize participant response burden, the AusDiab3 sitting time questionnaire was modified to provide discrete answer choices as follows: "None", "<30 minutes", "30–60 minutes", "1–2 hours", "2–3 hours", "3–4 hours", "4–5 hours", "5–6 hours", "6–7 hours", "7–8 hours", or ">8 hours." For analysis, the midpoint of each selected response value was taken (e.g., for "1–2 hours", a value of 1.5 hours was assigned) and an overall daily average time was calculated by multiplying the weekday value by 5 and the weekend value by 2 and dividing the sum of these calculations by 7 (e.g., for a participants reporting 1.5 hours/weekday and 3 hours/weekend day, the weekly average was $((1.5*5)+(3*2))/7 = 1.9$ hours/day).

Blood Pressure Measurement

BP was measured on the left arm using a validated Omron HEM-907XL automated monitor pre-COVID following

American Heart Association practice guidelines for BP measurement (Alpert et al., 2006; Smith, 2005). Participants were asked to refrain from caffeine and heavy exercise prior to the study measurement visit. Study staff measured participants' left bicep with a flexible tape measure to determine the appropriate cuff size for their measurement (El Assaad et al., 2002; Omboni et al., 2007). BP was taken after individuals had been resting while seated for 5 minutes, with their back supported, feet on the floor, and arm resting at heart level. Measures were taken three times using the mean of the last two readings for analysis. In the post-COVID remote procedures, participants received a validated (American Medical Association, 2021; OMRON Healthcare, 2021) Omron home automated monitor (Omron Bronze Upper Arm BP5100 HEM-7311 or the equivalent 3-series BP7100 depending on supply chain availability) by mail. A standard flexible cuff size (range 22–43 cm; covers both standard and large cuffs available in clinic) was used, which appropriately fit most participants (Ostchega et al., 2004). Study staff coached participants in taking their own BP during the measurement visit phone call, collecting readings three times after resting for 5 minutes. The final measure for analysis is the mean of the last two readings for both systolic and diastolic BP outcome measures.

Covariates

To adjust for known variations in the recruitment and measurement protocols and address other possible confounders, several covariates were included in analyses. The following were extracted from participant's Kaiser Permanente Washington electronic health record (EHR): age (continuous), sex (male vs. female), county of residence (King vs. other), and, based on ICD-9/10 codes from the prior year, Type 2 diabetes status and hypertension status (yes vs. no). BMI was calculated from height and weight measurements taken at the participants baseline measurement visit for the HART trial (Obese I, 30–34.9 kg/m^2 vs. Obese II, 35–39.9 kg/m^2 vs. Obese III, 40 + kg/m^2). Self-reported retirement status (retired vs. not) was also collected via survey at the participant's baseline measurement visit for the HART trial.

Race and ethnicity were also obtained from routinely collected self-report in the EHR. Reported race/ethnicity categories do not represent biological or genetic underpinnings or meaning. Rather, they represent self-identified race and ethnicity identities in a healthcare setting and serve as a proxy indicator for potential inequities in pandemic-related health and behavioral impacts driven by structural and systemic racism (Bailey et al., 2017; Kaplan & Bennett, 2003). Categories of report included White, Black, Asian, Hispanic/Latinx, American Indian/Alaska Native, Native Hawaiian or Other Pacific Islander, Other, and Unknown/Not Reported. Patients included in the "unknown/not reported" category may not have self-identified with any of the listed categories or clinic staff may not have inquired and recorded a response

in the record. The sample was characterized using all reported categories; however, due to small sample sizes in many groups, these categories were consolidated for modeling as White, Black, and other race and ethnicity.

