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Relationship between objectively measured sedentary behavior and health outcomes in schizophrenia patients: The PsychiActive project

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ABSTRACT

This study aimed to investigate possible relationships between sedentary behavior and body mass index (BMI), cardiorespiratory fitness (CRF), and health-related quality of life (HRQoL) in schizophrenia patients. Variables contributing to the variability in sedentary behavior were identified. Eighty-two schizophrenia outpatients (mean age ± SD: 41.0 ± 8.7 years, 87% men, mean illness duration ± SD: 17.1 ± 8.9 years) wore a multisensor armband for 7 consecutive full days to objectively measure sedentary behavior. BMI, walking capacity (6-minute walking test) as a proxy for CRF estimation and HRQoL (Short Form 36-Item Health Survey questionnaire version 2) were also assessed. Correlation (Pearson or Spearman coefficients) and multiple regression analysis were used. Sedentary behavior was significantly associated with BMI, CRF, and the physical component summary score of HRQoL (r values, −0.34–0.41; all $P < 0.001$) and remained significant after adjustments for age, illness duration, symptom severity, adherence to Mediterranean diet, smoking, and antipsychotic medication (all $P < 0.05$). BMI, CRF and vitality were identified as determinants of sedentary behavior. Consistent relationships between sedentary behavior and BMI, CRF, and the physical component summary score of HRQoL were found in schizophrenia patients. All the identified determinants of sedentary behavior are modifiable and may be important areas for future interventions in this population.

1. Introduction

Sedentary behavior (SB), defined as any waking activity characterized by energy expenditure ≤1.5 metabolic equivalents while in a sitting or reclining posture (Sedentary Behaviour Research Network, 2012), has been described as a major public health problem (Blair, 2009). High levels of SB are associated with increased risk of morbi-mortality, independent of physical activity (Biswas et al., 2015). Recent meta-analyses reported that severe mental illness patients including schizophrenia were more sedentary than controls (Stubbs et al., 2016b; Vancampfort et al., 2017a). Despite the increased mortality (Walker et al., 2015), mainly due to cardiovascular disease (Correll et al., 2017; Vancampfort et al., 2016, 2015c), research on health effects of SB in schizophrenia patients is scarce.

A key factor in improving the understanding of the health effects of SB and the effectiveness of interventions aimed to reduce SB time in schizophrenia patients is to use adequate methods for quantifying SB. As aforementioned meta-analyses (Stubbs et al., 2016b; Vancampfort et al., 2017a) suggest, self-report measures fail to capture the SB levels in schizophrenia, highlighting the need to prioritize the use of objective measures to obtain more accurate results. However, few studies have utilized objective measures of SB in schizophrenia patients, and all existing studies included modest sample sizes ($n < 50$) (e.g., (Gomes et al., 2014; Janney et al., 2013; Snethen et al., 2014)), except for three recent inpatient studies (Chen et al., 2016; Stubbs et al., 2017b, 2017a). Therefore, studies that objectively measure SB in schizophrenia patients, including outpatient studies with relatively large sample sizes, are needed.

It is well-known that schizophrenia patients have worse health-related quality of life (HRQoL) (Foldemo et al., 2014), higher prevalence of overweight/obesity (assessed as body mass index; BMI) (Subramaniam et al., 2014), and impaired cardiorespiratory fitness (CRF) (Vancampfort et al., 2015b, 2017b) compared with the general population, largely as a result of unhealthy lifestyle choices such as lack of physical activity, poor diet, and smoking (Dipasquale et al., 2013; Stubbs et al., 2016a). However, little is known regarding the extent to which SB in schizophrenia patients is associated with BMI and HRQoL, and the relationship between SB and CRF remains unexplored.

The primary aim of this study was to investigate possible relationships between objectively measured SB and BMI, CRF, and HRQoL in schizophrenia patients. A secondary aim was to identify variables that could explain the variability in SB.

