Association between ADHD symptom severity and motor activity in preschool children: A cross-sectional study

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ABSTRACT

Background: Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by inattention, hyperactivity, and impulsivity. Objective measurement of motor activity may complement parent-reported assessment of ADHD symptoms.

Objectives: This study aimed to examine the association between ADHD Rating Scale-5 scores and step counts, used as an objective indicator of motor activity, among children aged 4–6 years.

Methods: A cross-sectional observational study was conducted among 110 children aged 4–6 years selected through purposive sampling. ADHD symptoms were assessed using the parent-completed ADHD Rating Scale-5, while step counts were measured using a digital pedometer during a 15-minute school recess. Data normality was assessed using the Kolmogorov–Smirnov test. Pearson's product–moment correlation was used to examine the association between total ADHD Rating Scale-5 scores and step counts, whereas Spearman's rank correlation was used for the Inattention and Hyperactivity–Impulsivity domain scores.

Results: Total ADHD Rating Scale-5 scores showed a very strong positive correlation with step counts ($r = .865$, $p < .001$). At the domain level, Inattention scores showed a strong positive correlation with step counts ($\rho = .756$, $p < .001$), while Hyperactivity–Impulsivity scores showed a very strong positive correlation ($\rho = .818$, $p < .001$).

Conclusions: Higher ADHD symptom scores were strongly associated with higher motor activity, as indicated by step counts, among preschool children. Step-count measurement may provide a simple objective measure that complements parent-reported assessment of ADHD symptoms; however, it should not be interpreted as a diagnostic measure for ADHD.

Keywords: ADHD Rating Scale-5, attention-deficit, hyperactivity disorder, pedometer, preschool children, step count.

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INTRODUCTION

Child development is a dynamic and multidimensional process involving physical, motor, cognitive, social, emotional, and behavioral domains. Preschool age, particularly between 4 and 6 years, represents an important developmental period during which children experience substantial changes in cognitive and motor abilities, behavioral regulation, and social functioning (Santrock et al., 2002). Appropriate stimulation and developmental monitoring during this period are therefore important for supporting children's developmental potential and identifying possible developmental difficulties.

Early childhood development reflects the interaction between biological maturation and environmental influences. During this period, children undergo rapid changes in cognitive, motor, emotional, and behavioral functioning that require continuous stimulation and monitoring (Mingkala, 2021; Sarver et al., 2015). The development of attention regulation, impulse control, and behavioral adaptation is particularly important as children increasingly interact with structured social and learning environments. However, developmental trajectories vary among children, and some may exhibit symptoms associated with neurodevelopmental disorders, including attention-deficit/hyperactivity disorder (ADHD). ADHD is characterized by persistent patterns of inattention and/or hyperactivity–impulsivity that can interfere with functioning and development (Kurniawan et al., 2021; Rahmani, Kusumawicitra, & Karyani, 2022). These symptoms may affect learning, social interaction, and behavioral regulation during the preschool years.

ADHD symptoms can be assessed systematically using standardized instruments such as the ADHD Rating Scale-5, which was developed in accordance with the diagnostic criteria of the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) (DuPaul et al., 2016). The instrument consists of 18 items representing two domains: Inattention and Hyperactivity–Impulsivity. Ratings can be completed by parents or teachers based on observations of children's behavior in everyday settings. The ADHD Rating Scale-5 has demonstrated good psychometric properties and provides quantitative scores reflecting the severity of ADHD-related symptoms, supporting its use in clinical and research settings involving children.

ADHD symptoms are relatively common among children. Globally, the prevalence of ADHD among children aged 3–12 years has been estimated at 7.6% (Salari et al., 2023). In Indonesia, national epidemiological data remain limited, although local studies have reported indications of ADHD symptoms among preschool-aged children. For example, a study conducted in Gonilan Village reported that 21.9% of children aged 4–6 years exhibited ADHD symptoms (Naufal et al., 2023), while another study identified 15 children with indications of ADHD symptoms at Saymara Kartasura Kindergarten (Taqfani et al., 2023). Although these local findings should not be interpreted as estimates of national prevalence, they highlight the relevance of examining ADHD-related symptoms among preschool children in the local context.

