Motor Activity and Depression Severity in Adolescent Outpatients

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Key Words
Adolescents · Depression · Motor activity · Severity of depression · Actigraphy

Introduction
Depression in adolescence is a severe condition, which may jeopardize physical, psychological, and social development [1, 2]. Estimates of lifetime prevalence range from 15 to 20% (similar to those found in the adult population). These values suggest that for a portion of adults diagnosed with depression, the onset was probably during adolescence [4–7]. This possibility points to the need for accurate diagnosis and early intervention [8, 9].

However, a diagnosis of depression is difficult in childhood and adolescence due to certain factors, such as constant fluctuations in mood and behavior, difficulty in recognizing and reporting symptoms, and high rates of comorbidity [1, 10]. In this respect, the development of valid and reliable instruments for assessing depression and its severity has important implications for both the prognosis and treatment of depression [11].

Evidence suggests that psychomotor symptoms have special diagnostic, prognostic and possibly pathophysiological significance [12]. Within the present systems of diagnostic classification (ICD-10 and DSM-IV), psychomotor retardation is one of the descriptive characteristics of the depressive syndrome [13, 14]. Among other clinical features, psychomotor retardation has been considered predictive of a positive response to electroconvulsive

Abstract
Objectives: The present study investigated the association between motor activity and severity of depression in 6 depressed adolescent outpatients. Method: Motor activity was assessed by actigraphy and the severity of depression was assessed weekly using the CDRS-R. The levels of motor activity were analyzed by considering activity parameters. Results: Among the parameters of motor activity studied, the mean total activity, the mean 24-hour activity levels, the mean waking activity, and the mean activity level between 12:00 and 18:00 h were inversely correlated with severity of depression. The means of the 10 most active hours tended toward a negative correlation with the depressive severity score. Conclusion: The results seem to suggest an association between motor activity level and severity of depression in adolescents. Nevertheless, in order to reach a more conclusive understanding, it would be necessary to replicate this study using a larger number of individuals as well as a longer observation period.

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therapy and to tricyclic antidepressants in the severely ill [15]. In fact, psychomotor retardation is considered by some authors to be the main characteristic of depression [16, 17]. The reported frequency of psychomotor retardation in depressive adolescents ranges from 35.9 [18] to 46% [19].

Greden and Carroll [20] emphasize that an objective assessment of psychomotor alteration in depressed patients would contribute to the classification, study of clinical evolution, choice of treatment, and prognosis of depression.

The objective method of continuous monitoring of motor activity through actigraphy proved to be valid for the study of motor alterations in depressed patients [12, 21–23], and has produced a wealth of data [11].

In the last 3 decades, several researchers studied the association between motor activity and depression. These investigations showed alterations in the pattern of motor activity associated with the diagnostic subcategories, severity of depression, and response to treatment [20–25].

Aronen et al. [11] investigated hospitalized children up to 12 years of age, and found a significant correlation between low levels of motor activity and the severity of depression. In a more recent study of outpatient depressed adolescents, Armitage et al. [33] found lower total activity, lower activity in the light phase, and higher activity in the dark phase compared to control groups and depressed children.

Until now, there has been no study on motor activity levels and depression severity in adolescents. The aim of the present study was to investigate the association between alterations in the motor activity pattern and the severity of depression in adolescents.

**Patients and Methods**

**Subjects**

Six adolescents were diagnosed as depressed, and were followed-up in 2 psychiatric outpatient clinics (Program for Affective and Anxiety Disorders of the Federal University of São Paulo and the Outpatient Clinic for Affective Disorders in Children and Adolescents of the University of São Paulo Medical School) from April to October 2002 and from September to November 2003. Patients that had neurological disorders or were using psychoactive substances upon admission were excluded. The average age was 16.5 ± 0.8 years (range 14–17). There were 4 females and 2 males, none of whom appeared overweight.

Before the initial interview, the study was explained and written informed consent was obtained from the parent(s) along with assent from the patient. Patients were followed up weekly and treated with sertraline, introduced from the third day of the first week of observation.

**Methods**

Patients were diagnosed by 2 psychiatrists trained to apply the diagnostic criteria. Each patient and parent(s) were interviewed separately using the Brazilian version of the Schedule for Affective Disorders and Schizophrenia for School Aged Children: Present and Lifetime Version (K-SADS-PL) [36, 37]. The diagnosis of depressive disorder was made according to DSM-IV criteria [13].

