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# Real world sedentary behavior and activity levels in patients with schizophrenia and controls: An ecological momentary assessment study

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ABSTRACT

*Background:* People with schizophrenia often experience poor health, leading to shortened lifespans. The health of people with schizophrenia may be further exacerbated by increased sedentary behavior, which independently predicts health risk in the general population. However, the prevalence and patterns of objectively measured sedentary behavior in schizophrenia have not been studied extensively on a momentary basis.
*Methods:* Activity of 100 patients with schizophrenia was compared to that of healthy controls (HC; n = 71) using ecological momentary assessment (EMA). EMA provides real-time, real-world monitoring of behavior. We sampled behavior seven times per day for seven days, quantifying active versus inactive behaviors and four different movement patterns (recumbent, seated, standing, and moving). Due to different employment rates between samples, we focused on surveys completed at home.
*Results:* Four of the five most commonly reported activities for participants with schizophrenia involved sitting or lying down. When considering activity during the last hour, participants with schizophrenia were more likely to be sitting or pacing and less likely to be standing than HC. If participants with schizophrenia only did one thing in the last hour, it was more likely to involve sitting and less likely to involve standing compared to HC.
*Discussion:* People with schizophrenia were significantly more likely to be seated and less likely to be standing or active during the past hour than HC, despite high frequencies of seated behaviors in the HC as well. The adverse health consequences of sitting for extended periods may be especially relevant for people with schizophrenia and likely contribute to premature mortality in this population.

## 1. Introduction

Schizophrenia remains one of the most disabling illnesses worldwide (Charlson et al., 2018). Advances in psychopharmacology have allowed for effective treatment of positive symptoms, such as hallucinations, delusions, and disorganized speech and behavior. Impairment domains less amenable to pharmacological intervention such as negative symptoms (apathy, anhedonia, amotivation etc.), cognitive deficits, and decreased functional capacity contribute to the chronicity associated with schizophrenia and lead to ongoing problems in important areas of everyday functioning such as independent living and gainful employment (Buckley & Stahl, 2007; Arango, Garibaldi, & Marder, 2013; Harvey & Strassnig, 2012). This is compounded by physical health issues, including high rates of obesity and metabolic syndrome as well as low fitness levels, which all taken together, lead to shortened lives marred by disability. Increased sedentary behavior has the potential to interfere with everyday functioning not only through its impact on physical health, but also via preventing productive engagement with the environment. A sedentary lifestyle is well established in individuals with schizophrenia, who spend anywhere from eight to 13 waking hours or more per day engaged in sedentary behavior (Janney et al., 2013; Scheewe et al., 2019; Strassnig, Brar, & Ganguli, 2006; Stubbs, Williams, Gaughran, & Craig, 2016). While it is possible that productive tasks can be accomplished while sedentary (for example, working, emailing or

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paying bills on the computer), sitting is commonly associated with unproductive activities in people with schizophrenia (Granholm et al., 2020) and the successful completion of most everyday activities require more involved, sustained physical engagement. Excessive sedentary behavior on its own has the potential to interfere with the completion of many important activates such as gainful employment and independence in residence, defined broadly (Koyanagi, Stubbs, & Vancampfort, 2018).

The evidence for how people with schizophrenia spend their days, however, is hampered by sampling issues, such as relying on self-reports or using varying definitions of what comprises sedentary behavior, without a clear distinction between different types of sedentary and active behaviors. Due to difficulties with self assessment, self-reports of everyday performance and activities are inherently unreliable in schizophrenia and the most impaired patients, and often those who are the least active, are most likely to overestimate their abilities and accomplishments (Jones et al., 2019; Sabbag et al., 2012). In addition, measures of daily activities which collect reports from informants in lieu of patients themselves may lack accurate information about patients' everyday activities (Sabbag et al., 2011). For instance, previous EMA studies have reported that people with schizophrenia were home alone over 40% of time when surveyed (Depp et al., 2016), suggesting that their behavior could not have been observed in any case.

