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Complete List of Authors:	Rojo-Marticella, Meritxell; Universitat Rovira i Virgili, Psychology Arija, Victoria; Faculty of Medicine and Health Sciences, Research Group in Nutrition and Mental Health (NUTRISAM), Institut d'Investigació Sanitària Pere Virgili (IISPV), Universitat Rovira i Virgili, Nutrition and Public Health Unit; Institut Universitari d'Investigació en Atenció Primària Jordi Gol, Unitat de Suport a la Recerca Tarragona-Reus Morales, Paula; Universitat Rovira i Virgili, Psychology Esteban-Figuerola, Patricia; Universitat Rovira i Virgili, Psychology Voltas, Núria; Universitat Rovira i Virgili, Psychology Canals, Josefa; Universitat Rovira i Virgili, Psychology
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Anthropometric status of preschoolers and elementary school children with ADHD: EPINED study

Meritxell Rojo-Marticella,[123] Victoria Arija,[13] Paula Morales-Hidalgo,[1234] Patricia Esteban-Figuerola,[123] Núria Voltas-Moreso,[1235] Josefa Canals-Sans[123*]

[1]Nutrition and Mental Health Research Group (NUTRISAM), Universitat Rovira i Virgili (URV), Tarragona, Spain

[2] Research Centre for Behavioral Assessment (CRAMC), Department of Psychology, URV, Tarragona, Spain

[3] Institut d'Investigació Sanitaria Pere Virgili (IISPV), URV

[4] Psychology and Education Studies, Universitat Oberta de Catalunya (UOC), Barcelona, Spain

[5] Serra Hunter Fellow, Universitat Rovira i Virgili (URV), Tarragona, Spain

* Correspondence: Josefa Canals Sans, Department of Psychology, Universitat Rovira i Virgili, Carretera de Valls, s/n, 43007 Tarragona (Spain).

E-mail: josefa.canals@urv.cat

Phone number: 977257897

Impact statement:

Most of the data published on the relationship between ADHD and weight status have been extracted from clinical populations, do not analyze the control populations and do not consider the different presentations of the disorder. This study fills a gap in the literature as it provides a range of anthropometric data, not just weight status, from a school population of preschool children, as well as school-aged children, with and without ADHD, and considering the different presentations of the disorder. In addition, covariates such as diet, internalizing problems, pharmacological treatment and comorbidity of ASD are considered.

Bullet points:

- The anthropometric status of the school children with ADHD showed differences in terms of age and presentation.
- Preschoolers with hyperactive-impulsive ADHD are taller than their control peers.
- Elementary school children with combined ADHD, regardless of the pharmacological treatment, are shorter and smaller than their control peers.
- It is possible that medication anthropometrically affects the height of children with the inattentive presentation.

Paper type: Population Study Article

ABSTRACT

Background: A current area of research interest is the association between ADHD and weight status. This paper aimed to describe the anthropometric status of school children with ADHD, considering age and clinical presentation (inattentive, hyperactive-impulsive or combined), compared with control children.

Methods: Participants came from the "Epidemiological Research Project on Neurodevelopmental Disorders" (EPINED), and consisted of 198 preschoolers (41 with ADHD) and 389 elementary school children (163 with ADHD). ADHD was diagnosed using DSM-5 criteria. Anthropometric measurements were taken at various anatomical points, and height, weight and body composition were also measured.

Results: In preschoolers, an association was found between hyperactive-impulsive ADHD and greater height and lower waist-to-height ratio. In elementary school children, regardless of the medication, combined ADHD was associated with smaller head, hip, arm and thigh circumferences, and lower weight, height and BMI. A total of 19.7% of them were underweight. In contrast, children with the inattentive and hyperactive/impulsive presentations presented the highest percentage of overweight/obesity (56%).

Conclusion: The anthropometric status of the school children with ADHD showed differences in terms of age and presentation. Preschoolers with hyperactive-impulsive ADHD are taller and elementary school children with combined ADHD are shorter and smaller than their age-matched control peers.

INTRODUCTION

Attention deficit hyperactivity disorder (ADHD) is one of the most common neurodevelopmental disorders in childhood that usually persists in adolescence and adulthood [1]. In Spain, the prevalence in the school population is 5.5% (3% for preschoolers and 7.7% for children in elementary school) [2], while in the world as a whole it ranges between 2 and 7% [3]. ADHD has psychosocial implications, but it also has physical consequences and can affect growth and weight status. In this respect, authors from different countries have linked ADHD with overweight (OW) and obesity (OB) [4,5], but others have presented contradictory results linking it with shorter height, lower weight and smaller anthropometric measurements [6,7]. In this regard, it seems that anthropometric status may change throughout the developmental process depending on age and gender. It has been reported that preschool boys aged 2 to 6 years tend to gain in body weight as they grow older but decrease in height relative to children without ADHD [8]. In medication-naïve children between 6 and 12 years old, it has been seen that the younger ones are heavier and taller, and the older ones lighter and shorter than children with subthreshold ADHD or without ADHD [9]. The prevalence of OB is 19% in preschoolers between 4 and 6 years old [10], greater than in the general population. Also, in children and adolescents with ADHD aged between 7 and 18 years old the prevalence of OW and OB is higher than in controls (14.71% vs. 12.83% and 6.37% vs. 3.45%, respectively) [11]. In clinical samples, these prevalences are much higher than in controls and mainly affected older males [5]. Although the potential mechanisms are far from clear, the relationship between ADHD and weight status may be explained by a variety of multidirectional factors related to ADHD symptomatology, which can change. Hyperactivity and impulsivity symptoms tend to decline at a higher rate than inattention symptoms [12]. Factors such as poor-self regulation, adherence to unhealthy diets, increased reward sensitivity and food and satiety responsiveness found in ADHD can lead to lack of self-regulation and overeating [13,14]. Several authors have also pointed out that genetic factors associated with both ADHD and excessive body weight could underlie the observed association [13,15].

Although a considerable amount of literature studies the link between ADHD and anthropometric status and focuses on OW/OB, other studies report data that explain the relationship between ADHD and poor growth in children. Pharmacological treatment for reducing ADHD symptomatology can act by reducing body weight and height, especially when treatment started before adolescence [16–18]. However, although some authors have found this attenuation of growth, others have observed no changes [19–21] or a rebound to higher BMI in late adolescence [17]. The slower growth could be linked to a decrease in growth hormones associated with an increase in DA produced by stimulants [10,16]. In addition, other factors may be involved in the growth of children with ADHD: for example, physical activity (PA), which can be recommended as part of ADHD treatment [22,23], changes during puberty [24], altered eating behavior or special diets [25,26] and the high presence of psychopathological comorbidities. The coexistence of internalizing problems in children with ADHD, specifically anxiety [27,28] and comorbidities with other neurodevelopmental disorders such as ASD or Intellectual Disability (ID), may increase the OW/OB and cardiovascular risk (higher waist/height ratio) already found in these psychological conditions [29,30].

