

Association between Leptin, Adiponectin Levels, and Nutritional Status in Children with Down Syndrome

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Abstract: *Background:* Children with Down Syndrome (DS) have been associated with obesity. Leptin and adiponectin were also significant predictors of obesity and its comorbidity in DS. However, there was limited data regarding leptin and adiponectin in children with DS, particularly who were undernutrition. This study aimed to seek the role of leptin levels, adiponectin levels, and nutritional status in children with DS.

Methods: This cross-sectional study was conducted on 40 children with DS aged 1 - 5 years. Height and weight were measured, and then the growth was interpreted using a DS growth chart. The Weight for Height Z-Score (WHZ) and Height for Age Z-Score (HAZ) were determined, and Mid-Upper Arm Circumference (MUAC) was measured. Leptin and adiponectin serum were analyzed using the enzyme-linked immunosorbent assay (ELISA) method. Mann-Whitney test was done to compare leptin and adiponectin levels in normal and wasted groups, while Spearman's analysis was carried out to correlate laboratory results and anthropometric parameters.

Results: Forty children participated (23 males, 17 females) with a median age was 25.5 months. Ten out of 40 children with DS (25%) were wasted and leptin was significantly lower in wasted compared to normal children. In addition, leptin was significantly correlated with WHZ ($r = 0.415$; $p = 0.008$), and MUAC ($r = 0.427$; $p = 0.006$), while adiponectin did not significantly correlate with those anthropometric variables in both wasted or non-wasted groups.

Conclusion: Leptin is associated with WHZ and MUAC, and it decreases in wasted children with DS.

Keywords: Adiponectin, Down syndrome, leptin, nutritional status, wasted, young children.

1. INTRODUCTION

Down Syndrome (DS) is a genetic abnormality that CDC predicts occurs in 1 baby in every 691 babies born in the USA. Children who are born with DS have associated comorbidities such as congenital heart defects, hypotonia, feeding and swallowing difficulties, hypothyroidism, and an increased risk of recurrent infection and autoimmune disorders [1,2]. Compared to typical children, DS children tend to have a short stature, small head circumference, and higher Body Mass Index (BMI). Around 23% - 70% of children and adolescents with DS are overweight or obese [3,4]. However, due to congenital heart defects, oral motor difficulties, and pharyngeal dysphagia, younger children with DS would develop a condition of failure to thrive in early life [2,5,6]. A retrospective study of obesity in children with DS also reported BMI Z-scores significantly increased in those over 12 years old, and

age did not significantly associate with BMI Z-scores in DS children ages 2-7 [7].

In previous studies, leptin was significantly higher, while adiponectin was significantly lower in children with DS compared to typical non-obese children [8,9]. Leptin and adiponectin are two biochemical compounds produced by fat cells in white adipose tissue, and they are associated with metabolic syndrome, more specifically, obesity and insulin resistance. A higher concentration of leptin is found in overweight and obese individuals. Among those populations, its receptor becomes resistant to leptin, [10] which is characterized by increased appetite, reduced satiety, over-consumption of nutrients, decreased metabolism, and increased total body mass [11-13]. Higher adiponectin is associated with higher insulin sensitivity [14]. Adiponectin improves energy homeostasis by increasing fatty acid oxidation and glucose utilization in skeletal muscle and inhibiting gluconeogenesis in the liver. Adiponectin also acts as an anti-inflammatory agent which protects the heart, lungs, vascular system, and colon [15]. In

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malnourished children, serum leptin was lower than those in normal-weight children because of losing adipose tissue [16]. Low leptin levels would disturb the metabolic, endocrine, and immune systems [17]. Several factors could interfere with leptin concentration, such as glucose, estrogens, inflammatory cytokines, thyroid hormones, and androgens [18]. A previous study concluded that leptin is not only affected by fat mass. It is also affected by reproductive hormones, as the study found higher leptin in adolescents with rapid weight gain during their 0-18 months of life [19].

Although some studies mentioned the involvement of leptin and adiponectin in older children and adolescents with DS, there are limited data and descriptions on these hormones in younger malnourished children with DS. Therefore, this study aimed to determine the correlation between leptin and adiponectin levels and nutritional status in young children with DS.

