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Original Research

Prevalence of Anemia and Its Association with Body Mass Index Status among Allied Health Sciences Students at a Leading University in Sri Lanka: A Cross-sectional Study

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Abstract

Anemia and obesity are major global health issues associated with substantial mortality in developing countries. Although the student population was reported to be more vulnerable to anemia and Body Mass Index (BMI) outside the normal range, there is a lack of contemporary data in Sri Lanka. Thus, the present study aimed to investigate the prevalence of anemia in relation to BMI status among students in the Allied Health Sciences (AHS) at a leading university in Sri Lanka. After obtaining informed consent, blood samples were collected, and hemoglobin concentration was estimated. Weight and height were measured, and BMI was calculated. Additionally, a self-administered questionnaire was utilized to gather data on factors associated with obesity and anemia. Results revealed a prevalence of 22.9% for anemia and 50.1% for underweight or overweight/obesity, with a female predominance. Furthermore, anemic individuals had significantly higher BMI levels than healthy students ($p = 0.028$), although no significant differences were found between BMI categories and anemia status. The risk analysis revealed that students with BMI outside the normal range have a higher chance of being anemic than those with normal BMI. Irregular exercise and less consumption of green leafy vegetables were associated with anemia ($p < 0.05$), while a family history of anemia and obesity showed a significant association ($p < 0.05$) with obesity. In conclusion, the prevalence of anemia among AHS undergraduates with higher BMI levels is relatively high; however, further studies are recommended to find the association between obesity and anemia.

Keywords: *Anemia*, *Body Mass Index*, *Hemoglobin*, *Students*

Introduction

Anemia, defined by hemoglobin (Hb) concentrations below 12.0 g/dL in adult females and 13.0 g/dL in males by the World Health Organization (WHO), is one of the leading healthcare problems in developing countries [1]. Approximately 40% of children, 37% of antenatal women, and 30% of women aged between 15 and 49 years were affected by anemia in these nations [2]. In Sri Lanka, the national prevalence of anemia was reported as 29% by the WHO; however, the only national survey done in 2006 revealed that 20.7% and 13.3% of Sri Lankan females had mild and moderate to severe anemia, respectively [3, 4]. It was widely reported that factors, such as low dietary iron absorption, helminth infections, multiple pregnancies, postpartum hemorrhage, practicing veganism due to religious beliefs, living in urban areas, gastric ulcers, menorrhagia, and low socioeconomic status, were associated with anemia [5].

Obesity, by affecting approximately one in eight individuals in the world, has become another significant public health issue [6]. Obesity, defined by the WHO as a BMI of more than 30 kg/m², causes severe adverse health effects and reduced life expectancy due to excess body fat accumulation [7]. Furthermore, the increasing prevalence of obesity among adolescents was reported to contribute to the emergence of multiple obesity-related comorbidities and economic burdens in developing countries [8, 9]. Studies have shown that obese adults are at an increased risk of developing anemia due to obesity-induced chronic inflammation, insufficient dietary iron intake, and inflammation of fat cells [10, 11]. Nonetheless, some research suggests that anemia is less prevalent among obese teenagers, highlighting the ongoing debate regarding the correlation between BMI category and anemia across different demographic groups [12, 13, 14].

University students are vulnerable to being overweight or obese due to irregular and unbalanced dietary habits, as well as excessive consumption of fast foods [15]. Additionally, several studies have shown that anemia is more prevalent among students, who are also at a higher risk of developing serious health complications such as diabetes, heart disease, high blood pressure, high cholesterol, and cancer [16, 17, 18, 19, 20]. As a result, investigating the obesity related prevalence of anemia and its associated factors among university students is necessary for improving their overall health and academic performance. However, there is a lack of contemporary data on the prevalence of obesity and anemia among undergraduates at Sri Lankan universities. Therefore, the present study aimed to assess the prevalence of anemia in relation to BMI status among AHS students at a leading university in Sri Lanka. The findings of this study could contribute to improving the health status of students and enhancing their academic performance in the future.

Methods

Study design and study population

This was a single-center cross-sectional study conducted among 375 undergraduates aged between 20 and 29 years from the Faculty of AHS, University of Jaffna (UoJ), Sri Lanka. Participants were informed of the voluntary nature of the study, and written informed consent was obtained prior to data collection.

