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Iron Deficiency Anemia and its Association with Overweight and/or Obesity among In-School Adolescents in Addis Ababa, Ethiopia; A Cross Sectional Study

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Received: August 28, 2023; **Published:** September 22, 2023

Abstract

Background: Iron Deficiency Anemia (IDA) is a global public health problem in school aged children and adolescents affecting their psychomotor development and cognitive performance. Nonetheless, the magnitude of the problem among overweight and obese individuals is felt a gap in Ethiopian context. We therefore examined the issue under caption to generate evidences for some programmatic initiatives.

Methods: A School based, cross-sectional study was conducted among 363 high school adolescents in Addis Ababa from March to April 2019. A multi-stage random sampling procedure was followed and Interviewer-administered questionnaire was used to collect socio-demographic, economic, dietary and anthropometric data. In addition, venous blood was collected for determination of serum iron, CRP and complete blood count. The anthropometric data were converted into nutritional indices using WHO Anthro-plus software. The data were then cleaned, coded, and entered into SPSS software for windows version 20 for analysis. Binary logistic regression model was employed to identify the prediction of IDA. A 5% significance level was used for the inferential statistics to guide statistical significance with 95%CI of the crude and adjusted odds ratio.

Result: The magnitude of anemia, iron deficiency and IDA was 12.9%, 16.3% and 7.4%, respectively. The proportion of mild, moderate and severe anemia was 78.7%, 19.1% and 2.1%, respectively. The proportion of anemia was significantly higher among overweight/obese adolescents than those who had normal weight (AOR = 4.2; 95% CI = 1.21 - 17.29). Consumption of meat, egg and fish ≥ once per day (AOR = 0.13; 95% CI = 0.02 - 0.88), daily snack consumption (AOR = 4.7; 95% CI = 1.10 - 21.7), and duration of menses ≥ 5 days/month (AOR = 4.4; 95% CI = 1.13 - 21.2) were also associated with occurrence of IDA in this age groups.

Conclusion: IDA is a mild public health problem in-school adolescent and was significantly associated with overweight and/or obesity. To reduce the problem under caption, a multi-sectorial approach involving health, nutritional and educational sectors through targeting the above predictors through appropriate nutrition counseling, early detection of the problem and treatment of anemia is recommended.

Keywords: *In-School Adolescents; Iron Deficiency Anemia; Overweight/Obesity; Predictors; Ethiopia*

Abbreviations

AACAEB: Addis Ababa City Administration Education Bureau; AAU: Addis Ababa University; AOR: Adjusted Odd's Ratio; BAZ: BMI for Age Z-score; CDC: Center of Disease Control and Prevention; COR; Crude Odds Ratio; CSA: Central Statistics Agency; CI: Confidence Interval;

DBM: Double Burden of Malnutrition; DDS: Dietary Diversity Score; EDHS: Ethiopian Demographic and Health Survey; ENMS: Ethiopian National Micronutrient Survey; FERR: Ferritin; FFQ: Food Frequency Questionnaire; FMOH: Federal Ministry of Health; Hg: Hemoglobin; ID: Iron Deficiency; IDA: Iron Deficiency Anemia; IP: Intestinal Parasite; SOPs: Standard Operating Procedures; SPSS: Statistical Package for Social Sciences; STFR: Soluble Transferrin Receptor; WHO: World Health Organization

Background

The coexistence of under and over nutrition referred to double burden of malnutrition (DBM) existing at an individual level is overweight/obesity and Iron Deficiency Anemia (IDA) [1]. Anemia is established when the Hemoglobin (Hg) is below the cutoff point recommended by the World Health Organization (WHO) as mild when Hg level is between (10 - 11.9 g/dl), moderate (7.0 - 9.9 g/dl,) or sever (< 7 g/dl) [2,3]. Iron deficiency (ID) is the most widely prevalent nutritional disorder and is responsible for at least half of all anemia globally and is considered the main cause of anemia in women, adolescents and children from developing countries [4].