Sedentary behavior, defined as any waking behavior requiring 1.5 or less METs, includes a variety of activities and body positions while commuting, in the workplace or the domestic environment, and during leisure time (Panahi & Tremblay, 2018). This is because such behaviors (including TV viewing, computer use, or sitting in public transportation) are mostly done sitting or recumbent, typically requiring little energy expenditure beyond the basal metabolic rate. In contrast, even light intensity activity behaviors such as standing raises energy expenditure relative to sedentary behaviors. Activities that include even more physical involvement are considered moderate-to-vigorous, depending on the duration, the activity level, and energy expenditure involved.

Emerging evidence suggests that sedentary behavior on its own constitutes an independent health risk (deRezende, Rodrigues Lopes, Rey-López, Matsudo, & LuizOdo, 2014). This is because detrimental cardiometabolic correlates of prolonged sedentary behaviors appear to include a distinct constellation termed 'inactivity physiology' that consists of chronic, unbroken periods of muscular unloading. The result is the loss of local contractile muscular stimulation, suppressing the skeletal muscle lipoprotein lipase (LPL) activity necessary for triglyceride uptake and HDL-cholesterol production, as well as reduced glucose uptake. Standing, classified as light activity, causes only minor increases in energy expenditure, but involves isometric contraction of (postural) muscles sufficient to elicit EMG and skeletal muscle LPL changes (Hamilton, Hamilton, & Zderic, 2007; Hamilton, Healy, Dunstan, Zderic, & Owen, 2008), thus mitigating effects on lipid and glucose levels and resulting in less detrimental cardiometabolic consequences. In schizophrenia patients, therefore, it is likely that their increased sedentary behavior as compared to population standards accounts for at least some of the variance in their increased rates of obesity CVD risk observed (Hennekens, 2007).

Ecological momentary assessment (EMA) may provide an accurate estimate of daily activities and energy expenditure in people with schizophrenia. EMA is an ambulatory data collection technique that allows the *in vivo* assessment of everyday behaviors, including employment, socialization, active leisure, self-care, and home-care activities (Granholm, Loh, & Swendsen, 2008; Granholm et al., 2020). Modern EMA, also called Experience Sampling Method (ESM), uses smartphones to sample behavior frequently throughout the day, prompting the patient to respond to very brief (e.g., 3-min) questionnaires about their current activities. This allows for check-ins with the patient throughout the day to sample most waking hours. While wearable devices have been used in some studies (Naslund, Aschbrenner, Scherer, et al., 2016; Rosenbaum et al., 2020) focused on measurement and treatment of physical inactivity, sometimes in connection with smartphone-based applications. (Bort-Roig, Gilson, Puig-Ribera, Contreras, & Trost, 2014; Naslund, Aschbrenner, & Bartels, 2016), it appears that no studies to date have used EMA data to directly assess daily sedentary behaviors of community-dwelling patients on a momentary basis. Wearable devices targeting actigraphy are excellent strategies for measuring the extent of movement. However, if an individual is not moving, the actigraphy devcie cannot discriminate between being seated, recumbent, or standing still. In the case of people with schizophrenia in particular, large amounts of time are spent at home wherein the opportunity for substantial exercise, other than associated with benefits of standing versus being seated, are minimal. Also, the actigraph cannot discriminate between productive seated time (e.g., paying bills on the computer) versus unproductive seated time (e.g., sitting alone) Thus, our efforts in this study were to determine whether EMA could provide complementary information to actigraphy for the measurement of sedentary behavior.

To examine the extent of sedentary behavior in community-dwelling patients with schizophrenia, we used EMA surveys of everyday activities including self-care, home-care, leisure, as well as completely inactive behaviors such as sitting, watching television, and lying down to rest. A healthy control group was used as comparator, and four-week stability of reported behaviors was examined. The main results of this study were previously published and this constitutes a non-overlapping set of novel secondary analyses (Depp et al., 2019; Granholm et al., 2020). As the patients in this study were home during the majority of the surveys (80% of the patients were home at least 15 min in the last hour and 64% were home for the entire hour) and there were differences in rate of employment across the samples, we present data from surveys answered while at home. Further, some activities with high frequencies (lie down and rest) are rarely possible away from home. The previous papers examined out of home activities in detail, finding that when away from the home, participants with schizophrenia were significantly less likely to engaged in active leisure ($d = 0.6$, $p < .001$) or vocational activities ($d = 0.6$, $p < .001$) and were more likely to be engaged in physically inactive therapeutic activities ($d = 0.6$, $p < .001$) than healthy controls.

