The impact of anemia and body mass index (BMI) on neuromotor development of preschool children

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Summary

Objective: According to data from the World Health Organization (WHO), anemia is a prevalent health problem that leads to increased morbidity and mortality, especially in preschool children. Anemia is recognized as a major health problem due to its negative effects on the mental and physical development during childhood. The aim of our study was to determine the levels of anemia of children in a kindergarten affiliated to the Directorate of National Education using a non-invasive method, and to investigate the effects of anemia on the physical, mental and neuromotor development of children.
Method: The levels of anemia was evaluated by using a non-invasive measurement device. Data collection was performed by means of a questionnaire to evaluate the children's physical development and set Denver Developmental Screening Test II scores.
Results: Our findings show that 21% of non-anemic and 15% of anemic children are in the suspected abnormal group according to their DDST II total score. Furthermore, it has been identified that mild anemia has a positive effect on neuromotor development, while overweight and obesity affect neuromotor development in a negative way.
Conclusion: According to the results obtained from the study, mild anemia may have a positive effect on the children's neuromotor development, while malnutrition could have a negative impact.

Keywords: anemia, Denver Developmental Screening Test II (DDST II), neuromotor development, obesity, child, preschool.

Introduction

Anemia is defined as a decrease in the amount of red blood cells or hemoglobin in the blood and results in a decline of oxygen-carrying capacity and the amount of oxygen that reaches the body's tissues. Normal hemoglobin, hematocrit and average erythrocyte volume values are different according to age and gender. Therefore, a separate assessment of each patient is made to diagnose anemia. Levels two standard deviations below the normal value are considered to be anemia.[1,2] Since anemia is a symptom of many diseases rather than a primary illness itself, it may often worsen the dysfunction of other organs.[3]

The World Health Organization (WHO) sees anemia as a common health problem that especially leads to increased mortality and morbidity in preschool children. Worldwide prevalence of anemia is between 22.9 and 26.7%.[4,5] The WHO has issued a social health problem rating according to anemia prevalence and as a result of this, it was reported that countries with a prevalence of anemia at 5% or less do not have a health problem, while prevalence at the 5-19% range is considered a mild problem, between 20-39% is considered a moderate one, and above 40% is seen as a major health issue.[6] The anemia rate above 40% seen in Turkey is regarded by WHO as a serious public health problem.[4]

Considering that 47.4% of preschool children and 25.4% school children have anemia in the world, it has been recognized a major health problem due to its negative impacts on mental and physical development during childhood.[3] Given that childhood is the fastest growth and

development period, anemia-related problems (growth retardation, motor and mental performance decline, behavior disorders etc.) are of great concern.[7]

Similarly to anemia, obesity is also regarded as an important public health problem.[8] Childhood obesity occurs especially in developed countries but increased prevalence is observed all over the world.[9] This increased prevalence of obesity is so serious that it could be described as an epidemic. Although prevalence varies from country to country, it has rapidly grown over the last 20 years. Comparing the results between the years 1988-1994 and 2003-2004 according to the National Health and Nutrition Examination Survey (NHANES) in the United States (US), the prevalence of overweight in the age range between 2 and 5 years has increased from 7.2 to 13.9%. At the same time, the frequency between 6 and 11 years old rose from 11 to 19%.[10] It is reported that the obesity prevalence in Turkey has increased in the last 20 years from 6-7% to 15-16%.[11]

Obesity causes many physical, emotional and psychosocial problems, leading to educational and social issues (e.g., economic burden) as well. Awareness is thus extremely important in winning the battle against obesity. Obesity not only leads to chronic diseases later in life, but also during childhood. These include many diseases that affect the neurological system.[12,13] In addition, obesity has a negative impact on children's education. Studies performed on this topic determined that overweight/obese children have lower reading skills and mathematic scores, poorer classroom performance, less success as students, less connection to schoolmates, greater desire to quit school, and they cannot proceed to further education in life with the same level of success as normal weight children.[12,14]

Considering the clinical and social impacts of anemia and obesity, taking necessary measures are not only important for the purpose of individual treatment but also in terms of public health. Having in mind that health checks are not a habit in our society, every child must be evaluated individually according to their growth/development.

After having reviewed the available literature, we did not find any studies showing the impact of anemia and obesity on 5-6 year-old children regarding physical, mental and neuromotor development. Our study aimed to determine the presence of anemia and obesity in children at a kindergarten facility affiliated with the Directorate of National Education of Corum using a non-invasive method, and to investigate the impact of anemia and obesity on the children's physical, mental and neuromotor development.

