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Author Manuscript
Psychiatry Clin Neurosci. Author manuscript; available in PMC 2015 February 01.

Published in final edited form as:
Psychiatry Clin Neurosci. 2014 February ; 68(2): 120–126. doi:10.1111/pcn.12096.

One-week temporal stability of hyperactivity in preschoolers with ADHD during psychometric assessment

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Abstract

Aim—To examine the usefulness of temporal measures of motor activity during psychometric assessment on two different assessment days over a week with a scope to help identifying early onsets of hyperactivity.

Methods—We compared actigraph measures at the ankle and the waist on the first and the second days of psychometric assessment in a total of 169 children (93 children with ADHD and 76 children without ADHD) aged 3 years and 4 years.

Results—There was a significant interaction effect between group and time on the activity level at the waist. Whereas the activity levels of the waist in the children with ADHD did not significantly differ between Day 1 and Day 2, the activity levels of the children without ADHD declined significantly from Day 1 to 2. 70% of children were correctly classified into ADHD or non-ADHD groups only based on the activity data at the waist on Day 2.

Conclusion—These results confirm the temporal consistency of hyperactivity in young children with ADHD during psychometric assessment, and indicate that objective measures of motor activity at the waist over different days of psychometric assessment can provide additional information for the stability of hyperactivity.

Keywords

Motor activity; objective measure; activity level; attention-deficit/hyperactivity disorder; early childhood

INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD) is characterized by three cardinal dimensions contained in the term --- hyperactivity, inattention, impulsivity ---that are maladaptive and developmentally inappropriate with their symptomatic onsets prior to 7 years of age [1]. Despite its importance, early recognition of the onset of hyperactivity remains a challenge because young children are considered generally so active that it is difficult to determine a deviate activity level from the norm [2]. This challenge is, at least partly, based on the method of evaluating the level of activity, ranging in the spectrum from subjective to objective assessment in time and space [3]. Among the range of activity

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There is no conflict of interest.

evaluation, the present study is concerned with a temporal aspect of an objective activity measure in a specific context because of its implications for the development of adaptive and maladaptive behavior. We will first review the range of activity evaluation methods from subjective to objective, and then explain why the particular aspect of the measure in the context of our choice is worth investigating.

On the subjective end of activity evaluation, parents and teachers intuitively rate the general activity level of a child to determine the degree of hyperactivity by comparing it to what they consider to be an age norm. This approach is susceptible to response bias where the parents and the teachers are influenced by the frame of reference which they adopt. For example, special education teachers may be more used to hyperactivity in the classroom and rate a child more leniently than mainstream classroom teachers [4]. Such subjective impressions of hyperactivity can be contextualized and precisely described in objective measures of activity levels in specific environments.

Objective activity measures help to reduce subjective errors and to overcome bias of observers and raters. To date, researchers and clinicians have employed two kinds of objective activity measures: one method is structured observation and the other is mechanical measures of activity. Structured observation is time and labor intensive, and yet it does not necessarily produce clinically relevant information [5].

Mechanical measures can be further categorized into two types: 1) kinematic measures which use either a marker-based visual tracking system or an electromagnetic tracking system, and 2) activity monitor devices, such as pedometer, actometer or actigraph that contains a mechanical pendulum or an accelerometer that responds to the motion of the children who attach the device to the body. Kinematic measures are suitable to obtain exact positions of particular points in time and space under specific task environments, such as the body movements during the continuous performance task [6], the pen movements in handwriting [7], and the pen and the body movements in hand drawing [8] in children with ADHD.

Although not tracking the exact displacements of interested points in the body, activity monitor devices can be used not only to estimate overall physical activity level during specific time periods, as is often the case with a pedometer, but also to appraise motor activity under specific task environments, such as the continuous performance task [9, 10], neuropsychological assessments [11–15], and laboratory free play [11]. These studies employed cross-sectional snapshot assessments of hyperactivity in specific task environments. This makes sense given that children with ADHD have been known to display hyperactivity in specific contexts, such as, academic classes [16]. Less is known about the activity levels of children with ADHD across different situations, or within the same situation, that elicits familiarity, adaptation, fatigue, and boredom, over time.