2. MATERIAL AND METHODS

2.1. Study Design & Participants

A cross-sectional study with a consecutive sampling method was conducted on 40 children with DS. A correlation sample size calculation was applied using the alpha and beta of 0.20, with the reference *r* value 0,335, and the result of the minimum sample value is 39 children [20]. The inclusion criteria were children aged 1 – 5 years old who were clinically diagnosed with DS by an experienced pediatrician (AU) from three hospitals in Central Java Province (Dr. Kariadi Hospital, Semarang; Diponegoro National Hospital, Semarang and R. Soedjati Soemodiarjo Hospital, Purwodadi). Children who have severe acute illnesses were excluded. This study was approved by the Ethical Committee (No.100/EC/KEPK/FK-UNDIP/VI/2020), and written consent was obtained from parents or caregivers prior to the study.

2.2. Research Procedure

Demographic characteristics, history taking, and physical examination were done by an experienced pediatrician in managing Down Syndrome (AU). Body length/ height was measured using SECA 417 infantometer for children below two years and the SECA 213 stadiometer for children aged two years and older. Body weight was measured using AND UC-322 weight scale, and mid-upper arm circumference (MUAC) was also measured. Anthropometric data was

then calculated, including Weight for Height Z Score (WHZ) and Height for Age Z-score (HAZ), using the Peditools calculator for children with Down Syndrome [3] (accessible at <https://peditools.org/downpedi/>) to assess nutritional and growth status. The nutritional status was divided according to the WHZ cut-off. MUAC was compared using the cut-off point of 13.5 cm (see Table 1) [21]. For variable analysis, the WHZ classification of nutritional status was simplified into two categories (WHZ ≥ -2 or higher considered normal weight (normoweight) and below -2 SD considered wasted).

Table 1: Nutritional Status Cutoff

Variables	Interpretation
WHZ	
< - 3 SD	Severely Wasted
- 3 \leq SD < -2	Wasted
- 2 \leq SD < 2	Normal
2 \leq SD < 3	Overweight
≥ 3 SD	Obese
MUAC	
≥ 13.5 cm	Normal
< 13.5 cm	Wasted

2.3. Leptin and Adiponectin Assay

Peripheral blood vein was obtained in the morning from all participants before the first meal. Three mL of blood vein was collected and then centrifuged with 1000 G force for 15 minutes. The serum was then aliquoted and stored at -20°C temperature before assay. Leptin and adiponectin levels were measured from the blood's serum using Enzyme-Linked Immunosorbent Assay (ELISA) by DRG[®] Leptin Sandwich ELISA for Leptin and Quantikine[®] ELISA for Adiponectin. All the laboratory procedures were done at GAKI laboratory, Faculty of Medicine, Diponegoro University, Semarang.

2.4. Statistical Analysis

Data were analyzed using SPSS version 25 (SPSS, Chicago, IL). The Shapiro-Wilk normality test was used to determine the data distribution. We found that our data were not normally distributed, so we provided our data in the median, minimum-maximum values, and interquartile range. A comparison between nutritional status and laboratory data was carried out using Mann-Whitney's analysis. The correlation between leptin and adiponectin was calculated, and thus, between laboratory parameters and WHZ, HAZ, and MUAC. All

Table 2: Participant Characteristics (n=40)

Variables	Results
Gender	
Male	23 (57,5%)
Female	17 (42,5%)
Nutritional Status	
Normal	30 (75%)
Wasted	6 (15%)
Severely Wasted	4 (10%)
MUAC	
13.5 cm or higher	29 (72.5%)
Below 13.5 cm	11 (27.5%)
Age (months)	25.5 (12 – 56; 18)
BMI	14.95 (12.27 – 21.30 ;1.82)
HAZ	- 0.1 (-1.50 – 1.78; 1.35)
WHZ	-1.36 (-3.65 – 1.98; 1.35)
MUAC (cm)	14.45 (11.5 – 19.7; 2.10)

Note: Results are shown in n (%) for categorical variable and median (min-max; interquartile range) for continuous variable. MUAC: Mid Upper Arm Circumference, BMI: Body Mass Index. HAZ: Height-for-Age Z-Score, WHZ: Weight-for-Height Z-Score.

correlation analyses were done using Spearman's rho non-parametric analysis. Statistical significance was defined as p values < 0.05.