Adolescence is a period in which up to 50% of adult weight and skeletal mass and more than 20% of adult height is achieved [5]. Most adolescents live in developing countries and currently they constitute about one-fifth of the world's population [6]. It is a period when there is greater demand for iron due to their rapid pubertal growth, increase in lean body mass and blood volume [7], frequent exposure to infectious disease/ parasitic infestations [8] poor dietary intake and availability of iron in both gender [9]. Other than these, female adolescents requirement increases due to menses, early marriage, pregnancy and lactation [10]. Such groups in addition to IDA vulnerability, they are also exposed to overweight and/or obesity consequently leading to non-communicable disease which is another public health threat of the 21st century [11-13].

Other reasons for adolescents vulnerability to IDA is due to their increased iron demand, higher basal iron losses with higher body weight [14]. Impaired dietary iron absorption from the duodenum as a result of increased circulating hepcidin and obesity related chronic low grade inflammation as well as increased sequestration of iron in the reticulo-endothelial system by adipocyte mediated release of inflammatory cytokines, Interleukin 1 and 2, tumor necrosis factor and hepcidin are among other important reasons [15,16]. In addition, increased iron loss particularly among females during menses due to excess adiposity associated with early pubertal development are also important reasons suggesting the coexistence of both under and over nutrition within the same individual leading to intra-individual DBM [17].

The prevalence of anemia is varied substantially across regions with more cases in South East Asia, Eastern Mediterranean and particularly in sub-Saharan Africa [20,21]. In Ethiopia, about one-fourth (23%) of women aged 15 - 49 years, 13.4% of adolescent women aged 15 - 19 years and 17.8% of adolescent men aged 15 - 19 years were anemic [22,23]. The most common form of anemia during adolescence is IDA and it is the widespread nutritional deficiency attributed to 50% of all anemias worldwide [3,4] and has remained a major public health problem among adolescent girls [24-26]. Recent study documented the prevalence of ID among school aged children (5 to 14 years) using Soluble Transferrin Receptor (STFR) and Ferritin (FERR) to be 19.5% and 9.1%, respectively, while IDA was 7% [27]. Some previous studies documented the prevalence of ID to be higher in overweight and obese children and adolescents than non-obese children [16,28]. While most low and middle income countries continue to deal with the problem of under-nutrition, they are also experiencing a rapid increase in obesity and overweight at a rate of 30% faster than in developed nations [29]. Nonetheless the magnitude of IDA as a public health problem is still disputed and there is also scarcity of data in this regard in Ethiopia, a country having complex ecologic context of poverty, parasitism, and malnutrition. Therefore, we examined the relation of overweight and/or obesity with IDA among in-school adolescents in Addis Ababa, Ethiopia to generate evidences for some programmatic initiatives.

Methods

Study design, setting and period

A school based cross-sectional study was conducted among 388 in-school adolescents drawn from the capital city Addis Ababa, Ethiopia from March 1 to April 30, 2019. According to 2016 report of Addis Ababa City Administration Education Bureau (AACAEB), there are 2798 schools in all sub cities. Out of total school 806 are primary, 93 secondary (9 - 10), 10 preparatory (11 - 12), 114 general secondary and preparatory (9 - 12) [30].

Study participants

The main eligibility criteria for enrollment of the participants were being regular in-school adolescents aged between 14 and 19 years, enrolled in randomly selected private and government schools of Addis Ababa during the study period. Those adolescents on treatment for anemia and who had recent blood transfusion, visible physical deformity because of difficulty to measure height and weight, pregnant and lactating adolescents were excluded.

Sample size and sample technique

The sample size was determined separately for each specific objective using a single population proportion and double population proportion, respectively using Epi Info window version 7 statistical software. For the first objective: We assumed a 95% level of confidence, a 4% margin of error and a proportion value of 11% of IDA prevalence among school children 11% [31]. Based on these assumptions, a sample size of 235 was obtained. Using a 10% non-response rate and a design effect of 1.5, the sample inflated to 259 and 388, respectively. For the second objective: We assumed prevalence of IDA of 23.68% among overweight and obese adolescents [32] with an odds ratio of 4.23 yielded 80 inflated with 10% nonresponse and design effect of 1.5 added, the sample size reached 88 and 132, respectively. Since the first sample size estimated yielded the largest sample size, it was taken as the final working sample size.

