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The relationship between serum adiponectin levels, cardiometabolic indices and metabolic syndrome in schizophrenia

Yi Hang Tay[a,*], Jimmy Lee[b,c,d]

[a] Department of Forensic Psychiatry, Institute of Mental Health, Singapore
[b] Research Division, Institute of Mental Health, Singapore
[c] North Region & Department of Psychosis, Institute of Mental Health, Singapore
[d] Lee Kong Chian School of Medicine, Nanyang Technological University, Singapore

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ABSTRACT

Background: Adiponectin is a hormone secreted by adipose tissues that is thought to influence lipid and glucose metabolism, and the development of metabolic derangements, including metabolic syndrome (MetS), in schizophrenia. We aim to determine the serum adiponectin levels in Chinese patients with schizophrenia, and explore the relationship between adiponectin levels and metabolic parameters, including MetS and its components. We hypothesized that serum adiponectin levels are similar in schizophrenia patients and controls, but decreased amongst patients on atypical antipsychotics.

Methods: 81 patients and 81 controls were recruited. Anthropometric parameters and fasted blood samples for metabolic measurements were obtained. Serum adiponectin levels were measured using Bioplex assays.

Results: There was no difference in median adiponectin levels between schizophrenia patients and controls. Those taking typical antipsychotics alone had lower median adiponectin levels than those on mixed typical and atypical antipsychotics. Serum adiponectin level, controlled for age, gender and body mass index, was positively correlated with high-density lipoprotein cholesterol, and negatively correlated with diastolic blood pressure, total cholesterol, low-density lipoprotein cholesterol, and triglyceride levels in schizophrenia patients. Patients with MetS had lower median adiponectin levels than those without MetS, and serum adiponectin levels decreased as the number of MetS components increased. After adjusting for variables thought to influence MetS, our logistic regression model did not reveal any significant association between adiponectin levels and MetS in schizophrenia patients.

Conclusion: Our findings highlight the need for more studies focusing on serum adiponectin level and its relationship with MetS in schizophrenia, particularly in those taking typical antipsychotics.

1. Introduction

A growing body of studies has highlighted the increased prevalence of various metabolic abnormalities in the schizophrenia population, including dyslipidaemia, hypertriglyceridaemia, hypertension, impaired fasting glucose and central obesity, which form the metabolic syndrome (De Hert et al., 2006). There is increasing interest in the role of adipokines in the development of these metabolic abnormalities in schizophrenia (Beumer et al., 2012). Human adipose tissue is now known to be not just a passive structure for energy storage, but an active endocrine organ secreting these biologically active proteins known as adipokines (Ouchi et al., 2011). Adipokines have been suggested to play a major role in influencing energy and vascular homeostasis as well as immune response (Rosen and Spiegelman, 2006; Frankenberg et al., 2017). Among the adipokines, adiponectin is the most abundantly expressed (Maeda et al., 1996) and circulates at relatively high concentrations, accounting for up to 0.05% of total serum protein (Lihn et al., 2005).

Overall, adiponectin is thought to play a beneficial role in lipid and glucose metabolism (Jung and Choi, 2014). The secretion of adiponectin is altered with changes in adipose tissues. This affects endocrine balance, which may contribute to metabolic abnormalities (DeClercq et al., 2013). Lower adiponectin levels have been associated with raised triglycerides, central obesity and type 2 diabetes (Cnop et al., 2003; Nayak et al., 2010). Ethnic and intra-ethnic variations exist, with lower adiponectin levels found in Chinese people, as compared with European, aboriginal and South Asian people (Mente et al., 2010). In the Singapore Chinese cohort from the Singapore Chinese Health Study,

* Corresponding author at: Institute of Mental Health, Buangkok Green Medical Park, 10 Buangkok View, 539747, Singapore.
E-mail address: yihang.tay@mohh.com.sg (Y.H. Tay).

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adiponectin was associated with type 2 diabetes, but did not improve discrimination for diabetes beyond traditional risk factors and glucose markers (Wang et al., 2018), unlike in the Hong Kong Chinese cohort (Woo et al., 2012).

