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Original Article

Effect of dual tasking on postural control in individuals with schizophrenia

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Abstract

Objective: To investigate the effect of dual tasking on postural control in individuals with schizophrenia. **Methods**: Fifteen outpatients with schizophrenia and 15 healthy controls were included. Postural control was assessed with postural sway velocity (PSV) using Balance Master System during three different tasks: single task (standing on a force platform), cognitive task (categorical verbal fluency) and motor task (holding a cup of water) in four conditions: on firm surface with eyes open (1) and closed (2), on foam surface with eyes open (3) and closed (4). **Results**: Individuals with schizophrenia presented higher PSV during single standing on foam surface with eyes open and closed. During the cognitive task, they showed higher PSV on foam surface with eyes closed. During the motor task PSV in schizophrenia group was higher on firm surface with eyes closed and on foam surface with eyes open and closed. Individuals with schizophrenia showed higher PSV during cognitive task on firm surface with eyes closed compared to the single task. **Conclusions**: Dual tasking results in a deterioration in postural control in individuals with schizophrenia. A cognitive task specifically alters postural control in the absence of visual information suggesting a possible sensorimotor dysfunction in this population.

Keywords: Cognitive Task, Dual Tasking, Motor Task, Postural Control, Schizophrenia

Introduction

Postural control is defined as the act of maintaining, achieving or restoring a state of balance during any posture or activity[1]. Individuals with schizophrenia present a wide range of motor deficits mainly divided into five categories as abnormal involuntary movements, neurological soft signs, catatonic symptoms, Parkinsonism and psychomotor slowing[2]. Impairments in postural control, mostly associated with these motor symptoms, have been reported in individuals with schizophrenia[3-5].

Movement disorders including balance and gait disturbances occur as part of abnormal brain structures critical for postural control, cerebellum and the basal ganglia and neurological soft signs in schizophrenia[6,7]. Studies have shown abnormalities in cerebellar function, volume, and metabolism, white matter integrity, neuropathological alterations in Purkinje cell morphology and protein expression[8,9]. In a recent study, a reduction in basal ganglia activation was observed in schizophrenia across different cognitive and motor tasks[10]. Standing posture is also thought to be affected in schizophrenia due to extrapyramidal side effects of antipsychotic drugs, mainly dopamine blocking neuroleptics[11,12]. Tsuru indicated that increased awareness of the external world in patients with schizophrenia has a potential to result in physical expression of this mental tension, which may influence postural stability as a result of chronic psychological strain[13]. Teng et al. also suggested that postural control dysfunctions may be a part of the intrinsic nature of schizophrenia which was associated with compromised

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sensory integration and poor postural sequences[14].

Postural control, which requires little demand for attentional resources in healthy individuals, is maintained by the integration of sensory information from somatosensory, visual and vestibular systems to maintain Center of Gravity (CoG) within the base of support[15]. In some populations, such as elderly or individuals with neurodegenerative diseases, these automatic activities may require greater attentional demand especially while performing two different tasks simultaneously (dual tasking). Dual tasking in schizophrenia has been investigated as a hallmark of executive functioning responsible for making plans, solving problems, multi-tasking and adaptation to unexpected conditions[16-18]. Ability to perform concurrent tasks, whether they are cognitive or motor, may be deteriorated in schizophrenia as an indicator of abnormal executive functioning. Dual tasking was found to be associated with modification variability in very simple activities of daily living such as walking in schizophrenia[16]. Moreover, deterioration in dual task performance was found to be associated with higher fall risk in various populations[19-21]. Recent studies have focused on the increased fall risk in schizophrenia because of the importance of higher fracture incidence due to decreased bone mass, even in middle-aged patients[22,23]. Compared to the general population, individuals with schizophrenia were found to be at 72% increased risk of experiencing fractures[24].

Although sensory integration deficits related to the correction of automatic motor actions leading to abnormalities in the control of postural reactions during dual tasking were reported in schizophrenia[25], very little is known regarding the effect of dual tasking on postural control in this population[5]. Therefore, the current study aimed to investigate the effects of dual tasking on postural control using a cognitive and a motor task during balance measurements. We hypothesized that, performing a dual task (cognitive-motor or motor-motor tasks) will result in greater deterioration in postural control in individuals with schizophrenia suggesting a possible greater dependence on attentional resources during upright standing compared to healthy individuals.

Materials and methods

Subjects

Fifteen clinically stable outpatients between 18 and 65 years of age who met the Diagnostic and Statistical Manual of Mental Disorders-5th edition criteria for schizophrenia were recruited from the university hospital's department of psychiatry as the study group[26].