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2. Material and methods

2.1. Participants and setting

This was a cross-sectional study. From July 2014 to May 2016, adult outpatients with an established ICD-10 diagnosis of schizophrenia and stabilized on antipsychotic medication during the last month were recruited from 13 mental healthcare settings in southern Spain. Patients with clinical instability, co-morbid substance abuse, or evidence of uncontrolled cardiovascular, neuromuscular and endocrine disorders were excluded. Two visits per patient were scheduled. During the first appointment, anthropometric, sociodemographic, and medical record data were registered. In addition, patients were asked to wear a multisensor for 9 days, starting the same day they received the monitor. On day 9, during the second appointment, patients returned the monitor and completed standardized questionnaires about HRQoL, symptom severity, diet, and smoking. Finally, CRF was examined using a field-based test. The procedure was approved by the Universidad Pablo de Olavide Ethics Committee. All patients gave their informed written consent prior to enrolling and after receiving information about the study aims and protocol. There was no compensation for participation.

2.2. SB

SB that involved any waking activity characterized by energy expenditure ≤1.5 metabolic equivalents, was objectively assessed using the SenseWear Pro3 Armband (BodyMedia, Inc., Pittsburgh, PA, USA), previously used in non-clinical (Scheers et al., 2013) and clinical populations (Bond et al., 2011). Energy expenditure was accurately estimated (Johannsen et al., 2010) using data recorded from multiple sensors (a two-axis accelerometer and sensors measuring heat-flux, galvanic skin response and near body-temperature) and manufacturer-specific algorithms (SenseWear Professional software, version 8.1). Patients were required to wear the SenseWear on the triceps muscle of their left arm for 9 consecutive days, except when showering or swimming, and were asked to follow their usual lifestyle. The first and last days were excluded from the analysis to minimize reactivity (Corder et al., 2008). A total of 7 days of recording with a minimum of 1368 min per day (95% of a 24-hour period) was necessary for inclusion in the analysis. Although SB data are expressed both in minutes and as a percentage of waking time, only the relative SB time was used for analysis to account for individual differences in waking time.

2.3. Anthropometric data

Weight and height were measured with light clothing and without shoes to the nearest 0.1 kg and 0.1 cm using a scale (TANITA BC-420; Tanita, Tokyo, Japan) and a stadiometer, respectively, and BMI was calculated.

2.4. CRF

The 6-minute walking test, a feasible, reliable and valid method for assessing walking capacity in schizophrenia patients (Gomes et al., 2016), was used as a measure-of-proxy CRF estimation, as proposed by others (Vancampfort et al., 2015b). The test was performed according to Rikli and Jones (1999) on an indoor course with a flat, firm surface and with minimal external stimuli. Patients were instructed to walk as far as possible during a 6-minute period around a 45.7-meter rectangular course delimited by cones, without running or jogging. Resting was allowed if necessary, but walking was to be resumed as soon as possible. Standardized encouragements were used as recommended (Rikli and Jones, 1999). The same trained instructor explained the protocol, gave a demonstration prior to start, supervised the test and recorded the total distance walked to the nearest 0.1 m for each patient.

2.5. HRQoL

We used the Short Form 36-Item Health Survey version 2 (SF-36) (Ware and Sherbourne, 1992), which demonstrated good psychometric properties in schizophrenia patients (Su et al., 2014). The SF-36 examines eight domains of physical (physical functioning, physical role, body pain, and general health) and mental HRQoL (vitality, social functioning, emotional role, and mental health). The four physical-domains are summarized into a physical component score (PCS), and the four mental-domains constitute a mental component score (MCS). Scores range from 0 to 100, with higher scores indicating better HRQoL. A five-point difference (domain-scores) and two- to three-point difference (summary-scores) are considered clinically relevant (Ware et al., 1994).

2.6. Symptom severity

The severity of psychiatric symptoms during the previous week was assessed using the Brief Symptoms Inventory-18 (Derogatis, 2001), which is recommended as a more economical variant of the Symptom Checklist 90-R and as a clinically meaningful instrument (Prinz et al., 2013). Scores range from 0 to 72, with higher scores indicating higher severity.