A pooled analysis of individuals with schizophrenia showed that adiponectin levels were not significantly different from those in healthy controls. Although those taking second-generation antipsychotics were shown to have lower serum adiponectin levels than healthy controls in subanaylses (Bartoli et al., 2015), the serum adiponectin levels of individuals on first-generation antipsythotics were not compared with those on second-generation antipsychotics or mixed treatment. Furthermore, while several studies have looked into the associations between serum adiponectin level and metabolic parameters in individuals with schizophrenia, few have explored its association with the presence of metabolic syndrome (MetS) while accounting for factors like the type of antipsychotic medication, the antipsychotic dose and duration, which are important considerations in the schizophrenia group (Beumer et al., 2012; Bartoli et al., 2015; Oral et al., 2011; Paredes et al., 2014). MetS has been linked with higher risks of developing cardiovascular disease (Sarafidis and Nilsson, 2006), which is one of the leading contributors to the higher mortality rates among people who suffer from schizophrenia, as compared with the general population (Lawrence et al., 2010; Westman et al., 2017; Lin et al., 2018).

Therefore, the primary aim of this study is to determine the serum adiponectin levels of Chinese patients diagnosed with schizophrenia. The secondary aim is to explore the relationship between adiponectin levels and cardiovascular risk factors, including MetS and its components. We hypothesize that serum adiponectin levels are similar in patients with schizophrenia as compared with healthy controls, but decreased amongst patients on atypical antipsychotic medications.

2. Methods

2.1. Recruitment

Study participants were recruited from outpatient clinics at the Institute of Mental Health (IMH) in Singapore, the only psychiatric hospital in the country, between 2010 and 2011. The patients recruited fulfilled the following criteria: they were (a) of Chinese ethnicity, (b) aged 21 and above, (c) fulfilled the DSM-IV-TR diagnosis for schizophrenia, and (d) had no history of intellectual disability. All controls, recruited via referrals and advertisements, were community-dwelling individuals with no history of psychiatric disorders. Information related to the study was explained to all study participants, and only individuals who were capable of providing written informed consent were recruited. Ethics approval was given by the National Healthcare Group's Domain Specific Review Board.

2.2. Data collection

Demographic information and current smoking status were obtained from all study participants through interviews by a trained investigator. Medical records were reviewed to collect medical histories of patients with schizophrenia, which included the age of onset of illness, defined as the age at first onset of psychotic symptoms, and the duration of illness, defined as the duration from the onset of the first psychotic symptom to the date of recruitment. The current antipsychotic prescriptions and doses, as well as the duration of antipsychotic treatment were obtained from the medication administration records in our computerised database system. The current daily antipsychotic dosages were converted into total chlorpromazine equivalents (Woods, 2003). Additional medical histories, including information on current medications and supplements were self-reported by healthy controls during the research interview. For information that was not readily available, follow-up phone calls were made to clarify the information with the study participants.

2.3. Subject assessment

The diagnosis of schizophrenia was determined based on the Structured Clinical Interview for DSM-IV-TR Axis I Disorders, Patient Edition (SCID-I/P) (First et al., 2002a). Clinical symptoms of all participants with schizophrenia were assessed using the Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1987) by a single trained psychiatrist at the time of interview. Controls were assessed using the SCID-I, Non-patient Edition (SCID-I/NP) (First et al., 2002b) to ascertain that they had no history of psychiatric disorders at the time of recruitment.

All study participants were reminded to fast for 8 h prior to their blood tests and this was verified prior to sample collection. Fasted venous blood samples were collected from all study participants into serum separating tubes (SST). Fasting levels of glucose, total cholesterol, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C) and triglycerides were measured with analyser LX-20PRO (Beckman Coulter, Germany). Serum adiponectin levels were measured using commercially available Bioplex assays (Biorad, USA). Briefly, serum samples were diluted 1:4 in sample diluents provided and ran in duplicates according to the instruction's manuals. Height, weight and blood pressure measurements were taken using automated scales. Blood pressure was measured with subjects seated after at least 2 min of resting time, using an automated blood pressure machine (Welch Allyn). Waist circumference was measured with subjects standing, at the mid-point between the lower margin of the last palpable rib and the top of the iliac crest.

