

Association between actigraphy-derived physical activity and cognitive performance in patients with schizophrenia

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Background. An association between low levels of physical activity and impaired cognitive performance in schizophrenia has been proposed, but most studies have relied on self-report measures of activity. This study examined the association between actigraphy-derived physical activity and cognitive performance adjusting for multiple covariates in patients with schizophrenia.

Method. Patients with schizophrenia ($n = 199$) were recruited from chronic psychiatric wards, and 60 age-, sex- and body mass index-matched comparison participants were recruited from the staff of two hospitals and universities. Physical activity was assessed objectively for 7 days using an ActiGraph. Cognitive performance was assessed with the Cognitrone test from the Vienna Test System and the Grooved Pegboard Test. Demographic variables, metabolic parameters, positive and negative symptoms, duration of illness and hospitalization, and medication use were included as covariates. Pearson correlations and multivariable linear regressions were conducted to examine the associations between physical activity levels and cognitive performance.

Results. Patients with schizophrenia were less physically active and had poorer performance on attention/concentration and speed of processing than the comparison group. Patients with schizophrenia who spent more time in light physical activity showed better performance on attention/concentration ($\beta = 0.198$, $p = 0.020$) and speed of processing ($\beta = -0.169$, $p = 0.048$) tasks than those who were less active. Cognitive performance was also associated with moderate-vigorous physical activity, but the effect was no longer significant once light physical activity had been taken into account.

Conclusions. This study provides evidence for a positive association between objectively measured light physical activity and cognitive performance in people with schizophrenia, after adjustment for multiple confounders.

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Introduction

Schizophrenia is a chronic and severe mental illness (McGrath *et al.* 2008; National Institute of Mental Health, 2009), resulting in high economic costs (Wu *et al.* 2005). People with schizophrenia tend to have a high rate of unemployment (Ramsay *et al.* 2012), an unhealthy lifestyle (e.g. smoking and physical inactivity) (De Leon & Diaz, 2005; Wichniak *et al.* 2011; Yamamoto *et al.* 2011) and poor physical health status (Hauszwolf-Juhlin *et al.* 2009). Side effects of anti-psychotic drugs may contribute to an elevated risk of weight gain and the development of metabolic disturbances in schizophrenia (Hägg *et al.* 2006; Rege, 2008;

Malchow *et al.* 2013; Marder *et al.* 2014). Moreover, the presence of the metabolic syndrome limits physical activity in schizophrenia (Vancampfort *et al.* 2011), leading to a vicious self-perpetuating cycle of increasing metabolic syndrome and decreasing physical activity among patients with schizophrenia.

The physical health problems and physical activity levels of people with schizophrenia have been widely studied (Vancampfort *et al.* 2011; Ratliff *et al.* 2012; Vancampfort *et al.* 2013). Another critical issue in schizophrenia is cognitive impairment. Cognitive capacity is crucial for functioning in everyday life, since ability to attend to stimuli selectively, maintain concentration on tasks over prolonged periods, use language for communication and self-expression, learn new skills, make decisions, and execute actions are all important (Sharma & Antonova, 2003; Glisky, 2007). These abilities are impaired to some extent in patients

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with schizophrenia, with deficits in attention, executive function, verbal and visuospatial working memory, and learning and memory having been reported (Sharma & Antonova, 2003). Cognitive deficits are also associated with impaired functional status, work capacity, social behaviour and activities of daily living (Green, 1996; Matza *et al.* 2006).

The benefits of physical activity for cognitive performance are well documented in healthy populations (Angevaren *et al.* 2008; McMorris & Hale, 2012; Guiney & Machado, 2013; Verburgh *et al.* 2014). However, the impact of physical activity on individuals with mental illness has only recently been examined (Richardson *et al.* 2005; Holley *et al.* 2011; Zschucke *et al.* 2013). The available evidence suggests that high physical fitness or more physical activity are associated with better cognitive performance, including executive functioning, verbal working memory, and speed of processing among patients with schizophrenia (Kimhy *et al.* 2014; Leutwyler *et al.* 2014). These findings indicate that physical activity might have potential benefits for some domains of cognition in people with schizophrenia.