All individuals with schizophrenia were stable and receiving their prescribed treatment for at least 4 weeks. Eighty percent of the schizophrenia group was under combination treatments with atypical antipsychotics. An antidepressant treatment was also prescribed for 27%. Eighty percent of the group had been hospitalized at least once throughout the course of the illness. The presence and severity of psychotic symptoms of individuals with schizophrenia were evaluated using the Positive and Negative Syndrome Scale (PANSS) by a senior psychiatrist[27].

Fifteen age-matched healthy subjects without any chronic diseases and with no regular medication usage were recruited as a control group. Exclusion criteria for both groups included the presence of any neurological diseases, substance or alcohol abuse, history or presence of lower extremity injury and communication problems.

Prior to the study, the power analysis was performed using G Power 3.0.10 program based on the results of the study of Lallart et al.[16] and 15 subjects were found adequate for each group considering 95% (5% Type I error level) confidence interval and 80% power.

Study protocol

Postural control was assessed objectively using Balance Master System (NeuroCom System Version 8.1.0, NeuroCom® International Inc. USA) which is a computerized device providing real-time balance analysis. The system consists of a force platform connected to a computer, with a software program that continuously monitors the position and movement of the CoG. For the current study, the Modified Clinical Test of Sensory Interaction on Balance (mCTSIB) which quantifies the position of CoG in upright position was selected for the assessment of postural control. Trial data consisted of CoG sway velocity in degrees per second as postural sway velocity (PSV) with higher values indicating poorer postural balance control. The CoG sway velocity is the ratio of the distance traveled by the CoG (degrees) to the time (sec) of the trial.

The test is performed under four different conditions: 1) on firm surface with eyes open (EO), 2) on firm surface with eyes closed (EC), 3) on foam surface with EO and 4) on foam surface with EC. The foam was the original foam pad of the Balance Master System that was included as an accessory with 46 x 46 x 13 cm dimensions. After receiving appropriate information about the test procedure prior to the test protocols, subjects were asked to remove all footwear and then were positioned with standardized foot placement relative to their height. They were instructed to stand with their arms relaxed at their sides, look straight forward, and stand as still as possible. Each test consisted of three trials each of which lasts for 10 seconds. The mean sway velocities recorded during the three trials were used for statistical analysis.

Assessment of postural control was conducted under three different conditions: Single task (standing on the force platform), during a cognitive task and during a motor task. The order of the tasks was randomly determined using card selection method. Single task corresponded to the assessment of postural control without any concurrent task. For the cognitive task, categorical verbal fluency requiring spontaneous word production under pre-specified search conditions was used[16]. Within the scope of this task, subjects were requested to produce animal names as continuously as possible concurrently during postural control assessments.

Table 1. Demographic data of the groups and clinical characteristics of the individuals with schizophrenia.

	Schizophrenia Group (n=15)	Control Group (n=15)	*p*
Gender, n (%)			
Male	13 (87.0)	13 (87.0)	1.000
Female	2 (13.0)	2 (13.0)	
Age, (years)	40 (34-50)	45 (35-49)	0.724
Body Mass Index, (kg/m^2)	25.51 (24.60-33.51)	27.42 (25.01-28.37)	0.254
Duration of Illness, (years)	15 (10-23)	-	-
Duration of Education, (years)	11 (11-15)	-	-
Suicidal attempt, n (%)			
Yes	6 (40.0)		-
No	9 (60.0)	-	
Combination treatment, n (%)	12 (80.0)	-	-
Antidepressant treatment, n (%)	4 (27.0)	-	-
PANNS Score			
Positive	14 (10-17)	-	-
Negative	19 (22-25)	-	-
General Psychopathology	29 (26-39)	-	-
Total	62 (58-77)	-	-

PANNS: Positive and Negative Syndrome Scale. Values are expressed as median and interquartile range (25^{th}-75^{th}) or number of individuals (%).

Categorical verbal fluency was chosen as a cognitive task because it had shown the strongest effect on gait variability compared to other dual tasks in a previous study including individuals with schizophrenia[16]. For the motor task, subjects were asked to hold a cup of water with their elbows flexed at 90 degrees during postural control assessments. The verbal instruction to the participants for the cognitive task was "produce animal names as continuously as possible, while it was "hold the cup of water as still as possible" for the motor task.