2.4. Metabolic syndrome

Participants were determined to have MetS based on the American Heart Association/National Heart, Lung, and Blood institute (AHA/NHLBI) criteria (Grundy et al., 2005); if they fulfilled at least 3 of the following criteria: (a) elevated triglycerides ($\geq$1.7 mmol/L or on drug treatment for elevated triglycerides), (b) reduced HDL-C ($<$ 1.03 mmol/L in males and 1.3 mmol/L in females or on drug treatment for reduced HDL-C), (c) elevated blood pressure ($\geq$130 mmHg SBP or $\geq$85 mmHg diastolic blood pressure (DBP) or on treatment for hypertension), (d) raised fasting glucose ($\geq$5.6 mmol/L or currently on treatment for diabetes), and (e) central obesity as defined by the Asian criteria (waist circumference $\geq$90 cm for males and $\geq$80 cm for females), which has been validated in Singapore (Heng et al., 2006).

2.5. Statistical analyses

Statistical analyses were performed using the Statistical Package for Social Science (SPSS) for Macintosh, Version 25.0 (Armonk, NY: IBM Corp.). Descriptive analyses were tabulated for patients and controls. Comparisons of categorical variables were made using chi-squared tests, while comparisons of continuous variables were performed using student's t-tests for variables that were normally distributed, and Mann-Whitney U and Kruskal-Wallis tests for variables that were not normally distributed. As the distribution of triglyceride and adiponectin levels were positively skewed, they were logarithmically transformed for further analyses.

To determine whether there was a difference in metabolic parameters and adiponectin level between the types of antipsychotics (categorised into those on typical antipsychotics alone, atypical antipsychotics alone, and those on mixed treatment), univariate analysis of variance was performed, followed by Tukey's post-hoc tests for subgroup comparisons. Pearson's correlation was used to investigate the correlations between serum adiponectin level and various metabolic indices, and partial correlations were determined after adjusting for age, gender and body mass index (BMI), which have been previously shown to affect serum adiponectin levels (Cohen et al., 2011; Obata

Table 1
Demographics and metabolic characteristics of patients and controls.

	Patients (n = 81)	Controls (n = 81)	p-value
Age in years, mean (SD)	36.19 (7.65)	35.94 (7.92)	0.840
Gender, n (%)			0.872
Male	50 (61.7%)	49 (60.5%)	
Female	31 (38.3%)	32 (39.5%)	
Smoker, n (%)	20 (24.7%)	8 (9.9%)	0.013*
Years of smoking, mean (SD)	13.20 (8.12)	13.62 (7.15)	0.893
Number of cigarettes per day, mean (SD)	14.00 (8.37)	6.13 (2.03)	0.001*
BMI (kg/m^2), mean (SD)	25.87 (5.16)	25.20 (4.61)	0.383
Waist circumference (cm), mean (SD)	93.49 (11.00)	89.57 (11.64)	0.029*
SBP (mmHg), mean (SD)	123.40 (13.06)	127.25 (20.43)	0.154
DBP (mmHg), mean (SD)	80.11 (10.08)	81.04 (13.18)	0.616
Glucose (mmol/L), mean (SD)	5.46 (0.85)	5.47 (1.38)	0.984
Total cholesterol (mmol/L), mean (SD)	5.28 (1.00)	5.55 (0.88)	0.072
Triglycerides (mmol/L), median (IQR)	1.27 (0.78–1.81)	1.11 (0.68–1.86)	0.503
HDL-C (mmol/L), mean (SD)	1.26 (0.37)	1.27 (0.37)	0.847
LDL-C (mmol/L), mean (SD)	3.38 (0.88)	3.67 (0.76)	0.028*
Adiponectin (ug/ml), median (IQR)	2.44 (1.72–4.34)	2.79 (1.59–3.74)	0.606
Adiponectin in males (ug/ml), median (IQR)	2.36 (1.53–4.30)	2.07 (1.44–3.51)	0.334
Adiponectin in females (ug/ml), median (IQR)	2.73 (1.83–4.80)	3.46 (2.36–5.35)	0.306

SD: standard deviation, IQR: interquartile range, BMI: body mass index, SBP: systolic blood pressure, DBP: diastolic blood pressure, HDL-C: high density lipoprotein-cholesterol, LDL-C: low density lipoprotein-cholesterol.
* $p < 0.05$.

et al., 2013; Okauchi et al., 2009; Saltevo et al., 2009). Logistic regression was performed with metabolic syndrome as the dichotomous dependent variable, to assess the effect of serum adiponectin level after controlling for important variables including age, gender, BMI and smoking status (Kotani et al., 2012; Malhotra et al., 2013) as well as other clinical factors that have been thought to influence MetS including the type of antipsychotics (Pramyothin and Khaodhiar, 2010), antipsychotic dose(Lieberman, 2004) and duration of illness (Almeras et al., 2004; Grover et al., 2012). Statistical significance was set at $p < 0.05$ for all analyses.