3. RESULT

A total of 40 children with DS were included in this study (23 males, 17 females), with a median age was 25.5 months (12 – 56). Most of the participants (75%) were normoweight, and only ten children (25%) were wasted (WHZ < -2 SD) (see Table 2). Leptin concentration varied between 0.53 – 15.6 ng/mL, while adiponectin levels ranging from 7.82 to 11.19 µg/mL.

Leptin was found to be significantly higher in normoweight children with DS, but there was no significant difference in adiponectin levels (see Table 3).

Leptin was correlated with WHZ score and MUAC but not with HAZ; however, adiponectin did not significantly correlate with any of the measured three variables (see Figure 1).

4. DISCUSSION

In this study, 25% of the participant was classified as wasted, one of the malnutrition parameters. No DS children were found with overweight or obese. This finding is different from previous studies, as most of them found that children or adults with DS had a more significant risk of being overnourished [3,8]. Children with DS were more likely to become obese as they grew, and studies regarding obesity in children with DS involved children and adolescents of a wide range of ages, so the young age of our patients may be a contributing factor. However, in DS, hypotonia can lead to feeding and swallowing problems, such as masticatory dysfunction and aspiration. These will eventually hinder nutritional intake [5,22].

In our study, despite non-overweight nutritional status, leptin was still positively correlated with WHZ. Leptin level was also higher in normoweight children, compared with underweight children. This finding was similar to another study that found significantly lower leptin levels in malnourished children [16]. Leptin was widely known to correlate with adiposity, increased appetite, and obesity [5,9,10]. In children with DS, leptin was also correlated with obesity and lipid profiles. A previous study also found a higher concentration of leptin in children with DS than in their siblings [9]. Our study did not compare DS with the control group. However, we also found the median leptin value in children in normoweight DS children was 2.01 ng/mL, which this value was similar to the study from Tenneti

Table 3: Leptin and Adiponectin in Normal and Wasted Groups

Variables	Normal (n = 30) Median (min-max; IQR)	Wasted (n = 10) Median (min-max; IQR)	Total (n = 40) Median (min-max; IQR)	p*
Leptin (ng/mL)	2.01 (0.67 – 15.6; 2.54)	1.11 (0.53 – 2.68; 0.88)	1.79 (0.53 – 15.6; 1.84)	0.031
Adiponectin (µg/mL)	10.26 (7.82 – 11.18;1.34)	10.07 (8.40 – 11.19; 0.84)	10.23 (7.82 – 11.19; 0.85)	0.963

Note: IQR = interquartile range. *Mann-Whitney Test (p < 0.05).