Sample size and sampling technique

The sample size was calculated using the Daniel formula, with a prevalence (p) of 0.326 obtained from the literature [21]. The calculated sample size was 375, assuming a 0.05 absolute error and a 10% non-response rate. At the time of sample collection, 651 AHS students were enrolled at the UoJ. Therefore, 375 participants were randomly selected using a random number generator and invited to participate in the study.

Data collection and BMI calculations

All male and female undergraduate students of the Faculty of AHS, UoJ, were considered for the study. Pregnant and lactating students and those with a history of hematological disorders were excluded. From the eligible students, 375 were randomly selected and invited via email to attend the laboratory in the Department of Medical Laboratory Sciences. A self-administered questionnaire, containing information on sociodemographic and lifestyle factors, was provided to the students after explaining their right to withdraw and obtaining written consent. Upon completion of the questionnaire, anthropometric measurements of height and weight were taken, and BMI was calculated. Body weight was measured without footwear to the nearest 0.05 kg on a standard weighing scale, while height was measured with a stadiometer to the nearest 0.5 cm, with the subject standing upright. BMI was calculated using the formula: BMI = Weight (kg) / Height (m^2).

Blood sample collection and Hb estimation

2 mL of venous blood samples were collected from participants by well-trained nursing staff in a comfortable, undisturbed, and clean environment, using EDTA bottles. Collected samples were transported without delay to the laboratory at the Department of Medical Laboratory Sciences, and Hb concentration was measured by the cyanmethemoglobin method [22]. In brief, 20 µL of EDTA blood was added to 4 mL of Hb reagent, thoroughly mixed using a vortex, and kept at room temperature for 5 minutes. The absorbance was measured at 540 nm against a Hb reagent blank, and the Hb concentration was calculated using a standard curve.

Determination of anemia and BMI status

The prevalence of anemia was estimated according to the WHO criteria, where anemia was defined as Hb levels of <12.0 g/dL in females and <13.0 g/dL in males [1]. Conversely, the incidence of overweight/obesity was established based on the Asia-Pacific classification, where BMI was categorized as underweight (<18.5 kg/m^2), normal weight (18.5–22.9 kg/m^2), overweight (23.0–24.9 kg/m^2), and obese (≥25.0 kg/m^2) [23].

Statistical analysis

Statistical analysis was accomplished using the Statistical Package for the Social Sciences (SPSS) version 18.0. The prevalence of anemia, overweight/obesity, and their associated factors were determined by analysing the data obtained from laboratory results and questionnaires. Associations between sociodemographic and other related factors with anemia and obesity were analyzed using the Chi-square test or Fisher's exact test. Mean differences in Hb and BMI levels were assessed using the independent t-test or one-way ANOVA. Risk analysis was performed, and interpretations were made based

on odds ratios. A *p*-value of <0.05 was considered statistically significant.

Results

Baseline characteristics of study participants

In the present study, 341 students participated with a response rate of 90.9%. Most of the participants (63.9%) were female, with a male-to-female ratio of 1:1.77. Furthermore, the higher percentage of participants were Sinhala (78.5%) and Buddhist (76.8%), compared to students of other ethnic and religious backgrounds. The sociodemographic characteristics of the participants are shown in Table 1.

Table 1 Sociodemographic characteristics of participants (n=341). (Number of subjects and percentages)

Socio-demographic characteristics	Number of subjects (n)	Percentage of subjects (%)
Age		
20-24 years	151	44.3
25-29 years	190	55.7
Gender		
Male	123	36.1
Female	218	63.9
Marital status		
Married	3	0.9
Unmarried	338	99.1
Ethnicity		
Sinhala	268	78.6
Tamil	53	15.5
Muslim	20	5.9
Religion		
Buddhist	262	76.8
Hindu	45	13.2
Islam	20	5.9
Christian	14	4.1
Residence		
External boarding houses	143	41.9
University hostel	198	58.1
Family income		
≤ 50,000 LKR	233	68.3
> 50,000 LKR	108	31.7