3. Results

3.1. Sample characteristics

81 patients and 81 controls were recruited into the study. Table 1 shows the demographics and clinical variables of our study participants. There were no significant differences in age, gender and BMI between patients and controls recruited. There were significantly more smokers amongst the patients with schizophrenia, as compared with controls ($p = 0.013$). The patients had a mean duration of 11.58 (± 7.21) years of illness and 11.48 (± 7.11) years of psychiatric treatment. 34.6% of them were on typical antipsychotics, 38.3% on atypical antipsychotics, and 37.2% on both. The mean total PANSS score for the patients was 39.6 (± 9.1) and mean chlorpromazine equivalent dose was 280.01 (± 261.11) mg. There was no significant difference in median adiponectin level in patients with schizophrenia as compared with controls ($p = 0.606$).

3.2. Associations between adiponectin and type of antipsychotics

Table 2 shows the comparisons of metabolic parameters between antipsychotic types. Of these metabolic parameters, pairwise comparisons revealed that those on typical antipsychotics alone had significantly higher triglyceride levels than those on mixed typical and atypical antipsychotics ($p = 0.035$). There was also a significant difference in lg adiponectin levels between those taking typical antipsychotics alone, atypical antipsychotics alone, and those on both typical and atypical antipsychotics ($F(2,78) = 5.002$, $p = 0.009$). Lg adiponectin level was significantly lower in those taking typical antipsychotics alone, as compared to those on mixed treatment ($p = 0.006$), but not significantly lower than those taking atypical antipsychotics alone ($p = 0.233$). There was also no significant difference between the lg adiponectin levels of those on atypical antipsychotics alone, as compared with those on mixed treatment ($p = 0.215$).

3.3. Associations between adiponectin and metabolic indices

In the schizophrenia group, after controlling for age, gender and BMI, serum adiponectin level was positively correlated with HDL-C level, and negatively correlated with DBP, total cholesterol, LDL-C, and triglyceride levels (Table 3). Amongst the controls, the serum adiponectin level controlled for age, gender and BMI was only significantly correlated with HDL-C and triglyceride levels, and not DBP, total-cholesterol, or LDL-C levels (Table 4).

3.4. Serum adiponectin levels and metabolic syndrome

Patients with schizophrenia who had MetS had significantly lower adiponectin levels (1.87 ug/ml, IQR = 1.52–2.81) than those without (3.35 ug/ml, IQR = 1.97–5.78, $p < 0.001$). Furthermore, in the schizophrenia group, as illustrated in Fig. 1, serum adiponectin levels decreased as the number of MetS components increased ($p < 0.001$). However, in our logistic regression analysis, after adjusting for age, gender, BMI, smoking status, taking atypical antipsychotics, antipsychotic dose and duration of illness, the association of serum adiponectin level and the presence of MetS was not significant (OR = 0.696, 95% CI = 0.445–1.088, $p = 0.112$).

4. Discussion

Our results showed that serum adiponectin level was not significantly decreased in people with schizophrenia as compared with controls. This was in keeping with previous findings(Bartoli et al., 2015). Interestingly, those on typical antipsychotics alone had lower serum adiponectin levels as compared with those on both typical and atypical antipsychotics. The reason for this finding is unclear, although we note that comparisons of metabolic parameters between the two groups revealed that those taking typical antipsychotics alone had significantly higher triglyceride levels. One study that had investigated into the serum adiponectin levels of those taking typical antipsychotics found no significant differences in the type of antipsychotic medication on serum adiponectin level (Beumer et al., 2012). While second-generation antipsychotics have been frequently associated with metabolic side effects (Pramyothin and Khaodhiar, 2010; Riordan et al., 2011), the role of typical antipsychotics in the MetS epidemic is not to be neglected (de Leon, 2008). Findings of serum adiponectin levels in drug-naïve individuals with schizophrenia as compared with controls have been mixed (Cohn et al., 2006; Song et al., 2013), but we were unable to draw such comparisons as all of our study participants were on antipsychotic medications.