Statistical analysis

SPSS software version 22 (SPSS Inc., Chicago, IL, USA) was used for data analysis. Descriptive statistics and frequencies were used to present the demographic and clinical characteristics of the subjects. Shapiro-Wilk test was used to analyze the normality of data distribution. According to this test, most of the variables were not normally distributed. Therefore, non-parametric tests were used for statistical analysis. Medians and interquartile ranges (25^{th}–75^{th} percentile) were used for descriptive analyses of quantitative variables. Postural control assessments during three different tasks (single task, cognitive task and motor task) were compared using Friedman Variance Analysis in order to quantify differences in the study group. Significant results were then analyzed by post-hoc tests using Wilcoxon signed ranks test with Bonferroni correction. Schizophrenia and healthy control groups were compared using Mann Whitney U test. The significance level was set at <0.05, except for post-hoc analysis, in which the significance level was set at <0.016 (0.05/3) after Bonferroni corrections.

Results

Table 1 summarizes the demographic data of the groups and clinical characteristics of the individuals with schizophrenia The median age of the schizophrenia group (2 females, 13 males) was 40 (34-50) years while it was 45 (35-49) years in control group (2 females, 13 males). Median body mass index was 25.51 (24.60-33.51) kg/m^2 in schizophrenia group while it was 27.42 (25.01-28.37) kg/m^2 in the control group. The groups were similar in terms of demographic characteristics (p>0.05).

Group comparison analysis

Single task

PSV was higher on foam surface with both EO and EC conditions in schizophrenia group compared to the control group (*p=0.001* and *p=0.026*, respectively) (Table 2).

Cognitive task

PSV was higher on foam surface with EC in schizophrenia group compared to the control group (*p=0.040*) (Table 2).

Motor task

PSV was higher on firm surface with EC (*p=0.023*) and on foam surface with both EO and EC in schizophrenia group

Table 2. Comparison of postural sway velocity between the groups in three different tasks.

	Schizophrenia Group	Control Group	*p*
Single task			
Firm EO	0.33 (0.27-0.37)	0.33 (0.27-0.40)	0.440
Firm EC	0.37 (0.27-0.47)	0.33 (0.26-0.36)	0.198
Foam EO	0.56 (0.46-0.67)	0.43 (0.36-0.47)	**0.001****
Foam EC	0.70 (0.57-0.90)	0.57 (046-0.66)	**0.026***
Cognitive task			
Firm EO	0.37 (0.27-0.50)	0.33 (0.27-0.47)	0.901
Firm EC	0.47 (0.33-0.63)	0.43 (0.33-0.73)	0.803
Foam EO	0.57 (0.50-0.63)	0.47 (0.40-0.66)	0.648
Foam EC	0.76 (0.60-1.23)	0.57 (0.47-0.73)	**0.040***
Motor task			
Firm EO	0.30 (0.27-0.47)	0.26 (0.20-0.33)	0.077
Firm EC	0.47 (0.40-0.57)	0.36 (0.33-0.43)	**0.023***
Foam EO	0.53 (0.47-0.66)	0.40 (0.27-0.47)	**0.001****
Foam EC	0.76 (0.63-0.90)	0.53 (0.46-0.70)	**0.005****

*EO: Eyes open, EC: Eyes closed. Values are expressed as median and interquartile range (25^{th}-75^{th}), *p<0.05, **p<0.01, Mann-Whitney U Test.*

Table 3. Comparison of postural sway velocity between three different tasks within the groups.

Schizophrenia group				
PSV (°/sec)	**Single task**	**Cognitive task**	**Motor task**	***p***
Firm EO	0.33 (0.27-0.37)	0.37 (0.27-0.50)	0.30 (0.27-0.47)	0.390
Firm EC	0.37 (0.27-0.47)	0.47 (0.33-0.63)	0.47 (0.40-0.57)	**0.003****
Foam EO	0.56 (0.46-0.67)	0.57 (0.50-0.63)	0.53 (0.47-0.66)	0.882
Foam EC	0.70 (0.57-0.90)	0.76 (0.60-1.23)	0.76 (0.63-0.90)	0.423
Control group				
PSV (°/sec)	**Single task**	**Cognitive task**	**Motor task**	***p***
Firm EO	0.33 (0.27-0.40)	0.33 (0.27-0.47)	0.26 (0.20-0.33)	**0.013***
Firm EC	0.33 (0.26-0.36)	0.43 (0.33-0.73)	0.36 (0.33-0.43)	**0.034***
Foam EO	0.43 (0.36-0.47)	0.47 (0.40-0.66)	0.40 (0.27-0.47)	**0.002****
Foam EC	0.57 (046-0.66)	0.57 (0.47-0.73)	0.53 (0.46-0.70)	0.423

*PSV: Postural sway velocity, EO: Eyes open, EC: Eyes closed. Values are expressed as median and interquartile range (25^{th}-75^{th}), *p<0.05, **p<0.01, Friedman Variance Analysis.*

compared to the control group (*p=0.001* and *p=0.005*, respectively) (Table 2).