Method

Preparation

The study included all 5-6 year-old children enrolled in the kindergarten affiliated with the Directorate of National Education of Çorum. The research was done by means of a descriptive method and avoiding sample selection. All children (916) aged between 5 to 6 years who were present at the kindergarten during the study's dates (January – June 2015) and whose parents/guardians did not refuse the application of the Denver Developmental Screening Test II (DDST II) constituted the study sample. The DDST II was applied to all participating 5-6 year-old children. Additionally, hemoglobin values were measured using a non-invasive method, and body mass index (BMI) was determined.

Before initiating the study, approval was obtained from the Provincial Directorate of National Education (23.12.2014/6817100) and the Ankara Numune Education and Research Hospital ethics committee (19.02.2015/E-15-424). After receiving information pertaining the study's purpose and method, the parents/guardians of the children expected to participate signed a proper consent form. Furthermore, they were made aware that if anemia and/or obesity were detected, they would be informed and referred for treatment. DDST II was evaluated and performed by the screener.

Instruments

Research data was collected by interview using a questionnaire, the children's anemia and obesity status assessment form, and the DDST II screening test. The sociodemographic characteristics of the children were also investigated using the questionnaire.

The children's levels of anemia (hemoglobin value) assessment was performed using a non-invasive hemoglobin measurement device (Masimo, rainbow DCI-mini SC1000). This device was chosen due to its portability and capacity of proving fast results to determine anemia or blood loss in a non-invasive manner.[15,16] The purpose of hemoglobin measurement in children is to obtain a concrete feedback about their levels of anemia. In our study, the WHO hemoglobin cut-off values of anemia were taken as reference and, therefore, the lower limit for hemoglobin levels in children between the ages of 5 to 11 years was accepted as 11.5 g/dL. Children with hemoglobin levels lower than that were considered anemic.[3] Anemia is classified as mild, moderate or severe based on the concentrations of hemoglobin in the blood. In our study, hemoglobin concentration at 10.0 g/dL was accepted as the lower limit for mild anemia.[17]

To evaluate the children's BMI, we used the international standard indicators defined by the National Center for

Health Statistics (NCHS) and approved by the Center for Disease Control and Prevention (CDC) and the WHO. Percentage curves established for Turkish children yielded the BMI of the children evaluated.[18-20]

Height was measured using a standard stadiometer, with the children standing barefoot. During height measurement, researchers made sure that the most protruding point of the head, shoulders, hips and heels were in contact with the vertical plane and feet were adjacent to each other. Weight was obtained using a digital scale sensitive to 20 g variations, and the children were asked to remove their jackets before their weight was read. The remaining clothing was accepted as weighing approximately 1 kg, which was subtracted from the weight read from the digital scale. In order to compare the children's height and weight measurements in a healthy way, the same weight and height measurement device was used and the measurement was performed by the same person with the appropriate technique.

Body mass index was calculated by using the formula: Weight [kg]/height^2 [m^2]. The CDC defines the BMI percentage range 85-95% as overweight and over 95% as obese during childhood and adolescence.[19-21] In our study, the percentage curve defined for Turkish children was used, and the ones with BMI < 5 were accepted as underweight, 5-84 as normal, 85-95 as overweight and BMI > 95 as obese.

The evaluation of the neuromotor status of children was done based on the DDST II score. This test was developed by Frankenburg, Dodds, Fandal, Kazuk and Cohrs (1967) in order to help medical personnel detect developmental problems in children. The test was reviewed in 1990 and the Denver II was then created. The first standardization of the Denver Developmental Screening Test in Turkey was done in 1987 by Yalaz and Epir. The test-retest reliability of the Turkish version is 89%, while inter-rater liability is 95%.[22,23]

