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Anemia Predicts Physical Fitness Among Adolescent Athletes in Ghana

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ABSTRACT

Background: Anemia indicates low blood hemoglobin levels and has become a public health problem among adolescents in developing countries. The prevalence among adolescent athletes and its effect on physical fitness has not been studied in Ghana. The study aimed to assess the impact of anemia on physical fitness among adolescent athletes in Ghana.

Methodology: The sample of 194 adolescent athletes was randomly recruited from competitive athletic groups, boxing, and football clubs in Greater Accra, Ashanti, and Volta regions of Ghana. Anthropometric parameters and Hemoglobin concentration were measured. Physical fitness was assessed using, right and left-hand grip strength, reaction time, flexibility, and the Cooper-12-min run test, all following standard procedure.

Results: The adolescent athletes of mean age (15.8 ± 2.5 yrs) and weight (54.0 ± 12.8 kg) were mostly of normal weight-for-age and height. The overall prevalence of anemia among the adolescent athletes was 14.3%. Anemia was however, more common among early adolescents (20.7%). The average hemoglobin level was lowest among the early adolescents (12.8 ± 1.1 g/dl), however, there was no association between anemia and the adolescent age group ($X^2 = 2.112$ $p = 0.348$). Although the proportions of anemic males and females were similar (14.3%), the mean hemoglobin levels were significantly higher among males (13.6 ± 1.5 g/dl) than females (12.5 ± 1.2 g/dl). There was an association between hemoglobin and cardiorespiratory endurance ($r = 0.324$, $p = 0.005$), hand grip strength as well as relative handgrip strength ($r = 0.379$, $p = 0.001$). Hemoglobin significantly predicted 10.5% of the variation in cardiorespiratory endurance ($R^2 = 0.105$, $b = 0.623$, $p = 0.005$) of the athletes.

Conclusion: Hemoglobin levels could predict the cardiorespiratory endurance and muscular strength of adolescent athletes. Anemia is a public health problem among adolescent athletes and must be given the needed attention to make these athletes competitive and win laurels.

1 | Background

Anemia is a global public health concern but common in developing countries. It is defined as hemoglobin (Hb) concentrations below the physiological needs of an individual. When the blood Hb is below the standard cut-off, a person is said to be anemic [1]. The World Health Organization (WHO) considers anemia to be present when Hb < 12 g/dL in children below 15 yrs, females 15 years and above, Hb < 13 g/dL in males above 15 years [2]. Among other causes, anemia commonly results from deficiencies in micronutrients such as iron, vitamin C, folate, and Vitamin B_{12}. Vigorous-intensity sports engagement could lead to iron deficiency and anemia due to increased iron needs, exercise-associated iron losses through sweat and micro-trauma, and decreased dietary intake. There are reports of the significant variations in anemia prevalence among different age groups, gender, and type of sport [3]. Malaria and other parasitic infections also increase the risk of anemia [4]. Anemia affects different age groups, with about 25% of adolescents reportedly anemic in developing nations [4]. The World Health Organization (WHO) defines adolescents as persons within the age range of 10–19 years and can be subdivided into: early adolescence: 10/13–14/15, mid-adolescence: 14/15– 17 and late adolescence 17–21 according to social, physical, and psychological changes in developmental [5]. Adolescence is a transition from childhood to adulthood and comes with health, physiological, psychological, and financial challenges. It is a stage of rapid growth and an increased need for nutrients for physical, biological, and cognitive development. The increased needs make them more susceptible to deficiencies and related diseases like anemia when intake does not meet the demand over some time. Adolescents often learn and adopt certain eating practices that eventually affect their ability to meet physiological demands for optimal health. Female adolescents are generally more susceptible to anemia due to the loss of blood through menstruation. Anemia prevalence studies have also shown a higher prevalence among females than male adolescent [6–9]. Anemia impairs the physical growth development and productivity of adolescents [10]. The prevalence of anemia is generally highest in Africa with a prevalence of about 47.5%. The prevalence among male and female adolescents in rural areas of Saudi Arabia was reported as 44.9% and 46.3%, respectively [11]. South East Assia, America, and the United Arab Emirates have reported rates of 35.7, 17.8, and 14% respectively [4]. Anemia is a form of malnutrition and its prevalence in adolescents affects their growth, and development, and increases their susceptibility to infection [12]. Malaise, fatigue, and impaired muscular function are likely clinical manifestations of anemia [12–14]. Anemia has been linked to poor psychomotor skills and cognitive function [15, 16]. Studies among an active military group revealed that non-anemic men were more likely to perform better in an aerobic test than anemic men [17].