A stratified multi-stage random sampling procedure was employed to recruit the required representative sample of students. Initially we stratified the schools by ownership as governmental and non-governmental schools, then by grade level and sections, respectively. From these 114 general secondary and preparatory schools, of which 11 were governmental and 103, were non-governmental secondary schools. Subsequently 10 schools (7 non-governmental and 3 governmental secondary schools) were randomly selected and the required numbers of students were distributed proportionally across the schools according to their size. A systematic sampling technique (every third child) was used to select the participants till the sample size was reached.

Data collection process and instrument

Four data collectors (One laboratory professional and three health officers) and one supervisor recruited and were trained for two days to standardize the technique of interviewing and method of weight and height measurements. All participants during the study period were interviewed by the trained Health officers after their consent was obtained using a pre-tested tool containing socio-demographic, anthropometric measurements and individual lab tests. In addition, qualitative information on habitual food intake and usual food consumption pattern was assessed using Food frequency questionnaire (FFQ) modified from the Helen Keller International FFQ that was used previously Ethiopia to estimate the dietary practices of adolescents [33,34].

To avoid the confounding effect of intestinal parasites on the level of Hg, all participants a month prior to blood sample collection were dewormed with 400 mg Albendazole tablet.

Measurements

Height was measured using a wooden height measuring board with a sliding head bar with shoes off, heels together, eyes looking straight ahead (Frankfurt plane), hands freely by the side, head, shoulder blades and buttocks are against the board/wall. The moving head piece of the measuring board was lowered to rest flat on the top of the head and reading was noted to the nearest 0.1 cm.

Weight was measured without shoes and with minimum clothes using a battery powered digital scale to the nearest 0.1 kg. The same measurer took all the anthropometric measurements to avoid variability.

Complete blood count (CBC): Four ml venous blood was drawn aseptically by a laboratory professional for biochemical and hematological screening tests. Two milliliter of whole blood was kept in EDTA (Ethylene-diamine-tetra-acetic acid) containing test tube and was used for CBC analysis within 2 hours of collection using manual mode sample running by Sysmex xt-1800i hematology analyzer.

Serum iron and C-reactive protein (CRP): The remaining two milliliter of whole blood kept in serum separator tube (SST) at room temperature centrifuged to obtain serum and kept in plastic tube at -20°C. Serum iron and ferritin were measured using a COBAS INTEGRA 400 plus clinical Chemistry analyzer (Roche Diagnostics GmbH, D-68305 Mannheim, Germany). Since serum iron value is elevated in the presence of inflammation, its concentration was adjusted for inflammation using CRP and was then classified as high when CRP level is > 5 mg/L [35]; iron deficiency was considered when serum iron concentration of < 60 µg/dl [17,36]. All the laboratory tests were done at the Ethiopian public health institute.

Data processing and analysis

The data were coded, entered and cleaned using Epi Data Version 3.1. The WHO 2007 growth reference was used as a standard reference for classifying adolescents based on BMI for age Z-score (BAZ) using WHO Anthro-plus software version 1.0.4 and categorized the into underweight (BAZ ≤ -1), normal (BAZ >-1 and < +1), overweight (BAZ ≥ +1 and < +2) and obese (≥ + 2).

The Principal component analysis was used to compute wealth index from 17 household fixed items based on family ownerships in their house with a score of "1" given to those who own the asset and score of "0" given to those who did not own. Based on the items assessed, wealth index was categorized into quintiles to give poorest, poor, medium, wealthy and wealthiest status.