We hypothesized that sitting will be more common and standing and moving will be less common in our schizophrenia participant sample compared to HC. We also hypothesized that resting will be more common among schizophrenia patients than in HC and that among seated activities there will be evidence of greater preponderance of nonproductive seated activities. In line with the idea that sedentary behavior in participants with schizophrenia may have different clinical significance, being observable manifestations of negative symptoms such as amotivation and anergia, we hypothesized that participants with schizophrenia would be more likely than HC to engage in a single activity in the last hour and that activity would be more likely to be an inactive one compared to HC. Finally, in line with previous research suggesting temporal stability of negative symptoms and the life-long occurrence of sedentary behavior in participants with schizophrenia, we expected that activities would be quite stable over time at the 4-week follow-up.

## 2. Methods

### 2.1. Participants

Outpatients ($N = 100$) meeting diagnostic criteria for schizophrenia ($N = 82$) and schizoaffective disorder ($N = 18$) per the SCID for DSM-IV were recruited from boarding homes/supportive housing facilities, mental health clinics and clubhouses in the UC San Diego Health, San Diego County Mental Health and Veterans Affairs San Diego Healthcare Systems. They were included if they were taking antipsychotic medication(s), stable for four weeks and no immediately anticipated medication changes. Control participants ($N = 71$) were drawn from the community using advertisements. Inclusion criteria for controls were: no *DSM* diagnoses of past or current mood, anxiety, or psychotic disorders; age 18 to 65; fluent in English; and able to give valid informed consent. The smaller sample size for HC was due to our stopping sampling when we reached 100 participants with schizophrenia. Exclusion criteria for both groups were: history of head trauma with loss of consciousness longer than 15 min; seizure disorder; history of cerebrovascular accident or dementia; current substance dependence in the past year; uncooperativeness with in-lab assessments; and sensory limitations interfering with assessments.

### 2.2. EMA procedures

An Android OS smartphone was used to deliver EMA surveys. All smartphone functions except the survey app were disabled. In line with the suggestions of Liao, Skelton, Dunton, and Bruening (2016), we ensured that the elements of the CREMAS suggestions are presented. The device delivered interval-based surveys 7 times per day for 7 days, with data stored on the phone and accessed after returning the phone. Prompts occurred at stratified random intervals that varied from day to day within, on average, 1.5-h windows beginning at approximately 9:00AM and ending at 9:00PM each day. Only responses recorded within 15 min of the prompt were recorded. A second test-retest reliability follow-up assessment was offered to all participants four weeks following the initial week of EMA sampling continued until N = 75 patients and N = 50 controls were re-assessed. A training session (typically <20 min) provided instructions on operating and charging the device and responding to surveys, and explained the meaning of all questions and response choices. Participants were also contacted by telephone on the first and third day of EMA in order to troubleshoot and encourage adherence and an on-call staff person was available to answer questions.

To encourage EMA adherence, all participants were paid $1 per EMA survey ($49 maximum per survey week; with a running total displayed on the device after each survey). All payments were made when participants returned the device to the research center after the week of sampling.

EMA surveys were check-box questions asking about location and activities during the *past hour,* as well as number of social interactions and social context (e.g., family, friends, strangers, co-workers/classmates). One screen was presented with several activities listed, including work/school, self-care, home-care, at-home and outside-home leisure, transportation, treatment engagement activities, watching TV, resting, and pacing. Participants tapped the screen to check all of the boxes for activities performed in *the past hour*, and there was an option to check "None of these" on each screen. Thus, all questions were either endorsed positively with a check or were left blank. Branching was used to shorten the survey, such that questions about in-home (e.g., home leisure) or out-of-home (e.g., outside leisure) activities and transportation were contingent upon being in or out of the home during the past hour. See Fig. 1 for the relevant "at home" screen shots.