Although the relationship between ADHD and weight status has been widely analyzed, only a few studies consider the different clinical presentations of ADHD: inattentive (ADHD-I), hyperactive-impulsive (ADHD-HI) and combined (ADHD-C). However, the studies that focus on the different presentations report diverging results. Thus, it should be pointed out that the sample of children with ADHD-HI is often presented alongside with the sample of ADHD-C. Among Chinese children, those with ADHD-C had a higher risk of OW and OB [31]. On the other hand, in a recent study conducted in a clinical population in Spain, children with ADHD-I showed higher BMI than controls [32].

Our principal aim is to compare the anthropometric status of a Spanish sample of school children (from preschool and elementary school) with ADHD with their control peers. As well as weight, height and BMI, we studied numerous anthropometric measures and bioelectrical impedance analysis (BIA) adjusting for sociodemographic, clinical and nutritional variables.

In agreement with data from the literature and data on eating patterns reported in our previous study [25], we hypothesize that anthropometric status depends on ADHD presentation. Children with ADHD-I will have higher weights, BMI z-scores and fat mass values than controls and children with other ADHD presentations.

METHODS

Study Design and Participants

Participants come from the "Neurodevelopmental Disorders Epidemiological Research Project" (EPINED), a study carried out in the province of Tarragona (Catalonia, Spain). This two-phase study was performed between 2014 and 2019 with the main aim of estimating the prevalence of neurodevelopmental disorders such as ADHD and ASD in a school population of two age groups (preschoolers and elementary school children). In the first phase, using validated tests, the risk of both disorders was screened by parents and teachers (n=3727). In the second phase, children at risk and controls with no risk (n=589; 200 preschoolers) were individually assessed by trained psychologists to confirm ADHD and ASD diagnoses according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5). When the information from the Schedule for Affective Disorders and Schizophrenia for School-Age Children-Present and Lifetime Version (K-SADS-PL) [33], administered to the parents, met the DSM-5 criteria for any of the ADHD presentations – inattentive, hyperactive-impulsive, and combined – participants received a positive diagnosis of ADHD (i.e., "clinical ADHD"). Children with previous ADHD diagnoses provided by public mental health centers and those in partial remission due to pharmacological or psychological treatment were also considered to have ADHD. If participants were positive on screening for both parent and teacher Conners' 10-item indexes (T≥65) and presented four or five manifestations (DSM-5 criteria A) for any of the ADHD presentations in the K-SADS-PL with an impact on their functioning, they were considered to have "subclinical ADHD". For the ASD diagnosis, the information was collected with the two gold standard instruments of diagnosis, the ADOS-2 and ADI-R. Further descriptions of the EPINED project can be found in previously published papers [2].

The current report studied 151 children with ADHD (29 preschoolers and 122 from elementary school), 55 subclinical ADHD, and 383 controls without a neurodevelopmental disorder (ASD or ID) (157 preschoolers and 226 from elementary school).

Psychological Assessment

The parents of all the participants answered the Child Behavior Checklist (CBCL/1½-5 and /6-18) [34], providing information on psychological problems (externalizing, internalizing, and total problems). The elementary school children also answered the Youth Self Report (YRS/11-18) [35]. The Spanish versions of the Wechsler Scales of Intelligence for preschool (WPPSI-IV) and elementary school children (WISC-IV) were administered to obtain an estimation of global intelligence (IQ). Face-to-face interviews were carried out to administer the tests, and parents and children answered them separately. All diagnoses were made by trained clinicians.

Anthropometric Assessment

A SECA® measuring tape was used to measure head, chest, waist, hip, mid-thigh, and mid-upper arm circumferences in centimeters to the nearest 1mm. A SECA® stadiometer accurate to 0.1 mm (PERILB-STND) was used to measure height (cm), and TANITA scales (BC 420SMA) were used to measure weight (kg) and body composition. This data was obtained through BIA, which provided the fat mass (in kilos and percentage), lean mass (in kilos and percentage), and total body water, as well as the basal metabolism and bioimpedance.

The anthropometric proceedings were conducted following the international protocol established by The FANTA Guide to Anthropometry[36]. Weight and height were used to calculate body mass index (BMI)(Kg/m^2) based on the World Health Organization (WHO) Child Growth Standards [37]. Weight, height and head circumference (HC) are anthropometric measurements used to assess if children are growing properly. Body mass index (BMI) and other body measurements are commonly used to assess adiposity and the risk of obesity [38]. However, BMI does not take body composition into account, it does not distinguish the weight associated with muscle or fat, and it is not sensitive to detecting excess adiposity [39]. Fat mass (FM) and other anthropometric measurements as well as the waist-to-height ratio (WtH ratio) [40], can provide more specific information about fat, its body distribution, and the risk of cardiovascular diseases related to overweight and obesity [41].

In children it is better to use z-scores because they are calculated by taking the studied population as a reference [42]. Height-for-age, weight-for-age (only for children up to 9 years old), weight-for-height, and body mass index-for-age are z-scores which were converted from original measurements by using the macro-SPSS syntax files of Anthro and Anthro plus software provided by the WHO, which uses the WHO child growth standards for children aged under 5 years and WHO growth reference for children aged 5–19 years. BMI-for-age scores were classified as underweight (<-1), normal weight (≤-1 to ≥1), overweight and obesity (>1). Height-for-age scores were classified as stunting (<-2), normal (≥-2 to ≤2), and tall (>2).

Other Variables

Nutritional assessment was made using a food consumption frequency questionnaire (FCFQ) validated in our population for both age groups [25]. Then, the Spanish Quality Diet Index (SQDI) was calculated[43]. This index classifies food into nine groups on the basis of its nutritional quality, compares the recommended servings with real consumption and gives a score between 0 and 100 points. Finally, these scores are classified into three categories, ≥80 "Healthy", 50-79 "Needs to improve", and ≤49 "Unhealthy".

Sociodemographic data was reported by parents, and their educational level and profession (PELP) was calculated by adapting the Hollingshead index [44].

Physical activity was only obtained for elementary school-aged children. This variable was computed from CBCL/6-18 and YRS/11-18. It considered sports and favorite free time activities and classified them in terms of energy expenditure (more detailed description in [29]).

Statistical Analysis

To describe the study sample, we used ANOVA or the T-Test to analyze continuous variables and Chi-square to analyze non-continuous variables on sociodemographic characteristics and anthropometric status. When data did not have a normal distribution, non-parametric tests such as the U Mann-Whitney test were carried out.