Athletes are generally healthy subjects within the population [18]. Regular exercise places a high energy burden on the body, leading to nutrient deficiencies if intake is insufficient to meet demand. Regardless of the cause, anemia is considered a major nutritional problem among adolescents [5]. Anemia does not only negatively affect growth of adolescents but also their productivity, and among athletes, their fitness and overall performance [19]. Deficiencies in micronutrients such as iron cause one of the most common types of anemia, iron deficiency anemia. Under some conditions, iron deficiency anemia could limit the activity of the electron transport chain in the mitochondria and therefore limit endurance in exercise [20]. Hb is responsible for the transport of oxygen to meet the physiologic needs of an athlete. Low levels will diminish the oxygen-carrying capacity of the blood, and the maximal oxygen uptake (VO_{2max}) [21]. During exercise, the body consumes oxygen at the rate of exercise intensity. The maximum level at which oxygen consumption does not increase with exercise intensity is the maximal aerobic capacity measured as VO_{2max} [22]. VO_{2max} is a measure of the Cardiorespiratory endurance, of an athlete. Cardiorespiratory endurance measures the ventricular, muscular, and cardiac function determining how long an athlete can perform without fatigue. It is an indicator of the physical fitness of an athlete [23]. Anemia, therefore, negatively influences exercise performance and physical fitness [17]. Low levels of Hb results in reduced amounts of oxygen being supplied to the cells of the body and brain. This will also in fatigue and exhaustion, limiting the capacity of an exercising individual to train [24].

Some studies have been conducted on anemia among adolescents in Ghana [25, 26], however, limited research has been conducted on the impact of anemia on the physical fitness of adolescent athletes. This study sought to investigate the impact of anemia on the physical fitness of a group of adolescent athletes in Ghana.

2 | Methods

2.1 | Ethics, Design, and Sample Size

This was a cross-sectional study approved by the Committee on Human Research Publication and Ethics at the School of Medical Sciences, Kwame Nkrumah University of Science and Technology (CHRPE/AP/192/20). The sample comprised 194 adolescents, aged between 10 and 19 years, from football, athletics, boxing clubs and teams in Ghana.

The study was sanctioned by the National Sports Authority as well as the managers and coaches of the selected teams and clubs. Informed consent was sought from the players and their respective team managers who served as the authorized guardians of the young players in the clubs. Adolescents between the ages of 10 and 19 were included in the study. Injured players were excluded from the study.

2.2 | Data Collection

Trained dietitians and sports scientists did the data collection. Athletes provided information on their age, educational level, religion, knowledge and use of supplements, and medical history.

2.3 | Anthropometric and Biochemical Assessment

The anthropometric data were taken using standard protocols. Each measure was repeated once and the average values for each parameter were recorded. The Omron scale was used to measure the weight in kilograms (kg), and the heights of the football players were measured with a SECA stadiometer. The Body Mass Index (BMI) of each athlete was calculated with the BMI formula BMI = weight (kg)/height (m)^2. To determine the nutritional status, the weight and height measurements were converted to BMI-for-age *Z*-scores (BAZ), and weight-for-age *Z*-scores (WAZ), using the Anthro Cal software developed by the India Institute of Medical Sciences (based on WHO Growth Charts 2007 and IAP Growth Charts 2015). The WHO standard cut-offs were used for the classification of normal, underweight, overweight, and obese. BAZ was classified as normal weight (BAZ ≥ -2SD ≤ 1 SD), overweight (BAZ > 1 SD), obese (BAZ > 2 SD), and underweight (BAZ < -2SD) [27].

The Hb concentrations were measured using a HemoCue Hb 301 analyzer. Capillary blood was taken with a HemoCue microcuvette to read the Hb concentration. Anemia was defined by Hb levels < 12 g/dl and < 13.0 g/dl for under 15 years and above 15 years respectively, based on WHO reference [2].