Our findings of positive correlations between serum adiponectin level (controlled for age, gender and BMI,) with HDL-C level, and negative correlations with total cholesterol, LDL-C and triglyceride levels among the schizophrenia patients echoed previous studies in the schizophrenia group (Chen et al., 2011, 2018). Adiponectin has been shown to act as a regulator of energy homeostasis, through the activation of adenosine monophosphate activated protein kinase (AMPK) in the skeletal muscles and the liver. AMPK activation decreases de novo lipogenesis, and increases glucose transport and fatty acid oxidation in

Table 2
Comparisons of various metabolic parameters across types of antipsychotics.

Metabolic Parameter	Typical	Atypical	Mixed	p-value
BMI (kg/m^2), mean (SD)	26.23 (4.99)	26.56 (5.68)	24.44 (4.52)	0.311
Waist circumference (cm), mean (SD)	95.57 (10.80)	92.68 (12.86)	92.00 (8.15)	0.461
SBP (mmHg), mean (SD)	124.68 (14.01)	124.55 (10.77)	120.09 (14.68)	0.387
DBP (mmHg), mean (SD)	83.07 (10.71)	78.45 (8.49)	78.68 (10.90)	0.158
Total cholesterol (mmol/L), mean (SD)	5.30 (1.00)	5.38 (0.85)	5.11 (1.18)	0.633
Triglycerides[a] (mmol/L), mean (SD)	1.71 (1.04)	1.31 (0.72)	1.09 (0.45)	0.033*
HDL-C (mmol/L), mean (SD)	1.12 (0.30)	1.33 (0.41)	1.34 (0.37)	0.039*
LDL-C (mmol/L), mean (SD)	3.38 (0.90)	3.45 (0.67)	3.27 (1.13)	0.781
Glucose (mmol/L), mean (SD)	5.70 (0.89)	5.41 (0.89)	5.23 (0.70)	0.134
Adiponectin[a] (ug/ml), mean (SD)	2.48 (1.60)	3.21 (2.10)	4.28 (2.81)	0.009*

SD: standard deviation, BMI: body mass index, SBP: systolic blood pressure, DBP: diastolic blood pressure, HDL-C: high density lipoprotein-cholesterol, LDL-C: low density lipoprotein-cholesterol.
[a] Values were log-transformed before statistical analysis.
* $p < 0.05$.

Table 3
Correlations of serum adiponectin[a] levels with various metabolic indices in patients with schizophrenia.

Metabolic Parameter	Pearson's	p-value	Partial[b]	p-value
BMI	−0.455	< 0.001*	–	–
Waist circumference	−0.410	< 0.001*	−0.097	0.398
SBP	−0.408	< 0.001*	−0.210	0.065
DBP	−0.359	0.001*	−0.235	0.038*
Total cholesterol	−0.209	0.061	−0.244	0.032*
Triglycerides[a]	−0.626	< 0.001*	−0.481	< 0.001*
HDL-C	0.520	< 0.001*	0.392	< 0.001*
LDL-C	−0.215	0.055	−0.257	0.024*
Glucose	−0.289	0.009*	−0.188	0.098

BMI: body mass index, SBP: systolic blood pressure, DBP: diastolic blood pressure, HDL-C: high density lipoprotein-cholesterol, LDL-C: low density lipoprotein-cholesterol.
[a] Values were log-transformed before statistical analysis.
[b] Adjusted for age, gender and body mass index.
* $p < 0.05$.

Table 4
Correlations of serum adiponectin[a] levels with various metabolic indices in controls.