Hyperactivity–impulsivity is one of the core symptom domains of ADHD and may manifest behaviorally as restlessness, excessive movement, difficulty remaining seated, and difficulties with impulse control (Dekkers et al., 2020; DuPaul et al., 2016). Previous research has indicated that children with ADHD may demonstrate higher levels of objectively measured motor activity than typically developing children (Lin et al., 2013). Such motor activity represents an observable behavioral characteristic that may provide complementary information to symptom assessments based on parent or teacher reports. Nevertheless, motor activity itself should not be considered equivalent to pathological hyperactivity, particularly in young children for whom movement is a normal component of development and play.

Objective activity-monitoring devices provide an opportunity to quantify children's movement in natural settings. Pedometers and accelerometers, for example, can provide quantitative indicators of physical movement and have been used to characterize activity patterns in children (Villalba-Heredia et al., 2023). Step count provides a simple measure of locomotor activity and may therefore offer an objective indicator that complements behavioral ratings of ADHD symptoms. However, evidence directly linking standardized ADHD symptom scores with objectively measured step counts remains limited, particularly among preschool-aged children. Evidence is even more limited in the Indonesian context, where studies integrating parent-reported ADHD symptom assessments with objective measures of motor activity are scarce.

Children aged 4–6 years represent a particularly relevant population for examining this relationship because attention regulation, inhibitory control, and other executive functions continue to develop substantially during the preschool period (Best & Miller, 2010; Tanoyo, 2013). Understanding whether variation in ADHD symptom scores is associated with objectively measured motor activity may provide additional insight into the behavioral characteristics accompanying ADHD-related symptoms during early childhood (Figure 1). Therefore, this study aimed to examine the association between ADHD symptom severity, as assessed using the ADHD Rating Scale-5, and motor activity, as represented by step counts measured during school recess, among children aged 4–6 years.

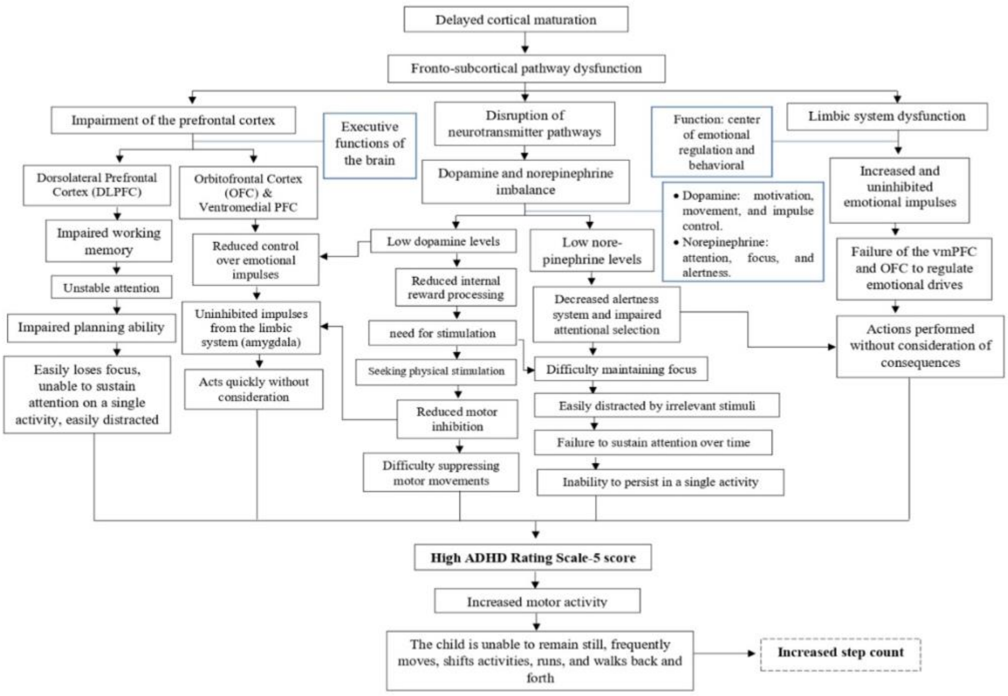

Figure 1. Fronto-subcortical dysfunction and neurotransmitter imbalances cause impaired attention, impulse control, and hyperactivity in ADHD.