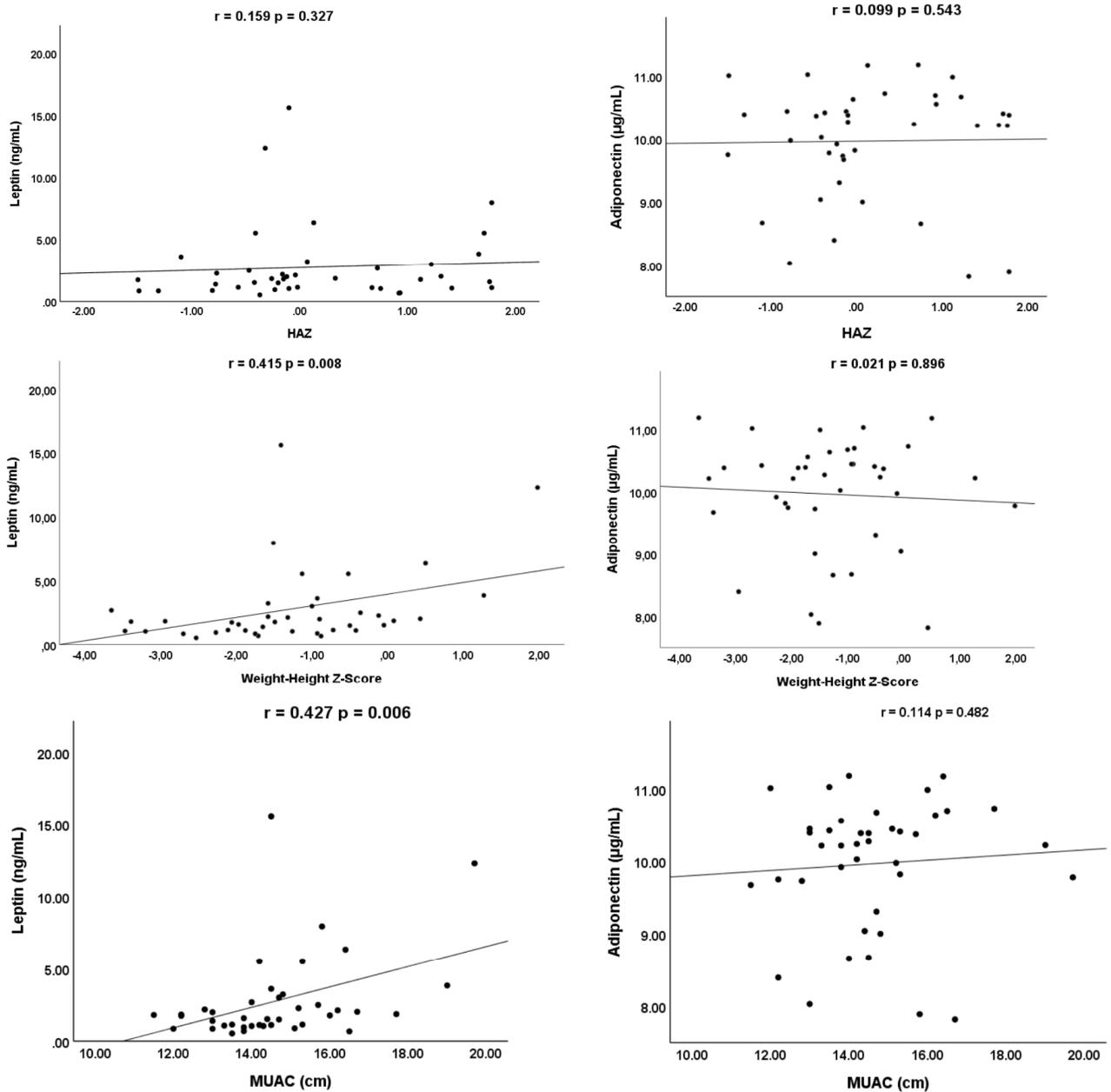


Figure 1: The correlation between leptin levels, adiponectin level, and nutritional status in all subjects (n=40).

*Spearman’s rho correlation test (significant if p < 0.05).

et al., who found the mean leptin value in DS children was 2.0 ng/mL [8]. The exact mechanism of increased leptin in normoweight children with DS is not yet known, but it may be caused by the genetic defect children with DS have [12]. Another study in Oregon stated an increasing rate of overweight and obesity in children with DS as children get older [23]. This finding can explain our findings regarding the significant correlation in leptin with WHZ despite the children being normoweight or undernourished. However, it should be considered that low leptin levels could affect the secretion of growth hormones and growth factors,

leading to growth retardation [24,25]. Leptin deficiency will also affect bone growth. A study in the mice model suggested a significant inhibition of chondrogenesis in the tibial plate in leptin-deficient mice [26]. In contrast, the same study also found that vertebral chondrogenesis was not inhibited by leptin deficiency. However, this would still decrease total bone mass, as appendicular bones contribute 80% of total bone mass [27].

Our study found a positive correlation between leptin level and arm circumference. As one of the

primary anthropometric measurements done routinely, arm circumference correlates to higher BMI and obesity [14,15]. Furthermore, arm circumference has been used as one variable for predicting weight in children. The measurement of arm circumference and humeral length used in Mercy TAPE is the most accurate way to predict the children's weight, with no exception for children with Down Syndrome [17,28]. MUAC has also been used as a useful screening tool for diagnosing malnutrition, particularly in the community. Moreover, a study found that MUAC > 12.5 cm had high sensitivity and specificity for diagnosing malnutrition and monitoring its treatment [29]. A study also explains that a component of MUAC measurement, specifically Total Arm Area (TAA), significantly correlated with BMI, as both represent body fat composition. They also mentioned that MUAC was better at diagnosing chronic malnutrition when compared to BMI [30]. Those studies support our finding that increased arm circumference refers to a higher fat mass, which might also increase leptin levels in children with DS despite their non-obese status.