Data Analysis

To be included in this analysis we required complete data capture of all outcome measures of interest and demographic and health status variables being assessed ($N = 10$ [5 Pre-COVID and 5 Post-COVID] were excluded due to missing data). We calculated the frequency distributions of study participants demographics and health status characteristics by pre-COVID and post-COVID groups. We separated the post-COVID group by those residing in the original pre-COVID recruitment area versus outside. Then to assess whether activity and BP measurements vary between the pre- and post-COVID groups we conducted a series of regression analyses. The outcomes of interest were: (1) daily mean activPAL measures including total sitting time (hours), total standing time (hours), cumulative steps and mean sitting bout duration (minutes); (2) self-reported average daily TV viewing time (hours) and computer time (hours); and (3) systolic and diastolic BP (mmHg).

Three models were implemented for each outcome of interest. Model 1 was an unadjusted linear regression model for each outcome with the binary exposure of enrolled pre-versus post-covid. Model 2 was a demographic-adjusted linear regression model, using the same outcome and exposure as model 1, but additionally adjusting for demographic variables including age, sex, BMI, race, county of residence, and retirement status. Finally, model 3 was a fully adjusted linear regression model, adjusting for all factors in model 2 and further for relevant health conditions of diabetes and, for BP outcomes only, hypertension status. In all models, linear regressions with robust standard errors were used to correct for any potential skewed dependent variables (Diggle et al., 2002). In addition, because the post-COVID expanded recruitment region included more rural communities which may lead to different baseline activity patterns, we repeated all the above analyses by excluding people residing outside of the King County, WA region in the post-COVID group as a sensitivity analysis. We also used scatter plots to graphically explore steps and sitting time over calendar time to visually assess seasonality trends in behavior.

We calculated unadjusted outcome means for the pre- and post-COVID groups respectively for model 1. For models 2 and 3, we calculate adjusted marginal outcome means for the pre- and post-COVID groups by setting adjusted variables at the population average values. We report point estimates, corresponding 95% confidence intervals (CIs), and two-sided p-values. The level of statistical significance was set at $p < .05$. Additional exploratory subgroup analyses are described in the Supplementary Material. All analyses were conducted using R software (v4.02).

Table 1. Baseline Demographic Characteristics of Participants by Enrollment Period.

	Pre-COVID	Post-COVID	
		All Participants	Within King County
Overall, N	95	60	31
DEMOGRAPHICS			
Female, N (%)	57 (60.0)	43 (71.7)	21 (67.7)
Age, mean (SD)	67.3 (5.9)	70.5 (7.0)	72.6 (7.0)
BMI category, N (%)			
Obese I, 30–34.9	54 (56.8)	25 (41.7)	13 (41.9)
Obese II, 35–39.9	22 (23.2)	24 (40.0)	11 (35.5)
Obese III, 40+	19 (20.0)	11 (18.3)	7 (22.6)
Race and ethnicity, N (%)			
White	75 (78.9)	41 (68.3)	20 (64.5)
Black	10 (10.5)	11 (18.3)	8 (25.8)
Asian[a]	2 (2.1)	2 (3.3)	1 (3.2)
Hispanic/Latino/x/a[a]	3 (3.2)	3 (5.0)	0 (0.0)
American Indian/Alaska Native[a]	3 (3.2)	2 (3.3)	2 (6.5)
Native Hawaiian or other Pacific Islander[a]	0 (0.0)	1 (1.7)	0 (0.0)
Other[a]	1 (1.1)	0 (0.0)	0 (0.0)
Unknown/not reported[a]	1 (1.1)	0 (0.0)	0 (0.0)
Retired, N (%)	44 (46.3)	42 (70.0)	21 (67.7)
Location, N (%)			
King	86 (90.5)	31 (51.7)	31 (100.0)
Outside	9 (9.5)	29 (48.3)	0 (0.0)
HEALTH STATUS			
Diabetes, N (%)	25 (26.3)	18 (30.0)	9 (29.0)
Hypertension, N (%)	45 (47.4)	30 (50.0)	15 (48.4)

[a]Due to small sample size, combined into a single "other race/ethnicity" group for analysis.