Multiple Linear Regressions (MLRs) were performed to evaluate if ADHD (any presentation) was associated with anthropometric measurements (weight, height, and head, chest, waist, hip, mid-upper arm, and mid-thigh circumferences), or any indexes and ratios (BMI, zBMI, and WHtR), and body composition was calculated by BIA (basal metabolism, bioimpedance, fat mass in percentage and kilos, lean mass in kilos and total body water). Dummy variables for each ADHD presentation compared to controls were used. ADHD presentations were entered into the MLRs with the Enter method and the covariates age, gender, PELP, ASD comorbidities, quality of the diet (SDQI), and presence of internalizing problems were entered with the Stepwise method. For the elementary school children, the variables physical activity, pharmacological treatment and interaction between ADHD presentations and pharmacological treatment were also entered into the model.

A sensitivity analysis of clinical cases only was also performed to make the MLR analyses more robust.

Logistic regressions (LRs) were performed to explore whether there was an association between underweight or overweight/obesity and ADHD presentations using the same models as in the MLRs.

A 95% confidence interval was provided for all estimations and the statistical software used was IBM SPSS 27.

RESULTS

Descriptive data on sociodemographic, psychological and nutritional variables

Table 1 presents the sociodemographic, psychological and nutritional data for each age group and ADHD presentation, and controls. The age range for preschoolers was from 3 to 6 years old, and for elementary school-aged children 10 to 12 years old. In the two age groups, there were more boys than girls and more autochthonous population (Spanish). The PELP of most of the sample for all groups was medium. When the children in the sample were classified by ADHD presentations, the inattentive group contained 77 children (only two preschoolers, who were removed so as not to alter the results with an unrepresentative sample), the hyperactive-impulsive group contained 34 children and the combined group contained 95 children.

Of the preschoolers, 65.9% had clinical ADHD and 34.1% had subclinical ADHD. In the elementary school-aged children, 74.8% had clinical ADHD and 25.2% had subclinical ADHD. Comorbidity with ASD was present in ADHD for both age groups. Only elementary school children received pharmacological treatment and the combined presentation was the most treated (67.7% were taking stimulant medication). As far as internalizing and externalizing problems are concerned, ADHD children in both age groups showed significantly higher T scores than controls. There were no differences in physical activity or SDQI between ADHD presentations and controls. Data showed that all participants needed to improve their diet.

Anthropometric data by ADHD presentation and age group: Univariate analyses

First, we explored differences between clinical and subclinical children within the presentations of ADHD for both age groups (Supplementary table 1). A trend to higher scores was found in some anthropometric measures (BMI, head, waist, hip, mid-thigh) for elementary school children with clinical ADHD-HI. Overall, no significant differences were found between the two groups in either age group. So, to increase the size of the sample, both severity groups were pooled for each ADHD presentation.

Table 2 presents the anthropometric data for each age group and ADHD presentation. There were no significant differences in the preschool group for any measure. However, preschoolers with ADHD-HI presented both greater height and percentage of underweight (UW) and lower OW/OB than ADHD-C and the control group. For elementary school-aged children, the ADHD-C group showed significantly lower values for weight ($p=0.033$), a higher percentage of UW (19.7%) and a lower percentage of OW/OB [38% (23.9% for OW and 14.1% for OB)] than those with ADHD-I [56% (32% and 31.3% separately)], ADHD-HI [56.3% (31.3% and 25%, separately)] and controls [46% (28.8% and 17.3%, separately)]. In addition, the ADHD-C group showed significantly lower values for hip ($p=0.020$), arm ($p=0.038$) and thigh ($p=0.001$) circumferences than the ADHD-I group. When the age groups were compared, elementary school children with ADHD-HI and controls showed a significant increase in OW/OB ($p=0.005$ and $p<0.001$, respectively) versus preschoolers. However, for the ADHD-C group, the elementary school children showed significantly a lower rate in normal weight than the preschoolers ($p<0.007$).

Anthropometry and ADHD presentations: Multivariate analyses

MLRs were performed to analyze associations between the ADHD presentations and the children's anthropometric measurements. Figure 1 and 2 present the estimates for significant MLR models for preschool and elementary school children, respectively.

In the preschool age children, with the control group as a reference, only the models for height and for waist/height ratio were statistically significant. ADHD-HI was found to be positively associated with height (β:2.924, 95%CI:0.359,5.488) and negatively with the waist/height ratio (β:-0.018, 95%CI:-0.035,-0.001).

For elementary school children, significant models are presented in Supplementary table 2. Also, with the control group as a reference, the MLR showed that the ADHD-C group was negatively associated with weight, height (and consequently BMI and its z-score), and head, hip, arm and thigh circumferences. As far as the other presentations are concerned, the ADHD-I group was positively associated with the chest circumference. Age, gender, and internalizing problems were significantly related with the anthropometric measures in most of the MLR models. Diet quality (SDQI), physical activity and pharmacological treatment were not related with anthropometric status. However, the covariate of interaction of medication with ADHD presentation showed a significant negative association with height in the inattentive presentation. For the other measures, the significant association with the ADHD-C was independent of the treatment.

To check the robustness of the results, we performed an MLR only for clinical cases. The results of the models did not change. A positive association was found with the hyperactive-impulsive presentation only for the waist circumference (data not shown).

LRs did not show a significant association between underweight or overweight/obesity with any of the ADHD presentations (data not shown).

DISCUSSION

Contrary to the previous evidence in the literature [11,13,15,45,46], the findings of this study could not support an association between ADHD and high BMI values in school children. Neither did school children with ADHD-I present a significantly higher level of OW/OB despite the fact that their diet was less healthy than that of children without ADHD [25]. However, the rate of OW/OB in ADHD-I and ADHD-HI was very high (56%), even higher than in controls (46%) and ADHD-C (38%). It is noteworthy that, in general, the prevalence of OW/OB in our study is higher than that found in the Aladino study (38%) conducted in Spain [47]. Obtained by SDQI, the data from the present study suggest that the whole sample, regardless of diagnosis, needs to improve their diet.