However, most studies have used self-report measures of physical activity, and these are subject to recall bias (Lindamer *et al.* 2008). The few studies examining associations between objectively measured physical activity and cognition in people with schizophrenia have been small scale (Lindamer *et al.* 2008; Leutwyler *et al.* 2014). Moreover, potentially confounding factors, such as education levels, body mass index (BMI), metabolic syndrome parameters, antipsychotic medication, smoking and drinking status have not been controlled (Leutwyler *et al.* 2014). This study was therefore designed to examine the association between actigraphy-derived physical activity and cognitive performance while adjusting for multiple confounders in people with schizophrenia.

Method

Participants

Participants were recruited from the chronic psychiatric wards at Jianan Mental Hospital, Taiwan. The diagnosis of schizophrenia was verified by psychiatrists based on the Diagnostic and Statistical Manual Disorders, fourth edition (American Psychiatric Association, 1994). Patients were included if they were stable on antipsychotic medicine and had used the same dosage for at least 3 months prior to inclusion. Those who were unable to communicate, unable to walk independently and had neurological disorders were excluded. A total of 200 potential in-patients were

suitable for the study. Among them, 199 in-patients provided their written informed consent.

Age-, sex- and BMI-matched comparison participants were recruited from the staff of two hospitals and universities. Individuals who had no present or past history of psychiatric disorder and were not taking any psychoactive medicines were invited. A total of 60 participants were selected to ensure comparable sex balance, age and BMI ranges to the schizophrenia group. The study was approved by the Institutional Review Board of Jianan Mental Hospital.

Measures

Physical activity

The wActiSleep-BT ActiGraph (USA) was used to assess physical activity levels objectively. This is a tri-axial accelerometer that has been validated and used in previous studies (García-Ortiz *et al.* 2010; Hansen *et al.* 2012; Cain *et al.* 2013; De Moura *et al.* 2015). Standardized instructions of wearing an accelerometer were provided by research assistants. Participants were asked to wear the accelerometer all day on the wrist of the non-dominant hand for 1 week and to remove it during bathing or water activities. The accelerometers were initialized, downloaded and analysed using ActiLife software version 6 (ActiGraph LLC, USA). The sleep period was excluded and the levels of physical activity were defined according to the cut-off points outlined by Freedson *et al.* (1998). Light physical activity was defined as between 101 and 1951 counts per min, and time in moderate-vigorous physical activity (MVPA) was defined as activities ≥ 1952 counts per min (Lindamer *et al.* 2008; Cain *et al.* 2013). Participants were excluded if the accelerometers were not worn for at least 10 h per day (excluding sleep period) for at least 5 days ($n = 38$). The mean wear time was 13.9 (S.D. = 2.1) h per day for the schizophrenia group and 16.3 (S.D. = 1.4) h per day for the healthy controls.

Cognitive function

Vienna Test System (VTS). The VTS is a computerized neurocognitive function assessment battery consisting of various tests of personality, intelligence and cognitive function (Schuhfried, 2013). It has been used in previous studies of healthy individuals, people with depression (Deijen *et al.* 1993; Lee *et al.* 2003) and people with schizophrenia (Klasik *et al.* 2011). The Cognitrone (COG) test used in this study is a general ability test assessing attention and concentration. Participants are presented with a series of abstract figures on the computer screen, and make judgments concerning their congruence (Schuhfried, 2013). The

number of responses made within the total working time of 7 min was recorded.