Denver II consists of 121 items and assesses four development areas, including the children's personal, social, fine and gross motor and language skills. There are five "Test Behavior" items at the end, which help the test screener assess how children use their behavior and skills. Each item is scored according to a combination of answers by the caregivers, the child's evaluation and observation. Children are assessed as a result of the performed test and in accordance with their total score by dividing them into four defining classes as normal, abnormal, suspect and untestable. While forming these groups, caution and delay of children's motor performance were taken into consideration. The caution concept in DDST II can be explained as follows: children who are to the left of the age line or on more than one item intersected by the age line in the area of 75-90% or refusing to perform those items get a caution point. The reason is that in the standardization sample more than 75% of the children were able to perform this task earlier than the surveyed child. A delay is indicated when a child fails or refuses an item that falls completely to the left of the age line or when a child refuses to fulfill that task. This indicates that the child has failed an item that 90% of children in the standardization sample passed at an earlier age. In light of this information, children who were included in the normal group in terms of his/her development have no delays and a maximum of one caution. On the other hand, children with one delay and/or two or more cautions have been included in the suspect group. Children with two or more delays were allocated into the abnormal development group. The age line of children is drawn in the test form from top to bottom. Age scales located on the top and bottom of the test scale show the ages from 15-day to 6 years. Every test item is shown with a horizontal rectangle on the test scale. If the child shows normal development in terms of behavior, he/she will pass. If abnormal development is detected, the child will fail, and if the child refuses to attempt the requested task, this will be evaluated as a refusal.[23]

The identification of children to be included in the study was done according to the following conditions: major congenital malformation absence, being a singleton, not having been born premature, dysmature and malnourished, lack of chronic illness, lack of metabolic disorders, not having been exposed to surgical intervention for any reason, and having considered to get the consent of families whose children have participated in the study. Furthermore, children who have refused to perform the test have not been included in the study. This study is limited to data obtained from 916 children who were at the kindergarten in Çorum, were available, and included in the study.

Statistical analysis

In the data evaluation, the SPSS (Version 22.0, SPSS Inc., Chicago, IL, USA; license, Hitit University) software was used. Hemoglobin and BMI values were presented to the neuromotor development groups as average±standard deviation (SD). The relation between neuromotor development groups and BMI, as well as hemoglobin levels, was investigated using Chi-square analysis. $p<0.05$ was accepted as a statistically significant level.

Results

Our study included 916 children, comprising 428 girls and 488 boys. DDST II has been analyzed in two sections by dividing it into a normal group and an abnormal-suspect group. Of the examined children, 19% were allocated into the suspect-abnormal group based on their DDST II scores for personal-social (4.6%), fine motor (5.9%), language (6.6%) and gross motor (9.1%) categories (Table 1).

While the hemoglobin average of 5-6 years old children who participated in the study was 11.94±0.84, 29.8% of children were found to be anemic (Table 1, Figure 1). Our study did not show any child with severe or moderate anemia. In Table 1, DDST II distribution results are given according to the hemoglobin value. When comparing the personal-social, fine motor, language and gross motor test results of DDST II separately with hemoglobin values, no statistically significant difference was seen ($p>0.05$). 21% of the children without anemia were allocated into the suspect-abnormal group, whereas 15% of the anemic children were also in the same group. Furthermore, it has been proven that total score of DDST II compared with hemoglobin values of the children shows a statistically significant difference according to the neuromotor development of children with and without anemia ($p<0.05$; Figure 1).

The average BMI of the surveyed children was 16.33±2.27, and it has been determined that 39.6% were normal, 8.2% were overweight, and 24.7% were obese. The distribution of DDST II results according to BMI is given in Table 2. Fourty-six (46) out of 252 underweight children, 63 out of 363 children with normal weight, 16 out of 75 overweight children and 49 out of 226 obese children were ranked in the suspect-abnormal group. Furthermore, it was seen that the total score of DDST II is statistically significant according to their BMI ($p<0.05$; Figure 2).

We have found a rate of underweight children of 27.5% in our study. Our study shows that 26.4% of suspect-abnormal children were underweight (Figure 2). However, being underweight did not prove to lead to significant changes in neuromotor development of children ($p>0.05$).

Discussion

The data which we have obtained from our study shows that obesity is affecting neuromotor development in a negative way according to the total score of DDST II, while mild anemia has a positive effect on neuromotor development.