In the present study, we found some anthropometric differences in terms of ADHD presentations and age group. In preschool children, multivariate analysis showed that belonging to the ADHD-HI group is related with being taller and having a lower waist-to-height ratio than controls. In this regard, our results are in agreement with those shown by the PATS study, in which preschoolers without stimulants were taller than expected [48]. In addition, the prevalence of OW/OB (11.1%) and UW (22%) was lower and higher, respectively, for children with ADHD-HI than for children with ADHD-C and controls. The differences, however, were not significant probably because of the size of the ADHD groups. The prevalence of OW/OB in ADHD-C was similar to the 19% of OB found in USA preschoolers with ADHD [10]. However, in elementary school-age children, the rates of weight status and their distribution within ADHD presentations changed. While the percentages of UW remained similar in the control group, the percentages of UW and OW/OB in ADHD-HI and ADHD-C were quite different. This finding is difficult to explain, and although it could be due to evolutionary changes in the ADHD, the small size of the sample in these presentations may provide less consistent data.

Considering the ADHD severity level, one of the aims of the EPINED project was to study the clinical and epidemiological characteristics of subclinical cases [2,49]. However, considering the small size of some groups within presentations in the present study, we decided to pool the ADHD clinical and subclinical participants because overall no significant anthropometric differences were found, which might add severity variety to our sample. In elementary school children with ADHD-HI, the clinical group tended to have higher BMI, rate of obesity, and hip circumference, and in the sensitivity test, children with a more severe hyperactive/impulsive presentation, had a larger waist circumference. In contrast, children with ADHD-I and ADHD-C did not show differences between the two severity levels. Other studies have found that different severity levels of ADHD (from symptoms to diagnoses in clinical samples) do not have an important effect on anthropometric status. Thus, studies in clinical samples [5], in school populations with ADHD [26], or in samples separated according to ADHD severity [4], all reported similar high prevalences of OW, OB or both. Furthermore, the literature indicates that the risk of OW and OB can depend on the symptomatology caused by psychobiological differences.

ADHD-C presented the lowest prevalence of OW/OB (38%) and the highest of UW (19.7%). In contrast, the results reported by Yang et al. [31] showed that of the three presentations studied, ADHD-C had the highest prevalence of OW/OB. The MLR analysis revealed that children in the ADHD-C group had a lower BMI (and z-score) and were less anthropometrically developed than controls. For this reason, and on the basis of previous literature [16,18,50], we included pharmacological treatment (stimulant) and the ADHD presentation x treatment interaction in the model as a factor related to slow growth. However, no significant association was found between the stimulant treatment and anthropometric variables, despite the high percentage of elementary school children who had been treated for ADHD-C. In this regard, our results agree with those of authors who have shown that the pharmacological treatment has no effect on growth in the developmental process [20,21,51]. All this evidence suggests that some children with ADHD may be smaller or develop more slowly because of the disorder itself. Pointing to this theory, Hanć & Cieślik [52] found that boys with ADHD had a higher level of growth in the pre-pubertal stage and growth suppression in the pubertal stage than those without ADHD. Furthermore, Faraone et al. [9] concluded from their sample that younger children were taller and heavier than controls (data found also in our sample), but as they grew older, they were lighter and shorter than expected. However, in their studies the ADHD sample was not separated into different ADHD presentations as it was in the present study. The change in ADHD symptomatology during growth is well known [12]. Some of our preschoolers with ADHD-HI could evolve to ADHD-C, which coincides with the anthropometric changes found. On the other hand, although we found no association between treatment in children with ADHD-C or ADHD-HI and anthropometric measures, the medication in elementary school children with ADHD-I was associated with lower height than in controls. This result seems to support the findings by other authors that psychostimulants have an effect on growth [16,18]. Since this study was not designed to determine the effect of medication, we do not know the age and anthropometric status at the start of pharmacological treatment we cannot assess whether or not medication is the cause. As expected, gender was associated with some anthropometric measures. For example, being female in the pubertal period was related to larger chest, hip and thigh circumferences and higher weight.

In our sample of both preschool and elementary school children, participants in the ADHD-C group showed that short stature – 4.3% and 2.8%, respectively – was more prevalent than in the other presentations and controls. Some authors have also suggested that there is a dysregulation in GH secretion after exercise in children with ADHD [53]. However, our results, cannot support the idea that lack of exercise is related to lower GH secretion and therefore lower growth in ADHD-C children. Likewise, another factor that could be related to altered growth hormone (GH) secretion in ADHD patients is their poor sleep quality [54,55]. It has been reported that children with ADHD-C showed greater sleep disturbances than children with ADHD-I and their control peers [32,56], and these problems may explain the lower growth. Although some studies have linked sleep problems to pharmacological treatment [57], others have found that, once again, they are caused by the disorder itself [54].

Study strengths and limitations

This study has several strengths. As it is a sample from an epidemiological study, we have been able to include children with different severities of ADHD (clinical and subclinical diagnosis) and controls. We have also collected nutritional, sociodemographic and psychological variables and used them as adjustment covariates. In addition, the study presents data for two age groups, enriching the literature in terms of anthropometric data in preschool children, and for all three presentations of ADHD. The anthropometric assessment was made by a trained and certified dietitian (first level accreditation) from the International Society for the Advancement of Kinanthropometry (ISAK) who collected numerous measurements as well as weight, height, and BMI, which provide insight into the physical development of children with or without ADHD.

However, the study also has limitations. The first limitation is that the sample is too small to form large comparison groups for ADHD presentations or to separate into levels of severity. Secondly, we did not take into account whether the stimulants were immediate or prolonged release, which might have an effect on appetite, and we did not have the anthropometric baseline data before medication so we cannot know if it has any effect. Finally, we have no data on the sleeping habits of the participants and the data on physical activity were collected from the CBCL test, not from a specific questionnaire for measuring exercise, which could have given us more information to postulate why the results were obtained.

Conclusions

The anthropometric development of children with ADHD can vary with age and presentation of the disorder. While preschool children with ADHD-HI are taller than ADHD-C and controls, elementary school children with ADHD-C are significantly shorter, lighter, and have smaller body perimeters than the other presentations and their control peers. In these children, medication was not related with their anthropometric characteristics. In children with the inattentive presentation, medication may have a negative effect on height. Further studies are needed to understand the underlying mechanisms that explain these developmental anthropometric differences.

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Statements and Declarations

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Figure 1. Association between ADHD presentations [hyperactive-impulsive, combined vs. control (ref)] and height (A) and Waist/Height ratio (B) in preschool children. ADHD, attention-deficit/hyperactivity disorder; WtH, Waist/Height; CI, confidence interval; HI, hyperactive-impulsive; C, combined. Multiple linear regressions were used to calculate β coefficient and 95% CI, Stepwise method was used to include covariates: age, gender, PELP, ASD comorbidities, SDQI score and internalizing problems. * indicates significant results ($p<0.05$).