Grooved Pegboard Test (GPT). The GPT is regarded as a test of manual dexterity, upper-limb motor speed, hand–eye coordination, and speed of processing and has been widely used in previous research (Nuechterlein *et al.* 2004; Wang *et al.* 2011; Bezdicek *et al.* 2014; Belsky *et al.* 2015). It consists of 25 holes with randomly positioned slots. The task involves inserting pegs into the board in a fixed order and in the correct direction using only one hand. Participants are encouraged to perform the task as quickly as possible, and the total time needed for the test is recorded. In this study, participants were tested twice, once with the dominant hand and once with the non-dominant hand, and the average time taken for the two tests was calculated.

Covariates

Positive and Negative Syndrome Scale (PANSS). The PANSS was developed to assess the severity of positive and negative symptoms and to measure general psychopathology in schizophrenia (Kay *et al.* 1987). It was completed by the registered nurses looking after each patient with schizophrenia. The 30-item rating scale consists of three subscales: seven-item Positive Symptoms, seven-item Negative Symptoms, and 16-item General Psychopathology. Each item is assessed on a seven-point rating scale ranging from 1 (asymptomatic) to 7 (extremely symptomatic). The PANSS was summed across items, so could range from 7 to 49 for the Positive and Negative Scales and 16–112 for the General Psychopathology Scale. Higher scores indicate more severe symptoms.

Medication use. Information about years since illness onset, duration of hospitalization, and the use of antipsychotic medication and sleeping pills was collected from hospital records. Antipsychotic medication use was converted into a daily equivalent dosage of chlorpromazine (Gardner *et al.* 2010), while sedatives were converted to the daily equipotent dosage of Lorazepam, according to the defined daily dose of World Health Organization Collaborating Centre for Drug Statistics Methodology (http://www.whocc.no/ddd/definition_and_general_considera/).

Metabolic parameters. Waist circumference, systolic/diastolic blood pressure, serum triglycerides (TG), high-density lipoprotein cholesterol (HDL-C) and fasting glucose (FG) were obtained through regular health checks in the hospital.

Demographic variables. Data on age, sex, smoking habits, alcohol consumption and years of schooling were collected. Participants were categorized into two groups: ‘yes (current/former smoker or drinker)’ and ‘no’ (never). Groups of current and former smoker or alcohol consumer were combined, due to there being few current smokers ($n=18$) or current alcohol consumers ($n=2$). Body weight and height were measured in light clothes and BMI was calculated.

Psychiatric nurse practitioners who had completed psychiatric professional training and research ethics training to degree level or higher administered the tests.

Statistical analyses

Descriptive statistics were calculated and χ^2 tests and t tests were performed to compare schizophrenia and comparison groups. Pearson correlations were used to test the univariate associations between physical activity levels and cognitive performance in each group. To examine the independent association between physical activity levels and cognition, multivariable linear regression analyses were conducted. Separate regressions were conducted for each of the cognitive measures and groups. Results are presented in terms of standardized (β regression coefficients and associated p values). All models were adjusted with demographic variables (age, sex, education), behavioural variables (smoking and alcohol consumption), metabolic parameters and accelerometer wear time in the comparison group. Clinical factors (years since illness onset, duration of hospitalization, medication use, and PANSS) were additional covariates in patients with schizophrenia. All analyses were performed with IBM SPSS statistics 20 (USA) and a p value less than 0.05 was considered as statistically significant in this study.

Ethical standards

All procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimental and with the Helsinki Declaration of 1975, as revised in 2008.

Results

Table 1 shows the descriptive statistics for participants with and without schizophrenia. It can be seen that patients with schizophrenia were aged 44 years on average, with a slight majority of men. They were long-term patients averaging 23.8 years since diagnosis, and had been hospitalized for an average of 14.2 months. There was no significant difference between the patients with schizophrenia and the non-psychiatric