To date, four studies have included multiple measures of activity levels. The first study by Porrino et al [17] found that elementary school children with ADHD were significantly more active than control children, not only when they were attending their reading and math classes at school, but also when they were playing at home. These findings confirmed the presence of cross-situational and cross-temporal hyperactivity in the children with ADHD. However, temporal stability of hyperactivity was not examined in the same setting. The second study by Marakovitz and Campbell [11] measured activity levels during free play, a cookie delay task, and the Standford-Binet test, and found no group difference in activity level between preschool children with and without ADHD. Similarly, another study [18] failed to find any significant ADHD vs. non-ADHD group difference in the activity levels of primary school children across in-seat classes, not-in-seat classes, physical education classes, or lunch/recess periods. The fourth study [19] echoed the second and third studies, and found no group differences during psychometric assessment in the morning, but found that primary school children with ADHD were more active than non-ADHD counterparts during a speech and language assessment in the afternoon. Taken together, it seems difficult to differentiate hyperactivity in children from objective measures across different situations, but that group differences may be pronounced from repeated measures in the same environment.

The main limitation of the fourth study was the inability to determine whether the increased activity levels found in primary school children with ADHD was due to the speech and language assessment setting compared to the neuropsychological assessment setting, fatigue in the afternoon, or familiarity with the environment. The present study minimized fatigue and tester/test-context factors by examining the temporal variation of activity levels on two days over a week apart in a similar testing environment at a similar time of the day in preschool children with and without ADHD. Based on the increased hyperactvity found by Dane et al. [19] on the second assessment, we hypothesized that preschool children with ADHD would be more active, while preschoolers without ADHD be less active on the second day than the first day.

The first purpose of this study was to examine temporal variance in the activity levels of two groups of young children, children with and without ADHD in a neuropsychological assessment setting on two days over a one-week period. We were particularly interested in the possible group differences in activity level on both days. The second purpose of our study was to examine the predictability of activity measures for the identification of ADHD within a preschool sample.

METHODS

Participants

This study forms part of a large prospective study [3, 15] to identify predictive factors of preschool children with externalizing behavior problems. The whole study was reviewed and approved by the Institutional Review Board at Queens College of the City University of New York. Parents of children were initially informed about the goals of the study through letters and consent forms distributed at their child's preschool, which, upon their return, allowed us to gather parent and teacher ratings on the Attention Deficit Hyperactivity Disorder-Rating Scale-Fourth Edition (ADHD-RS-IV) Home Version [20] and School Version [20]. Parents whose children appeared to meet inclusion criteria were contacted by telephone and invited to participate in the study. At the onset of their laboratory visit, following a thorough description of the study, a new signed informed consent was obtained from parents. From a total of 169 children drawn from a community sample recruited from city-sponsored pre-kindergarten programs and a clinical sample who were professionally diagnosed by mental health professionals (e.g, pediatricians, neurologists, school psychologists) in New York City, 76 children (51 males and 25 females) were classified as No Diagnosis group, and 93 children identified with ADHD symptoms were classified into the four subtypes of ADHD (i.e., inattentive, hyperactive/impulsive, combined, and not otherwise specified [NOS]) based on parent (ADHD-RS-IV Home Version) [20] and teacher (ADHD-RS-IV School Version) [20] ratings. ADHD-NOS was defined in terms of 5 symptoms in a domain with impairment. The breakdown of the diagnostic status, sex and age ratios are presented in Table 1.

Procedure

Solid-state actigraphs (model # AM7164; ActiGraph, LLC, Fort Walton Beach, FL) were used to collect objective activity level. Reliability of this device has been demonstrated in a structured test environment, and validity has been demonstrated with parent and teacher ratings of hyperactivity [12]. During two sessions less than 2 weeks apart, one of six clinically trained testers individually administered a comprehensive assessment battery, consisting of measures of cognitive and neuropsychological functioning, to each child who wore a solid-state actigraphs around the waist and the nondominant ankle. The assessment took approximately two hours each day, and involved administration of the Wechsler Primary and Preschool Intelligence test (WPPSI) [21], A Developmental Neuropsychological battery (NEPSY) [22], and two computer-based continuous performance tasks designed for this study. All of these tests involve the examiner and the child sitting at a desk and the child being asked to complete various tasks (e.g., replicating designs with blocks, providing definitions for words, remembering visual and audio stimuli, and responding to computer stimuli using a mouse). There is one exception for a task in the NESPY where children are asked to stand up and be still like a statue. Children were provided breaks as necessary during the testing. These break times were recorded and actigraph data during these periods were removed from the dataset. Because the duration of the assessment varied among the children, mean activity counts were computed for each day at the waist and the ankle.

Statistical analysis

We use descriptive statistics to show the sample characteristics and activity levels. To examine the interaction between diagnosis and time, we performed mixed ANOVAs for ankle and waist actigraphs. Finally, we used discriminant analyses to assess whether the diagnostic status of the children could be discriminated on the basis of the activity data. We designated $P < 0.05$ as statistically significant.