Adjusted Hb concentration was calculated as Hg = −0.032× (altitude in meters ×0.0032808) +0.022× [(altitude in meters ×0.0032808)^2] to subtract the adjustment from the measured Hg concentration at the relevant altitude (2,355 meters above the sea level) to get the sea-level value [37]. Furthermore adjusted serum iron concentration was calculated using regression correction approach formula, that is $(\text{serum iron})_{\text{adjusted}} = (\text{serum iron})_{\text{unadjusted}} - B_1 (\text{CRP}_{\text{observed}})$ for those with raised level of CRP > 5 mg/l. CRP regression coefficient (B_1) is calculated by running a linear regression model where the dependent variable is serum iron values and the independent variable is CRP values and then by extracting slopes from explanatory variables [35,38].

Descriptive statistical analysis was conducted using frequency, percentage, mean (SD), median (IQR). Summary tables, graphs and charts were also used to describe the study population by explanatory variables. Both bivariate and multivariate logistic regression analysis were performed to determine the association between explanatory and outcome variable. First a bivariate analysis was done for each independent variable and crude odds ratio (COR) with 95% confidence intervals to identify factors crudely associated with the outcome variable (IDA), then the significant variables were subsequently included in the multivariable logistic regression model. Stepwise backward logistic regression procedure was applied. Finally, adjusted odds ratio (AOR) with 95% Confidence Interval at p-value < 0.05 was considered as statistically significant. All the analysis and above adjustments were done using SPSS version 20 Software.

Results

Socio demographic and economic characteristics

As displayed in table 1, 363 out of 388 had participated with 93.6% response rate. Over half (55.6%) were in the age group of 17 - 19 years with a mean age of 16.6 (SD ± 1.32) years. Slightly over half (52.6%) of them were from governmental schools. There were 200 (55.1%) female respondents. About two-thirds (66.4%) had less than 5 family members. The proportion of biological fathers and mothers of the participants who had college degree and above was 34.7% and 26.7%, respectively. Most (62.8%) of the participants father was government/private employee and above one-third (36.2%) of them were in the category of rich wealth quintiles.

Variables	Response categories	Number	Percent (%)
Sex	Male	163	44.9
	Female	200	55.1
Age (year)	Middle adolescent (14 - 16)	168	46.3
	Late adolescent (17 - 19)	195	53.7
Religion	Orthodox	270	74.4
	Catholic	7	1.9
	Protestant	42	11.6
	Muslim	35	9.6
	Other	9	2.5
School type	Governmental	191	52.6
	Non-governmental	172	47.4
Grade level	9^{th} grade	93	25.6
	10^{th} grade	89	24.5
	11^{th} grade	95	26.2
	12^{th} grade	86	23.7
Family size	1 - 5	241	66.4
	> 5	122	33.6
Father educational status	No formal education	27	7.4
	Primary school	31	8.5
	Secondary school	136	37.5
	Technical school and above	126	34.7
	Other	43	11.8
Mother educational status	No formal education	46	12.7
	Primary school	65	17.9
	Secondary school	129	35.5
	Technical school and above	97	26.7
	Other	26	7.2
Wealth quintile	Poorest	76	21.0
	Poor	75	20.7
	Medium	80	22.1
	Rich	70	19.3
	Richest	61	16.9

Table 1: *Socio-demographic and economic characteristics of governmental and non-governmental in-school adolescents in Addis Ababa, Ethiopia.*

Prevalence of iron deficiency, anemia and iron deficiency anemia

Figure 1 displays the prevalence of iron deficiency, anemia and iron deficiency anemia among in-school adolescents by gender. As shown in the figure, 83.7% had normal iron status (Adjusted serum iron ≥ 60 µg/dl), 8.9% had ID without anemia and 7.4% had IDA (both low ID and anemia adjusted for age). Out of 59 ID subjects, 18 were boys (30.5%) and 41 were girls (69.5%). The prevalence of IDA was significantly lower in males (3.7%) than females (10.5%) ($p < 0.05$).