Table 1. Characteristics of individuals with and without schizophrenia

Variables	Schizophrenia (<i>n</i> = 199)	Comparison group (<i>n</i> = 60)	<i>p</i>
Demographic variables			
Age, years	44.0 (9.9)	41.1 (9.6)	0.052
BMI, kg/m ²	24.3 (4.3)	23.9 (3.7)	0.520
Sex: male, %	61.3	56.7	0.520
Smoke: never, %	57.3	81.7	0.001
Alcohol: never, %	83.4	85.0	0.771
Schooling, years	11.4 (2.2)	14.9 (3.5)	<0.001
Metabolic syndrome parameters			
Waist circumference, cm	86.8 (11.1)	81.0 (10.5)	<0.001
SBP, mmHg	112.6 (13.2)	114.5 (11.9)	0.303
DBP, mmHg	71.2 (8.8)	73.4 (7.0)	0.053
TG, mg/dl	133.6 (71.7)	106.8 (64.3)	0.010
HDL-C, mg/dl	47.0 (13.3)	54.5 (16.1)	0.001
FG, mg/dl	100.2 (28.8)	93.9 (11.3)	0.012
Physical activity level			
Light PA, min/day	158.6 (71.4)	496.0 (90.1)	<0.001
MVPA, min/day	95.0 (54.2)	154.5 (72.1)	<0.001
Cognitive function			
Cognitron test	171.9 (100.5)	392.4 (134.3)	<0.001
GPT, s	137.7 (45.6)	72.4 (32.1)	<0.001
PANSS			
PANSS-P	63.0 (20.0)		
PANSS-N	15.4 (5.7)		
PANSS-G	16.9 (6.2)		
Medications, mg/d			
Chlorpromazine equivalent doses	847.6 (783.8)		
Lorazepam equivalent doses	1.1 (1.3)		
Time since illness onset, years	23.8 (6.5)		
Duration of hospitalization, months	14.2 (17.0)		

Data are given as mean (standard deviation) unless otherwise indicated).

BMI, Body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglycerides; HDL-C, high-density lipoprotein-cholesterol; FG, fasting glucose; PA, physical activity; MVPA, moderate-vigorous physical activity; GPT, Grooved Pegboard Test; PANSS, Positive and Negative Syndrome Scale; PANSS-P, Positive and Negative Syndrome Scale positive symptoms; PANSS-N, Positive and Negative Syndrome Scale negative symptoms; PANSS-G, Positive and Negative Syndrome Scale general symptoms.

comparison group in respect to age, sex and BMI. However, patients with schizophrenia had poorer performance on the GPT and the COG test than the comparison group (all $p < 0.001$).

Participants with schizophrenia spent 158.6 min/day in light physical activity, which was significantly less time than the comparison group (496.0 min/day). The time spent in MVPA was also less in the schizophrenia group (95.0 min/day) than the comparison group (154.5 min/day). The remaining time was spent in sedentary activities. These findings indicate that patients with schizophrenia were less active than the comparison group. Additionally, the schizophrenia group had greater waist circumference, higher TG and FG,

and lower HDL-C than the non-psychiatric comparison group (Table 1).

The univariate associations between physical activity levels and cognitive performance among patients with schizophrenia and the comparison group are shown in Table 2. Significant associations were found between each level of physical activity and all cognitive measures among the patients with schizophrenia, so spending more time in any intensity of physical activity was related to better performance on the GPT and COG test. However, no significant association was found between any level of physical activity and the cognitive measures in the comparison group.

Table 2. Correlations of PA with cognitive performance in people with and without schizophrenia

	Light PA	MVPA	Cognitrone test	GPT
Patients with schizophrenia (<i>n</i> = 199)				
Light PA	1			
MVPA	0.551**	1		
Cognitrone test	0.217**	0.300**	1	
GPT	-0.287**	-0.368**	-0.412*	1
Comparison group (<i>n</i> = 60)				
Light PA	1			
MVPA	0.153	1		
Cognitrone test	0.172	0.125	1	
GPT	-0.177	-0.224	-0.466**	1

PA, Physical activity; MVPA, moderate-vigorous physical activity; GPT, Grooved Pegboard Test.