Statistical Power

We conducted power calculations for the primary outcomes of interest of sitting time, daily step count, and systolic BP. Given the sample size of 95 Pre-COVID and 60 Post-COVID we have 80% power to detect a difference of 0.9 hour (i.e. 54 minutes) in sitting time, 1274 daily steps, and 7.6 mmHg systolic BP. These assume a standard deviation of 2 hours in sitting time, 2740 in step count, and 16.3 mmHg for systolic BP and a two-sided T-test with equal variance.

Results

Pre-COVID participants ($N = 95$) were enrolled between February 2019 (HART trial start) and March 4, 2020, when enrollment was suspended due to COVID-19. The post-COVID sample ($N = 60$) represents participants enrolled between September 2020, when enrollment resumed post-COVID, and April 2021, when widespread vaccination for older adults had occurred. Table 1 describes demographic and health characteristics of both the pre-COVID and post-COVID sample as assessed at the HART baseline measurement time point. Due to the intentional changes in recruitment strategy described above, there are demographic differences between the pre- and post-COVID groups. Post-COVID participants were more geographically diverse, older, more female, and more racially and ethnically diverse. The post-COVID sample also had more participants in the obese II category.

Results from the unadjusted and fully adjusted linear regression models for all outcomes of interest are summarized in Table 2. Differences between the demographically adjusted and the fully adjusted model were unremarkable. Therefore, only the unadjusted and fully adjusted models are displayed. In the unadjusted models, statistically significant pre-versus post-COVID differences were noted for steps, mean sitting bout duration, TV viewing time, and systolic BP. The post-COVID group engaged in fewer steps/day (−1256, 95% CI:[−2078, −435]), had higher; mean sitting bout duration (2.92 minutes, 95% CI:[0.61, 5.23]), and approximately 45 minutes more self-reported TV time (0.75 hours, 95% CI:[0.09, 1.40]). Systolic BP was approximately 7 mmHg higher in the in post-COVID sample (7.33 mmHg, 95% CI:[2.05, 12.60]). However, after adjustment for demographics and health factors, only the systolic BP finding retained significance (6.78 mmHg, 95% CI:[0.29, 13.30]). Sensitivity analyses limiting post-COVID participants to those who

Table 2. Activity and Blood Pressure Outcomes by Pre-Versus Post-COVID Controlling for Demographics and Health.

	UNADJUSTED			
			Post-Pre	
	Pre-COVID Mean	Post-COVID Mean	Difference (95% CI)	p-Value
activPAL ACTIVITY				
Sitting time (h)	10.69	11.32	0.63 (−0.04, 1.29)	.064
Standing time (h)	3.50	3.31	−0.19 (−0.76, 0.39)	.527
Cumulative steps	**5894**	**4637**	**−1256 (-2078, -435)**	**.003**
Mean bout duration (min)	**16.54**	**19.46**	**2.92 (0.61, 5.23)**	**.013**
SELF-REPORT ACTIVITY				
TV viewing time (h)	**4.51**	**5.25**	**0.75 (0.09, 1.40)**	**.026**
Computer time (h)	3.34	3.86	0.52 (−0.23, 1.27)	.173
BLOOD PRESSURE				
Systolic BP	**132.65**	**139.97**	**7.33 (2.05, 12.60)**	**.006**
Diastolic BP	77.06	78.52	1.45 (−1.93, 4.84)	.400
	ADJUSTED FOR DEMOGRAPHICS AND HEALTH CONDITIONS[a]			
	Pre-COVID	Post-COVID	Post-pre	
	Adj mean[b]	Adj mean	Difference (95% CI)	p-value
activPAL ACTIVITY				
Sitting time (h)	10.77	11.19	0.41 (−0.31, 1.13)	.260
Standing time (h)	3.40	3.47	0.07 (−0.54, 0.68)	.821
Cumulative steps	5512	5242	−270 (−1078, 538)	.512
Mean bout duration (min)	16.88	18.91	2.02 (−0.68, 4.72)	.142
SELF-REPORT ACTIVITY				
TV viewing time (h)	4.64	5.03	0.394 (−0.32, 1.11)	.280
Computer time (h)	3.38	3.81	0.43 (−0.50, 1.36)	.368
BLOOD PRESSURE				
Systolic BP	**132.86**	**139.64**	**6.78 (0.29, 13.30)**	**.041**
Diastolic BP	76.73	79.05	2.32 (−1.74, 6.38)	.262