Based on these considerations, this study aimed to examine the association between ADHD symptom severity, as assessed using the ADHD Rating Scale-5, and motor activity, as represented by step counts, among children aged 4–6 years using a cross-sectional design. The findings are expected to provide further evidence on the relationship between parent-reported ADHD symptoms and objectively measured motor activity in preschool children and to inform future research on complementary approaches to developmental assessment and monitoring.

METHODS

Study Design and Participants

This study employed a quantitative cross-sectional analytical observational design to examine the association between ADHD Rating Scale-5 scores and step counts among children aged 4–6 years. Data were collected in November 2025 at four kindergartens in the Kartasura area: Kindergarten (TK) Aisyiyah 1 Gumpang, Kindergarten (TK) Aisyiyah Pucangan 1, Kindergarten (TK) Aisyiyah Gonilan, and Kindergarten (TK) Aisyiyah 1 Makamhaji. No intervention was administered, and all measurements were conducted during the study period under the predefined data collection procedures.

The study population comprised 237 children aged 4–6 years enrolled in the four participating kindergartens, based on administrative records provided by each school. The minimum required sample size was determined using an a priori statistical power analysis in G*Power. For a two-tailed correlation analysis, the calculation assumed a medium effect size ($r = .30$), a significance level of $\alpha = .05$, and statistical power of 80%. Based on these parameters, a minimum sample of approximately 84–85 participants was required. The final sample consisted of 110 children, exceeding the minimum sample size required by the power analysis.

Participants were recruited using purposive sampling according to predefined eligibility criteria. During the data collection period, 110 children met the eligibility criteria, were present during data collection, and had obtained parental or guardian consent to participate. Only participants with the required questionnaire and step-count data were included in the final analysis. Participant selection was conducted based on criteria aligned with the objectives of the study (Table 1).

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Children in good physical health and able to move independently.	Children who were absent during data collection or were ill at the time of measurement.
Parents provided informed consent and were willing to complete the ADHD Rating Scale-5 questionnaire via Google Forms.	Children who were unable to use the pedometer according to the procedure or removed the device during the measurement period.
	Children who did not move independently, resulting in recorded steps that did not reflect their actual activity.
	Parents who did not provide consent or were unwilling to complete the questionnaire.

Ethical approval statement

The study protocol was reviewed by the Health Research Ethics Committee of the Faculty of Health Sciences, Universitas Muhammadiyah Surakarta, and was granted ethical exemption under Decree No. 1619/KEPK-FIK/X/2025. Prior to participation, informed consent was obtained from the parents or legal guardians of all participating children.

Research Instruments

Two primary variables were assessed: ADHD symptom severity, measured using the ADHD Rating Scale-5, and motor activity, represented by step counts. The ADHD Rating Scale-5 consists of 18 items based on DSM-5 criteria and comprises two domains: Inattention and Hyperactivity–Impulsivity. The questionnaire was administered to parents via Google Forms distributed through WhatsApp groups. Parents were instructed to rate their child's behavior in daily activities according to the instrument guidelines.

The ADHD Rating Scale-5 has demonstrated high internal consistency, with Cronbach's alpha coefficients ranging from .89 to .96, as well as good test–retest reliability. Its construct validity has been supported by confirmatory factor analysis, and evidence of concurrent and predictive validity has also been reported (DuPaul et al., 2016).