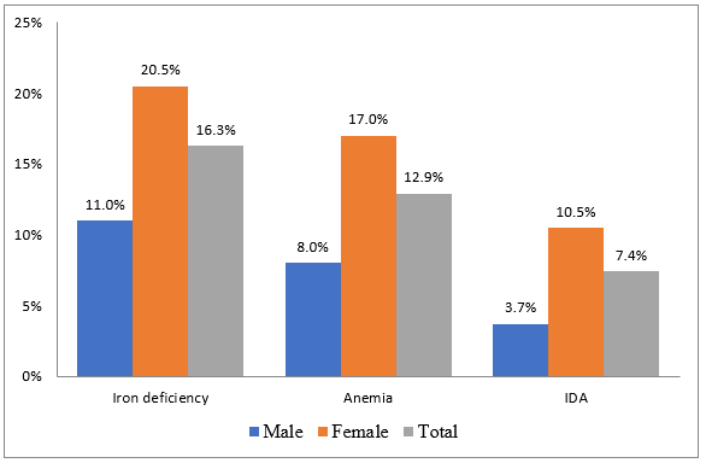

Figure 1: *Percentage of iron deficiency, anemia and iron deficiency anemia among Addis Ababa in-school adolescents by gender.*

Prevalence of anemia, ID and IDA across different BMI categories

Figure 2 demonstrates the prevalence of Anemia, ID and IDA across different BMI categories. BMI for age z-score was used to assess the nutritional status of adolescents and were categorized into underweight (96: 26.4%), normal (215: 59.2%), overweight/obese (52: 14.3%). The proportion of anemia, ID and IDA among overweight/obese was 26.9%, 21.2% and 15.4% while among those with underweight was 21.9%, 18.8% and 11.5%, respectively. On the other hand, the proportion of anemia, ID and IDA was significantly lower among those optimum weight than the two extremes of malnutrition ($p < 0.05$).

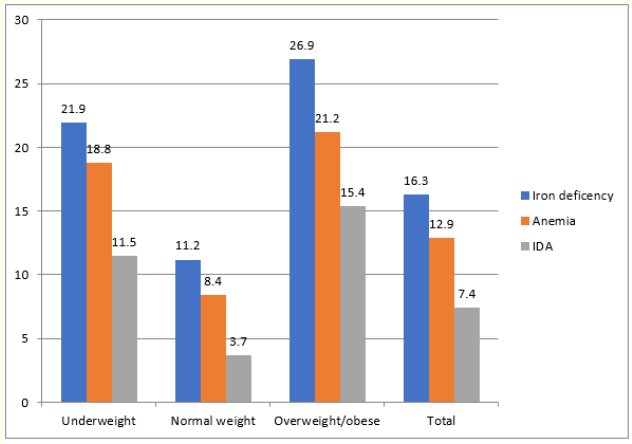

Figure 2: *Prevalence of Anemia, ID and IDA among Addis Ababa in-school adolescents across different BMI categories.*

Inflammation status

Inflammatory condition of the adolescents was assessed by using C-reactive protein level. Raised CRP (> 5 mg/l) indicates those who are infected but not yet showing clinical evidence of a disease. The value of CRP among the study participants ranged from < 0.00 mg/l to 102.13 mg/l with mean CRP concentration of 1.86 mg/l (SD ± 6.49). The overall magnitude of inflammation was 9.4%, in which females and age groups between 17 - 19 years accounted for 67.6% and 52.9%, respectively.

Characters	Response categories	Frequency	Percentage (%)
Sex	Male	11	32.4
	Female	23	67.6
Age (years)	Middle adolescent (14 - 16)	16	47.1
	Late adolescent (17 - 19	18	52.9
BAZ	Underweight (< -1 SD)	6	17.6
	Normal (>-1 and < 1 SD)	13	38.2
	Overweight (> 1 and < 2 SD)	9	26.5
	Obese (> 2 SD)	6	17.6

Table 2: *Inflammation status of in-school adolescents stratified by sex, age and BAZ in Addis Ababa, Ethiopia.*

BAZ: BMI for Age Z-Score; CRP > 5 mg/l stratified of high.