RESULTS

Descriptive data on activity levels

As shown in Table 2, relatively high activity levels are observed not only in the Hyperactive/Impulsive and Combined groups, but also in the Inattentive group. Because of the prevalent elevated activity across subgroups of ADHD and the small numbers of Inattentive and NOS subgroups, we decided to combine all clinical subgroups into one ADHD group and compared it to the No diagnosis group in Table 3. Regardless of more similar sample sizes across groups, the data still violate the assumptions of normality and homogeneity. Nevertheless, we still conducted parametric tests, relying on the robustness of the tests, and interpret and conclude our findings with caution.

Diagnosis vs. Day Interaction

Separate mixed ANOVAs for ankle and waist actigraphs were conducted to assess main effects of Group (ADHD vs. no ADHD) and Time (Day 1 vs. Day 2) as well as the Group × Time interaction.

Recordings from the ankle indicated a significant main effect for Group, $F(1,167) = 12.33$, $P = .001$, $\eta^2 = .069$, such that those with ADHD were more active. The main effect for Time was not significant, $F(1,167) = 3.33$, $P = .070$, $\eta^2 = .020$, although there was a trend that the groups were less active on Day 2. The Group × Time interaction was not significant, $F(1,167) = .009$, $P = .92$, $\eta^2 = .00$.

Recordings from the waist indicated a significant main effect for Group, $F(1,167) = 28.97$, $p < .001$, $\eta^2 = .148$, such that those with ADHD were more active. The main effect for Time was also significant, F (1,167) = 16.67, $P < .001$, $\eta^2 = .091$, such that the children were less active on Day 2. The Group × Time interaction was also significant, F (1,167) = 4.30, $P = .040$, $\eta^2 = .025$. This interaction reflected the fact that as compared to those with ADHD, those without ADHD had a significantly greater drop in activity level, as measured from the waist, on Day 2 relative to Day 1 (Figure 1).

In contrast, the main effect of Day on the activity level at the ankle only approached statistical significance, F (1, 167) = 3.33, $P = .07$, $\eta^2 = .05$, Power = .77. The main effect of Day and the interaction effect between Day and Diagnosis were not significant on the activity level at the ankle.

Discriminant Analysis

The first discriminate analysis assessed whether the four activity levels, Ankle Day 1, Waist Day1, Ankle Day 2, and Waist Day 2 could distinguish children with ADHD and without ADHD. Wilk's lambda was significant, $\lambda = .83$, $\chi^2 = 30.43$, $P < .001$, which indicates that the model including these four activity measures was able to significantly discriminate the two groups. Table 4 presents the standardized function coefficients, which suggest that Waist Day2 contributes most to distinguishing children with ADHD from children without ADHD. Although Ankle Day 1, Waist Day 1 and Ankle Day 2 do not contribute strongly to the discriminant function, they are highly correlated with the overall discriminant function as indicated by the correlation coefficients in Table 4. The classification results (Table 5) show that the model correctly predicts 69.8% of children into correct diagnostic status.

Finally, stepwise discriminant analysis was used to determine which of the four activity measures had the most discriminant ability. The first step of the analysis yielded a model with the waist activity on Day 2 as the sole predictor of the children with and without ADHD, Wilk's lambda (λ) = .85, $\chi^2 = 27.41$, $P < .001$, classifying 69.8% of children into correct diagnostic status (Table 6). No further step, or addition of any of the remaining three activity measures did not significantly improve the predictability.

DISCUSSION

Accumulating efforts have been made to quantify hyperactivity for theoretical understanding and clinical aid to diagnose ADHD. And yet the temporal aspect of activity levels has not been sufficiently investigated despite its potential theoretical and clinical contributions. The present study was designed to examine the usefulness of measuring motor activity at the waist and the ankle during two sessions of neuropsychological assessment over one week apart. The results indicated differential patterns of activity between pre-schoolers with and without ADHD. Although both groups of children were similarly active on Day 1, the children without ADHD tended to be less active on Day 2, whereas the children with ADHD remained active on Day 2. The activity measures at the waist on Day 2 could accurately classify approximately 70% of children into ADHD or non ADHD group.

Our results indicate that the pre-schoolers were similarly active during the neuropsychological assessment on Day 1, whether they had ADHD or not. It seems to be the nature of pre-schoolers to fidget around, while taking assessment in an unfamiliar environment. It was when the environment was no longer novel about a week later on Day 2 that the group difference was pronounced. The relatively less diminution of activity in the children with ADHD can be interpreted in terms of adaptation to environment. Indeed, poor adaptation to environment has been implicated as an underlying mechanism of ADHD [23]. If this is the case, it may be important to administer activity measures in the same environment over time because poor adaptation can be inferred only by repeated measures. Not until the second measure is compared to the first measure, we realize that some children were still active. Therefore, if clinicians are to use actigraph to aid the diagnosis of ADHD, they should be mindful of the risk of overestimating the activity levels of non-ADHD children from the first visit to the clinic.