Motor activity was objectively assessed using step counts recorded with a commercially available unbranded three-dimensional (3-D) digital pedometer (49 × 36 × 20 mm). The same type of pedometer and placement procedure were used for all participants. Before each measurement, the device was checked for proper functioning by confirming that the display was operational and that steps were registered during a brief walking test. The step counter was then reset to zero and placed in the child's trouser pocket.

Step counts were recorded for 15 minutes during the children's regular school recess. Participants were instructed to engage in their usual recess activities without any prescribed exercise or structured movement task. Step count was used solely as an objective indicator of motor activity and was not intended as a diagnostic measure of ADHD or as a criterion for classifying physical activity levels. Previous research has reported acceptable validity of pedometers for measuring step counts in preschool children ($r = .59$, $p = .04$), with good reliability across different placement positions (Oliver et al., 2007).

Data Analysis

Descriptive statistics were used to summarize participant characteristics and study variables, including age, sex, ADHD Rating Scale-5 scores, and step counts. Data were summarized using frequencies and percentages for categorical variables and appropriate measures of central tendency and dispersion for continuous variables.

The association between ADHD Rating Scale-5 scores and step counts was examined using bivariate correlation analyses. Data normality was assessed using the Kolmogorov–Smirnov test. Pearson's product–moment correlation was used to examine the association between total ADHD Rating Scale-5 scores and step counts because both variables were normally distributed. Spearman's rank correlation was used to examine the associations between the Inattention and Hyperactivity–

Impulsivity domain scores and step counts because the domain scores were not normally distributed.

Statistical significance was set at $p < .05$. The absolute magnitude of the correlation coefficients was interpreted as follows: .00–.19, very weak; .20–.39, weak; .40–.59, moderate; .60–.79, strong; and .80–1.00, very strong. Positive coefficients indicated that higher ADHD Rating Scale-5 scores were associated with higher step counts, whereas negative coefficients indicated that higher scores were associated with lower step counts.

RESULTS

Table 2 presents the demographic and clinical characteristics of the study participants. A total of 110 children aged 4-6 years were included in the analysis. Regarding gender, 60 participants (54.5%) were male and 50 (45.5%) were female, indicating a relatively balanced distribution.

Table 2. Characteristics of the Study Participants

Characteristics	n	%	Min	Median	Max	Mean	SD
Sex							
Male	60	54.5	-	-	-	-	-
Females	50	45.5	-	-	-	-	-
Aged							
4-Year-Old	31	28.2					
5-Year-Old	41	37.3	4	5	6	5.06	0.793
6-Year-Old	38	34.5					

A total of 110 children aged 4–6 years were included in the analysis. Of these, 60 (54.5%) were male and 50 (45.5%) were female. The mean age was 5.06 years (SD = 0.79), with the largest proportion of participants aged 5 years (37.3%)

Table 3. Descriptive Statistics for the Main Study Variables

Variable	n	Min	Median	Max	Mean	SD
Total ADHD Rating Scale-5 score	110	0	11	33	12.42	8.92
Step Count	110	120	315	700	325.54	116.73

Based on Table 3, the ADHD Rating Scale-5 scores among the 110 respondents ranged from 0 to 33. The mean score was 12.42, with a median of 11. The standard deviation was 8.92, indicating variability in ADHD symptom scores among participants. The mean step count was 325.54 (SD = 116.73), with a median of 315 and values ranging from 120 to 700 steps, indicating substantial variability in step counts among participants.

Table 4. Normality Test Results for Study Variables

Variable	p-value	Distribution
Total ADHD Rating Scale-5 score	0.055	Normally distributed
Inattention domain score	< .001	Not normally distributed
Hyperactivity–Impulsivity domain score	0.001	Not normally distributed
Step Count	0.693	Normally distributed

Note. Normality was assessed using the Kolmogorov–Smirnov test.