2.7. Adherence to Mediterranean diet

We used the 14-Item Mediterranean Diet Tool (Martinez-Gonzalez et al., 2012) to assess the adherence to Mediterranean diet. Scores range from 0 to 14; scores ≥ 8 indicate high adherence, established as protective in terms of morbi-mortality (Sofi et al., 2014).

2.8. Smoking, illness-related factors and antipsychotic medication data

Smoking was self-reported. Age, diagnosis, illness duration, and antipsychotic medication were retrieved from patients' medical records. Antipsychotic medication was converted into a daily equivalent dosage of chlorpromazine (Gardner et al., 2010).

2.9. Statistical analysis

Student's *t*-test was used to calculate differences in SB according to gender, adherence to Mediterranean diet, and smoking. Patients were divided into low and high levels of SB using the median split, and Chi-square, Student's *t*, and Mann–Whitney *U* tests were applied to establish differences according to the nature and distribution of variables. Adjustments for multiple comparisons were made using the Bonferroni method by dividing the significance level of 0.05 by the number of comparisons; in this case, $0.05/20 = 0.0025$. To quantify relationships between SB and BMI, CRF or HRQoL, Pearson or Spearman correlation coefficients were used, depending on whether the data followed a normal distribution. Correlations were corrected for age, illness duration, symptom severity, adherence to Mediterranean diet, smoking, and antipsychotic medication. Correlation values were interpreted as follows: <0.25, weak or null; 0.25–0.50, fair; 0.50–0.75, moderate to good; and >0.75, good to excellent. Multiple stepwise regression model analysis was applied to identify significant determinants (independent variables) for SB (dependent variable). To prevent overfitting, significant correlates from the univariate tests were included in the model. Only patients with a complete dataset for the significant correlated variables were included in the multiple regression analysis. Variance inflation factor values > 3 were used to indicate a multicollinearity problem in the model (Kleinbaum et al., 2013). Graphic and statistical analyses of residuals were used to verify normality, linearity and homoscedasticity of the regression analysis. The data were analysed in 2016 using SPSS Statistics for Windows, Version 22.0 (Armonk, NY: IBM Corp).

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3. Results

Eighty-two of the 95 (86%) participants had valid SenseWear data. Reasons for invalid SenseWear data included refusal to wear the device ($n = 1$), unregistered data attributed to technical problems ($n = 4$), and unmet wear-time criteria ($n = 8$). Patients' characteristics are summarized in Table 1. In total, 13%, 38% and 49% of the patients were normal-weight, overweight and obese, respectively. Mean percentage of waking time spent in SB was 58.7 (range 27.1–92.5) which corresponds to 8.8 h/day (range 3.9–13.2). No differences in SB were found between men and women (57.5 ± 13.7 and 65.3 ± 12.7% of waking time, respectively; $P = 0.061$), between non-smokers and current smokers (60.9 ± 13.3 and 56.9 ± 14.1%, respectively; $P = 0.190$) and between those with low and high adherence to Mediterranean diet (59.6 ± 12.6 and 59.6 ± 14.6%, respectively; $P = 0.995$).

Characteristic comparisons of SB levels are shown in Table 2. The high-SB group had a significantly higher BMI than the low-SB group ($P = 0.0018$). Differences in HRQoL were clinically significant for PCS, MCS, and almost all SF-36 domains.

The simple correlation model between SB and sample characteristics is presented in Table 3. Significant correlations with SB were found for symptom severity, BMI, CRF, and HRQoL, specifically in physical function, pain, and vitality domains and in PCS (all $P < 0.05$). The associations between BMI, CRF, and HRQoL remained significant after adjusting for age, illness duration, symptom severity, adherence to Mediterranean diet, smoking, and antipsychotic medication; exceptions were pain and vitality domains ($P = 0.329$ and 0.135, respectively; data not shown). Additional analysis found that the association between SB and CRF remained significant and fair even when BMI was included with the rest of the confounders ($P = 0.018$; data not shown).