2.4 | Assessment of Physical Fitness

The parameters assessed as a measure of physical fitness were: sensorimotor (reaction time), Flexibility, muscular strength (Hand Grip strength), and cardiorespiratory endurance (Maximal oxygen Uptake (VO2max). Flexibility was measured using the sit-and-reach method. The athlete was made to sit and bend over at the waist to touch the farthest point possible on a tape measure with the fingertips. The distance, the athletes were able to reach was recorded in duplicates and the average was noted as a measure of their flexibility. The reaction time was measured using the standard Ruler Drop Reaction Time (RDT) [28] protocol. The athlete was made to position the elbow of his active hand on a flat surface, with the open thumb and index finger over the edge of the flat surface. The zero (0) edge of the centimeter ruler was placed between the two fingers. The ruler was randomly dropped and the athlete was instructed to catch it as fast as possible. The distance from the edge of the ruler to the point that was grabbed was measured and converted to reaction time (t) using the formula $t = (\sqrt{2}\,d/g)$. The reaction time was calculated in milliseconds (ms), distance (d) in centimeters (cm), and the constant (g) acceleration due to gravity = 9.8 ms^{-2}. The strength of the left handgrip (LHG) and right handgrip (RHG) was measured with the handgrip dynamometer [29]. The dynamometer was set at zero and each athlete was asked to pull with the left and right hand consecutively in triplicates. The average pull for each hand was recorded in kilograms (kg). The athletes' relative hand grip strength (RHGS) was calculated by dividing the handgrip strength by the BMI of each individual. The maximal oxygen uptake (VO_2 max) was measured using the Cooper 12-min run. The test was carried out by instructing the athletes to cover as much distance as they possibly could in 12 min around the perimeter of a football field. The total distance covered at the end of the 12 min was measured and used to calculate the VO_2 max using the formula:

VO_2 max (mL/kg/min) = (22.351 * distance covered in kilometers)–11.288 [30].

2.5 | Statistical Analysis

The data collected were analyzed using the Statistical Package for Social Sciences (SPSS) version 25. The participants were grouped into early (10–13 years), mid (14–16 years), and late (17–19 years) adolescents [5]. The variables measured were tested for normality using the Shapiro–Wilk test. Descriptive statistics was used to analyze the background demographics. Independent sample *t*-tests were used to evaluate the parametric data, determining associations among the various continuous variables such as BMI, Hb, VO_2 max, handgrip strength, and reaction time. The non-parametric data were tested with the Mann–Whitney "U" Test. The chi-square test of association was used to determine associations among the categorical data (anemia, cardiorespiratory endurance).

3 | Results

3.1 | Anthropometric Characteristics and Anemia Prevalence

The mean age of the early, mid, and late adolescent athletes was 12 ± 1.1, 15.8 ± 0.9, and 18.7 ± 0.6 yrs. The age group-specific anthropometric parameters of the athletes are summarized in Table 1. There was a significant ($p < 0.001$) difference between the weight of the early adolescents (41.2 ± 6.8 kg), mid-adolescents (54.5 ± 8.6 kg) and late adolescents (64.7 ± 10.0 kg). The weight was higher with the older age group, but the mid and late adolescents had similar heights significantly higher than the early adolescents. The mid-adolescents had the lowest Body fat (11.7 ± 3.6) and visceral fat (2.8 ± 1.3) but had the highest skeletal muscle mass (43.4 ± 4.0) among the three adolescent groups though not significantly different from the rest. Generally, there were some significant differences between the two or all the groups for all the anthropometric parameters measured except for waist-to-hip ratio and skeletal muscle mass. Most of the adolescent athletes were of normal weight for their height. There were no overweight or obese adolescents among the study participants.

The proportion of anemic adolescent athletes was 14.3%. Hb was significantly higher in late adolescent athletes (14.1 ± 1.6 g/dl) than in early adolescent athletes (12.8 ± 1.1 g/dl). Of the three groups, anemia was the least common among late adolescent athletes (8.9%). The proportion of anemic early adolescent athletes (20.0%) was more than twice that of late adolescent athletes. Although there was a significant difference between the Hb levels of early adolescents and late adolescents, there was no association ($X^2 = 2.112$, $p = 0.348$) between the anemia and adolescent group which was based on age. Because the number of male and female adolescents was not normally distributed, the Mann–Whitney U Test for non-parametric data was used to compare the data among males and females. From the study, the Hb levels among adolescent female athletes were significantly lower than those of the males' Table 2.