The Kolmogorov-Smirnov test was used to assess the normality of the data at a significance level of 0.05 (Table 4). The ADHD Rating Scale-5 total score had a p-value of 0.055, while the step count variable had a p-value of 0.693; both values were greater than 0.05, indicating normal distributions. In contrast, the Inattention and

Hyperactivity-Impulsivity scores were not normally distributed, with p-values of < .001 and 0.001, respectively. Therefore, the Pearson product-moment correlation test was used to examine the relationship between the total ADHD Rating Scale-5 score and step count. In contrast, Spearman's rank correlation test was used for the domain-level analyses.

Table 5. Correlations Between ADHD Rating Scale-5 Scores and Step Counts

Variable	Correlation coefficient	*p-value*
Total ADHD Rating Scale-5 score	$r = 0.865$	< .001
Inattention domain score	$\rho = 0.756$	< .001
Hyperactivity–Impulsivity domain score	$\rho = 0.818$	< .001

Note. r = Pearson's correlation coefficient; ρ = Spearman's rank correlation coefficient. All correlations were calculated with step counts.

Pearson's correlation analysis showed a very strong positive correlation between the total ADHD Rating Scale-5 score and step counts ($r = .865$, $p < .001$; Table 5). At the domain level, Spearman's rank correlation analysis showed a strong positive correlation between the Inattention domain score and step counts ($\rho = .756$, $p < .001$), whereas the Hyperactivity–Impulsivity domain score showed a very strong positive correlation with step counts ($\rho = .818$, $p < .001$). All analyses included 110 participants.

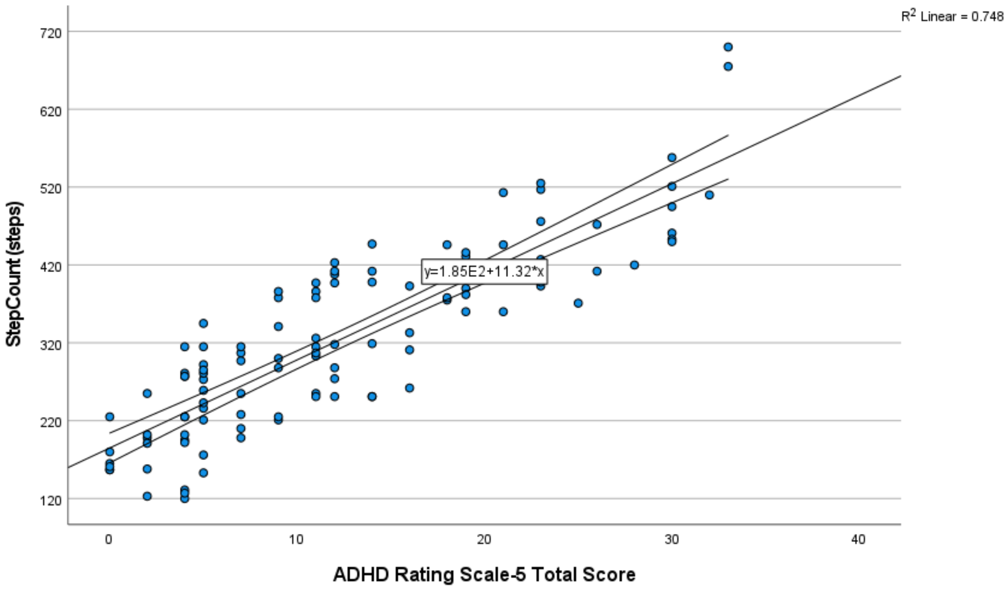

Figure 2. Relationship between total ADHD Rating Scale-5 scores and step counts among children aged 4–6 years, showing a very strong positive correlation ($r = .865$, $p < .001$).