Within group analysis

Schizophrenia group

Between three test conditions (single task, cognitive task and motor task), schizophrenia group presented significantly different PSV on firm surface with EC (*p=0.003*) (Table 3). Following Bonferroni corrections, this significant difference was found between the single task and the cognitive task. Individuals with schizophrenia showed higher PSV values during cognitive task on firm surface with EC compared to the single task (*p=0.009*) (Table 4).

Control group

Between three test conditions (single task, cognitive task and motor task) there were significant differences in terms of

Table 4. Posthoc analysis.

PSV (°/sec)	Single task (I)	Cognitive task (II)	Motor task (III)	p_{I-II}	p_{I-III}	p_{II-III}
Schizophrenia group						
Firm EC	0.37 (0.27-0.47)	0.47 (0.33-0.63)	0.47 (0.40-0.57)	**0.009***	0.032	1.000
Control group						
Firm EO	0.33 (0.27-0.40)	0.33 (0.27-0.47)	0.26 (0.20-0.33)	0.551	**0.005***	0.033
Firm EC	0.33 (0.26-0.36)	0.43 (0.33-0.73)	0.36 (0.33-0.43)	**0.010***	0.174	0.066
Foam EO	0.43 (0.36-0.47)	0.47 (0.40-0.66)	0.40 (0.27-0.47)	0.059	**0.003***	0.073

*PSV: Postural sway velocity, EO: Eyes open, EC: Eyes closed. Values are expressed as median and interquartile range (25th-75th), *p<0.016, Wilcoxon signed ranks test with Bonferroni corrections.*

PSV on firm surface with both EO and EC and on foam surface with EO (*p=0.013, p=0.034, p=0.002*, respectively) (Table 3). After Bonferroni corrections, these differences were found to be significant between single task and cognitive task (higher PSV in favor of cognitive task on firm surface with EC; *p=0.010*); between single task and motor task (higher PSV in favor of single task on firm surface with EO; *p=0.005* and on foam surface with EO; *p=0.003*) (Table 4).

Correlations

There was no significant correlation between age and PSV in any conditions in schizophrenia group, while it was positively correlated with PSV during single task on firm surface with EC (*p=0.013*, r=0.663), foam surface EO (*p=0.043*, r=0.528) and during motor task on foam surface with EC in healthy control group (*p=0.003*, r=0.711). PANNS score and duration of the disease were not correlated with PSV in any conditions in schizophrenia group (p>0.05).

Discussion

In our study, in which we investigated the effects of dual tasking on postural control in individuals with schizophrenia, cognitive task resulted in an increased PSV during postural control in the absence of visual information similar to healthy individuals on firm surface. Whereas motor task did not seem to alter postural control in any condition in schizophrenia group, it resulted in lower PSV in the presence of visual input in the control group suggesting the idea that individuals with schizophrenia were not able to react as properly as healthy individuals to maintain postural control in case of a concurrent motor task. Moreover, PSV was found consistently higher in individuals with schizophrenia on all occasions when the visual input was hindered.

Although dual task performance is closely associated with increased fall risk in different populations[21-23], it has been investigated as a hallmark of executive functioning in individuals with schizophrenia. Lin et al. investigated dual task performance involving hand dexterity and cognitive tasks in individuals with schizophrenia and found a decline in hand dexterity in dual task conditions indicating greater cognitive interference with motor function in this population compared to healthy controls[17]. In addition to the recent literature focusing on increased fall risk and its predictors in individuals with psychiatric populations[28-30], studies investigating the relationship between dual tasking and parameters linked to fall incidence, such as postural control, in schizophrenia are limited. Stensdotter et al. measured postural control in quiet standing with a concurrent cognitive task, counting backward from one hundred on even numbers, in individuals with psychotic conditions and found no effect of dual tasking on postural sway neither in study group nor in healthy controls[5]. However, seven of twelve individuals had been diagnosed with schizophrenia in that study. Therefore, it is not possible to generalize their findings specifically to individuals with schizophrenia. Five individuals in their study group had also an additional substance use disorder, which was an exclusion criterion in our study as it could independently affect postural control[31].