LKR, Sri Lankan Rupees

Prevalence of anemia associated with different categories of BMI

Overall, the mean Hb concentration of the participants was 138.23 ± 22.07 g/L, and the BMI was 22.18 ± 3.54 kg/m^2, which were generally under the normal levels. However, 22.9% of the students were found to be anemic, with the majority (12.3%) having mild anemia (Table 2). Furthermore, BMI analysis revealed that 50.1% of the participants had abnormal BMI, among whom 19.9%, 17.3%, and 12.9% were obese, overweight, and underweight, respectively (Table 2). Notably, the results found that anemia and abnormal BMI were more prevalent in female students, accounting for 35.3% and 50% of the total female population. The comparative analysis between different categories of BMI and Hb indicated that anemic individuals had significantly higher BMI levels compared to non-anemic participants (p = 0.028) (Figure 1c), albeit there was no significant association between BMI categories and anemia status (p = 0.675). Interestingly, risk analysis revealed that students with abnormal BMI had a higher chance of developing anemia (OR = 1.149, 95% CI: 0.778–1.698) compared to those with normal BMI. Notably, a higher prevalence of anemia (6.59%) and a greater risk ratio of 1.309 (95% CI: 0.814–2.104) were observed among obese students (Figures 1a and 1b).

Factors associated with anemia and BMI status

The sociodemographic characteristics, categorized by BMI status and Hb levels, are illustrated in Table 3. Overall, a higher percentage of underweight (12.6%) and anemic (23.7%)

individuals were observed among students aged 25 and above, while obesity (22.5%) was more prevalent among the students aged below 24 years.

Table 2 Prevalence of anaemia and BMI status of study population (n=341).

Characteristics	Frequency (%)[a]
Non-anemic	263 (77.1%)
Anemic	78 (22.9%)
Severe anemia	1 (0.3%)
Moderate anemia	35 (10.3%)
Mild anemia	42 (12.3%)
Normal BMI	170 (49.9%)
Abnormal BMI	171 (50.1%)
Underweight	44 (12.9%)
Overweight	59 (17.3%)
Obese	68 (19.9%)

Mild anemia: Hb 11–11.9 g/dL in women and 11–12.9 g/dL in men; moderate anemia: Hb 8–10.9 g/dL; severe anemia: Hb < 8 g/dL; BMI, body mass index; underweight: BMI < 18.5 kg/m^2; overweight: BMI 23.0-24.9 kg/m^2; obese: BMI ≥ 25.0 kg/m^2, [a] Unless stated otherwise

Moreover, anemia was found to be associated with gender, and being female had a significantly higher chance of being affected by anemia (35%, $p < 0.001$). Additionally, an association between family income and BMI status was observed, where students from higher-income households had a significantly higher chance of being obese (31.5%, $p = 0.003$). Nonetheless, no significant association was found between ethnicity, religion, and place of residence and BMI categories or anemia status (Table 3).

The results obtained from the analysis of lifestyle factors in relation to anemia and abnormal BMI revealed that irregular exercise ($p = 0.016$), exercising for less than 20 minutes per session ($p = 0.010$), and consuming green leafy vegetables fewer than four times per week ($p = 0.034$) were significantly associated with anemia. Although students who walked or cycled, slept less than six hours, followed non-vegetarian diets, consumed two or more extra meals per day, ate three or fewer eggs per week, consumed red meat fewer than two times per week, and had a family history of anemia or obesity showed slightly higher anemia prevalence, these associations were not statistically significant (Table 4). Moreover, students with a family history of obesity ($p < 0.001$) and anemia ($p = 0.042$) demonstrated a significantly higher prevalence of overweight and obesity.