As illustrated in Figure 2, the scatterplot shows a clear positive linear pattern between total ADHD Rating Scale-5 scores and step counts. Children with higher ADHD symptom scores generally recorded higher numbers of steps during the 15-minute school recess. The relatively close distribution of observations around the fitted regression line is consistent with the very strong positive correlation observed between the two variables ($r = .865$, $p < .001$). The coefficient of determination ($R^2 = .748$) further indicates that approximately 74.8% of the variation in step counts was statistically associated with variation in total ADHD Rating Scale-5 scores within this sample. These findings indicate a strong statistical association but should not be interpreted as evidence of a causal relationship.

DISCUSSION

This study demonstrated a very strong positive association between total ADHD symptom scores and objectively measured step counts in preschool children. Domain-level analyses also showed significant positive associations between step counts and both Inattention and Hyperactivity–Impulsivity scores. The association was strong for Inattention ($\rho = .756$, $p < .001$) and very strong for Hyperactivity–Impulsivity ($\rho = .818$, $p < .001$), while the total ADHD Rating Scale-5 score showed a very strong positive association with step counts ($r = .865$, $p < .001$). These findings indicate that higher ADHD symptom scores were associated with greater ambulatory activity during the measurement period. The numerically higher correlation coefficient for Hyperactivity–Impulsivity may reflect a closer relationship between step counts and the motor-behavioral characteristics represented by this symptom domain. However, because the correlations between the two domains were not formally compared, this difference should be interpreted cautiously.

The association between Hyperactivity–Impulsivity and step counts is consistent with the behavioral characteristics represented by this domain, including excessive movement, restlessness, difficulty remaining seated, and frequent changes in activity or position (Feng et al., 2025). Such behavioral characteristics could contribute to a greater number of steps during periods of unrestricted activity. Previous studies have similarly reported elevated motor activity among children with ADHD symptoms. Sarver et al. (2015) described motor behaviors associated with hyperactive symptoms, including frequent movement and changes in position, while Reetzke et al. (2022) reported higher levels of motor activity among young children at risk for ADHD. Fitriyani et al. (2023) also described motor and behavioral characteristics among children with ADHD symptoms, whereas Rahmani et al. (2022) reported associations between manifestations of hyperactivity–impulsivity and difficulties in behavioral regulation. Collectively, these findings provide a plausible behavioral context for the positive association observed between Hyperactivity–Impulsivity scores and step counts in the present study.

The significant association between Inattention scores and step counts is also noteworthy. Although inattention is not primarily characterized by excessive motor behavior, children with higher levels of inattentive symptoms may experience difficulties sustaining attention, maintaining engagement with tasks, and regulating their behavior during structured activities (Adamou et al., 2025). One possible explanation is that difficulties in sustained engagement may coincide with more frequent transitions between activities or locations, potentially contributing to greater ambulatory activity. Previous studies have also described relationships among ADHD symptoms, behavioral regulation, and activity patterns in children (Fitriyani et al., 2023; Rahmani et al., 2022). Nevertheless, step count should not be interpreted as a direct measure of inattention. The observed association may instead reflect the complex relationship between attention regulation and patterns of activity during early childhood. Accordingly, the present findings do not indicate that inattention causes greater step counts but rather that higher inattentive symptom scores were associated with greater ambulatory activity within the context examined.

The present findings are broadly consistent with previous research using objective measures of physical activity. Villalba-Heredia et al. (2023), using accelerometry to assess physical activity among school-aged children with ADHD, reported differences in step counts and physical activity according to ADHD characteristics. Similarly, Kofler et al. (2025) reported associations between objectively measured activity and ADHD symptom ratings, including hyperactivity–impulsivity symptoms. Curzon et al. (2024), studying children aged 4–7 years, also reported differences in daily step counts between children with and without ADHD and variation in activity associated with hyperactive symptoms. Taken together, these studies support the use of objective activity monitoring to characterize movement patterns associated with ADHD symptoms. However, because the present study identified significant associations for both ADHD symptom domains, step counts should not be interpreted as a specific indicator of Hyperactivity–Impulsivity.