An in-lab questionnaire about the EMA experience was administered. Statements regarding burden (e.g., "The device was comfortable to carry," "The beeps interfered with my activities"), difficulty (e.g., "I had difficulties understanding the questions," "I had difficulties operating the device"), pleasantness (e.g., "Overall, this experience was pleasant," "Overall, this experience was stressful") and other aspects of acceptability were rated on a 5-point Likert scale (reverse coded when necessary such that higher ratings indicated more positive experience).

For purposes of analysis, we categorized activities based on activity level as recumbent (resting), seated, standing, or moving. Table 1 presents the conceptual organization of the sampled activities. Because "pacing" was combined with "hanging out", we examined that item separately because we could not determine the extent to which an endorsement of that item reflected movement or not. We identified all activities that were performed while seated and examined individual and combined scores. We also identified all activities that were performed while standing and also identified those that involved movement as active. Thus, we set a low bar for activity.

**In the past hour, did you (check all that apply):**
- **Lay down and rest**
- **Watch TV**
- **Listen to music/radio**
- **Sit alone**
- **Hang out or pace**
- **None of these**

**In the past hour, did you (check all that apply):**
- **Wash/dry/fold/sort laundry**
- **Change clothes/get dressed**
- **Brush teeth (or dentures)**
- **Groom (hair, nails, etc.)**
- **None of these**

**In the past hour, did you (check all that apply):**
- **Work on arts and crafts/hobby**
- **Read book/magazine newspaper**
- **Play a musical instrument**
- **Use internet or computer**
- **Play cards/games**
- **None of these**

**Fig. 1.** Screenshots (simulated) of activity surveys.

**Table 1**
EMA sampled activities/categorization.

| | |
|---|---|
| Recumbent | |
| Lie down and rest | |
| Seated Activities | |
| | Sit alone |
| | Watch TV |
| | Computer or Internet |
| | Listen to Music/Radio |
| | Reading |
| | Playing Cards |
| | Working on a Hobby |
| Standing Activities (summed) | |
| | Cooking |
| | Brush Teeth |
| | Grooming |
| | Bathing |
| Moving Activities (summed) | |
| | Clean the House |
| | Wash, fold, and put away Laundry |
| Hang out or Pace | |

#### 2.2.1. Statistical analyses

We examined the data in three ways. First, we examined the total number of answered surveys reporting each of the activities. We identified the 5 most common activities for the schizophrenia participants and compared those activities to their characteristics in the HC sample. Multiple activities could be endorsed in a single survey, based on behavior during the past hour, but it was also possible to endorse only one. We used mixed-model repeated measures analysis of variance (MMRM) in order to examine effects of time of day and study day (1–7) on all variables across diagnoses as a between-subjects factor. For these analyses, we created an intercept only model and compared the fitted model to the intercept only statistics. We used full information procedures and examined all available data, without any imputation of missing values. Then, we examined the rate with which the most common activities had been the only activity engaged in for the past hour, using the same MMRM analysis plan. We then calculated the proportion of all of the activities endorsed in each of the completed surveys that each movement pattern comprised. We summed active, standing, and individual seated activities, as well as hanging out or pacing. For these analyses, our unit of analysis was survey by survey, so averages were based on the number of surveys returned by each participant. We then compared proportions for each activity domain in schizophrenia participants versus controls with t-tests. We examined the stability of these activity patterns by computing Pearson Product Moment correlations across the first and second sampling periods in those participants who provided data at both assessments.

## 3. Results

### 3.1. Sample

Controls did not differ significantly from participants with schizophrenia with regard to age (C: M = 50.2, SD = 10.8; S: M = 51.7, SD = 9.3; $t(168) = 1.00$, $p = .318$), gender (HC: Female = 37% (N = 26); S: Female = 29% (N = 29); $X^2(1) = 1.25$, $p = .264$), or race (C: Caucasian = 46% (N = 32); S: Caucasian = 36%, (N = 36); $X^2(1) = 1.62$, $p = .203$). Controls (M = 14.6, SD = 1.8) had approximately 1.5 more years of education that those with schizophrenia on average (M = 13.0, SD = 1.9; $t(167) = 5.47$, $p < .001$). Rates of employment were significantly lower in the participants with schizophrenia, HC: 57%, schizophrenia: 10%, $X^2(1) = 42.92$, $p < .001$.