N = 95 pre-COVID versus N = 60 post-COVID; items in bold denote statistical significance at the p < .05 level.
All estimates, confidence intervals and p-values are from linear regression models fit using robust standard errors.
[a]Adjustment includes age (continuous), sex (M/F), race (white/black/others), BMI (obese I/II/III), retirement status (retired/not), location (King/not) and diabetes. For blood pressure outcomes we further adjust for hypertension as denoted in the EHR.
[b]Adj Mean is the adjusted mean calculated from the regression model for each COVID group while setting adjusted variables at the population average values.

resided in King County (approximating original recruitment region) had similar findings (data not shown). Additionally, graphical explorations of seasonal trends in steps and sitting time did not suggest indications of seasonal behavioral trends for either measure (data not shown).

Exploratory findings indicate that there could be different COVID impacts to steps and sitting time by sex, age, retirement status, and race/ethnicity (Supplementary Table 1), but no trends were noted descriptively for BP outcomes (Supplementary Table 2)

Discussion

Overall, our findings suggest the pandemic could be impacting older adult health – systolic BP, in particular – and contributing to increased SB and decreased PA, though

changes were not statistically significant. Systolic BP was significantly higher in the post-COVID compared to the pre-COVID sample. We interpret these results cautiously, as the devices and setting used for measuring BP changed between the pre- and post-COVID period and because we looked at group differences rather than within-person changes. However, in general BP is around 5 mmHg lower at home than in clinic (Muntner et al., 2019), thus our results may be conservative estimates. One study reported that the number of BP assessments in the US decreased by over 50% in the second quarter of 2020 from the compared to the second quarter of 2019 (Alexander et al., 2020). Decreased monitoring of BP might lead to less identification of high BP which could lead to lower rates of medication initiation or intensification (Alexander et al., 2020; Schuster et al., 2021). The literature on the impact of COVID-19 on BP is limited and mixed.

Three studies found decreases in BP in the post-COVID period, and two studies, indicated an increase in resting BP, likely mediated through changes in activity, diet, stress, and weight gain (Freiberg et al., 2021), though most prior studies were conducted outside the United States and were not specific to older adults (Aajal et al., 2021; Fucile et al., 2021; Girerd et al., 2021; Laffin et al., 2021; Pengo et al., 2021). If replicated, small population-wide increases in systolic BP as suggested here could lead to marked increases in cardiovascular events and deaths, particularly among older, overweight, and sedentary populations such as those studied here (Lewington et al., 2002).

Though non-significant in fully adjusted models, we note an effect size estimate of approximately 25 minutes additional sitting and 270 fewer daily steps in the post-COVID. For sitting time, these findings align with two of the three accelerometer-based studies currently in the literature for older adults, which reported increases of 5–30 minutes for daily sitting time during the pandemic period (Browne et al., 2020; Fernández-García et al., 2021; Rowlands et al., 2021). Only two of the three accelerometer-based studies in older adults in the literature reported steps; our estimate for difference in steps, while congruent in direction of effect, is lower than the approximately 800 fewer steps reported in both (Browne et al., 2020; Rowlands et al., 2021). Importantly, we were under-powered to detect differences of the magnitude suggested in these other studies for both steps and total sitting time. These results add to the small but growing literature examining the impact the COVID-19 pandemic has had on older adult PA and SB, but replication in future studies with larger samples is still warranted.