Bivariate and multivariate logistic regression analysis

To examine the association of overweight/obesity versus optimum weight with IDA, sub-analysis was performed while excluding the underweights from the analysis. After controlling for the confounding effect of other predictor variables, overweight/obesity, consumption of meat, egg and fish ≥ once per day, daily snack consumption and duration of menses ≥ 5 days per month were the variables that were significantly associated with IDA (Table 3). The odds of developing IDA were 4.2 times higher among overweight/obese than in normal weight (AOR = 4.2; 95% CI = 1.21 - 17.29). Meat, egg and fish consumption of ≥ once per day was found to have 0.13 times decreased odds of being iron deficiency anemic than those who consumed twice or less per month (AOR = 0.13; 95% CI = 0.02 - 0.88). Similarly, the odds of being iron deficiency anemic was 4.7 times higher among those who had a daily snack consumption pattern than those who did not (AOR = 4.7; 95% CI = 1.10 - 21.7). Female adolescents with a menstrual bleeding of ≥ 5 days had 4.4 times higher odds of being iron deficiency anemic than those with a menstrual bleeding of < 5 days (AOR = 4.4; 95% CI = 1.13 - 21.2).

Variable	Iron deficiency anemia		COR (95%CI)	AOR (95%CI)	P-value
	Yes (n, %)	No (n, %)			
Sex					
Male	2 (1.9%)	105 (98.1%)	1.0	1.0	
Female	14 (8.8%)	146 (91.2%)	5.03 (1.12-22.62)*	0.68 (0.005-95.9)	0.88
Age					
14-16 years	7 (6.1%)	107 (93.9%)	1.0	1.0	
17-19 years	9 (5.9%)	144 (94.1%)	0.96 (0.35-2.65)	0.69 (0.19-2.52)	0.57
Family size					
1 - 5	6 (3.3%)	174 (96.7%)	1.0	1.0	
> 5	10 (11.5%)	77 (88.5%)	2.85 (1.02-7.93)*	2.4 (0.62-8.93)	0.21

BAZ					
Normal	8 (3.7%)	207 (96.3%)	1.0	1.0	
Overweight and obese	8 (15.4%)	44 (84.6%)	4.7 (1.7-13.2)*	4.2 (1.21-17.29)*	0.034
Meat, egg and Fish					
Once/more	1 (1.5%)	65 (98.5%)	0.11 (0.01-0.88)*	0.13 (0.02-0.88)*	0.037
3 - 6 times weekly	2 (4.2%)	46 (95.8%)	0.31 (0.07-1.47)	0.46 (0.06-3.45)	0.12
1 - 2 times per week	3 (4.2%)	69 (95.8%)	0.31 (0.08-1.17)	0.14 (0.01-1.69)	0.45
Twice/less monthly	10 (12.3%)	71 (87.7%)	1.0	1.0	
Daily consumption of Fried foods					
Once/more	10 (8.8%)	103 (91.2%)	1.0	1.0	
3 - 6 times weekly	1 (2.0%)	49 (98.0%)	0.21 (0.03-1.69)	0.23 (0.02-2.51)	0.23
1 - 2 times per week	2 (4.7%)	41 (95.3%)	0.50 (0.11-2.39)	0.49 (0.05-4.81)	0.55
Twice/less monthly	3 (4.9%)	58 (95.1%)	0.53 (0.14-2.01)	1.21 (0.18-7.95)	0.84
Habit of meal skipping					
Yes	13 (9.0%)	131 (91.0%)	3.96 (1.1-14.3)*	4.96 (0.99-24.9)	0.052
No	3 (2.4%)	120 (97.6%)	1.0	1.0	
Dinner consumption pattern					
Daily	8 (4.7%)	163 (95.3%)	1.0	1.0	
Not daily	8 (8.3%)	88 (91.7%)	1.85 (0.67-5.10)	2.05 (0.49-8.64)	0.33
Daily Snack consumption pattern					
Yes	13 (9.2%)	129 (90.8%)	4.1 (1.14-14.73)*	4.66 (1.10-21.7)*	0.042
No	3 (2.4%)	122 (97.6%)	1.0	1.0	
Taking tea/coffee within one hour of meal					
Yes	12 (9.0%)	121 (91.0%)	3.22 (1.01-10.3)*	3.60 (0.88-14.7)	0.07
No	4 (3.0%)	130 (97.0%)	1.0	1.0	
Age of onset of menses					
< 13 years	8 (10.8%)	66 (89.2%)	1.0	1.0	
> 13 years	6 (7.2%)	77 (92.8%)	0.64 (0.21-1.95)	0.52 (0.12-2.25)	0.38
Duration of menstrual bleeding					
< 5 days	4 (4.3%)	90 (95.7%)	1.0	1.0	
> 5 days	10 (15.9%)	53 (84.1%)	4.25 (1.27-14.2)*	4.44 (1.13-21.2)*	0.044