### 3.2. Adherence

Only four phones were lost (1 S; 3 C), and two phones (1 S; 1 C) malfunctioned resulting in EMA data loss. Lost or malfunctioning phones were replaced. Adherence was excellent with 42 (SD = 7.6) of the 49 (85%) programmed surveys being completed on average, (C = 41.6 (SD = 7.4); S = 41.9 (SD = 7.8); $t(169) = 0.20$, $p = .84$) and the two groups did not differ significantly in adherence. The groups also did not differ significantly in the number of participants excluded for inadequate adherence (defined as <33% surveys completed) (C = 6.6% [5/76]; S = 2.9%[3/103]; $\chi$ 2(1) = 1.38, P = .241). All later analyses were based on nonexcluded cases.

The patients with schizophrenia reported being home for the entire last hour for 64% of the surveys and home for part of the last hour for an additional 16%. HC were home for the entire hour 47% of the time and part of the hour for an additional 14%. HC responded to a total of 1586 surveys (Mean = 22.3) while at home for at least part of the past hour. Participants with schizophrenia provided 3241 (mean = 32.1) such at home survey responses.

### 3.3. Activity data

The 5 most common individual activities for the participants with schizophrenia, in order of occurrence, are presented in the top of Table 2. Standing activities were the most commonly endorsed activities for both samples. Following that, however, were three seated activities and one recumbent activity, all of which were endorsed on more of the total number of surveys completed by participants with schizophrenia than HC. We also examined the data in terms of the proportion of surveys answered with each activity endorsed as the only activity performed during the past hour. These data are presented in the bottom of Table 2.

For the analyses of the 5 most common activities performed in the hour, in the MMRM analyses the fitted model was significantly better than the intercept only model in all cases, all $X^2(13)>76.08$, all $p < .001$. The MMRM analyses found a significant effect of group (($X^2[1] = 8.2$, $p < .014$), day ($X^2[1] = 7.3$, $p < .007$) and time of day (($X^2[6] = 15.9$, $p < .001$) for standing, with HC standing more often overall, on the first day of the study, and on the first two surveys of the day. There were also significant effects of group ($X^2[1] = 44.63$, $p < .001$) and time of day for watching TV, with more TV watching for the HC and significantly less TV watching for the entire sample on the final survey of the day ($X^2[6]>14.1$, $p < .001$). For resting, participants with schizophrenia reported resting on more surveys than the HC ($X^2[1] = 42.9$, $p < .001$) and both groups were resting more in the first survey of the day ($X^2(6) = 70.0$ $p < .001$). As these data suggested the possibility that participants were seeming to rest more because they had not gotten up by the time of the first survey, this analysis was repeated for surveys other than the first. That analysis found a significant effect of group ($X^2[1] = 56.07$, $p < .001$), but no significant effect of time of day, $X^2(5) = 7.54$, $p = .18$. Thus, removing the first assessment of the day increased the group differences, leading to a new mean difference of 0.12 (0.38 for schizophrenia participants and .26 for HC), in contrast to a difference of 0.09 before. For sitting alone, participants with schizophrenia endorsed this activity on more surveys, ($X^2[1] = 88.7$, $p < .001$). Finally, for listening to music or the radio, participants with schizophrenia endorsed this activity on more surveys, ($X^2[1] = 106.5$, $p < .001$), and the first survey of the day was significantly less frequently endorsed, ($X^2 6] = 16.2$, $p < .001$).