Growth retardation is shown as one of the most common problems in children within the first 6 years of life, and there is a growth retardation rate of 12-16% during childhood.[24] As developmental disorders may pass unnoticed during regular inspections, especially in early childhood, it is necessary to perform a standard assessment in order to diagnose growth retardation. For this reason, developmental screening tests have to be used for the age group 0-6.[25-27] In light of these findings, the standardized DDST II, which provides information about a child's personal-social, fine motor, language and gross motor features, was used. In total, 19% of the 5-6 year-olds in our study were allocated into the suspect-abnormal group

TABLE 1 Distribution according to the hemoglobin values of DDST II results (N=916).

		n	%	X±SS	Median	Minimum	Maximum
Personal-social	Normal	874	95.4	11.93±0.83	12.00	8.60	15.70
	Suspect	20	2.2	12.11±0.92	12.30	10.00	13.50
	Abnormal	22	2.4	12.01±0.97	12.00	10.00	13.90
Fine motor-adaptive	Normal	862	94.1	11.94±0.84	12.00	8.60	15.70
	Suspect	47	5.1	12.01±0.69	12.00	10.10	13.40
	Abnormal	7	0.8	11.62±0.86	12.00	10.20	12.60
Language	Normal	855	93.3	11.93±0.84	12.00	8.60	15.70
	Suspect	47	5.1	12.05±0.76	12.10	10.10	13.70
	Abnormal	14	1.5	12.17±0.78	12.05	10.80	13.50
Gross motor	Normal	833	90.9	11.92±0.84	12.00	8.60	15.70
	Suspect	54	5.9	12.57±0.72	12.15	10.70	14.20
	Abnormal	29	3.2	12.10±0.88	12.10	10.00	12.50
Total	Normal	742	81	11.92±0.84	11.90	8.60	15.70
	Suspect	101	11	12.04±0.82	12.10	10.00	14.20
	Abnormal	73	8	12.02±0.86	12.00	10.00	13.90
	Total	916	100	11.94±0.84	12.00	8.60	15.70

due to their total DDST II score (Table 1). It was reported that in the study performed by Güven et al.,[26] 25.7% of the 0-6 age group of children were in the abnormal and suspect group. The study published by Doğan and Baykoç[27] shows that 19.45% of 5-6 year-old children were in the abnormal and suspect group, which is in line with our research findings. Our study included preschool children and comprised a large sample to represent all children in this age group. It is reported that early identification of developmental delays is kept equivalent with early treatment and is helping to reduce loss of function and secondary behavioral problems.[28] Children with identified developmental delays in our study were referred to the departments responsible for the provision of early treat-