In contrast with leptin, obesity and metabolic syndrome are associated with a low adiponectin level. A study found that adolescents with DS have a significantly lower adiponectin level than the control group. They also found that adiponectin levels in DS tend to increase during adulthood, serving as a cardioprotective agent [31]. A previous study in Northwest India found lower adiponectin levels in children with DS compared to healthy children, although not statistically significant. They also reported that there is no correlation between adiponectin with BMI in DS and control groups [8]. It is similar to our study, which showed that adiponectin level was not significantly correlated with BMI-Age Z-Score. In another research studying older children with peritoneal dialysis, adiponectin was higher than in children without renal disease. This finding was in line with the lower BMI in the study group. The researcher suggested that the catabolic state of renal failure triggered adiponectin release to increase insulin sensitivity and energy expenditure [32]. In this study, although we found malnourished children, we did not find any severely malnourished children. It may explain our insignificant negative correlation between adiponectin and body composition parameters.

This study had some limitations. We did not thoroughly measure the body composition, especially fat body composition, as leptin and adiponectin are

adipokine and should be correlated with body fat. We also did not measure insulin and insulin resistance, as those two variables could better explain the adipocytokines measured in our study. Finally, this study did not exclude patients with hypothyroidism, congenital heart defect, and other chronic illnesses that may affect leptin and adiponectin levels.

5. CONCLUSION

In conclusion, there is a difference in leptin levels among wasted and normoweight children with DS, but not adiponectin. In addition, leptin correlates with WHZ and MUAC but not HAZ, while adiponectin is not correlated with WHZ, MUAC, and HAZ. Future study is needed to consider detailed body composition measurements such as body fat mass, fat-free mass, visceral fat mass, and skeletal body mass using the dual X-Ray absorptiometry (DXA) method [33]; thus the correlation between leptin and fat composition in children with Down Syndrome can be better analyzed.

ACKNOWLEDGEMENT

We would like to thank GAKI and CEBIOR Faculty of Medicine, Universitas Diponegoro staffs, who helped in the laboratory procedure of this study. We would also like to thank all of the study participants and their respective parents/guardians.

ABBREVIATIONS

BMI	=	Body Mass Index
DS	=	Down syndrome
HAZ	=	Height for Age Z-Score
MUAC	=	Mid-Upper Arm Circumference
WHZ	=	Weight for Height Z-Score

FUNDING

This research was funded by Universitas Diponegoro Grant for International Publication Research (233-13/UN7.6.1/PP/2022).

ETHICAL APPROVAL

This research has been approved by the Ethical Committee of the Faculty of Medicine Diponegoro University (EC number: 100/EC/KEPK/FK-UNDIP/VI/2020).

CONFLICT OF INTERESTS

All authors declare no conflict of interest in this research.