Figure 2. Association between ADHD presentations [inattentive, hyperactive-impulsive, combined vs. control (ref)] and significant anthropometric indexes and measurements in elementary school children. ADHD, attention-deficit/hyperactivity disorder; CIR, circumference; CI, confidence interval; HI, hyperactive-impulsive; C, combined; I, inattentive. Multiple linear regressions were used to calculate β coefficient and 95% CI, Stepwise method was used to include covariates: interaction between ADHD presentations and Tx, age, gender, PELP, Tx, ASD comorbidities, physical activity, SDQI score and internalizing problems. * indicates significant results ($p<0.05$).

Table 1. Sociodemographic, psychological and nutritional description per age group and ADHD presentation

		Pre-school children				Elementary school-children				
		ADHD presentation				ADHD presentation				
		H-Impulsive	Combined	Control	p	Inattentive	H-Impulsive	Combined	Control	p
		n=18	n=23	n=157		n=75	n=16	n=72	n=226	
Age (Years)		5.22(0.49)	5.08(0.52)	5.06(0.73)	0.665	11.04(0.49)	11.21(0.56)	11.06(0.52)	11.07(0.50)	0.655
Gender (Males)		61,1[11]	65.2[15]	55.4[87]	0.632	64.0[48]	50.0[8]	72.2[52]	59.3[134]	0.171
Origin (Spanish)		88,9[16]	87.0[20]	79.6[125]	0.482	85.3[64]	81.3[13]	84.7[61]	88.1[199]	0.770
PELP	Low	22.2[4]	39.1[9]	11.5[18]	0.014	20.0[15]	31.3[5]	23.6[17]	12.4[28]	0.049
	Medium	61.1[11]	47.8[11]	65.6[103]		69.3[52]	43.8[7]	56.9[41]	67.3[152]	
	High	16.7[3]	13.0[3]	22.9[36]		10.7[8]	25.0[4]	19.4[14]	20.4[46]	
ADHD	Clinical	24.4[10]	41.5[17]	0.0[0]	0.219	31.9[52]	6.1[10]	36.8[60]	0.0[0]	0.072
	Subclinical	19.5[8]	14.6[6]	0.0[0]		14.1[23]	3.7[6]	7.4[12]	0.0[0]	
ASD	Clinical	20.0[4]	5.0[1]	0.0[0]	<0.001	11.5[3]	3.8[1]	15.4[4]	0.0[0]	0.072
Pharmacological Tx		-	-	-	-	12.0[9]	6.3[1]	29.2[21]	0.0[0]	<0.001
Internalizing problems		63.83(9.31)	68.48(10.58)	54.97(10.64)	<0.001	59.99(9.07)	59.5(11.12)	59.29(9.57)	53.46(9.63)	<0.001
Externalizing problems		68.22(7.61)	69.87(10.02)	53.23(9.92)	<0.001	55.24(9.6)	63.31(9.27)	61.81(9.46)	49.29(9.56)	<0.001
Physical activity score		-	-	-	-	41(10)	40(8)	40(9)	42(10)	0.369
SDQI score		62.92(9.23)	62.20(6.61)	63.08(7.73)	0.878	60.41(6.99)	60.06(7.70)	60.59(7.84)	60.07(7.85)	0.959
	Unhealthy	5.6[1]	4.3[1]	3.8[6]	0.983	8.0[6]	6.3[1]	8.3[6]	7.1[16]	0.979
	Need to improve	94.4[17]	95.7[22]	95.5[150]		92.0[69]	93.8[15]	91.7[66]	92.9[210]	
	Healthy	0.0[0]	0.0[0]	0.6[1]		0.0[0]	0.0[0]	0.0[0]	0.0[0]	

ADHD, attention-deficit/hyperactivity disorder; H, hyperactive; PELP, parent's educational level and profession; ASD, autism spectrum disorder; Tx, treatment; SDQI, Spanish diet quality index. Mean (SD), percentage [n]. Significant differences $p<0.05$.

Table 2. Anthropometrical data by age group and ADHD presentation

	Preschool children				Elementary school children					
	ADHD presentation				ADHD presentation					
	H-Impulsive n=18	**Combined** n=23	**Control** n=157	**p**	**Inattentive[1]** n=75	**H-Impulsive[2]** n=16	**Combined[3]** n=72	**Control[4]** n=226	**p**	
Weight	20.12(3.51)	19.32(2.41)	19.05(2.72)	0.289	44.69(11.10)	46.38(13.46)	40.12(10.16)	42.88(10.26)	0.033	
Weight z-score	0.42(1.11)	0.28(0.84)	0.21(0.92)	0.666	-	-	-	-		
Height	113.75(5.50)	110.64(5.73)	110.23(5.90)	0.056	147.59(7.13)	148.02(7.75)	145.37(7.44)	147.51(7.56)	0.122	
Height z-score	0.60(0.88)	0.12(1.00)	0.09(1.12)	0.163	0.53(0.97)	0.40(1.05)	0.20(1.10)	0.47(1.07)	0.224	
Stunting	0.0[0]	4.3[1]	1.9[3]	0.694	0.0[0]	0.0[0]	2.8[2]	1.3[3]	0.859	
Normal	94.4[17]	95.7[22]	95.5[150]		92.0[69]	93.8[15]	90.1[64]	91.6[207]		
Tall	5.6[1]	0.0[0]	2.5[4]		8.0[6]	6.3[1]	7.0[5]	7.1[16]		
BMI	15.45(1.61)	15.76(1.27)	15.64(1.51)	0.812	20.35(4.07)	20.80(4.14)	18.79(3.53)	19.55(3.67)	0.057	
BMI z-score	0.05(1.15)	0.29(0.85)	0.18(1.04)	0.759	0.98(1.35)	1.09(1.17)	0.43(1.45)	0.71(1.29)	0.067	
Underweight	22.2[4]	4.3[1]	12.7[20]	0.455	10.7[8]	6.3[1]	19.7[14]	12.4[28]	0.294	
Normal	66.7[12]	73.9[17]	65.6[103]		33.3[25]	37.5[6]	42.3[30]	41.6[94]		
OW and OB	11.1[2]	21.7[5]	21.7[34]		56.0[42]	56.3[9]	38.0[27]	46.0[104]		
Head CIR	51.53(2.28)	50.98(1.69)	51.32(1.79)	0.633	54.18(1.74)	54.32(2.39)	53.50(1.91)	54.16(1.98)	0.095	
Head CIR z-score	0.35(1.49)	0.33(0.81)	0.70(1.28)	0.540	-	-	-	-	-	
Chest CIR	57.41(3.49)	57.41(2.84)	56.64(3.04)	0.405	76.97(8.37)	75.37(11.42)	73.15(7.84)	74.68(7.92)	0.058	
Waist CIR	54.31(3.32)	55.27(3.18)	55.02(3.96)	0.734	72.21(9.15)	72.39(12.84)	68.73(8.92)	69.74(8.89)	0.100	
Waist/Height ratio	0.48(0.03)	0.50(0.03)	0.50(0.03)	0.071	0.49(0.06)	0.49(0.07)	0.47(0.05)	0.47(0.05)	0.168	
Hip CIR	59.58(3.69)	60.32(4.49)	58.86(4.56)	0.349	81.00(9.80)	79.25(10.47)	75.96(8.88)	78.94(9.10)	0.020	0,011 [13]
Mid-upper arm CIR	18.78(1.44)	19.21(1.46)	18.75(1.80)	0.516	24.90(3.63)	24.57(2.92)	23.33(3.08)	24.03(3.03)	0.038	0,028 [13]
Mid-thigh CIR	32.44(4.01)	32.74(3.67)	32.17(3.32)	0.764	46.99(6.12)	46.75(6.57)	43.28(5.05)	45.14(5.46)	0.001	<0,001 [13]
Basal metabolism	-	-	-		1346.2(154.9)	1384.1(181.6)	1326.7(162.2)	1334.4(155.3)	0.667	
Bioimpedance	-	-	-		568.39(69.75)	566.93(61.82)	590.14(68.58)	575.67(60.46)	0.223	
Fat mass percentage	-	-	-		22.24(9.47)	22.83(8.99)	19.02(7.69)	20.76(8.82)	0.123	
Fat mass	-	-	-		10.77(6.80)	11.68 (8.17)	8.28(5.11)	9.71(6.33)	0.064	
Lean mass	-	-	-		33.90(5.47)	34.70(5.87)	31.92(5.63)	33.10(5.10)	0.086	
Total body water	-	-	-		25.27(5.72)	25.40(4.29)	23.34(4.15)	24.54(4.98)	0.103	