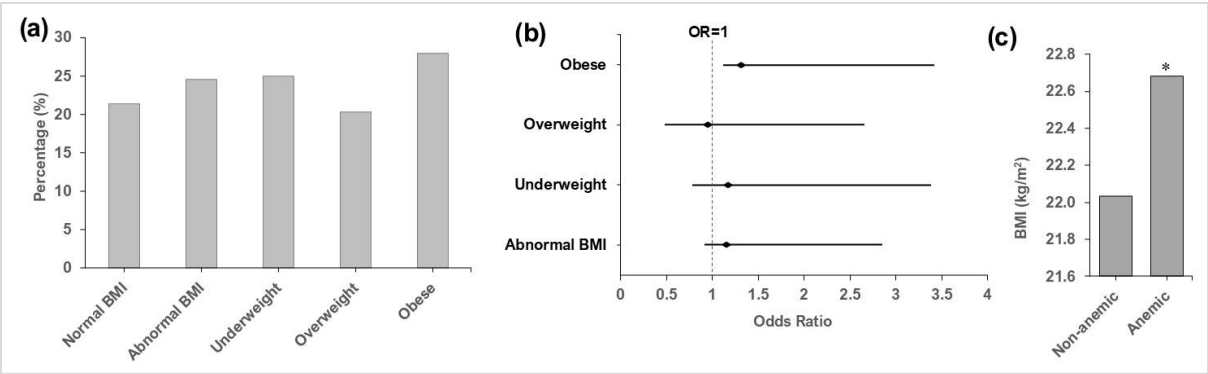

Figure 1 Prevalence of anemia in different BMI categories

(a), anemia risk in different BMI statuses (b), and the level of BMI between anemia and healthy participants (c) were shown. BMI outside the refence range (OR=1.149, CI=0.778-1.698), underweight (OR=1.171, CI=0.622-2.204), overweight (OR=0.953, CI=0.534-1.699), and obese (OR=1.309, CI=0.814-2.104). *p*-values obtained from an independent t-test. Statistical significance determined as *$p < 0.05$. BMI, Body Mass Index.

Table 3 Sociodemographic characteristics by BMI status and Hb status

Characteristics	BMI status (%)					Hb status (%)		*p* value
	Underweight	Normal weight	Overweight	Obese	*p* value	Anemia	Non-anemia	
Age								
20-24 years	7.9	53.0	16.6	22.5	0.429	21.9	78.1	0.689
25-29 years	12.6	51.6	17.9	17.9		23.7	76.3	
Gender								
Male	8.9	56.1	16.3	18.7	0.728	0.8	99.2	<0.001*
Female	11.5	50.0	17.9	20.6		35.3	64.7	
Marital status								
Married	33.3	0	0	66.7	0.075	66.7	33.3	0.070
Unmarried	10.4	52.7	17.5	19.5		22.5	77.5	
Ethnicity								
Sinhala	11.6	54.1	16.4	17.9		23.1	76.9	0.906
Tamil	5.7	52.8	20.8	20.8	0.063	20.8	79.2	
Muslim	10.0	25.0	20.0	45.0		25.0	75.0	
Religion								
Buddhist	11.8	54.2	16.0	17.9		22.9	77.1	0.873
Hindu	6.7	53.3	17.8	22.2	0.070	24.4	75.6	
Muslim	10.0	25.0	20.0	45.0		25.0	75.0	
Christian	0	50.0	35.7	14.3		14.3	85.7	
Family monthly income								
< 50,000 LKR	11.2	57.1	17.2	14.6	0.003*	23.6	76.4	0.637
> 50,000 LKR	9.3	41.7	17.6	31.5		21.3	78.7	
Residence								
Boarding place	9.1	53.1	16.8	21.0	0.870	19.6	80.4	0.218
Hostel	11.6	51.5	17.7	19.2		25.3	74.7	

p-values obtained from Chi-squared tests. Statistical significance determined as $*p < 0.05$.

Students with irregular exercise habits, shorter sleep duration, vegetarian diets, irregular meal patterns, and low intake of eggs, red meat, and green leafy vegetables were more likely to be underweight. On the other hand, obese students reported engaging in regular exercise exceeding 20 minutes, using alternative modes of transport, following vegetarian diets, having irregular meal patterns, and consuming more than two additional meals per day. However, these factors were not statistically significantly associated with underweight or obesity (Table 4).