REFERENCES

- [1] Ivan DL, Cromwell P. Clinical Practice Guidelines for Management of Children With Down Syndrome: Part I. *J Pediatr Heal Care* 2014; 28: 105-10. <https://doi.org/10.1016/j.pedhc.2013.05.002>
- [2] Stanley MA, Shepherd N, Duvall N, Jenkinson SB, Jalou HE, Givan DC, et al. Clinical identification of feeding and swallowing disorders in 0-6-month-old infants with Down syndrome. *Am J Med Genet Part A* 2019; 179: 177-82. <https://doi.org/10.1002/ajmg.a.11>
- [3] Zemel BS, Pipan M, Stallings VA, Hall W, Schadt K, Freedman DS, et al. Growth Charts for Children With Down Syndrome in the United States. *Pediatrics* 2015; 136: 1204-11. <https://doi.org/10.1542/peds.2015-1652>
- [4] Bertapelli F, Pitetti K, Agiovlasis S, Guerra-Junior G. Overweight and obesity in children and adolescents with Down syndrome—prevalence, determinants, consequences, and interventions: A literature review. *Res Dev Disabil* 2016; 57: 181-92. <https://doi.org/10.1016/j.ridd.2016.06.018>
- [5] Anil MA, Shabnam S, Narayanan S. Feeding and swallowing difficulties in children with Down syndrome. *J Intellect Disabil Res* 2019; 63: jir.12617. <https://doi.org/10.1111/jir.12617>
- [6] Nordstrøm M, Retterstøl K, Hope S, Kolset SO. Nutritional challenges in children and adolescents with Down syndrome. *Lancet Child Adolesc Heal* 2020; 4: 455-64. [https://doi.org/10.1016/S2352-4642\(19\)30400-6](https://doi.org/10.1016/S2352-4642(19)30400-6)
- [7] Basil JS, Santoro SL, Martin LJ, Healy KW, Chini BA, Saal HM. Retrospective Study of Obesity in Children with Down Syndrome. *J Pediatr* 2016; 173: 143-8. <https://doi.org/10.1016/j.jpeds.2016.02.046>
- [8] Tenneti N, Dayal D, Sharda S, Panigrahi I, Didi M, Attri SV, et al. Concentrations of leptin, adiponectin and other metabolic parameters in non-obese children with Down syndrome. *J Pediatr Endocrinol Metab* 2017; 30. <https://doi.org/10.1515/jpem-2016-0422>
- [9] Magge SN, O'Neill KL, Shults J, Stallings VA, Stettler N. Leptin Levels among Prepubertal Children with Down Syndrome Compared with Their Siblings. *J Pediatr* 2008; 152: 321-6. <https://doi.org/10.1016/j.jpeds.2007.08.008>
- [10] Mazurek D, Wyka J. Down syndrome—genetic and nutritional aspects of accompanying disorders. *Rocz Panstw Zakl Hig* 2015; 66: 189-94.
- [11] Sáinz N, Barrenetxe J, Moreno-Aliaga MJ, Martínez JA. Leptin resistance and diet-induced obesity: Central and peripheral actions of leptin. *Metabolism* 2015; 64: 35-46. <https://doi.org/10.1016/j.metabol.2014.10.015>
- [12] Farr OM, Gavrieli A, Mantzoros CS. Leptin applications in 2015. *Curr Opin Endocrinol Diabetes Obes* 2015; 22: 353-9. <https://doi.org/10.1097/MED.0000000000000184>
- [13] Obradovic M, Sudar-Milovanovic E, Soskic S, Essack M, Arya S, Stewart AJ, et al. Leptin and Obesity: Role and Clinical Implication. *Front Endocrinol (Lausanne)* 2021; 12. <https://doi.org/10.3389/fendo.2021.585887>
- [14] Yadav A, Kataria MA, Saini V, Yadav A. Role of leptin and adiponectin in insulin resistance. *Clin Chim Acta* 2013; 417: 80-4. <https://doi.org/10.1016/j.cca.2012.12.007>
- [15] Fang H, Judd RL. Adiponectin Regulation and Function. *Compr. Physiol.*, Wiley 2018; pp. 1031-63. <https://doi.org/10.1002/cphy.c170046>
- [16] Akib RD, Aminuddin A, Hamid F, Prihantono P, Bahar B, Hadju V. Leptin levels in children with malnutrition. *Gac Sanit* 2021; 35(Suppl 2): S278-80. <https://doi.org/10.1016/j.gaceta.2021.10.033>
- [17] Blüher S, Shah S, Mantzoros CS. Leptin Deficiency. *J Investig Med* 2009; 57: 784-8. <https://doi.org/10.2310/JIM.0b013e3181b9163d>