3.2 | Fitness, Vitals, and Anthropometrics, of Anemic and Non-Anemic Athletes

Table 3 summarizes the vitals and fitness parameters measured among the athletes. Maximal oxygen uptake (VO2max) was significantly ($p = 0.042$) higher among non-anemic athletes (43.4 ± 7.2) compared to anemic athletes (37.1 ± 13.9), suggesting that athletes who were not anemic had better cardiorespiratory endurance. The average, physical fitness parameters such as reaction time, and left-hand, and right-hand grip strength of non-anemic adolescent athletes (195.4 ± 17.6, 31.2 ± 9.3, 31.7 ± 9.1, respectively) looked better than those of anemic athletes (204.2 ± 29.2, 26.1 ± 8.5 and 26.7 ± 7.3, respectively), though the differences were not significant statistically. The mean reaction time, which is also a measure of cognitive function was also

TABLE 1 | Anthropometric characteristics of study participants.

Variable	Early adolescents Mean ± SD	Mid adolescents Mean ± SD	Late adolescents Mean ± SD	*p*-value	Total Mean ± SD
Age (years)	12.8 ± 1.1[a]	15.8 ± 0.9[a]	18.7 ± 0.6[a]	< 0.001	15.8 ± 2.5
Weight (kg)	41.2 ± 6.8[a]	54.5 ± 8.6[a]	64.7 ± 10.0[a]		54.0 ± 12.8
Height (m)	1.5 ± 0.1[a]	1.7 ± 0.1[a]	1.7 ± 0.1[a]		1.6 ± 0.1
BMI (kg/m²)	17.5 ± 1.4[a]	19.3 ± 1.8[a]	22.0 ± 2.8[a]		19.7 ± 2.8
WC (cm)	62.7 ± 3.9[a]	68.3 ± 4.5[a]	72.2 ± 3.4[a]	< 0.001	68.9 ± 5.2
HC (cm)	76.2 ± 6.0[a]	85.1 ± 5.4[a]	90.6 ± 4.7[a]		85.7 ± 7.4
WHR	0.8 ± 0.0	0.8 ± 0.0	0.8 ± 0.0	0.125	0.8 ± 0.0
Body fat (%)	12.2 ± 3.2[a]	11.7 ± 3.6[a]	16.6 ± 5.8[a]	< 0.001	14.4 ± 5.4
Skeletal muscle	42.9 ± 3.6	43.4 ± 4.0	41.9 ± 4.9	0.258	42.5 ± 4.5
Visceral fat	2.9 ± 1.2[a]	2.8 ± 1.3[a]	3.7 ± 1.8[a]	0.027	3.3 ± 1.6
BMI categories	*n* (%)	*n* (%)	*n* (%)		*n* (%)
Normal	58(98.3%)	63(94.0%)	59(87.9%)		179(93.2%)
Underweight	1(1.7%)	4(6.0%)	1(1.5%)		6(3.1%)
Overweight	0	0	4(6.1%)		4(2.1%)
Obese	0	0	3(4.5%)		3(1.6%)

Abbreviations: BMI, body mass index; cm, centimeters; HC, hip circumference; SD, standard deviation; WC, waist circumference; WHR, waist-to-hip ratio.
[a]All values in different columns of a particular row, with the same alphabet were not significantly different from each other. However, values in different columns of the same row, with different alphabet superscripts were significantly different from each other. In those instances, the *p*-values as indicated, were < 0.05.

TABLE 2 | Proportions of Anemia and BMI categories by adolescent groups.

	Hemoglobin (g/dl)		Anemia Status			
	Mean ± SD	*p*-value	Anemia	Non-Anemia	Chi-square	*p*-value
Early adolescents	12.8 ± 1.1[a]	0.001	6 (20.7%)	23 (79.3%)	2.112	0.348
Mid-adolescents	13.4 ± 1.3[ab]		6 (15.8%)	32 (84.2%)		
Late adolescents	14.1 ± 1.6[b]		4 (8.9%)	41 (91.1%)		
Males	13.6 ± 1.5	0.049	15 (14.3%)	90 (85.7%)		
Females	12.5 ± 1.2		1 (14.3%)	6 (85.7%)		
Total	13.6 ± 1.5		16 (14.3%)	96 (85.7%)		

[ab]The mean hemoglobin values in the same column but different rows, with the same superscript were not significantly different from each other. Those with different superscripts were significantly different from each other, with *p*-values indicated.

TABLE 3 | Vitals and physical fitness characteristics among anemic and non-anemic adolescent athletes.