Due to some missing data, a subsample of 74 patients (63 men and 11 women) with no changes in the correlation coefficients of the significant correlates (all $P < 0.05$; data not shown) was included in the multiple regression analysis (Table 4). Within the fully adjusted model, BMI, CRF, and vitality were identified as determinants of SB, explaining 37.4% of the SB variability. There was no multicollinearity among the variables within the final model.

Table 1
Patients' characteristics ($n = 82$).

Variables	Values
Age (years)	41.0 ± 8.7
Severity of psychiatric symptoms (0–72)[a,b]	15.6 ± 11.6
Illness duration (years)[a]	17.1 ± 8.9
Chlorpromazine equivalent dose (mg/day)[a]	756.8 ± 568.5
Sedentary time (% of waking time)	58.7 ± 13.8
Body mass index (kg/m^2)	30.7 ± 5.3
6-Minute walking test (m)[a]	589.6 ± 90.6
Short Form 36-Item Health Survey[a] (0−100)	
Physical function	73.7 ± 23.4
Physical role	72.4 ± 24.1
Pain	69.7 ± 23.8
General health	59.0 ± 22.9
Vitality	53.3 ± 21.7
Social function	63.6 ± 27.9
Emotional role	70.3 ± 28.0
Mental health	62.6 ± 20.7
Physical component summary	48.4 ± 9.1
Mental component summary	41.7 ± 12.3
Gender (women)	13 (15.9)
Adherence to Mediterranean diet (high)[a,c]	28 (39.4)
Smoking status (current smoker)	45 (54.9)
Marital status	
Married	2 (2.4)
Unmarried	74 (90.2)
Separated/divorced	6 (7.3)
Educational status	
Unfinished studies	16 (20.3)
Primary school	29 (36.7)
Secondary school	28 (35.4)
University degree	6 (7.6)
Occupational status	
Working	11 (13.6)
Unemployed	25 (30.9)
Retired	45 (55.6)

Values are in mean ± SD or *n* (%). Sedentary data are for an average day.

[a] Missing data. Reasons: Incomplete patient medical record data for illness duration and chlorpromazine equivalent dose ($n = 4$ and 9, respectively); incomplete questionnaire data for severity of psychiatric symptoms ($n = 4$), Short Form 36-Item Health Survey ($n = 3$), and adherence to the Mediterranean diet ($n = 11$); incomplete 6-minute walking test ($n = 1$).

[b] Severity of psychiatric symptoms was assessed using the Spanish version of the Brief Symptoms Inventory-18, with higher scores indicating high severity of psychiatric symptoms.

[c] Adherence to Mediterranean diet was assessed using the 14-Item Mediterranean Diet Tool, with scores ≥ 8 indicating high adherence to Mediterranean diet.

Table 2
Characteristic comparisons of sedentary behavior levels in schizophrenia patients.

Variables % or mean (SD)	Low sedentary		High sedentary		*P*[*]
	n[a]	Values	*n*[a]	Values	
Age (years)	41	40.7 ± 8.6	41	41.3 ± 8.9	0.7361
Severity of psychiatric symptoms (0–72)[b]	38	12.0 ± 10.3	40	19.1 ± 11.9	0.0045
Illness duration (years)	40	16.8 ± 7.7	38	17.4 ± 10.0	0.7692
Chlorpromazine equivalent dose (mg/day)	37	781.6 ± 633.3	36	731.3 ± 501.0	0.9340
Body mass index (kg/m^2)	41	28.8 ± 3.8	41	32.6 ± 6.0	0.0018[*]
6-Minute walking test (m)	41	611.9 ± 96.5	40	566.7 ± 78.9	0.0522
Short Form 36-Item Health Survey (0–100)					
Physical function	40	78.3 ± 24.2	39	69.1 ± 21.9	0.0200
Physical role	40	73.9 ± 23.0	39	70.8 ± 25.3	0.5847
Pain	40	74.7 ± 22.4	39	64.7 ± 24.4	0.0777
General health	40	64.0 ± 23.3	39	53.8 ± 21.6	0.0612
Vitality	40	59.7 ± 18.2	39	46.8 ± 23.3	0.0065
Social function	40	67.2 ± 23.5	39	59.9 ± 31.7	0.2825
Emotional role	40	70.8 ± 26.4	39	69.7 ± 29.8	0.9678
Mental health	40	65.0 ± 17.8	39	60.1 ± 23.4	0.2989
Physical component summary	40	50.4 ± 8.9	39	46.3 ± 9.1	0.0478
Mental component summary	40	42.9 ± 10.8	39	40.5 ± 13.8	0.3891
Gender (women)	41	4 (9.8)	41	9 (22.0)	0.1310
Adherence to Mediterranean diet (high)[c]	35	14 (40.0)	36	14 (38.9)	0.9242
Smoking status (current smoker)	41	26 (63.4)	41	19 (46.3)	0.1201