Significant correlation: * $p < 0.05$, ** $p < 0.01$ (two-tailed).

The fully adjusted linear regressions relating physical activity with cognitive performance in the patients with schizophrenia are presented in Table 3. Light physical activity and MVPA were entered separately into regression models. Significant associations were found between the amount of activity at each level of physical activity and the two cognitive measures even after multivariable adjustments (light: $\beta = 0.224$, $p = 0.002$ in the COG test; $\beta = -0.245$, $p = 0.001$ in the GPT; MVPA: $\beta = 0.167$, $p = 0.036$ in the COG test; $\beta = -0.254$, $p = 0.001$ in the GPT, respectively). The results suggest that participating in more light physical activity or MVPA was associated with better cognitive performance among patients with schizophrenia.

In order to determine the relative contributions of physical activity levels to cognitive performance, light physical activity and MVPA were simultaneously entered as independent variables into regression models with multivariable adjustments (Table 4). Interestingly, the relationship was stronger for light activity than for MVPA in the schizophrenia group. Patients with schizophrenia who spent more time doing light activity had better performance on the COG test ($\beta = 0.198$, $p = 0.020$) and the GPT ($\beta = -0.169$, $p = 0.048$). However, MVPA was not associated with any cognitive measures in the presence of light physical activity and other covariates.

No significant association was found in multivariable regression models between levels of physical activity and cognitive performance in the comparison group. The fully adjusted models are shown in Table 4.

Discussion

This study showed lower physical activity levels in patients with schizophrenia compared with a non-

psychiatric comparison group. Within the schizophrenia group, higher levels of objectively measured light physical activity were associated with better performance on both cognitive tests independently of demographic factors such as age, sex and schooling, physiological risk factors, schizophrenia symptoms, duration of illness and hospitalization, or medication. The amount of MVPA was also associated with cognitive performance, but not after light activity and other covariates were included in the models.

The difference in physical activity between patients with schizophrenia and healthy controls is consistent with the findings from previous research (Wichniak *et al.* 2011; Yamamoto *et al.* 2011). However, Lindamer *et al.* (2008) found no significant difference in physical activity measured with accelerometry between the two groups. One of the reasons might be the age difference of the sample between studies. Lindamer *et al.* (2008) included older adults (mean age = 50.7, S.D. = 6.4 years), while the mean age of the participants in our study was younger. Moreover, participants in the earlier study were out-patients, whereas our study only included in-patients. The small sample size with valid accelerometry data in the earlier study (16 from people with schizophrenia and six from the comparison group) may have resulted in a lack of statistical power to make the comparison. Hospitalization and duration of illness might also contribute to the different findings of other studies (Wichniak *et al.* 2011).

It should be noted that the participants with schizophrenia in this study were all in-patients, while the comparison group was free living. This makes it difficult to conclude whether differences are the result of the mental illness of the patient group, or whether differences are due to restrictions in activity in the

Table 3. Multivariable linear regressions relating cognitive function with physical activity levels in participants with schizophrenia