Motor activity was monitored over 9 weeks by actigraphs (Actiwatch-Score, Mini Mitter Company) positioned on the wrist of the non-dominant arm. The actigraph is a programmable device with digitized memory that stores motor activity data. It monitors the occurrence and intensity of the movement by detecting any acceleration >0.01 g force through an accelerometer. By integrating the intensity and speed of movement, this sensor produces an electric current that varies in its magnitude. An increase in voltage is the result of an increase in frequency and speed of movement. In brief, the instrument counts the number of movements within a 1-min period. Actigraphic activity is given in counts (activity units) per 1-min periods. Data were transferred weekly to a microcomputer for posterior analysis through the software included (version 3.3) [38].

In order to characterize the periods studied, the daily routine activities (such as waking hours, sleep hours, times when the device was removed, school, work and transport) were registered in an activity diary by the patients [39].

The response to treatment was accessed weekly by the Children’s Depression Rating Scale Revised (CDRS-R), an instrument designed to access levels of depressive severity [40–43]. It was applied weekly, and when the patient did not attend the clinical evaluation, the CDRS-R total score considered was the one obtained on the following week.

The influence of individual variability in motor activity upon the data, such as daily routine, body mass, age, gender and anxiety [30, 44, 45], were controlled for by comparing the data of the same group throughout 9 weeks.

For unknown reasons, one subject’s actigraph did not register motor activity in the 7th week of observation. The motor activity of this corresponding week was not included in the analysis.

**Data Analyses**

Three consecutive weekdays (Tuesday, Wednesday, and Thursday) of each of the 9 weeks studied were considered in the analysis. On these days, according to the activity diary filled out, the patients were engaged in their daily routines, with attending school as the main activity, except for 1 of the patients. Notwithstanding this, the average motor activity obtained from these 3 weekdays provided more stable values [25, 46].

The evaluation of variations in motor activity was carried out through the inter-weekly analysis considering the data obtained from the 72-hour mean of activity per week. For the purpose of this study, the following items were calculated: mean total activity, mean waking activity, mean sleeping activity, the 10 most active hours, low 24-hour activity, low waking activity, low sleeping activity, and the mean activity in 4 time periods (00:00–6:00 h; 6:00–12:00 h; 12:00–18:00 h; 18:00–24:00 h). Sleep-wake periods were determined by the activity diary and a visual inspection of the actogram [39, 47]. The 10 most active hours (M10) is a parameter used by Glod et al. [48], which is a complementary measure that is probably not as significantly affected by individual differences in length of waking and sleeping periods. Low activity (LA)
was defined as the proportion of time in which the patients’ motor activity was low, during waking, sleeping, and 24-hour periods; these periods were named respectively: LA_wake, LA_sleep, and LA_24h. This parameter was based on the ‘immobility periods’ previously studied by Benoit et al. [25] and Royant-Parola et al. [46]. Aronen et al. [11] defined this parameter as the number of 5-min periods in which the person presented periods of activity lower than 120 counts/5 min (24 counts/min). Based on the latter measurement and the specific characteristics of the software used for the analyses (Actiware Sleep software 3.3) [38], 1-min periods with actimetric counts ≤20 counts/min were defined as periods of LA. Puyau et al. [49], in a validation study of the Mini Mitter Actiwatch with healthy children and adolescents, considered sedentary activity equivalent to <100 counts/min when the device was placed on the hips, and <200 counts/min when placed on the leg. To estimate the resting metabolic rate, children were placed in an inclined position to rest or watch TV while awake. The authors considered this ‘lying still’ as <50 counts/min. Circadian activity (4 time periods) is a parameter used previously by Ueda et al. [35].

The measurements of depressive severity expressed through the CDRS-R total scores were compared with the motor activity parameters mentioned previously [11, 25, 31, 32, 35, 37, 46–48].

The method also combines the effect size analyses by comparing the group’s final variables of the 9th week with their initial data of the 1st week. These weeks were chosen because the related measurements were less likely to be subject to false readings throughout the longitudinal study.

The analyses concerning circadian rest-activity and sleep-wake rhythm measurements were performed separately, and are the subject of another manuscript [Mesquita M, in submission].

Statistical Analyses

The mean level of motor activity from the group data was calculated according previous studies [11, 21, 22, 25, 26, 29–31, 33, 46, 47]. In the present work, the mean values of motor activity were obtained from weekly samples of activity corresponding to each individual. As the data found did not present a normal distribution (analyzed by the Kolmogorov-Smirnov test, p < 0.05), non-parametric tests were applied.