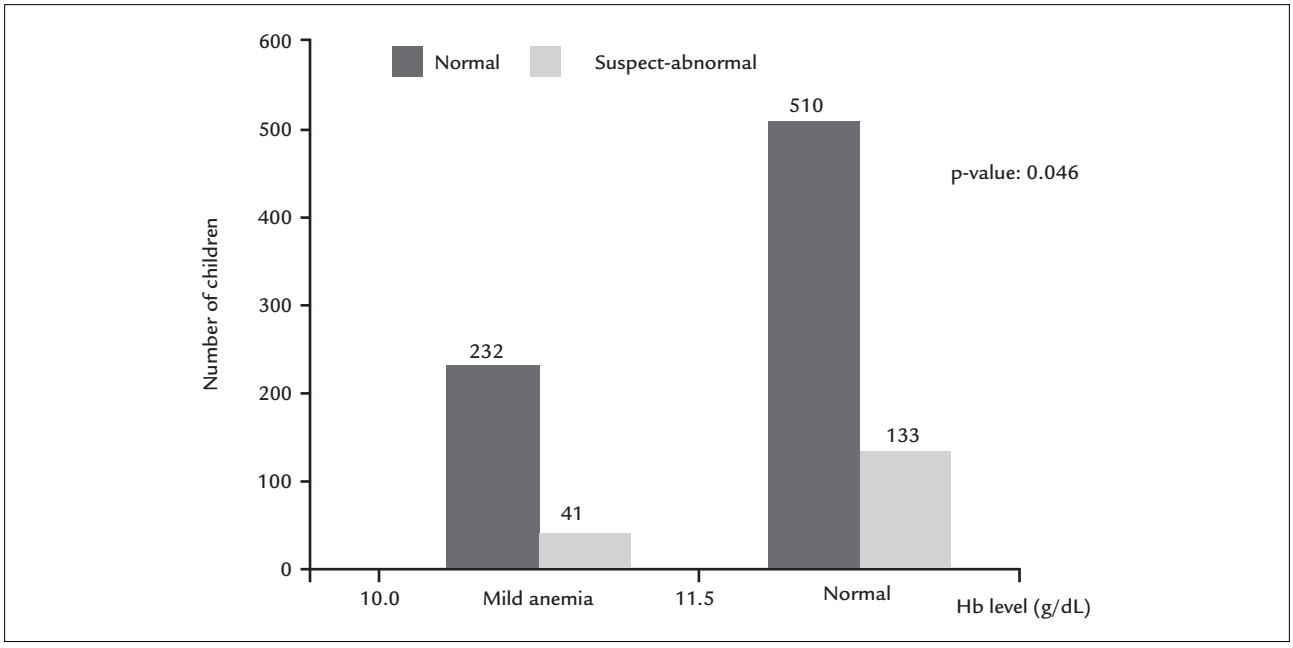

FIGURE 1 Comparison between total score of DDST II and hemoglobin levels (N=916).

TABLE 2 Distribution according to body mass index (BMI) of DDST II results (N=916).

		n	X±SS	Median	Minimum	Maximum
Personal-social	Normal	874	16.35±2.28	15.99	8.33	26.59
	Suspect	20	15.49±2,53	16.54	8.46	19.01
	Abnormal	22	16.47±1.74	16.15	13.55	20.14
Fine motor-adaptive	Normal	862	16.31±2.29	15.97	8.33	26.59
	Suspect	47	16.61±2.08	16.53	13.19	22.31
	Abnormal	7	16.57±2.16	16.74	14.05	19.44
Language	Normal	855	16.33±2.80	16.00	8.33	26.59
	Suspect	47	16.15±2.05	15.90	13.10	23.00
	Abnormal	14	16.75±3.00	16.67	12.31	23.97
Gross motor	Normal	833	16.30±2.28	15.94	8.33	26.59
	Suspect	54	17.20±2.02	16.97	13.22	23.58
	Abnormal	29	15.55±2.23	16.07	8.46	19.01
Total	Normal	742	16.32±2.30	15.94	8.33	26.56
	Suspect	101	16.40±2.14	16.16	12.40	23.58
	Abnormal	73	16.30±2.27	16.53	8.46	23.97
	Total	916	16.33±2.27	16.00	8.33	26.59