The sample was divided into low levels of sedentary behavior ($n = 41$, <59% of waking time, which corresponds to 7.3 h/day) and high levels of sedentary behavior ($n = 41$, ≥59% of waking time, which corresponds to 10.4 h/day) using the median split of the percentage of waking time spent engaging in sedentary behavior.

[a] *n* varies due to missing data. Reasons: Incomplete patient medical record data for illness duration and chlorpromazine equivalent dose ($n = 4$ and 9, respectively); incomplete questionnaire data for severity of psychiatric symptoms ($n = 4$), Short Form 36-Item Health Survey ($n = 3$), and adherence to the Mediterranean diet ($n = 11$); incomplete 6-minute walking test ($n = 1$).

[b] Severity of psychiatric symptoms was assessed using the Spanish version of the Brief Symptoms Inventory-18, with higher scores indicating high severity of psychiatric symptoms.

[c] Adherence to Mediterranean diet was assessed using the 14-Item Mediterranean Diet Tool, with scores ≥ 8 indicating high adherence to Mediterranean diet.

[*] Significant when $P < 0.0025$.

4. Discussion

The main findings are the identification of BMI, CRF, and vitality as determinants of SB, with higher BMI, lower CRF and worse PCS score associated with a more sedentary lifestyle. The statistical power of the correlations remained after adjustments for age, illness duration, symptom severity, adherence to Mediterranean diet, smoking, and antipsychotic medication, highlighting the importance of considering SB as a health risk behavior in schizophrenia patients.

The finding showing the association between SB and BMI in schizophrenia patients is consistent with previous studies that used self-reported SB (Vancampfort et al., 2014, 2012) but inconsistent with studies that used objective SB measurements (Janney et al., 2013;

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Table 3
Relationship between sedentary behavior and sample characteristics.

Variables	n[a]	Correlation	P
Age (years)	82	−0.01	0.914
Severity of psychiatric symptoms (0–72)[b]	78	0.26	0.020*
Illness duration (years)	78	−0.04	0.736
Chlorpromazine equivalent dose (mg/day)	73	−0.11	0.377
Body mass index (kg/m^2)	82	0.41	<0.001*
6-Minute walking test (m)	81	−0.34	<0.001*
Short Form 36-Item Health Survey (0–100)			
Physical function	79	−0.35	0,002*
Physical role	79	−0.35	0,291
Pain	79	−0.24	0,036*
General health	79	−0.19	0,087
Vitality	79	−0.37	0,001*
Social function	79	−0.15	0,176
Emotional role	79	0.01	0,934
Mental health	79	−0.13	0,240
Physical component summary	79	−0.35	<0.001*
Mental component summary	79	−0.08	0,480
Gender (men/women)	82	0.21	0.061
Adherence to Mediterranean diet (low/high)[c]	71	0.00	0.995
Smoking status (non-smoker/current smoker)	82	0.15	0.190