Table 3: *Bivariate and multivariate analysis showing association between overweight/obesity and IDA among in-school adolescents in Addis Ababa, Ethiopia.*

** = Statistically Significant.*

Discussion

The main purpose of the study was to examine the occurrence of IDA among overweight/obese in-school adolescents in Addis Ababa and its contributory factors. On the basis of our findings, one from eight adolescent was anemic and one from six was iron deficient, which indicated that both anemia and ID are of public health problem. Compared with magnitude the nationwide study done among reproductive age women the prevalence of anemia (12.9% vs. 30.4%,), ID (16.3% vs. 49.7%) and IDA (7.4% vs. 17.0%) suggests our findings to be lower [39]. Such differences are likely because of the differences in the sample size used (27000 vs. 363), the age group

studied (15 - 49 years Vs 15 - 19 years), in terms of gender (women of reproductive age vs. male and female adolescents) and the study settings assessed (nine administrative regions vs. Addis Ababa).

On the other hand, the study found a significantly higher prevalence of anemia among adolescent girls than boys (16.5% vs. 8.3%) and our finding concurs with the EDHS report of 2016 which reported 15.9% among women and 6.9% for men living in Addis Ababa [22]. This variation might be due to the difference in the age group used by EDHS which estimates women of 15 - 49 and men with age of 15 - 59 years, unlike our study which examined adolescents of age 14 - 19 years as well as the differences in the sample size used. Another study also shows a 5.83% prevalence of anemia among school children in Addis Ababa and the possible explanation for this could be the age differences and the use of altitude-adjusted hemoglobin concentration in our study [40].

The magnitude of iron deficiency was 6.3% (based on serum iron) in our study while the Ethiopian National Micronutrient Survey (ENMS) documented 25% of iron deficiency (using STFR) and 9.1% (using FERR) among non-pregnant women of reproductive age in Addis Ababa in the diagnosis of ID [27]. This variation is likely as we used different the diagnostic kits. We used serum iron levels for diagnosing ID and in-school adolescents with both female and male in the age group of 14 - 19 years unlike the ENMS study which included non-pregnant women of reproductive age. In contrast the magnitude of IDA (7.4%) was much lower than a study conducted among adolescent girls aged 14 - 20 years in Iran which documented 21.4%, 23.7% and 12.2% for anemia, ID and IDA, respectively [47]. Similarly, the study done in south west Ethiopia reported 37.5% for IDA [33] and were attributed to high burden of intestinal parasitic infestation of 20% and above unlike our study in which we took care of this issue before the commencement of the study by treating all participants with albendazole.

Another important finding of our study is that the prevalence of overweight among adolescents was 11.0% and that of obesity was 3.3% based on BMI for age Z score classification. This finding was nearly similar with the result of a systematic review conducted among Sub-Saharan African countries which reported 10.6% and 2.5% prevalence of overweight and obesity among school-aged children and adolescents, respectively [41]. When compared with the US findings [38] our finding is lower. This variation is likely since adolescents from affluent countries dietary intake often constitutes diet rich in protein due to their better socio-economic status, and possibly due to early onset of puberty.