Table 4 Influence of dietary and lifestyle factors on BMI and Hb status

Characteristics	BMI status (%)					Hb status (%)		
	Under weight	Normal weight	Over weight	Obese	*p* value	Anemia	Non-anemia	*p* value
Exercise								
Regular	3.8	53.8	11.5	30.8	0.333	3.8	96.2	0.016*
Irregular	11.1	52.1	17.8	19.0		24.4	75.6	
Exercise ≥20 min								
Yes	7.5	50.9	17.9	23.6	0.489	14.2	85.8	0.010*
No	11.9	52.8	17.0	18.3		26.8	73.2	

Travelling mode								
Walking/cycling	10.3	54.8	16.2	18.8	0.291	23.5	76.5	0.567
Others	11.6	42.0	21.7	24.6		20.3	79.7	
Sleeping ≥6h								
Yes	9.2	54.6	16.4	19.7	0.826	21.7	78.3	0.646
No	11.6	50.3	18.0	20.1		23.8	76.2	
Dietary pattern								
Vegetarian	13.3	40.0	20.0	26.7	0.805	13.3	86.7	0.535
Non-vegetarian	10.4	52.8	17.2	19.6		23.3	76.7	
Meal pattern								
Regular	8.8	60.2	12.4	18.6	0.169	23.0	77.0	0.967
Irregular	11.4	48.2	19.7	20.6		22.8	77.2	
Breakfast pattern								
Regular	12.1	51.5	15.8	20.6	0.734	22.4	77.6	0.848
Irregular	9.1	52.8	18.8	19.3		23.3	76.7	
Extra meals								
Yes	13.7	49.3	17.1	19.9	0.424	24.0	76.0	0.676
No	8.2	54.4	17.4	20.0		22.1	77.9	
Number of extra meals/day								
≥ 2 meals	16.7	39.4	21.2	22.7	0.357	24.2	75.8	0.941
< 2 meals	10.1	55.1	15.9	18.8		21.7	78.3	
None	8.7	55.3	16.5	19.4		22.8	77.2	
Consumption of Eggs/week								
≤ 3 eggs	11.2	53.9	17.0	17.8	0.776	23.7	76.3	0.647
> 3 eggs	8.2	49.4	17.6	24.7		22.4	77.6	
Never	13.3	40.0	20.0	26.7		13.3	86.7	
Consumption of red meat								
Yes	9.7	53.4	16.5	20.3	0.798	22.5	77.5	0.784
No	12.4	49.5	19.0	19.0		23.8	76.2	
Consumption of red meat/week								
< 2 meals	9.4	51.2	18.1	21.3	0.588	27.5	72.5	0.145
> 2 meals	6.6	56.6	15.8	21.1		17.1	82.9	
Never	15.2	50.5	17.1	17.1		20.0	80.0	
Consumption of green leaves/week								
≥ 4 times	5.9	45.6	19.1	29.4	0.092	13.2	86.8	0.034*
< 4 times	11.7	53.8	16.8	17.6		25.3	74.7	
Consumption of Junk foods								
Every day	10.2	49.2	16.9	23.7	0.110	22.0	78.0	0.912
Once a week	10.0	57.3	9.1	23.6		21.8	78.2	
Not so often	11.0	50.0	22.7	16.3		23.8	76.2	
Consumption of soft drinks								
Everyday	3.2	64.5	9.7	22.6	0.422	16.1	83.9	0.228
Once a week	13.4	53.5	16.2	16.9		20.4	79.6	
Not so often	9.3	48.1	19.8	22.8		25.3	74.7	
Never	16.7	66.7	16.7	0		50.0	50.0	
Family history of anemia								
Yes	13.6	27.3	18.2	40.9	0.042*	27.3	72.7	0.612
No	10.3	53.9	17.2	18.5		22.6	77.4	
Family history of Obesity								
Yes	3.3	30.0	23.3	43.3	<0.001*	31.7	68.3	0.074
No	12.1	56.9	16.0	14.9		21.0	79.0	

*p-values obtained from Chi-squared tests. Statistical significance determined as *p < 0.05.*

Discussion

Higher BMI and obesity are associated with metabolic complications and non-communicable diseases, and a possible link with anemia has also been suggested; however, the exact nature of this relationship remains controversial [24, 25]. The present study assessed the prevalence of anemia in relation to BMI status and its associated factors among AHS undergraduates at a leading university in Sri Lanka. Overall, 22.9% of subjects with anemia and 37.2% of subjects with obesity/overweight were found in this study. Furthermore, female sex, irregular exercise, exercise less than 20 minutes, consumption of green leaves less than four times a week, were associated with anemia, while lower family income and family history of obesity were associated with abnormal BMI status.