Correlation values are either Pearson or Spearman correlations.
[a] n varies due to missing data. Reasons: Incomplete patient medical record data for illness duration and chlorpromazine equivalent dose ($n = 4$ and 9, respectively); incomplete questionnaire data for severity of psychiatric symptoms ($n = 4$), Short Form 36-Item Health Survey ($n = 3$), and adherence to the Mediterranean diet ($n = 11$); incomplete 6-minute walking test ($n = 1$).
[b] Severity of psychiatric symptoms was assessed using the Spanish version of the Brief Symptoms Inventory-18, with higher scores indicating high severity of psychiatric symptoms.
[c] Adherence to Mediterranean diet was assessed using the 14-Item Mediterranean Diet Tool, with scores ≥ 8 indicating high adherence to Mediterranean diet.
* Significant when $P < 0.05$.

Snethen et al., 2014). The lack of association between SB and BMI in the aforementioned studies could be explained by the limited statistical power of the sample size ($n < 50$), the ceiling effect observed for BMI (Janney et al., 2013; Snethen et al., 2014) or the use of different devices and requirements to evaluate objective SB. Other research in schizophrenia (Stubbs et al., 2017b) also found no association between SB objectively measured and waist circumference, suggested as a better predictor of cardiovascular risk than BMI (Janssen et al., 2004). Nonetheless, current studies reported that no obesity index is consistently superior to others (Lam et al., 2015) and that the combined obesity indices had a better predictive capacity than either alone (Tao et al., 2016). Future studies investigating the association between combined obesity indices and SB measured objectively through energy expenditure and body position for multiple and consecutive 24-hour periods are necessary to gain better insights into this issue.

The finding demonstrating the relationship between SB and BMI independent of various confounders, including diet, may be explained by the use of total SB time instead of time spent engaging in certain SBs such as television viewing, that are associated with weight gain mediated by unhealthy dietary patterns (de Rezende et al., 2014). Future research combining both objectively measured and self-reported SB patterns using appropriate tools (Bueno-Antequera et al., 2017a) is required to improve the understanding of the impact of specific SBs on BMI and on other health outcomes of schizophrenia patients.

Table 4
Final model of the backward stepwise regression analysis with the mean percentage of waking time spent engaging in sedentary behavior as the dependent variable ($n = 74$).

Variables[a]	B	SE	β	t	VIF	P
(Constant)	61.12	14.45		4.23		
Body mass index	0.93	0.26	0.35	3.50	1.15	0.001*
6-Minute walking test	−0.04	0.02	−0.24	−2.28	1.27	0.026*
Vitality	−0.16	0.07	−0.25	−2.53	1.13	0.014*

B: unstandardized coefficient; β: standardized coefficient; SE: standard error; VIF: variance inflation.
[a] Only significant correlates in the univariate tests were included in the model (severity of psychiatric symptoms, body mass index, 6-minute walking test, physical function, pain, vitality and physical component summary).
* Significant when $P < 0.05$.

A significant relationship between SB and CRF can be expected because SB has a deleterious impact on circulatory, respiratory and muscular systems (Allen et al., 1999) involved in CRF. Similar results have been recently found in psychosis patients (Bueno-Antequera et al., 2017b), and the association persisted even when BMI was included with the rest of the confounders. These findings are of clinical interest because a low CRF is associated with an enhanced risk of cardiovascular disease, all-cause mortality, and mortality rates attributable to various cancers (Ross et al., 2016). Therefore, regardless of BMI, reducing SB may protect against two critical health issues in schizophrenia patients - impaired CRF (Vancampfort et al., 2015b) and elevated premature mortality (Olfson et al., 2015) - suggesting a shift in clinical focus from fatness towards fitness in this population, as previously proposed (Vancampfort et al., 2017b). Future research should investigate whether these findings are applicable considering other health-related fitness components, such as muscular strength, which is also impaired in schizophrenia patients (Vancampfort et al., 2013) and is related to mortality (Volaklis et al., 2015).