Data were analyzed using the statistical packages Statistica® and SPSS-PC. Variance analysis (Friedman ANOVA, augmented by the Wilcoxon matched-pairs post-test, p < 0.05) evaluated statistical differences in the weekly variations of motor activity. The simple linear regression test was applied to verify whether there was a linear trend in variations of the CDRS-R total scores and activity measurements. The association between the CDRS-R scores and the activity measurements was verified by Spearman’s correlation analysis.

The scores of CDRS-R and the mean values of motor activity from the group at the beginning and end of the study period were analyzed by Cohen’s d criteria of effect size [50, 51]:

\[
d = (M_1 - M_0)/SD_{pooled}
\]

where SD_{pooled} = \sqrt{((SD_1)^2 + (SD_0)^2)/2}.

The Cohen’s d effect size of CDRS-R was computed with means and SD obtained through the median and the range of scores, as suggested by Hozo et al. [52].

Results

Age, gender, use of sertraline, and the daily routines of the patients are described in table 1.

The mean motor activity presented a significant variation across the 9-week period (Friedman ANOVA; p < 0.00003), particularly between the first and the following weeks (Wilcoxon matched pairs; fig. 1).

Additionally, a Wilcoxon matched-pairs post-test was performed, from which it was possible to observe a significant difference between week 1 and weeks 2, 3, 4, 7, 8, and 9 (p < 0.05).

The simple linear regression test showed a linear increase in the mean motor activity throughout the 9-week period (r^2 = 0.72; p = 0.004). The effect size of the mean motor activity from the initial to the final week of observation was medium (d = 0.56, p = 0.03).

The median of the CDRS-R scores varied across the 9 weeks studied (fig. 2). The simple linear regression test showed that CDRS-R median scores (r^2 = 0.71; p = 0.004) decreased in a linear trend. In addition, the group showed a strong reduction in the severity of the depression revealed by a large effect size (d = −0.85, p = 0.02).

Table 1. Gender, age, sertraline start and dosage alterations, and day-to-day routine in 6 depressed adolescents

<table>
<thead>
<tr>
<th>Patient</th>
<th>Gender</th>
<th>Age years</th>
<th>Start of medication (all 50 mg/day)</th>
<th>Alterations in medication</th>
<th>School routine</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>male</td>
<td>17</td>
<td>3rd day/1st week</td>
<td>3rd day/7th week to 75 mg/day</td>
<td>night</td>
</tr>
<tr>
<td>B</td>
<td>female</td>
<td>15</td>
<td>3rd day/4th week</td>
<td></td>
<td>morning</td>
</tr>
<tr>
<td>C</td>
<td>female</td>
<td>16</td>
<td>3rd day/1st week</td>
<td>3rd day/7th week to 100 mg/day</td>
<td>morning</td>
</tr>
<tr>
<td>D</td>
<td>female</td>
<td>17</td>
<td>3rd day/5th week</td>
<td></td>
<td>morning (training); night (school)</td>
</tr>
<tr>
<td>E</td>
<td>female</td>
<td>17</td>
<td>3rd day/1st week</td>
<td></td>
<td>night</td>
</tr>
<tr>
<td>F</td>
<td>male</td>
<td>17</td>
<td>3rd day/1st week</td>
<td></td>
<td>–</td>
</tr>
</tbody>
</table>
There was a strong and statistically significant correlation between the increase in mean motor activity and decrease in CDRS-R scores ($r = -0.83; p = 0.005$).

The increase in the mean waking activity showed a statistically significant correlation with the decrease in the CDRS-R scores ($r = 0.75; p = 0.02$).

The M10 showed an increasing linear trend across the 9-week period ($r^2 = 0.58; p = 0.02$). Spearman’s correlation test showed a negative correlation between the M10 and the CDRS-R scores ($r = -0.64; p = 0.066$). The Cohen’s $d$ effect size of M10 was medium ($d = 0.43, p = 0.045$).

The motor activity analysis in each of the 4 time periods (00:00–6:00 h; 6:00–12:00 h; 12:00–18:00 h; 18:00–24:00 h) revealed that significant results were obtained only in the 12:00–18:00 h period. The mean motor activity in this period increased linearly across the 9 weeks studied ($r^2 = 0.44; p = 0.05$) and the effect size from the beginning to the end of observation was medium ($d = 0.39; p = 0.05$). Spearman’s correlation test showed a statistically significant correlation between the increase in the mean motor activity and the decrease in the median CDRS-R scores in the 12:00–18:00 h interval.