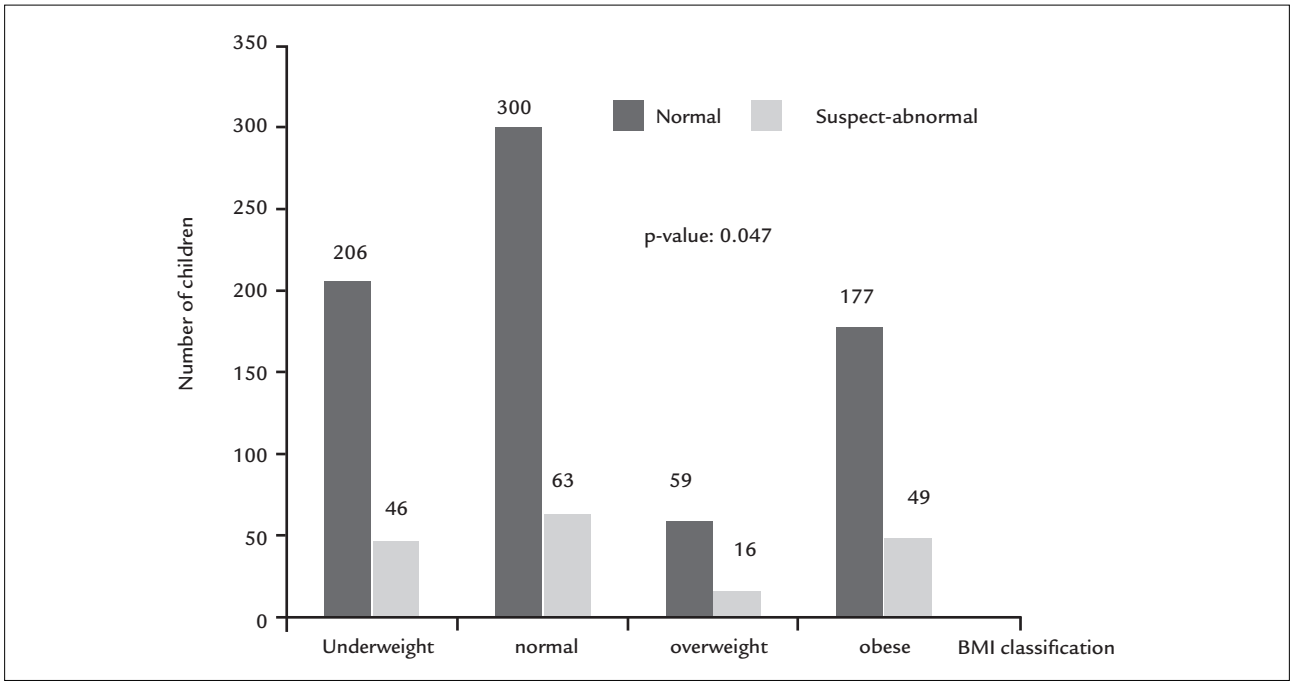

FIGURE 2 Comparison between total score of DDST II and body mass index (N=916).

ment, which shows the importance of our study in terms of social contribution.

Anemia is defined as having a hemoglobin value under -2 SD according to age group.[3] Anemia is commonly reported all over the world and should be monitored by screening programs due to more severe effects in infancy.[29]

Out of 2,872 4-6 year-old children, 3.4% surveyed by Karagün et al. were determined to be anemic.[30] In the retrospective study conducted in Balıkesir (Turkey), 563 children between the ages of 0 to 18 were investigated and the frequency of anemia among 5-7 year-old children was found at 13.6%.[31] In our study, 5-6 years old children have been taken into consideration and all of those with a value of 11.5 g/dL or lower were considered anemic. Based on the non-invasive evaluation, it was determined that the hemoglobin average of 916 children is 11.94±0.84 (Table 1). Furthermore, it was seen that 29.8% (n=273) of children who participated in the study have a hemoglobin value of ≤ 11.5 g/dL (Figure 1). The high incidence of anemia in our study reveals the importance of follow-up with anemia screening programs in the preschool period, and treatment support.

Anemia is a disease that has an impact on biochemical processes, cellular function, growth and development, mental and behavioral development, the immune system, physical capacity, thermoregulation and many hematologic and non-hematologic systems, such as the gastrointestinal tract.[30-33] According to conducted studies, the decrease of one unit in hemoglobin in a child increases the mild to moderate mental retardation risk 1.28 times. Even if these children get treated, their Bayley test scores (used for developmental follow-up) will still be low after ten years.[34] Furthermore, it is emphasized that early diagnosis and treatment of anemia is very important due to anemia's significant effects on children's growth, development and cognitive functions.[31] The relation of total DDST II score between anemic and non-anemic 5-6 year-old children was found to be statistically significant ($p<0.05$; Figure 1). Additionally, it was determined that 21% of non-anemic and 15% of the anemic children was in the suspect-abnormal group according to their DDST II scores. Considering that children who participated in our study did not show any severe or moderate anemia, our study's results show that the neuromotor development of children with mild anemia is better than that of children without anemia. While some published studies[35,36] support neurogenesis of physiological hypoxia (3% O_2), they reported that anoxia (< 1% O_2) and severe hypoxia (1% O_2) have negative effects. Data obtained by our study reveals that mild hypoxia may have positive effects on neuromotor development. In order to explain the mechanisms behind this, new studies must be conducted.

In terms of growth and development, the age range 3 to 6 years is an important period. As for body adiposity, the preschool period is of great importance. While

the amount of adipose tissue decreases after infancy until the age of 6-8 years, it than increases thereafter. This early adiposity increase poses a big risk with regard to obesity.[21] The BMI average of 916 children within our study was determined at 16.33±2.27 (Table 2); 8.2% of these were overweight and, 24.7% were obese (Figure 2). In addition to obesity, protein energy deficiency is a very common nutritional problem among pre-school children in our country. Nevertheless, our study revealed that being underweight does not have a significant impact on the children's neuromotor development. The relationship between the children's BMI and DDST II total scores was considered statistically significant, and we found that 26.4% of the suspect-abnormal children were underweight, 36.2% were normal, 9.2% were overweight and 28.2% were obese (Figure 2).

As a result, mild anemia seems to present a positive effect on neuromotor development, while malnutrition may have a negative impact on children's neuromotor development. To investigate the underlying causes of the relationship between neuromotor development and malnutrition, further studies are required. In addition, new studies also are needed to evaluate the effects of severe or moderate anemia on neuromotor development. Raising awareness in families regarding anemia, malnutrition and neuromotor development is expected to provide a positive contribution in terms of early diagnosis and treatment of diseases.

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Conflict of interest

The authors declare no conflict of interest.

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