Furthermore, when attempting to assist children with ADHD to reach their full potential within familiar environments, we need to take the characteristics of the environment into account, as well as the characteristics of the tasks that the children are engaged in. ADHD symptoms have been found to decrease within a novel setting and increase as familiarity heightens,[23] but only if the novel task and environment are more stimulating than the familiar ones. Thus enhanced stimulation is recommended within tasks, particularly ones that are difficult and complex[23].

The sole measurement of activity at the waist on Day 2 predicted the diagnostic status of ADHD reasonably well. The activity levels at the ankle had no predictive value for the diagnostic status on both Day 1 and Day 2. This finding appears to be inconsistent with Wood et al.'s study (2009)[24] which significantly distinguished ADHD from non-ADHD based on a single measure of activity level during a computer based cognitive test battery whether the location of the activity measure was at the waist or the leg. Note that the age range of Wood et al.'s study was from 6 to 18 years, and the activity patterns at the waist and the leg in this older sample might be quite different from the patterns in our young sample.

Matier-Shama *et al.* [25] found that activity levels measured by actigraph during one-hour psychometric test battery was useful to identify ADHD from other childhood psychiatric disorders, but they concluded that the measures were unsuitable as a screening tool due to low sensitivity, missing ¾ of children with ADHD. Our temporal measures of activity levels increased the sensitivity, and missed less than a half of the children with ADHD. This figure is still far from satisfactory for a screening purpose. Therefore, we suggest the use of temporal measures of objective activity levels in the same environment as supplementary information to confirm other evidence of hyperactivity obtained from questionnaires and clinical observation.

Our study has several limitations. Firstly, the order of the different neuropsychological tests was not counter-balanced. The decreased activity levels in both groups of children may not be only due to adaptation to the testing environment, but to the specific content of the assessment and fatigue effect on Day 2. Secondly, normality and homogeneity of variance assumptions were violated in our data sets, although we attempted various transformations, non-parametric statistics, and removals of outliers. It is the nature of clinical data to have outliers even within a diagnostic subgroup, and each individual's data are of vital importance. Therefore, we decided to rely on the robustness of parametric tests, instead of removing outliers. As such, the significant interaction effect between Day and Diagnosis at the waist should be interpreted as a theoretical tendency to test the idea in a controlled experiment in future research.

Acknowledgments

This work was supported by grant number R01 MH68286 from the National Institute of Mental Health.

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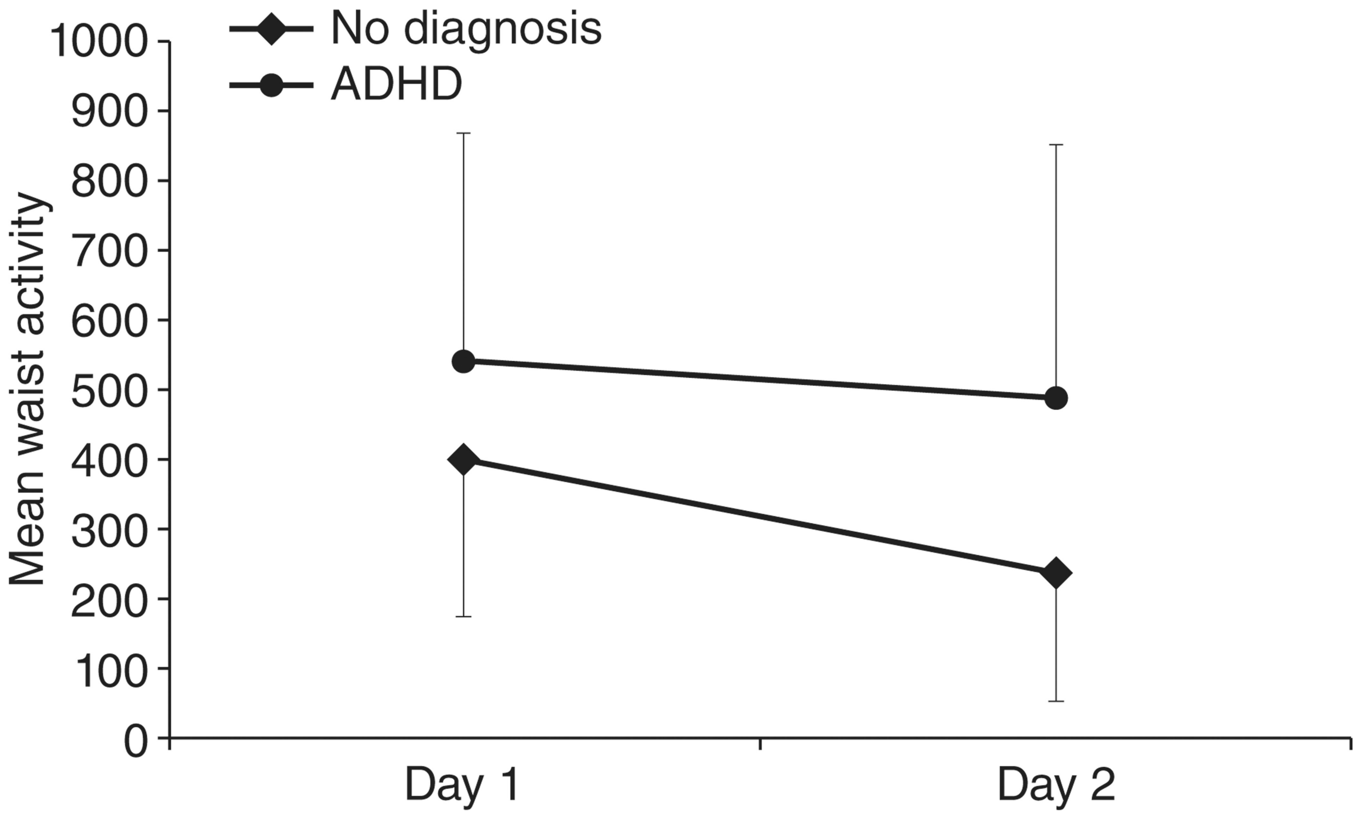