No correlation was found between the percentage proportion of time in low motor activity (LA_24 h; LA_wake; LA_sleep) and the CDRS-R score variation across the weeks considered.

**Discussion**

This study investigated whether disturbances in motor activity were correlated with depressive severity in adolescents. To reach the proposed objective, 6 individuals (4 females and 2 males), aged from 14 to 17 years old, took part in the protocol. The participants were all very cooperative, remained under treatment during the 9 weeks, and used the actigraphs all the time and appropriately filled out the activity diaries. There was quite strong agreement between the activities registered in the diaries and the actogram.

The treatment was assessed using a CDRS-R, an instrument developed to evaluate the level of severity of depression in children. The obtained measurements correspond to the clinical improvement during the 9 weeks of study (fig. 2) and presented a negative correlation.

Higher depression scores were associated with lower motor activity. A negative correlation between the CDRS-R scores and the following parameters was found: the mean motor activity, the mean waking activity, M10, and the mean motor activity in the 12:00–18:00 h interval. The LA (LA_wake, LA_sleep, LA_24h) and the other 3 motor activity periods (0:00–6:00 h, 6:00–12:00 h, 18:00–24:00 h) presented no correlation with the CDRS-R scores.

The previous related studies were carried out using adult participants, except for 1 which investigated the issue in prepubescent children [11, 21, 22, 25, 28, 31, 46, 53]. Godfrey and Knight [21] have shown that motor activity of depressed adult patients increased following successful treatment. One study on motor activity in depressed patients treated with carbamazepine found that the activity counts were negatively correlated with ratings of global severity of depression [53]. Benoit et al. [25] carried out an investigation in which wrist motor activity was continuously monitored in 10 major unipo-
lar depressed inpatients. Clinical state and motor activity parameters were studied. The data obtained at the beginning of the hospitalization, before the antidepressant treatment, were compared to those found just before discharge. The 8 patients improved. Significant differences were also observed in motor activity parameters. The 24-hour mean level of activity increased, and the number of immobility periods during the night decreased.

Another important study monitored long-term motor activity in 12 depressed patients. In that sample, the activity level progressively increased, while the duration of immobility decreased, with clinical improvement [46]. Dantchev et al. [22] studied 13 depressive inpatients that were evaluated both clinically by depression scales and actometry before and after trimipramine treatment. They found a significant increase in motor activity in association with the clinical response to the antidepressant treatment. Raoux et al. [31] published a study in which the 24-hour motor activity pattern was evaluated in 26 inpatients with major depression at treatment onset and after 4 weeks of antidepressant therapy. The activity level increased significantly on discharge.

Aronen et al. [11] investigated the correlation between motor activity levels, registered during 72 h, and depressive severity in 27 hospitalized prepubescent children. The results revealed that children with greater degrees of depressive symptoms had lower levels of daytime activity. The mean motor activity was negatively correlated with physical complaints and depressed feelings.

In fact, the mean motor activity represents a general measure of activity, and is the most frequently analyzed parameter in the overall literature concerning depression and motor activity assessed by an actigraph [11, 21, 22, 25, 28, 31, 46, 53]. Regarding motor activity levels and depressive severity, the present data are consistent with the overall findings in the literature. As in adults and prepubescent children, the decrease in depressive severity in the adolescents studied was associated with the increase in motor activity levels.

Mean waking activity is a parameter especially useful in studies with outpatients, who are in a more natural environment and are not under a fixed routine as inpatients are. It was previously used by Volkers et al. [54] in 1 case-control study on motor activity disturbances in depressive adult outpatients. The depressed subjects were found to be significantly less active during waking periods than healthy controls.

Among the previously mentioned studies, Aronen et al. [11], Dantchev et al. [22], Benoit et al. [25], and Raoux et al. [31] used the mean daytime activity as a measure of motor activity. These authors found lower levels of this parameter in patients with greater degrees of depressive symptoms. The mean waking activity and the mean daytime activity, although not exactly the same, are important motor activity measurements. Both refer to the waking period, precisely ascertained or presumed. As reported, our data demonstrated a significant correlation between the increases in the mean waking activity and less severe depression indicators in the adolescents studied.