The findings also suggest that step counts may provide a simple objective measure that complements behavioral assessments in preschool children (Fang et al., 2020). Pedometers offer a relatively simple method for quantifying ambulatory activity without relying exclusively on subjective observation. In the context of ADHD symptom assessment, such measurements may provide additional information about children's movement patterns in natural settings. However, step counts represent only one dimension of motor activity and primarily capture locomotor or ambulatory movement (Blanco-Martínez et al., 2025). They do not capture other manifestations of motor behavior, such as fidgeting, upper-limb movements, postural changes without locomotion, or the qualitative characteristics of movement. Therefore, the associations observed in this study should be interpreted specifically as relationships between ADHD symptom scores and ambulatory activity rather than as evidence that step counts comprehensively measure hyperactivity.

Overall, this study demonstrated that higher Inattention and Hyperactivity–Impulsivity scores were positively associated with greater step counts among preschool children, with a numerically higher correlation coefficient observed for the Hyperactivity–Impulsivity domain. These findings indicate that step counts may provide complementary information about ambulatory activity associated with ADHD symptom severity, particularly behaviors related to hyperactivity–impulsivity. Nevertheless, step counts should not be considered a diagnostic measure of ADHD or a stand-alone indicator of hyperactivity. Rather, objective measures of ambulatory activity may complement standardized behavioral assessments when characterizing activity patterns associated with ADHD symptoms.

Limitations of the study

Several limitations should be considered when interpreting these findings. First, the cross-sectional design precludes causal inference; therefore, the observed associations do not demonstrate that higher ADHD symptom severity causes greater motor activity. Second, ADHD symptoms were assessed through parental reports and may therefore have been influenced by subjective perceptions or reporting bias. Third, step counts were recorded during only a 15-minute school recess period and may not represent children's habitual motor activity across different times, settings, or days. Activity during recess may also be influenced by contextual factors, including the physical environment, peer interactions, opportunities for movement, and activities available during the measurement period (Xu et al., 2022). Fourth, the use of an unbranded digital pedometer may limit measurement precision and reproducibility, particularly because device-specific validity was not established in the present study. Fifth, potentially relevant child-level or contextual factors that could influence motor activity were not fully controlled. Finally, although the correlation coefficient was numerically higher for Hyperactivity–Impulsivity than for Inattention, no formal statistical test was conducted to determine whether these two correlation coefficients differed significantly. Future studies should consider longitudinal designs, repeated or longer monitoring periods, validated accelerometry-based measures, and adjustment for potential confounding factors to provide a more comprehensive understanding of the relationships between ADHD symptom domains and motor activity.

CONCLUSION

Higher ADHD symptom severity was significantly associated with greater motor activity, as represented by step counts, among preschool children aged 4–6 years. Significant positive associations were observed for both the Inattention and Hyperactivity–Impulsivity domains, with a numerically stronger correlation observed for Hyperactivity–Impulsivity. These findings indicate that objectively measured step counts may provide complementary information about ambulatory activity associated with ADHD symptoms in preschool children. However, step counts reflect only one aspect of motor activity and should not be interpreted as a diagnostic measure of ADHD or a stand-alone indicator of hyperactivity.

Future studies should employ longer or repeated monitoring periods across different daily settings to better characterize children's habitual motor activity. The use of validated objective measures, such as accelerometers, together with behavioral assessments and direct observation, may provide a more comprehensive assessment of activity patterns. Future research should also consider potential contributing or confounding factors, including sleep patterns, habitual physical activity, play environments, and family or contextual characteristics.

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AI DISCLOSURE STATEMENT

During the preparation of this manuscript, the authors used Grammarly to improve language clarity, readability, grammar, and overall linguistic quality. These tools were used solely for language refinement and did not contribute to the study design, data collection, data analysis, interpretation of the results, or formulation of the scientific conclusions. All AI-assisted revisions were carefully reviewed, edited, and verified by the authors. The authors take full responsibility for the accuracy, originality, integrity, and final content of the manuscript.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to participant privacy and confidentiality considerations.

FUNDING

This research does not receive external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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