Though fully adjusted findings were not statistically significant, we observed a trend towards increased self-reported TV viewing time of just under half an hour. Of note, the estimated increase in TV time parallels the observed increase in activPAL measured total sitting time (also not statistically significant). This suggests that more time watching TV could account for the additional sitting time during COVID. This is supported by other recent self-report findings in the literature (Heid et al., 2021) and a recent qualitative study from this ongoing trial in which a subset of participants directly reported watching substantially more TV during the pandemic period as a coping mechanism to occupy time and distract themselves from the stresses of the pandemic environment (Greenwood-Hickman et al., 2021). A growing body of evidence suggests TV viewing may be independently deleterious for health above and beyond the effects of sitting alone (Biddle et al., 2017; Fancourt & Steptoe, 2019). Future studies with a larger sample size, particularly those with objective measurements of TV time and/or within-individual pre- and post-COVID measurements of sitting time would be helpful in more precisely estimate the impact the COVID-19 pandemic period has had on older adult TV viewing and other screen time.

Strengths and Limitations

This study presented a unique opportunity to explore pre- and post-COVID SB patterns using device-based accelerometer measurement, the most accurate tool for measuring SB in daily life. Furthermore, because the sample was pulled from an ongoing trial exploring BP as a primary outcome, research quality BP measures were also available, presenting an opportunity to explore pandemic impacts on older adults' resting BP in a way that has not yet been documented in the literature. Furthermore, we believe the analysis presented here represents an early use-case of inclinometer-assessed PA and SB data collection using an entirely remote protocol. With the continued uptake of wearable sensors to measure behavior and the precipitating forces of the COVID-19 pandemic, we believe more studies will leverage remote protocols for wearable device data collection in the future.

The results from this study must be considered in the context of several limitations. First, due to vaccine dissemination limiting our post-COVID data collection window and subsequent limitations in sample size, these analyses may have been under-powered. The pre- and post-COVID samples were recruited from different geographic areas which impacted the demographics of the sample. We minimized these differences by adjusting for several demographic and health factors, but the possibility of residual confounding by unmeasured factors remains. Data for each sample was collected during different seasons (pre-COVID: February 2019–March 2020; post-COVID: September 2020–April 2021) which could have resulted in different PA patterns (Cepeda et al., 2018; Kimura et al., 2015). However, SB is thought to be less impacted by seasonality (Cepeda et al., 2018). Future studies with larger sample sizes and matched seasonal measurement widows are needed. Finally, the change in BP measurement device and manner of data collection (in-clinic vs. at-home) meant we could not individualize cuff sizing or standardize the time of day the data were collected (pre-COVID visits were always in the morning; post-COVID could be any time of day). The use of different devices, the move to a cuff size that may not appropriately fit 5–10% of an obese population (Ostchega et al., 2004), and changes in measurement timing could lead to systematic measurement error; however, evidence suggests that home measurements tend to be lower than clinic measurements, rather than higher as we see here. This suggests our observed *higher* BP in the post-COVID sample may be an underestimation (de Gaudemaris et al., 1994; Muntner et al., 2019). Furthermore, because we compare two groups rather than within person changes, it is possible unidentified and uncontrolled confounders remain for all outcomes of interest.

Conclusions

For both activity and BP outcomes, these findings contribute to a sparse literature quantifying the population impact of

COVID-19 pandemic restrictions in older US adults. These are the first findings to report thigh-based accelerometer measurements, the ideal for quantifying sitting time and patterns (Janssen & Cliff, 2015; Kim et al., 2015; Montoye et al., 2016), of older adult activity. While these results were not statistically significant, if replicated in larger samples and in within-person comparisons, they could portend the need for additional interventional support to reduce SB and promote PA in older populations post-pandemic. Findings for resting BP represent the first reports of COVID-19's potential impact on BP for older, obese adults in the United States. More reports of BP change are needed to better understand the true impact of the COVID-19 pandemic, particularly studies assessing within-person changes using the same measurement device to replicate the BP increases reported here.

Declaration of Conflicting Interests

Funding

Ethical Approval

All research activities were reviewed and approved by the Kaiser Permanente Washington Institutional Review Board (#1315055). Additional detail on the parent trial can be found at ClinicalTrials. gov (NCT03739762).

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Supplemental Material

Supplemental material for this article is available online.

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