Metabolic Parameter	Pearson's	p-value	Partial[b]	p-value
Body mass index	−0.360	0.001*	–	–
Waist circumference	−0.386	< 0.001*	−0.090	0.431
SBP	−0.190	0.089	0.025	0.831
DBP	−0.281	0.011*	−0.078	0.497
Total cholesterol	−0.119	0.291	−0.081	0.479
Triglycerides[a]	−0.473	< 0.001*	−0.350	0.002*
HDL-C	0.528	< 0.001*	0.403	< 0.001*
LDL-C	−0.193	0.092	−0.152	0.196
Glucose	−0.090	0.425	0.031	0.789

BMI: body mass index, SBP: systolic blood pressure, DBP: diastolic blood pressure, HDL-C: high density lipoprotein-cholesterol, LDL-C: low density lipoprotein-cholesterol.
[a] Values were log-transformed before statistical analysis.
[b] Adjusted for age, gender and body mass index.
* $p < 0.05$.

peripheral tissues (Tomas et al., 2002). The inverse correlation found between age, gender and BMI-adjusted serum adiponectin level and DBP in our schizophrenia patients can also be explained. Reports in the general population had similarly indicated an inverse association between serum adiponectin levels and hypertension (Iwashima et al., 2004). Circulating adiponectin accumulates in vascular endothelial cells damaged in hypertension, and modulates the endothelial inflammatory response to vascular injury through its anti-inflammatory and anti-atherogenic properties (Orchard et al., 2003). Through AMPK activation, adiponectin stimulates the synthesis of nitric oxide, which is an important endothelial factor and potent vasodilator (Morrow et al., 2003). There were several correlations between serum adiponectin level and metabolic parameters that appeared to reach a level of significance only in the schizophrenia group, but not the healthy controls in our study. The reason for this is unclear but it is a phenomenon that had been previously described (Tanyanskiy et al., 2015), and postulated to be related to modulatory effects of antipsychotics on the metabolic effects of adipokines (Oh et al., 2011).

Previous studies had shown decreased serum adiponectin levels in schizophrenia patients with MetS as compared to those without MetS (Hanssens et al., 2008), and this was also observed in our study. The focus on MetS in its entirety, defined as 3 or more of 5 metabolic derangements (Alberti et al., 2006) described earlier, is of particular importance as its presence had been shown to be useful in identifying individuals at risk of developing cardiovascular disease (Sarafidis and Nilsson, 2006). Furthermore, we demonstrated a trend of decreasing adiponectin levels with increasing MetS components. The effects of adiponectin on hypertension and dyslipidaemia have been described above. Additionally, an accumulation of visceral abdominal fat reduces the production of adiponectin and activates hepatic gluconeogenesis, which then reduces insulin sensitivity in the muscle and liver, resulting in increased glucose levels (Berg et al., 2001; Combs et al., 2001). These mechanisms explain the association of decreased adiponectin levels with central obesity and diabetes, which are the other components in MetS (Alberti et al., 2006).

We found that serum adiponectin level was not significantly associated with the presence of MetS after controlling for important variables including age, gender, BMI, smoking, taking atypical antipsychotics alone, antipsychotic dose and duration of illness. To the best of our knowledge, only one study had found that after adjusting for variables including age, gender, BMI, antipsychotic dose, duration of illness, and concomitant use of mood stabilizers, serum adiponectin level was a potential biomarker for MetS in patients with schizophrenia, although all the study participants were on clozapine and no controls were studied (Bai et al., 2007). A possible reason for the difference in our findings could be that participants in our study were on a range of antipsychotic medications. Clozapine has been frequently highlighted to be highly associated with diabetes, dyslipidaemia, obesity and MetS (Lieberman, 2004; Papanastasiou, 2013). More studies on serum adiponectin levels and the presence of MetS in the schizophrenia group taking other antipsychotic medications, especially typical antipsychotic medications, would be helpful to better evaluate this association.