**Table 2**
Most common individual activities for participants with schizophrenia and HCs.

Top 5 Most Common Activities During the Last Hour for Schizophrenia Participants Compared to HC: Proportion of Surveys Endorsed with Each Response Across All Surveys

| Activity | Schizophrenia | | HC | | Effects |
|---|---|---|---|---|---|
| | M | SD | M | SD | |
| Standing | .57 | .50 | .62 | .49 | Group, Day, Time |
| Watch Television | .40 | .49 | .50 | .50 | Group, Time |
| Lay Down and Rest | .40 | .49 | .31 | .46 | Group, Time |
| Sit Alone | .32 | .46 | .18 | .38 | Group |
| Listen to Music/Radio | .31 | .46 | .17 | .37 | Group, Time |

Note. More resting and standing early in the day, less television and radio on the final survey of the day. More standing on the first day of the protocol.

Proportion of Surveys with Only 1 of the 5 Most Common Activities Endorsed in the Last Hour

Proportion of Surveys with Each Activity being the Only Activity Performed

| Activity | Schizophrenia | | HC | | Effects |
|---|---|---|---|---|---|
| | M | SD | M | SD | |
| Standing | .05 | .05 | .12 | .06 | Group, Time |
| Watch Television | .07 | .07 | .07 | .07 | Time |
| Lay Down and Rest | .13 | .15 | .15 | .15 | Time |
| Sit Alone | .05 | .03 | .03 | .05 | Group, Time |
| Listen to Music/Radio | .03 | .04 | .003 | .05 | Group, Time |

Note. All time of day effects are for activities being performed more commonly during the surveys earlier in the day.

The bottom of Table 2 presents the proportion of the surveys endorsing only a single activity performed throughout the entirety of the last hour. Schizophrenia participants had more surveys where they endorsed either sitting alone, $X^2(1) = 11.28$, $p < .001$, or listening to the radio only, $X^2(1) = 17.40$, $p < .001$, for the past 60 min, wherein the healthy controls endorsed more surveys where they had been standing only for the last 60 min, $X^2(1) = 80.53$, $p < .001$. There were no group differences in the frequency of only sleeping or only watching television in the last 60 min, both $X^2(1)<0.32$, both $p > .57$. Thus, standing as the only activity in the last hour was more than twice as common in the HC and three seated activities as the only activity in the last hour summed to account for 15% of the total at home surveys on the part of participants with schizophrenia, contrasting to 10% for the HC.

Table 3 presents the distribution of activities performed in the last hour in the two samples. Resting did not differ between the groups and the HC participants had a significantly higher proportion of surveys endorsing watching television, standing, and active. Participants with schizophrenia had a significantly higher proportion of their surveys being sitting alone, listening to music or the radio, and hanging out or

**Table 3**
Schizophrenia participant and Healthy Control Differences in Proportion of All Surveyed Activities Performed During the last Hour across All Surveys.

| Activity | Schizophrenia | HC | | | | | |
|---|---|---|---|---|---|---|---|
| | M | SD | M | SD | d | t | p |
| Watch Television | .17 | .16 | .19 | .13 | .13 | 0.78 | .44 |
| Computer use | .05 | .12 | .12 | .12 | .53 | 3.44 | .001 |
| Lay Down and Rest | .19 | .13 | .18 | .14 | .01 | .05 | .99 |
| Sit Alone | .11 | .07 | .05 | .06 | .86 | 3.74 | .001 |
| Listen To Music/ Radio | .11 | .10 | .05 | .07 | .50 | 3.15 | .001 |
| Hang Out or Pace | .09 | .09 | .03 | .05 | .67 | 3.97 | .001 |
| Standing | .23 | .10 | .28 | .12 | .50 | 2.45 | .017 |
| Active | .05 | .05 | .10 | .12 | 1.0 | 2.81 | .001 |
| Total Seated Activities | .44 | .15 | .41 | .15 | .20 | 1.29 | .20 |

pacing. When we summed all seated activities, there were no group differences. The two of the three largest effect sizes for differences between the groups were for two seated activities, sitting alone being more common in the schizophrenia patients and computer use in the HC.

Table 4 presents the persistence of the different activity patterns at the four-week follow-up. All correlations over time in both groups were significant at $p < .001$. However, the temporal stability of sitting and pacing were significantly greater in the participants with schizophrenia than the HC sample, both $z > 2.25$, both $p > .024$.