Variables	Light physical activity						MVPA					
	Cognitrone test			GPT			Cognitrone test			GPT		
	R ²	β	<i>p</i>	R ²	β	<i>p</i>	R ²	β	<i>p</i>	R ²	β	<i>p</i>
	29.4			28.2			27.4			27.8		
Age		-0.264	<0.001		0.262	<0.001		-0.229	0.003		0.203	0.009
Sex ^a		0.036	0.687		-0.030	0.745		0.029	0.756		-0.013	0.885
Smoke ^a		0.047	0.559		-0.060	0.457		0.047	0.569		-0.045	0.584
Alcohol ^a		-0.025	0.726		0.129	0.072		-0.031	0.666		0.136	0.059
Schooling		0.047	0.487		-0.092	0.184		0.072	0.295		-0.122	0.078
Metabolic syndrome parameters												
Waist		0.022	0.775		0.016	0.839		0.021	0.784		0.016	0.834
SBP		-0.227	0.014		-0.046	0.619		-0.201	0.031		-0.070	0.446
DBP		0.223	0.014		0.074	0.417		0.224	0.015		0.065	0.480
TG		0.051	0.485		-0.058	0.433		0.045	0.551		-0.048	0.523
HDL-C		-0.021	0.776		0.011	0.880		0.010	0.890		-0.023	0.763
FG		0.028	0.694		0.060	0.401		-0.007	0.923		0.099	0.162
Physical activity level												
Light		0.224	0.002		-0.245	0.001						
MVPA								0.167	0.036		-0.254	0.001
PANSS												
PANSS-P		-0.151	0.068		0.249	0.003		-0.117	0.162		0.205	0.015
PANSS-N		-0.316	0.005		0.181	0.106		-0.251	0.028		0.093	0.409
PANSS-G		0.140	0.268		-0.141	0.271		0.092	0.470		-0.085	0.505
Medications												
Chlorpromazine equivalent doses		0.154	0.026		0.094	0.179		0.142	0.043		0.104	0.137
Lorazepam equivalent doses		-0.092	0.176		0.003	0.961		-0.101	0.144		0.021	0.766
Time since illness onset		0.004	0.952		-0.012	0.864		0.017	0.819		-0.042	0.565
Duration of hospitalization		-0.115	0.098		0.007	0.922		-0.183	0.228		-0.022	0.750

MVPA, Moderate-vigorous physical activity; GPT, Grooved Pegboard Test; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglycerides; HDL-C, high-density lipoprotein-cholesterol; FG, fasting glucose; PANSS, Positive and Negative Syndrome Scale; PANSS-P, Positive and Negative Syndrome Scale positive symptoms; PANSS-N, Positive and Negative Syndrome Scale negative symptoms; PANSS-G, Positive and Negative Syndrome Scale general symptoms.

^a Dummy variable.

hospital environment. The hospital which housed the patients has an indoor gym where patients can play table tennis, basketball and snooker, and stationary bikes and treadmills are also available. Patients were also encouraged to attend 20-min stretching and walking sessions in the morning and afternoon. However, with hundreds of patients and limited facilities, patients may be restricted in the space and time available to engage in physical activity.

The current study also indicated that spending more time on light activity was associated with better cognitive performance on attention/concentration and processing speed in patients with schizophrenia. The relationship was stronger for light activity than for

MVPA. A similar study using objective physical activity measures found significant associations of moderate physical activity with speed of processing and verbal working memory among 30 older schizophrenia participants; however, no significant association between other cognitive measures and physical activity was found (Leutwyler *et al.* 2014). The inconsistent findings may be due to difference in physical activity categorization. Sedentary and light activities were combined into one level by Leutwyler *et al.* (2014). It is more appropriate to separate sedentary from light physical activity, since low activity is commonly found in patients with schizophrenia (Yamamoto *et al.* 2011), and the association of sedentary and light

Table 4. Multivariable linear regressions relating cognitive function in participants with and without schizophrenia