H, hyperactive; CIR, circumference. Mean (SD), percentage [n], Weight, fat/lean mass and total water measured in Kg; height and body circumferences mesured in cm; basal metabolism measured in KCal and bioimpedance measured in Ω. Significant differences $p<0.05$.

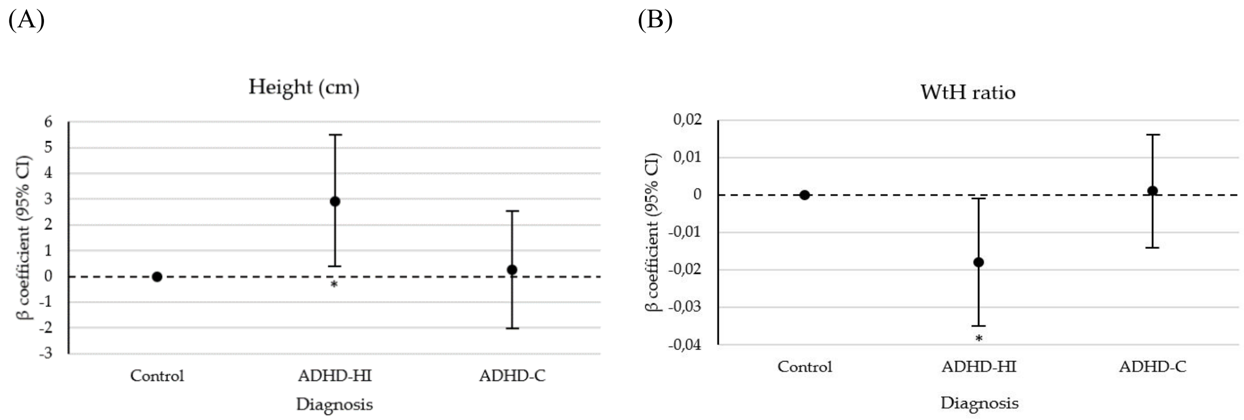

Figure 1. Association between ADHD presentations [hyperactive-impulsive, combined vs. control (ref)] and height (A) and Waist/Height ratio (B) in preschool children. ADHD, attention-deficit/hyperactivity disorder; WtH, Waist/Height; CI, confidence interval; HI, hyperactive-impulsive; C, combined. Multiple linear regressions were used to calculate β coefficient and 95% CI, Stepwise method was used to include covariates: age, gender, PELP, ASD comorbidities, SDQI score and internalizing problems. * indicates significant results ($p<0.05$).