## 4. Discussion

Community-dwelling patients with schizophrenia spend most of their time at home, sedentary and not engaged in productive activities, as determined by ecological momentary assessment (EMA). Thus, the use of EMA as a digital biomarker is expanded to the direct measurement of sedentary behavior. The predominant sedentary behavior is sitting, followed by recumbent positioning, a pattern that shows stability over two full-week assessment periods separated by a month. Although the overall proportion of surveys reflecting resting was greater in participants with schizophrenia, the proportion of all activities in the past hour reflecting resting was the same across groups. However, adjusting for the time of day in the survey increased group differences and suggests that some of the similarities in resting are due to the HC possibly sleeping late. Standing at home (i.e., light activity) likely involves activities of short duration, such as brushing teeth, and due to their short duration probably have less benefit than the measurements would suggest. Movement (i.e., moderate activity) was less common amongst patients with schizophrenia. As we reported earlier, all outside recreation activities, which include exercise and other activities such as going to a park, were rare in both samples and occurred in less than 10% of the surveys in participants with schizophrenia (Gould, Sabbag, Durand, Patterson, & Harvey, 2013er differences when the occurrences of each activity per hourly survey were examined, the raw proportions of activities performed and activities that were only performed once per hour clearly reveal a sedentary pattern of behavior on the part of the schizophrenia participants.

The healthy controls in our study also spend a significant amount of time sitting. This extensive amount of time sitting appears to be consistent with developments in our society in general wherein that people generally move less and sit more (Owen, Sparling, Healy, Dunstan, & Matthews, 2010). It should be noted that sitting on the part of HC includes considerably more computer use than the patients with schizophrenia and less sitting alone or listening to music or the radio. In fact, number of surveys endorsed as sitting alone was the largest single difference between our samples ($d = 0.85$). Thus, the lack of differences in overall seated time across all activities reported per hour reflects a differential distribution of seated activities and possibly differences in what could be considered productive (Computer use) as compared to generally unproductive (sitting alone) activities. We previously reported that not leaving the home and traveling shorter distances from home was significantly correlated with the severity of negative rated with clinical rating scales (Depp et al., 2019). Our idea that some of the elements of sedentary behavior on the part of schizophrenia may reflect amotivation or anergia is supported by the fact that 15% of the 3241 surveys responded to by participants with schizophrenia reflected a single seated and activity for the entirety of the last hour.

The US population is generally becoming increasingly sedentary, with lower energy expenditure activities gradually replacing those requiring higher energy expenditure. In the year 2000, 4 in 10 adults worked light activity jobs, whereas 2 in 10 worked high activity jobs, almost doubling the number of people working light activities and a commensurate large reduction in those working high activity jobs as compared to the 1970s (Brownson, Boehmer, & Luke, 2005). Computer use and screen time (watching TV, smartphone use) in general has increased dramatically as well, and is usually performed while sitting or recumbent, further adding sedentary behaviors to already decreasing job activity (Biddle et al., 2017). Moreover, sedentary behavior, with the most compelling evidence for sitting screen time, is now considered a risk factor for obesity, cardiometabolic disease, certain cancers, gallstones, hypertension, and all-cause mortality, independent of time spent in exercise (Patterson et al., 2018; Thorp, Owen, Neuhas, & Dunstan, 2011). Thus being seated, even if engaged in a productive activity such as paid employment, appears to increase health risks. Finally, recent research suggests sedentary behavior is a metabolic risk factor distinct from physical inactivity, with sedentary behavior independently predicting metabolic risk regardless of an individual's compliance with current physical activity guidelines (Booth & Lees, 2007), accounting for 9% of premature mortality worldwide (Lee et al., 2012).

Our study has limitations that need mention. Forty-one percent of the controls, primarily recruited from ads in a local free newspaper, were unemployed. This may have led to a relative over-sampling of lower functioning control which would tend to decrease differences between groups. The patient sample in this study was also somewhat older than typical schizophrenia samples, which may have contributed to some effects on activity level, although patients and controls were of comparable age. The study was funded by the Department of Veterans Affairs, resulting in a larger proportion of Veterans in both groups than is typical of schizophrenia research, which may limit generalization. There is an issue of causal direction in the study, in that participants who are unemployed may not have the financial resources to travel extensively outside the home. The generally elevated prevalence of never being married could also increase the chances for sitting alone, rather than with another person, but this factor would not seem to be directly related to using a computer less than healthy people.