The strength of our study lies in our recruitment of participants with schizophrenia from a single site, and controls from the same base population. It improved the reliability of our data collection and analyses. All blood samples from both patients and controls were collected after an overnight fast, and processed and analysed in a central laboratory,

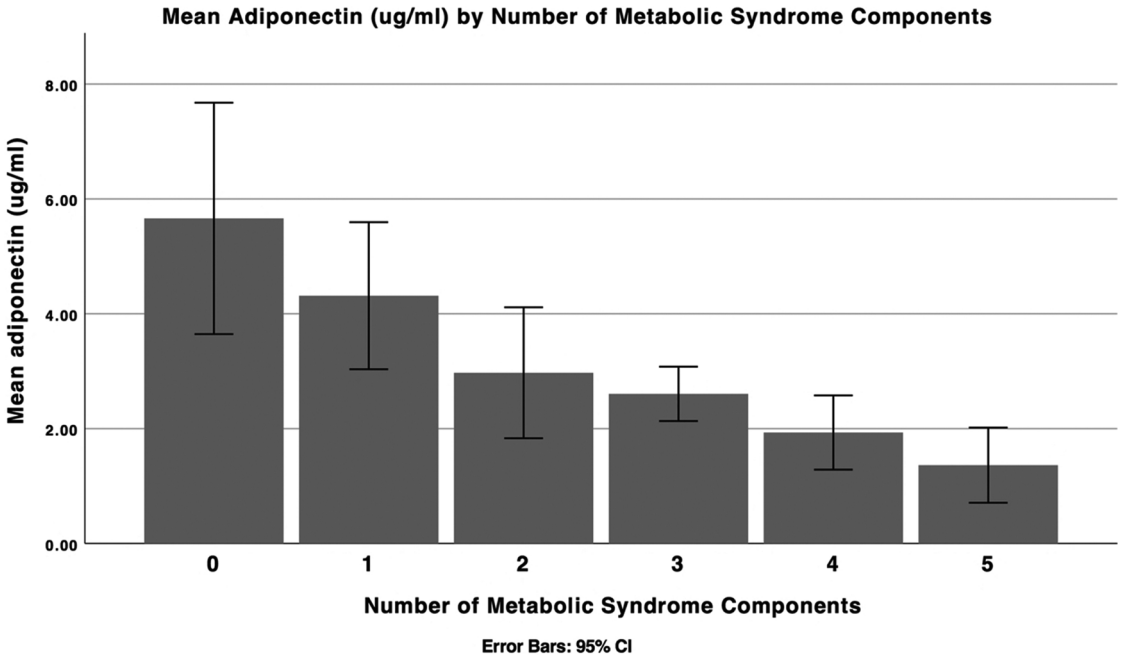

Fig. 1. Comparisons of mean adiponectin levels across the number of metabolic syndrome components in patients with schizophrenia.

minimising erroneous results that could arise due to poor sample collection and inter-laboratory variations. All participants were also assessed with the SCID-I and on the PANSS by a single trained psychiatrist, eliminating the possibility of inter-rater variation. However, the cross-sectional nature of our study limits any causal link that could be drawn from our examination of the association between serum adiponectin levels and MetS in patients with schizophrenia. The participants recruited in this study were Chinese patients who were able to provide informed consent, so our findings may not be generalizable to other ethnic groups, or the more severely-ill individuals with schizophrenia. Other possible confounding factors that might have effects on serum adiponectin levels like diet and exercise (Mantzoros et al., 2006; Wycherley et al., 2010) were also not evaluated in our study.

In conclusion, we found similar serum adiponectin levels in Chinese schizophrenia patients and controls, and an interesting finding of decreased serum adiponectin levels in patients on typical antipsychotics alone as compared with those on mixed treatment. Although serum adiponectin level was significantly decreased in schizophrenia patients with MetS, with decreasing adiponectin levels as the number of MetS components increased, this association was no longer significant when controlling for age, gender, BMI and other important variables that have been thought to influence the presence or absence of MetS. While serum adiponectin level had been previously evaluated as a potential biomarker for MetS, most of these analyses were performed in patients taking only atypical antipsychotics, specifically clozapine and olanzapine (Chen et al., 2018; Bai et al., 2007). Our findings highlight the need for more longitudinal studies investigating into the serum adiponectin levels of individuals with schizophrenia who are on typical antipsychotic medications as compared with those who are on atypical antipsychotics, and evaluating the possible role of serum adiponectin level as a biomarker of metabolic syndrome in schizophrenia after controlling for variables including the type of antipsychotic medications.

Contributors

JL was involved in recruitment, data and sample collection. All authors were involved in planning and execution of the data analysis. All authors have read and approved the submission of this manuscript.

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Conflict of interest

All authors have no conflict of interest.

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