During standing, the human body is inherently unstable and its stabilization requires constant regulation of ankle torque which has two components as intrinsic and active torque[32]. Intrinsic torque is generated by ankle intrinsic stiffness, which is the joint mechanical resistance to its movement[32]. Despite the studies suggesting that ankle intrinsic stiffness is constant during standing[33,34], Amiri and Kearney indicated higher ankle intrinsic stiffness when the Center of Pressure (CoP) is closer to the limits of stability[35]. In standing, ankle torque and angle change continuously with sway. Although individuals with psychotic conditions and healthy controls responded similarly to dual tasking during postural control in their study, Stensdotter et al. found significantly higher postural sway at baseline measurements and during the concurrent cognitive task due to exaggerated ankle joint torque relative to CoP frequency[5]. Parallel to their findings, individuals in our study presented higher PSV during single task on foam surface in eyes open and closed conditions suggesting a probable difficulty in integrating somatosensory information in schizophrenia in both the presence and absence of visual information. We also found similar results for other tasks, that individuals with schizophrenia exhibited greater postural sway with a cognitive and a motor task on a foam surface, especially in the absence of visual information. Matsuura et al. investigated standing postural stability in individuals with schizophrenia and pointed out the difficulties in visual information and proprioceptive signals as their subjects were less stable in eyes closed condition[12]. Similar to our findings, individuals with schizophrenia presented inefficient adaptation to the loss of visual information during maintenance of posture representing abnormal integration of sensory information, which was critical in postural control process suggesting a possible sensory integration dysfunction in schizophrenia[36].

An interesting conclusion of Stensdotter et al.'s study was the suggestion of insufficient difficulty of the cognitive task used in the study protocol and the advice for future studies to involve tasks that are more demanding[5]. Within this context, Lallart et al. used verbal fluency as a cognitive task in their study investigating the association between executive dysfunction and gait in 17 recent-onset schizophrenia patients[16]. They indicated a stronger impact of verbal fluency on gait regularity compared to the other tasks. Therefore, in this current study, we have used verbal fluency in order to create an adequate cognitive load, as it required higher cognitive functions compared to forward or backward counting as it included short-term memory, verbal attention and semantic memory and involved high demands on frontally mediated strategic processes[16]. Functional MRI studies have shown increased brain activation in specific regions including frontal cortex, cingulate and parietal cortex during verbal fluency in individuals with schizophrenia[37]. Cerebellum and its afferent/efferent structures, the basal ganglia and parieto-frontal neocortex are related to postural control[38]. Cerebellum also regulates cognitive and automatic processes of postural control[39]. Specifically, standing with eyes closed increases the brain activation in prefrontal cortex[40]. We conclude that reduced performance in dual task conditions may further deteriorate postural control with a concurrent cognitive task, requiring the activation of similar brain regions, in specific populations such as schizophrenia who present abnormalities in both postural control and verbal fluency, independently. Within the context of dual-tasking, an adequate cognitive task would probably hinder very simple automatic actions such as quiet standing depending on the activation of similar brain regions.

Individuals with schizophrenia in our study presented significantly higher PSV indicating the alteration in postural control during verbal fluency in the absence of visual information. However, a similar alteration was also found in healthy subjects during the same cognitive load. Previous studies reported that healthy individuals could perform postural control tasks with minimum or no interference if the amount of dual tasking is small[41]. Therefore, the cognitive load of the concurrent task is important in dual tasking conditions as lower and less demanding loads might be associated with no dual task interference.

In addition to the results of concurrent cognitive task, the other interesting finding of the current study indicates higher PSV during motor task in all conditions except EO on foam surface among individuals with schizophrenia compared to healthy controls. According to within group analyses, schizophrenia group consistently increases PSV if their standing surface gets softer and/or visual input is hindered independent of the task required. However, in healthy individuals motor task seem to decrease PSV if visual input is not restricted. It may suggest that in healthy individuals' visual data is used more successfully for controlling body sway compared to individuals with schizophrenia.

We acknowledge that our study has several limitations. We had a relatively small sample size that might have affected the significance of our results. We also could not compare our measurements within the study group according to their clinical features such as PANNS score, disease duration or medication type. All these factors possibly affect the baseline and dual tasking postural control measurements and should be considered in future studies. Furthermore, PSV should be considered as one of the many parameters related to postural control. Higher velocities may indicate an inability to control Center of Mass (CoM) but at the same time, it may be the result of a more strict control on CoM initiated by the central nervous system. For these reasons, the readers are encouraged to keep in mind that the above-mentioned alterations in PSV and related explanations are mostly assumptions as the body of knowledge in the area of research is still developing.

Ethics approval

The study was conducted in accordance with the ethical standards of Helsinki Declaration and was approved by the Institutional Non-invasive Research Ethics Board (Approval ID:2015/09-19).

Consent to participate

All subjects, both in study and control groups, gave written consent to participate in the study after receiving appropriate verbal and written information.

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