Figure 1.
Interaction between group (ADHD vs. Non ADHD) and time (Day 1 vs. Day2) on the activity level at the waist.

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Table 1

Sample children by diagnostic status, sex, age, and IQ

	Male	Female	3 year	4 year	Subtotal	WPPSI
No diagnosis	51	25	23	53	76	111.92±12.20
Inattentive	7	2	1	8	9	94.11±14.05
Hyperactive	25	13	9	29	38	104.37±11.80
Combined	33	6	13	26	39	98.54±11.84
NOS	4	3	2	5	7	101.71±10.55
Total	120	49	48	121	169	105.76±13.41

NOS: Not otherwise specified; WPPSI: Wechsler Primary and Preschool Intelligence

Table 2

Means and SDs of mean activity levels at the ankle and the waist on Day 1 and Day 2 in four subtypes of children with attention deficit hyperactivity disorders and children with no diagnosis.

	n	Ankle Day 1	Waist Day 1	Ankle Day 2	Waist Day2
No diagnosis	76	929.00±596.75	400.42±224.30	736.33±509.18	236.96±183.71
Inattentive	9	1489.37±1761.32	452.84±312.35	623.58±228.71	340.28±319.26
Hyperactive	38	1395.72±816.06	536.69±269.30	1003.08±673.32	507.41±402.26
Combined	39	1446.48±1025.90	580.35±392.88	1503.95±2441.18	514.77±344.40
NOS	7	813.76±450.44	451.84±219.74	896.91±769.95	411.84±290.11

NOS: Not otherwise specified.

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Table 3

Means and SDs of mean activity levels at the ankle and the waist on Day 1 and Day 2 in children with no diagnosis and children with attention deficit hyperactivity disorders.

	n	**Ankle Day 1**	**Waist Day 1**	**Ankle Day 2**	**Waist Day 2**
No diagnosis	76	929.00± 596.75	400.42± 224.30	736.33± 509.18	236.96± 183.71
ADHD	93	1382.26± 1006.52	540.50± 326.47	1168.41± 1667.54	487.13± 362.57

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Table 4

Standardized function coefficients and correlation coefficients

	Standardized function coefficients	Correlations between variables and discriminant function
Ankle Day 1	.24	.94
Waist Day 1	.15	.60
Ankle Day 2	.07	.55
Waist Day 2	.80	.37

Table 5

Classification matrix for discriminant function analysis of activity levels at Waist Day2 and Ankle Day1.

	Predicted group membership		
Group	**ADHD**	**Non ADHD**	**Total**
ADHD	54	39	93
Non ADHD	15	61	76

Note. Of the children, 68.0% were correctly classified.

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Table 6

Classification matrix for discriminant function analysis of activity level at the waist on Day 2.

	Predicted group membership		
Group	**ADHD**	**Non ADHD**	**Total**
ADHD	54	39	93
Non ADHD	12	64	76

Note. Of the children, 69.8% were correctly classified.