In our participants with schizophrenia, none of the predominant activities appeared to confer health benefits.. The higher rates of obesity and cardiovascular disease observed compared to the general population (Correll et al., 2017) may be in part due to the increased rate of sedentary behavior observed, which showed stability in terms of its behavioral topography over time in our sample. Healthy controls were stable over time in their rates of seated behavior as well. We suggest this pattern of sedentary behavior contributes significantly to the increased health risk in schizophrenia, and unfolds in context of other detrimental

**Table 4**
Temporal stability of different activities.

| | Schizophrenia Patients | Healthy Controls |
|---|---|---|
| | n = 79 | n = 47 |
| Resting | .74 | .73 |
| Total Sitting | .87 | .72 |
| Standing | .85 | .77 |
| Active | .61 | .65 |
| Pacing | .76 | .62 |

lifestyle factors, contributing to the observed long-term weight gain with ensuing cardiometabolic complications (Strassnig, Kotov, et al., 2017).

On a different note, many challenging everyday tasks, including living and working independently, require *physically* active engagement in order to be successfully initiated and sustained. Even simple rehabilitative efforts such as cognitive and functional skills training, or primary care visits require patient attendance for the most part. Home delivered training interventions are being piloted, but success in these interventions requires, at the very least, motivation to engage in these training activities from home instead of choosing alternative nonproductive activities (Fisher et al., 2015; Loewy et al., 2016). On a practical level, the impact of pervasive sedentary behaviors on everyday activities (or lack thereof) cannot be overstated, mirroring their extremely low level of cardiovascular fitness (Strassnig et al., 2006). Moreover, motivational deficits and negative symptoms appear to considerably overlap with sedentary behaviors, which may directly impact on other aspects of outcome. For instance, in our previous work we have demonstrated 20-year progressive weight gains in schizophrenia (Strassnig, Kotov, et al., 2017) that have a direct impact on employment outcomes (Strassnig, Cornacchio, et al., 2017) by inducing mobility limitations, even partially displacing the impact of cognitive performance on labor force participation (Strassnig et al., 2018).

We have argued that further investigation into the relationship between cognitive and negative symptoms, sedentary behaviors, and eating and diet may be warranted (Harvey & Strassnig, 2019). Cognition and metabolic syndrome are related in schizophrenia (Bora, Akdede, & Alptekin, 2017) and cognitive deficits are directly related to cooking related skills deficits (Semkovska, Bédard, Godbout, Limoge, & Stip, 2004). In fact, cognitive deficits are also related to grocery-shopping deficits in both first episode (Ventura et al., 2020) and older schizophrenia patients (Keefe et al., 2016). These findings suggest targeted interventions to improve everyday functioning and physical health in this population of community-dwelling patients with schizophrenia with a clearly defined focus on negative symptoms and everyday functioning in relation to sedentary behavior. Because sedentary behavior, poor diet, and unproductive activities are broader than a simple lack of physical exercise, new interventions aimed at reducing sedentary behaviors in conjunction with knowledge and skills-based interventions might offer considerable benefits for everyday functioning and health benefits (Strassnig, Caceda, Newcomer, & Harvey, 2012). Our findings suggest EMA technology is a viable digital biomarker strategy to measure the outcomes of such interventions in the schizophrenia population and would have the potential to be a mechanism through which interventions aimed at increasing activity could be delivered. These survey methods could be augmented by passive measurement through wearable devices, whose use was described above, which could also quantify movement directly.

## Declaration of competing interest

In the past year, Dr. Harvey has served as a consultant to: Alkermes, Bioexcel Therapies, Boehringer-Ingelheim, Intracellular Therapies, Otsuka Digital Health, Roche, Sanofi, Sunovion, and Takeda Pharma. He is Chief Scientific Officer of iFunction, Inc.

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The other authors report no commercial interests related to the presented research.

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