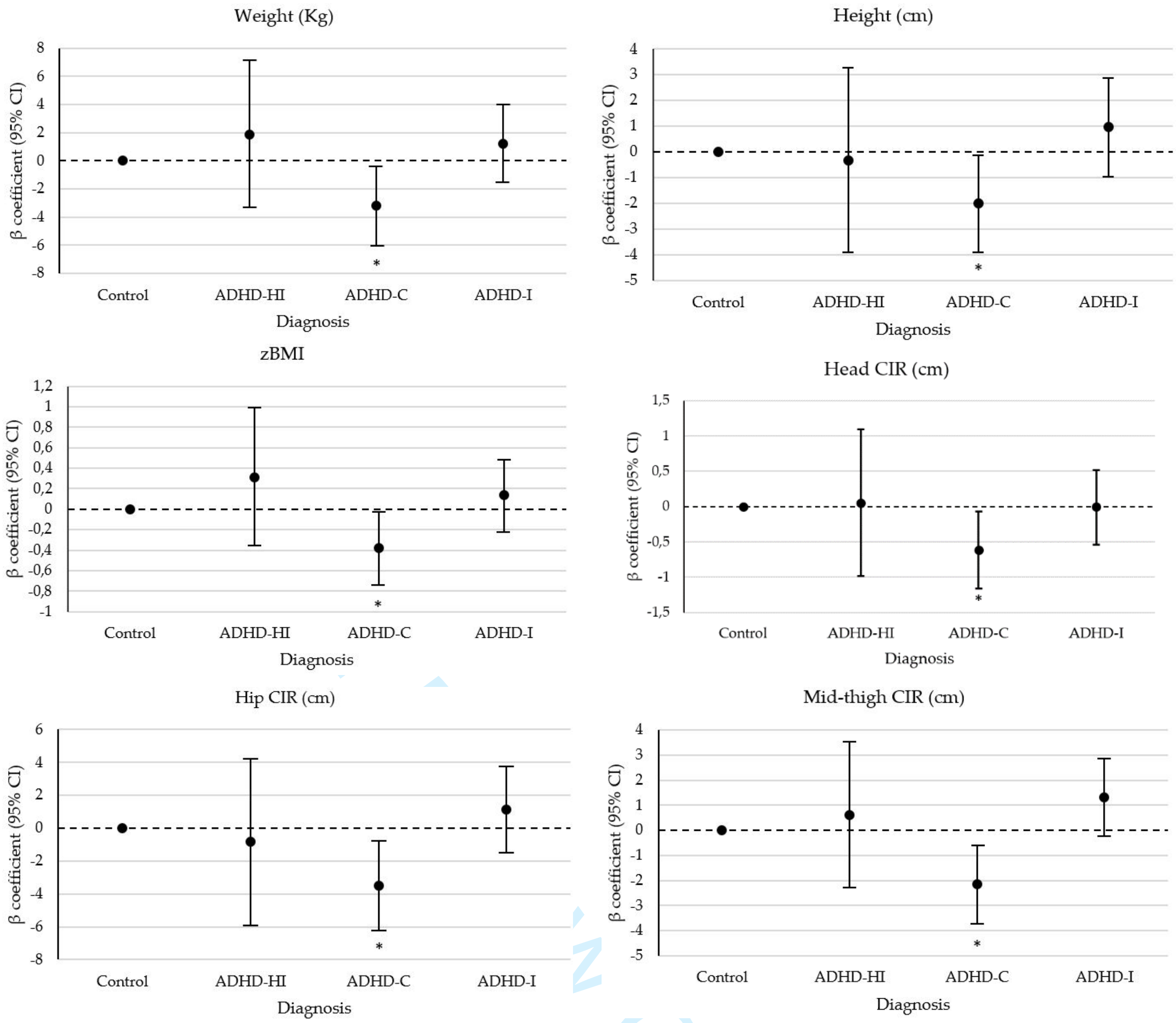

Figure 2. Association between ADHD presentations [inattentive, hyperactive-impulsive, combined vs. control (ref)] and significant anthropometric indexes and measurements in elementary school children. ADHD, attention-deficit/hyperactivity disorder; CIR, circumference; CI, confidence interval; HI, hyperactive-impulsive; C, combined; I, inattentive. Multiple linear regressions were used to calculate β coefficient and 95% CI, Stepwise method was used to include covariates: interaction between ADHD presentations and Tx, age, gender, PELP, Tx, ASD comorbidities, physical activity, SDQI score and internalizing problems. * indicates significant results ($p<0.05$).

Supplementary Table 1. Anthropometrical data by ADHD presentation, age and severity grade

	Preschool children						Elementary school children								
	H-Impulsive			Combined			Inattentive			H-Impulsive			Combined		
	Clinical	Subclinical	p	Clinical	Subclinical	p	Clinical	Subclinical	p	Clinical	Subclinical	p	Clinical	Subclinical	p
	n=10	n=8		n=17	n=6		n=52	n=23		n=10	n=6		n=60	n=12	
Weight	20.93(4.20)	19.11(2.28)	0,351	19.24(2.40)	19.55(2.67)	1,000	45.17(11.57)	43.59(10.13)	0,574	51.13(14.75)	38.45(5.63)	0,065	39.58(9.65)	42.96(12.14)	0,293
Height	114.45(5.18)	112.88(6.12)	0,689	110.22(4.88)	111.83(8.12)	0,779	147.34(7.01)	148.15(7.52)	0,651	150.60(7.80)	143.72(5.92)	0,082	144.83(7.15)	147.16(9.19)	0,336
Height z-score	0.48(0.94)	0.76(0.85)	0,423	-0.08(1)	0.68(0.82)	0,086	0.43(0.92)	0.75(1.06)	0,189	0.54(1.15)	0.17(0.91)	0,386	0.20(1.10)	0.20(1.18)	0,999
Stunting	0[0]	0[0]	0,357	5.9[1]	0[0]	0,544	0[0]	0[0]	0,883	0[0]	0[0]	0,424	3.4[2]	0[0]	0,801
Normal	90[9]	100[8]		94.1[16]	27.3[6]		92.3[48]	91.3[21]		90.0[9]	100[6]		89.9[53]	91.7[11]	
Tall	10[1]	0[0]		0[0]	0[0]		7.7[4]	8.7[2]		10[1]	0[0]		6.8[4]	8.3[1]	
BMI	15.83(1.86)	14.99(1.20)	0,328	15.80(1.31)	15.63(1.25)	0,779	20.63(4.18)	19.72(3.82)	0,375	22.16(4.63)	18.54(1.77)	0,159	18.72(3.51)	19.53(3.79)	0,472
BMI z-score	0.27(1.36)	-0.24(0.83)	0,398	0.33(0.86)	0.18(0.90)	0,834	1.07(1.29)	0.79(1.48)	0,410	1.36(1.31)	0.64(0.79)	0,159	0.41(1.47)	0.62(1.39)	0,650
Underweight	20[2]	25[2]	0,407	0[0]	16.7[1]	0,225	7.7[4]	17.4[4]	0,455	10[1]	0[0]	0,159	22[13]	8.3[1]	0,384
Normal	60[6]	75[6]		76.5[13]	66.7[4]		34.6[18]	30.4[7]		20[2]	66.7[4]		39[23]	58.3[7]	
OW and OB	20[2]	0[0]		23.5[4]	16.7[1]		57.7[30]	52.2[12]		70[7]	33.3[2]		39[23]	33.3[4]	
Head CIR	52.06(2.38)	51(2.20)	0,293	50.99(1.87)	50.97(1.30)	0,638	54.04(1.80)	54.50(1.59)	0,305	55.44(2.11)	52.83(1.99)	0,045	53.50(1.74)	5.50(2.80)	0,998
Chest CIR	58.38(4.06)	56.44(2.73)	0,289	57.24(3.12)	57.83(2.16)	0,969	76.99(8.24)	76.94(8.82)	0,982	78.28(14.54)	71.50(3.41)	0,197	72.77(7.33)	75.20(10.42)	0,373
Waist CIR	54.81(4.31)	53.81(2.12)	0,458	55.58(3.46)	54.50(2.41)	0,482	73.15(9.12)	70.21(9.08)	0,216	77.43(14.90)	65.67(4.83)	0,219	68.63(4.83)	69.25(13.18)	0,889
Waist/Height ratio	0.48(0.03)	0.48(0.03)	0,529	0.51(0.03)	0.49(0.04)	0,350	0.50(0.06)	0.47(0.06)	0,121	0.51(0.08)	0.46(0.04)	0,245	0.48(0.05)	0.47(0.07)	0,695
Hip CIR	60.25(4.44)	58.90(2.91)	0,635	59.57(4.54)	62.22(4.12)	0,137	81.18(9.41)	80.61(10.81)	0,825	84.38(10.19)	72.42(5.97)	0,020	75.85(8.42)	76.55(11.60)	0,821
Mid-upper arm CIR	18.88(1.79)	18.68(1.11)	0,710	19.03(1.37)	19.67(1.72)	0,474	25.10(3.63)	24.47(3.68)	0,511	25.81(3.15)	22.92(1.59)	0,105	23.24(3.11)	23.85(3.06)	0,568
Mid-thigh CIR	34.38(3.20)	30.50(3.96)	0,073	32.77(3.72)	32.67(3.87)	0,815	47.34(5.92)	46.25(6.60)	0,494	49.50(7.22)	43.08(3.32)	0,093	43.10(5.00)	44.25(5.48)	0,513
Basal metabolism	-	-	-	-	-	-	1352.07(158.16)	1333.86(150.94)	0,661	1443.57(220.54)	1300.80(53.91)	0,223	1318.29(153.61)	1385.71(218.26)	0,308
Bioimpedance	-	-	-	-	-	-	564.57(71.71)	576.52(66.20)	0,502	561.88(72.54)	573.67(49.75)	0,699	593.07(65.17)	572.22(89.14)	0,402
Fat mass percentage	-	-	-	-	-	-	22.23(9.20)	22.25(10.27)	0,994	25.35(10.34)	18.63(4.04)	0,302	18.68(7.76)	20.87(7.38)	0,389
Fat mass	-	-	-	-	-	-	10.86(6.99)	10.58(6.49)	0,871	14.30(9.37)	7.30(2.36)	0,104	7.99(5.02)	9.86(5.57)	0,267
Lean mass	-	-	-	-	-	-	34.28(5.76)	33.02(4.73)	0,360	36.83(6.05)	31.15(3.68)	0,083	31.52(5.28)	34.09(7.20)	0,166
Total body water	-	-	-	-	-	-	25.76(6.44)	24.17(3.45)	0,271	26.96(4.42)	22.80(2.66)	0,083	23.04(3.89)	24.96(5.27)	0,160