As previously mentioned, the M10 was previously used by Glod et al. [48] in a study on circadian rest-activity disturbances in children with seasonal affective disorders. Being the same as the mean waking activity, this complementary parameter is also convenient in studies with populations submitted to a free routine. In the present work, a negative correlation was found between the increase in M10 and the decrease in depressive severity.

In order to verify the circadian variations in motor activity, the means of motor activity in 4 different time zones were calculated. Ueda et al. [35] found an increase in activity rates in adults with melancholy-type major depression in the 12:00–18:00 h period compared to themselves after symptom remission and to the controls. In the 18:00–24:00 h period, they found that the patients had significantly lower rates of activity than the controls. Raoux et al. [31] reported a significant increase in the mean motor activity in the 13:00–20:00 h period, at discharge, compared to the admission time, in the treatment group that responded well to the medication. Assessing the minute-averaged horizontal movement through a heart and activity level monitor, Iverson [34] investigated the relationship between activity level and depression in primary care outpatients. Forty-eight patients with depression and 25 general medical controls were evaluated. Patients with depression were divided into 2 different groups according to the depression severity. The results found showed lower activity levels in the 12:00–18:00 h period in the more severely depressed group, compared to the less severely depressed and non-depressed groups. Except for Ueda [35], the other 2 studies found results similar to the data obtained by the present authors. In the 12:00–18:00 h period, the mean motor activity presented an increased linear trend and a statistically significant negative correlation with depressive severity scores throughout the 9-week study period.
It is widely known that many depressive patients report more difficulties in the mornings, including waking and starting activities. Benoit et al. [25] found that motor retardation was preferentially observed in the morning in endogenous depression and in the afternoon in nonendogenous depression. Dantchev et al. [22] observed that 13 depressed inpatients, under antidepressant treatment, took relatively more time to return to normal levels of motor activity in the morning period, compared to other periods. Armitage et al. [33] found high motor activity in depressed adolescents in the period of exposure to the dark, compared to controls and depressed children. Therefore, it seems that the study of motor activity fragmented in the circadian cycle permits the assessment of relevant data with important implications for understanding the clinical course of depression.

The present investigation found no association between depressive severity measurements and LA. In 2 studies [25, 46], immobility appeared as a sensitive indicator of the intensity of the depressive state. Aronen et al. [11] found an association between the severity of depression and the percentage of low activity periods. According to Benoit et al. [25], the motor component of depressive psychomotor retardation seems related to changes firstly in the activity level, that is the number of spontaneous movements, and secondly in immobility, which corresponds to the lack of initiation of spontaneous movements [46]. The authors add that activity and immobility may represent different physiological mechanisms, since their temporal pattern and relation to the depressive state are different. In fact, our results seem to corroborate the idea that activity and immobility are differentially related to depressive severity. It is possible that an association between the variation of LA and depressive severity would appear if the adolescents were monitored for a longer time with a larger number of study participants.

Concerning the different patterns of psychomotor activity (agitation × motor retarded) in the differentiation of the various types of depression, most research shows that bipolar depressive patients show psychomotor slowness compared to the depressive unipolar patients [24, 55]. However, studies that assessed these subtypes of depression through actigraphy found no significant differences in the levels of motor activity and immobility between the 2 diagnostic categories, indicating the need for further studies [26, 29].

The present study was carried out with a small number of patients. Consequently, a larger number of patients could have provided a greater variability of data, as well as demonstrating possible differences in the motor quantity and periods of immobility in the different types of depression and different degrees of severity. The present findings suggest that the mean motor activity, the mean waking activity, the M10, and the mean motor activity in the circadian cycle are useful parameters for studying the motor activity variation and depression severity in adolescents.

The results demonstrated an association between the motor activity variation and depression severity in the adolescent outpatients studied. The present findings are similar to those obtained in studies carried out with depressive adults and children; nevertheless, these are regarded as preliminary.

The use of the effect size analyses allowed for comparison of the magnitude of change across parameters within the study. In the present work, the heterogeneity of the group or the size of the sample may have affected the ‘medium’ increase in total mean motor activity from the initial to the final week of monitoring. However, the strong change in CDRS-R scores reinforced the hypothesis of negative association between both measurements and their convenience as parameters for the evaluation of depressive outpatients throughout longitudinal studies.

In order to obtain more conclusive data, it would be necessary to replicate the present study in a larger sample for a lengthier time period.

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References


42. Poznanski EO, Mokros HB: Children's Depression Rating Scale, Revised (CDR-S-R). Los Angeles, Western Psychological Servic es, 1996.