As expected, IDA among overweight and obese adolescents was 4.2 times higher than that of adolescents with optimum weight with nearly one in seven overweight/obese adolescents suffered IDA. This finding concurs with some previous which documented a positive association between obesity and IDA [16,28,42] and differed with some other studies [17,42-44]. The possible reason for this discrepancy might be due to the use of serum ferritin as one of the diagnostic criteria for ID in those studies, because ferritin is an acute-phase protein whose serum levels are plausibly elevated in states of inflammation, independently of body iron stores thus underestimating the true magnitude of ID. Lack of data on inflammatory marker (CRP) of the studies which reported negative association was probably the reason for the different assertion.

Although hepcidin concentration was not measured in the present study, measurement of CRP clearly indicated that magnitude of inflammation increased with increasing BMI and found to be 44.1%. This supports the view that overweight and obesity in adolescents is an inflammatory state that increases the acute-phase proteins such as CRP. This is in line with other studies in which higher BMI was associated with higher levels of CRP [43-45] and characterized by production of pro-inflammatory cytokines such as interleukin-1 (IL-1), IL-6 and tumor-necrosis-factor-α (TNF-α) sustaining a chronic low-grade systemic inflammation.

Strength and Limitations of the Study

This study is the first of its kind using a standardized methods of nutritional assessment tools that included anthropometry, bio-chemical (iron status in relation to body weight), and dietary for assessing the association of overweight and/or obesity with IDA in-school

adolescents contextually with 93.6 percent response rate. The inclusion of males and females as well as the different socio-economic strata such as the enrollment of private and government made the study representative to some extent. We have also elucidated the key factors that need multi-faceted approach of the line ministries to curb the problem. Nonetheless, the dietary approach employed which to measure the absolute intake for specific nutrients which mostly relies on respondent's memory and was prone to recall and social desirability bias. The level of serum ferritin which is the most appropriate test for the diagnosis of IDA was not measured, because of stock out and unavailability of hepcidin at the time of the study are among some of our limitations.

Conclusion

Despite our limitations, we generated evidences and demonstrated that IDA is a mild public health problem among in-school adolescents in Addis Ababa. Other than this, we showed the coexistence of IDA with overweight and/or obesity. To combat both excess body weight and poor iron status, a multi-facetted approach involving health, nutritional and educational sectors through appropriate nutrition counseling, early detection of the problem and treatment of anemia is recommended. Further research with advanced dietary assessment method (repeated 24 hour recall) with the inclusion of serum ferritin test and hepcidin is also recommended.

Acknowledgements

The authors thank all participants of the study as well as the Ethiopian public health institute/ EPHI and the Federal Ministry of health for their great support. We are grateful to Addis Ababa city administration educational bureau and the sampled school administrators including the data collectors and supervisors for their perseverance.

Authors' Contributions

Sara Gosaye was responsible for project inception and has collected the data and drafted the manuscript as part her fulfillment for the Requirement for the Degree of Masters of Public Health in Public Health Nutrition; while Professor jemal Haidar and Yalework Getnet supervised the entire research work. In addition Professor Jemal Haidar wrote the final manuscript. All authors read and approved the final manuscript.

Funding Support

The authors report no external funding source for this study.

Availability of Data and Materials

All data generated or analyzed are included in this published article.

Ethics Approval and Consent to Participate

Ethical clearance was obtained from the ethical Review Committee of Addis Ababa University, College of Health Sciences School of public health prior to initiation of the study. The management of Addis Ababa city administration educational bureau and the sampled school administrators Were communicated for approval of the study through formal letter from Addis Ababa University. In addition, informed written consent for those greater than 18 years old and from parents/guardians for the minors was also obtained from each study participant after being introduced to the purpose of the study and informed about their rights to interrupt the interview at any time. Confidentiality was maintained at all levels of the study. All the procedures were done in accordance in accordance with relevant guidelines and regulations. In addition all participants were informed about their Hg level and heath/nutrition advice was given to all anemic adolescents and those with severe anemia were referred to the nearby health facility.

Consent for Publication

Not applicable.

Competing Interests

The authors declare that they have no competing interests.

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