- [18] Kelesidis T, Kelesidis I, Chou S, Mantzoros CS. Narrative review: the role of leptin in human physiology: emerging clinical applications. *Ann Intern Med* 2010; 152: 93-100. <https://doi.org/10.7326/0003-4819-152-2-201001190-00008>
- [19] Samaranayake D, Lanerolle P, Waidyatilaka I, de Lanerolle-Dias M, Hills AP, Wickremasinghe AR, et al. Association between early weight gain and later adiposity in Sri Lankan adolescents. *J Dev Orig Health Dis* 2021; 12: 250-9. <https://doi.org/10.1017/S2040174420000331>
- [20] Hulley S, Cummings S, Browner W, Grady D, Newman T. *Designing Clinical Research: An Epidemiologic Approach*. 4th edn. Philadelphia: Lippincott Williams & Wilkins 2013.
- [21] World Health Organization. *Training Course on Child Growth Assessment* 2008.
- [22] Faulks D, Collado V, Mazille M-N, Veyrune J-L, Hennequin M. Masticatory dysfunction in persons with Down's syndrome. Part 1: aetiology and incidence. *J Oral Rehabil* 2008; 35: 854-62. <https://doi.org/10.1111/j.1365-2842.2008.01877.x>
- [23] Pierce M, Ramsey K, Pinter J. Trends in Obesity and Overweight in Oregon Children With Down Syndrome. *Glob Pediatr Heal* 2019; 6: 2333794X19835640. <https://doi.org/10.1177/2333794X19835640>
- [24] Soliman AT, ElZalabany MM, Salama M, Ansari BM. Serum leptin concentrations during severe protein-energy malnutrition: correlation with growth parameters and endocrine function. *Metabolism* 2000; 49: 819-25. <https://doi.org/10.1053/meta.2000.6745>
- [25] Beghini M, Brandt S, Körber I, Kohlsdorf K, Vollbach H, Lennerz B, et al. Serum IGF1 and linear growth in children with congenital leptin deficiency before and after leptin substitution. *Int J Obes (Lond)* 2021; 45: 1448-56. <https://doi.org/10.1038/s41366-021-00809-2>
- [26] Yu B, Jiang K, Chen B, Wang H, Li X, Liu Z. Leptin differentially regulates chondrogenesis in mouse vertebral and tibial growth plates. *BMC Musculoskelet Disord* 2017; 18: 235. <https://doi.org/10.1186/s12891-017-1601-6>
- [27] Chen XX, Yang T. Roles of leptin in bone metabolism and bone diseases. *J Bone Miner Metab* 2015; 33: 474-85. <https://doi.org/10.1007/s00774-014-0569-7>
- [28] Kilic M, Taskin E, Ustundag B, Aygun AD. The evaluation of serum leptin level and other hormonal parameters in children with severe malnutrition. *Clin Biochem* 2004; 37: 382-7. <https://doi.org/10.1016/j.clinbiochem.2003.12.010>
- [29] Mogendi JB, De Steur H, Gellynck X, Saeed HA, Makokha A. Efficacy of mid-upper arm circumference in identification, follow-up, and discharge of malnourished children during nutrition rehabilitation. *Nutr Res Pr* 2015; 9: 268-77. <https://doi.org/10.4162/nrp.2015.9.3.268>
- [30] Muñoz Esparza NC, Vasquez-Garibay EM, Larrosa Haro A, Romero Velarde E. Relationship of anthropometric indexes and indicators of body composition by arm anthropometry on hospitalized pediatric patients. *Nutr Hosp* 2019; 36: 611-7. <https://doi.org/10.20960/nh.2309>
- [31] Nixon DW. Down Syndrome, Obesity, Alzheimer's Disease, and Cancer: A Brief Review and Hypothesis. *Brain Sci* 2018; 8. <https://doi.org/10.3390/brainsci8040053>

- [32] Kamariski M, Biscardi M, Cestino L, Miatello R, Guntsche E, Valles PG. Adiponectin in children on peritoneal dialysis: relationship to insulin resistance and nutritional status. *Nephron Clin Pract* 2009; 113: c24-32.
<https://doi.org/10.1159/000228072>
- [33] Weber DR, Leonard MB, Zemel BS. Body composition analysis in the pediatric population. *Pediatr Endocrinol Rev* 2012; 10: 130-9.

Received on 20-07-2022

Accepted on 27-10-2022

Published on 15-12-2022

<https://doi.org/10.6000/2292-2598.2022.10.06.5>

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