The significant association between SB and the HRQoL PCS score could be attributable to a higher BMI and lower CRF in more sedentary patients (see Table 3), which were significantly related to the HRQoL PCS ($r = -0.27$ and 0.43, respectively; both $P < 0.05$; data not shown), consistent with previous research in schizophrenia patients (Vancampfort et al., 2015a). In addition to the PCS, lower clinically relevant scores for MCS were found in the high-SB group, suggesting possible associations between mental aspects of HRQoL and SB in line with a longitudinal study of older adults (Balboa-Castillo et al., 2011). These results are inconsistent with the one study that investigated the relationship between SB and HRQoL in schizophrenia patients (Gomes et al., 2014). The small sample size employed ($n = 8$) in the aforementioned study (Gomes et al., 2014) and the use of different tools to measure HRQoL and SB may explain the discrepancy.

Finally, the relationship between SB and symptom severity did not remain significant in the multiple regression model, suggesting that its importance in SB in schizophrenia patients is weak and can be explained by its interaction with other variables. All the identified determinants of SB are modifiable and may be important areas for future interventions in this population. It should be noted that our model only explained approximately a third of variability in SB suggesting that other outcomes not included in this study such as the socioeconomic (Stamatakis et al., 2014), geographical (Vancampfort et al., 2017a), and environmental status (Vancampfort et al., 2014) could explain part of the remaining variability.

As for clinical implications, this study could help to raise health professionals' awareness of the importance of reducing excessive SB in schizophrenia patients. However, randomized controlled trials aimed to reduce SB in schizophrenia patients are needed to determine whether reduced health outcomes can be improved (Williams et al., 2016). Researchers should consider all reported determinants of SB in this work when designing trials.

The findings need to be interpreted cautiously. The major limitation of this study is the cross-sectional design. Longitudinal and intervention studies are needed to identify any causal relationships. The convenience sample of outpatients, predominantly men, may also affect generalization. Future research should determine whether the results are also applicable in inpatient settings and for women with schizophrenia. The absence of a control group is an additional limitation. The objective SB measurement employed also presents limitations. The SenseWear device is unable to differentiate body position (i.e., sitting, lying, and standing). However, it may solve the limitations of accelerometers and inclinometers through heat production measurements and placement on the upper arm. Further studies using multiple sensors and

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inclinometers simultaneously should be performed to objectively measure SB. CRF was estimated through a submaximal exercise test that evaluates walking capacity. Future studies should confirm our findings using maximal or submaximal tests with direct measurement of peak oxygen uptake, the gold standard for CRF assessment (Vanhees et al., 2005). Finally, data on symptom severity and diet were collected with self-report questionnaires. This may involve recall bias (Raphael, 1987) that could be even more pronounced in schizophrenia patients, who are prone to memory and cognitive difficulties (Hill et al., 2013).

Despite these limitations, this study has strengths. Major strengths of this multicenter study are the relatively large sample size and the strict requirements used to measure SB. All patients wore the SenseWear for 7 consecutive days with at least 1368 min/day of registered time, and reactivity was minimized. Another strength was the adjustment for confounders that could influence the relationships between SB and BMI, CRF, and HRQoL. These include age, illness duration, symptom severity, adherence to Mediterranean diet, smoking, and antipsychotic medication. Finally, using the relative SB time to avoid the potential confounding influence of waking time could be considered another strength.

In conclusion, consistent relationships between higher SB and higher BMI, lower CRF and worse HRQoL PCS scores were found in schizophrenia patients. In addition, lower clinically relevant scores for HRQoL PCS and MCS were found in the high-SB group. Finally, BMI, CRF, and vitality were identified as determinants of SB. Therefore, reducing SB may lead to improvements in health outcomes that are commonly impaired in schizophrenia patients.

Conflict of interest

All authors declare no conflicts of interest.

Contributors

DM designed the study and wrote the protocol. All authors were responsible for the acquisition of the data. JB and DM performed the statistical analyses and wrote the manuscript. All authors provided critical review of the manuscript and approved the final version.

Role of the funding source

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