In the present study, anemia was more prevalent (35.3%) among females, and these findings were closely aligned with the previous studies. The WHO reported that the anemic prevalence in Sri Lanka and other Asian countries were 31.6% and 33%, respectively. Furthermore, a study done in 2011 in Sri Lanka indicated that the prevalence of anemia among non-pregnant females aged between 20 and 29 years was 32% [26].

The prevalence of obesity in the world has increased by 6% between 1975 and 2014, reaching 38% by 2023, with developing nations facing the most significant increase [27, 28]. In the present study, over half of the students were found to have BMI outside the reference range: 12.9% of subjects were underweight, 17.3% of subjects were overweight, and 19.9% of subjects were obese. Whereas the previous national survey carried out in Sri Lanka in 2006 indicated that 25% were overweight and 9.2% were obese among the adult population [29], while another study done by Somasundaram et al. (2019) revealed that 7.7% were underweight, 34.3% were overweight, and 31.2% were obese among urban Sri Lankan adults [30]. In our study, there was a slight increase in the prevalence of underweight and a decline in the prevalence of overweight and obesity when compared to previous studies.

In the present study, significant associations were found between anemia and irregular physical activity, exercised for less than 20 minutes, and consumption of green leafy vegetables fewer than four times per week. Evidence from both male and female populations suggests that regular exercise enhances the body's oxygen-carrying capacity by increasing total Hb and red cell mass due to bone marrow stimulation, an improved microenvironment, hormone and cytokine-driven acceleration of erythropoiesis [31]. Furthermore, essential micronutrients, including iron and vitamins, are rich in green leafy vegetables, and insufficient consumption of these vegetables can be associated with anemia [32]. Studies have also reported that children who consume fewer plant-based foods and green leafy vegetables are more likely to be anemic [29, 33, 34].

Although the link between BMI and anemia is continuously under investigation, the exact connection remains a subject of debate. Some studies have suggested that an increase in BMI is associated with higher blood Hb levels and a reduced risk of anemia. Conversely, others

indicated that the prevalence of anemia among obese or overweight women was higher due to inflammation caused by obesity [24, 35, 36]. This study revealed a significant increase in BMI among anemic students, although no significant association between BMI category and anemia prevalence was found. Moreover, individuals with abnormal BMI were found to be anemic, with obese individuals demonstrating a 6.59% higher prevalence and a 1.31 times higher risk ratio. Nonetheless, the risk of anemia among the overweight was slightly lower than that of students with normal BMI. Previous reports indicated that obesity has been associated with anemia by lowering dietary iron uptake from the duodenum, with lower serum iron concentrations linked to higher BMI. As a result, these discrepancies in findings could be attributed to obesity-related inflammation and cytokine production in obese individuals [37, 38]. However, the present study has several limitations, which limit the conclusion that BMI, irregular exercise, or poor dietary habits are the direct causes of anemia. First, it was performed in an institution, which limits the generalizability of the findings. Second, the sample size of the population and gender-biased ratio limit the association of the study, and third, the cross-sectional nature of the study limits the associations of the essential contributors to anemia and obesity/overweight. Fourth, the types of anemia were not studied due to limited resources.

Conclusion

The prevalence of anemia and BMI outside the reference range among AHS undergraduates in Sri Lanka is high and associated primarily with irregular exercise, poor dietary habits, and a family history of the conditions. Although a higher prevalence of anemia and an increased risk ratio were observed in obese students, further studies are recommended to further understand the relationship between obesity and anemia.

List of abbreviations

BMI - Body Mass Index
AHS - Allied Health Sciences
UoJ - University of Jaffna
Hb - Hemoglobin

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Ethical considerations

This study was conducted after obtaining approval from the Ethics Review Committee of the Faculty of Medicine, University of Jaffna, Sri Lanka (approval granted at the 136th meeting held on 23rd June 2022).

Declaration of conflicting interest

The authors declare that they have no conflict of interest.

Author contributions

KR and SS conceived the idea and design of the methodology. SAOUS, SHH, TMBST, and KR collected data and did laboratory experiments. SAOUS, SHH, TMBST, SS, SMR, and KR analyzed the data. KR supervised the data analysis, interpreted the statistical analysis, created tables and figures, and drafted the manuscript. SS and KR reviewed and edited the manuscript. All authors read and approved the final manuscript.

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