H, hyperactive; Tx, treatment; CIR, circumference. Mean (SD), percentage [n], Weight, fat/lean mass and total water measured in Kg; height and body circumferences mesured in cm; basal metabolism measured in KCal and bioimpedance measured in Ω. Due to sample size, for preschool children and for H-impulsive in the elementary school children, non parametric analyses were used. Significant differences $p<0.05$.

Supplementary table 2. Associations between ADHD presentations and anthropometry in elementary school children

Ref.: Control (0)	Weight β (95% CI)	Height β (95% CI)	BMI β (95% CI)	zBMI β (95% CI)	Head CIR β (95% CI)
ADHD-HI	1.851 (-3.384 , 7.086)	-0.323 (-3.919 , 3.272)	0.882 (-1.005 , 2.769)	0.308 (-0.366 , 0.982)	0.053 (-0.990 , 1.096)
ADHD-C	-3.204 (-6.029 , -0.378)*	-2.003 (-3.910 , -0.096)*	-1.140 (-2.055 , -0.025)*	-0.382 (-0.745 , -0.019)*	-0.620 (-1.171 , -0.069)*
ADHD-I	1.233 (-1.533 , 4.000)	0.974 (-0.970 , 2.917)	0.390 (-0.609 , 1.389)	0.136 (-0.221 , 0.492)	-0.006 (-0.535 , 0.523)
Age	4.490 (2.428 , 6.552)**	4.632 (3.207 , 6.057)**	0.794 (0.049 , 1.538)*	-	0.699 (0.242 , 1.156)*
Gender	2.478 (0.362 , 4.593)*	1.685(0.210 , 3.159)*	-	-	-
PELP (High)	-	-	-1.093 (-2.051 , -0.134)*	-0.375 (-0.717 , -0.033)*	-
Intern. problems	0.132 (0.024 , 0.239)*	-	0.052 (0.013 , 0.091)*	0.016 (0.002 , 0.030)*	-
ADHD-I*Tx	-	-5.660 (-10.642 , -0.678)*	-	-	-
	$R^2c=0.084$ $F_{385,6}=6.875$ $p<0.001$	$R^2c=0.117$ $F_{385,6}=9.506$ $p<0.001$	$R^2c=0.054$ $F_{385,6}=4.671$ $p<0.001$	$R^2c=0.035$ $F_{385,5}=3.797$ $p=0.002$	$R^2c=0.029$ $F_{333,4}=3.515$ $p=0.008$

Ref.: Control (0)	Chest CIR β (95% CI)	Waist CIR β (95% CI)	Hip CIR β (95% CI)	Mid-upper arm CIR β (95% CI)	Mid-thigh CIR β (95% CI)
ADHD-HI	0.058 (-4.309 , 4.425)	1.765 (-3.206, 6.737)	-0.847 (-5.86 , 4.165)	0.261 (-1.469 , 1.991)	0.623 (-2.318 , 3.563)
ADHD-C	-1.350 (-3.668 , 0.966)	-2.100 (-4.794 , 0.594)	-3.51 (-6.236 , -0.784)*	-0.994 (-1.931 , -0.056)*	-2.157 (-3.755 , -0.559)*
ADHD-I	2.321 (0.108 , 4.534)*	1.498 (-1.101 , 4.097)	1.154 (-1.464 , 3.773)	0.556 (-0.348 , 1.461)	1.324 (-0.211 , 2.859)
Age	2.726 (0.814 , 4.639)*	-	-	-	1.965 (0.669 , 3.261)*
Gender	2.886 (1.101 , 4.671)*	-	2.815 (0.780 , 4.851)*	-	2.363 (1.17 , 3.557)**
PELP (High)	-	-	-	-	-
Intern. problems	-	0.153 (0.050 , 0.257)*	0.151 (0.047 , 0.256)*	0.048 (0.012 , 0084)*	0.084 (0.022 , 0.146)*
ADHD-I*Tx	-	-	-	-	-
	$R^2c=0.061$ $F_{333,5}=5.346$ $p<0.001$	$R^2c=0.033$ $F_{333,4}=3.812$ $p=0.005$	$R^2c=0.057$ $F_{333,5}=4.999$ $p<0.001$	$R^2c=0.033$ $F_{333,4}=3.817$ $p=0.005$	$R^2c=0.120$ $F_{333,6}=8.558$ $p<0.001$

Multiple linear regression significant models, Stepwise method was used to include covariates: interaction between ADHD presentations and Tx, age, gender, PELP, Tx, ASD comorbidities, physical activity, SDQI score and internalizing problems. CIR, circumference; CI, confidence interval; HI, hyperactive-impulsive; C, combined; I, inattentive; ADHD, attention-deficit/hyperactivity disorder; Tx, pharmacological treatment; PELP, parent's educational level and profession; Intern., internalizing. Significant differences: *for p<0.05 and ** for p<0.001.