Variables	Patients with schizophrenia						Comparison group					
	Cognitrone test			GPT			Cognitrone test			GPT		
	R^2	β	p	R^2	β	p	R^2	β	p	R^2	β	p
	29.6			29.4			55.8			56.3		
Age		-0.250	<0.001		0.222	0.004		-0.187	0.208		0.275	0.066
Sex ^a		0.032	0.727		0.016	0.861		0.214	0.165		0.122	0.423
Smoke ^a		0.039	0.628		-0.039	0.635		-0.062	0.696		-0.203	0.200
Alcohol ^a		-0.026	0.720		0.131	0.066		-0.039	0.755		0.121	0.330
Schooling		0.052	0.451		-0.105	0.130		0.344	0.019		-0.514	0.001
Metabolic syndrome parameters												
Waist		0.022	0.775		0.016	0.839		-0.059	0.705		0.138	0.375
SBP		-0.225	0.015		-0.050	0.591		-0.243	0.146		-0.281	0.092
DBP		0.227	0.013		0.062	0.491		0.130	0.345		-0.079	0.560
TG		0.049	0.507		-0.051	0.487		-0.100	0.502		-0.031	0.836
HDL-C		-0.018	0.813		0.001	0.986		0.129	0.393		0.019	0.898
FG		0.023	0.746		0.073	0.302		-0.317	0.006		0.178	0.107
Physical activity level												
Light		0.198	0.020		-0.169	0.048		0.034	0.791		-0.139	0.275
MVPA		0.054	0.551		-0.158	0.085		0.124	0.325		-0.100	0.425
PANSS												
PANSS-P		-0.144	0.086		0.227	0.007						
PANSS-N		-0.300	0.009		0.135	0.238						
PANSS-G		0.133	0.296		-0.120	0.347						
Medications												
Chlorpromazine equivalent doses		0.154	0.027		0.094	0.178						
Lorazepam equivalent doses		-0.096	0.159		0.016	0.811						
Time since illness onset		0.001	0.985		-0.029	0.691						
Duration of hospitalization		-0.114	0.101		0.005	0.947						

GPT, Grooved Pegboard Test; SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglycerides; HDL-C, high-density lipoprotein-cholesterol; FG, fasting glucose; MVPA, moderate-vigorous physical activity; PANSS, Positive and Negative Syndrome Scale; PANSS-P, Positive and Negative Syndrome Scale positive symptoms; PANSS-N, Positive and Negative Syndrome Scale negative symptoms; PANSS-G, Positive and Negative Syndrome Scale general symptoms.

^aDummy variable.

activities with cognitive performance might differ (Steinberg *et al.* 2015). We further tested the associations of sedentary and light activity with cognitive performance in the present study (results not shown). The findings confirm that light activity but not sedentary activity was associated with better cognitive performance.

Additionally, no significant association was found between any level of physical activity and either cognitive test in the non-psychiatric comparison group. This contrasts with substantial literature showing positive relationships (Angevaren *et al.* 2008; McMorris & Hale, 2012; Guiney & Machado, 2013; Verburgh *et al.* 2014). One of the reasons might be the small size of the comparison group. Moreover, individuals in the

comparison group generally had good cognitive performance, leaving little scope for observing any effects of physical activity.

Physical activity interventions may be particularly appealing for individuals with mental illness in hospital settings, since they are relatively safe, low cost and easily integrated into daily schedules (Richardson *et al.* 2005). Studies have shown enhancement in composite cognitive test scores (Kimhy *et al.* 2015), hippocampal volume, short-term memory (Pajonk *et al.* 2010), working memory and speed of processing (Oertel-Knöchel *et al.* 2014) in patients with schizophrenia after aerobic exercise training, although not all results have been positive (Falkai *et al.* 2013; Scheewe *et al.* 2013). However, previous research has

mainly focused on the effects of MVPA. Promoting light physical activity might be more feasible than MVPA among patients with schizophrenia, since they spend much of the time in sedentary activities. This study has demonstrated that even light physical activity is associated with better cognitive performance in people with schizophrenia.

The current study provides evidence of positive associations between light physical activity and cognitive performance in patients with schizophrenia after taking multiple potential confounders into account. However, interpretation of the results is limited by the cross-sectional design, which is not able to determine causal relationships. All the participants with schizophrenia were long-term psychiatric in-patients, and findings might not generalize to less severe out-patients. Moreover, this study only included two cognitive tests and did not collect information about menstrual status, which may affect cognitive performance and physical activity in female patients. Well-designed prospective cohort studies or randomized controlled trials are needed to establish whether light and moderate physical activity can improve cognitive function among patients with schizophrenia.

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Declaration of Interest

None.

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