	Anemia Mean ± SD	No anemia Mean ± SD	*p*-value
SpO_2	97.9 ± 1.7	97.3 ± 2.1	0.561
Pulse	72.8 ± 14.7	72.9 ± 12.5	0.974
Systolic Blood Pressure (mmHg)	107.9 ± 13.5	111.5 ± 12.6	0.307
Diastolic Blood Pressure (mmHg)	63.9 ± 6.0	63.3 ± 10.0	0.823
VO2max	37.1 ± 13.9	43.4 ± 7.2	0.042
Reaction time (ms)	204.2 ± 29.2	195.4 ± 17.6	0.137
Flexibility (cm)	28.9 ± 20.1	26.4 ± 13.3	0.628
Left-hand grip strength (kg)	26.1 ± 8.5	31.2 ± 9.3	0.067
Right-hand grip strength (kg)	26.7 ± 7.3	31.7 ± 9.1	0.067
Relative hand grip strength	1.40 ± 0.3	1.58 ± 0.3	0.090

better among nonanemic (195.4 ± 17.6 ms) than anemic adolescent athletes (204.2 ± 29.2 ms). Oxygen saturation (SpO_2) and blood pressure (diastolic and systolic values) were normal among both anemic and non-anemic athletes Table 3.

3.3 | Maximal Oxygen Uptake Among Adolescent Subgroups

From Table 4, there were more early adolescents (33.3%) with "very low" endurance levels compared to Mid-adolescent (10.3%) and late-adolescent athletes (28.6%). No early adolescents had a good or excellent endurance level. The best rating for early adolescents was "average," suggesting that early adolescents were more likely to have poorer endurance than mid and late adolescents. More late adolescents (8.6%) had excellent respiratory endurance ratings compared to the mid-adolescents (3.4%). Generally, most athletes had "average" (34.1%) endurance. The lowest proportion of the study participants had "excellent" cardiorespiratory endurance.

3.4 | Association between Hb and Physical Fitness Variables

There was no significant association between Hb levels and reaction time ($r = 0.120$, $p = 0.249$) and the athletes' flexibility ($r = 0.072$, $p = 0.530$) of the athletes. There was however, a significant association between Hb and VO_2 max, as well as Hand grip strength from Table 5. A bivariate regression analysis was done to evaluate the $VO_{2\ max}$ and Hand grip strength predictability at the Hb level of athletes. The dependent variables $VO_{2\ max}$ and muscular strength (LHG, RHG, and RHGS) were regressed independently on the predicting variable Hb. Hb significantly predicted maximal oxygen uptake $F\,(1{,}72) = 8.449$ which suggests that Hb concentration plays a role in improving maximal oxygen uptake in adolescent athletes ($b = 0.623$, $p = 0.005$). The $R^2 = 0.105$ predicts that the model explains 10.5% of the variance in maximal oxygen uptake. Similarly, Hb influenced hand grip strength. From Table 5, Hb accounted for 19.4%, 19.6%, and 14.3% of the variance in left-hand grip, right-hand grip, and relative hand grip strength of the adolescent athletes respectively. Reaction time and flexibility were independent of Hb concentration.

4 | Discussion

The study evaluated anemia status, anthropometric parameters, and the relationship with indicators of physical fitness (cardiorespiratory endurance, reaction time, muscular strength, and flexibility) among three age groups of adolescent athletes: the early, mid, and late adolescents. The adolescent athletes studied were recruited from football, athletic, and boxing clubs, and academies in Ghana. Most of the adolescent athletes had a normal BMI for their age. The athletes were generally active persons with routine training and exercise schedules similar to each other.

The study revealed a decreasing prevalence of anemia with the increasing age group of adolescents. The early adolescents had the highest prevalence of anemia and the late adolescents had the least proportion being anemic. Several research findings have demonstrated a higher prevalence of anemia among the younger age group as was observed in this study [15, 31, 32]. Early adolescents may not have developed and defined appropriate eating habits [33] to obtain optimal dietary iron intake. With a higher growth spurt in early adolescence and an increased demand of

TABLE 4 | Physical fitness category based on cardiorespiratory endurance stratified by adolescent group.

Cardiorespiratory Eendurance	Adolescent subdivisions			
	Early adolescents	Mid-adolescents	Late adolescents	Total
Very low	33.3%	10.3%	28.6%	23.5%
Low	47.6%	27.6%	14.3%	27.1%
Average	19.0%	41.4%	37.1%	34.1%
Good	0.0%	17.2%	11.4%	10.6%
Excellent	0.0%	3.4%	8.6%	4.7%
Total	100.0%	100.0%	100.0%	100.0%

TABLE 5 | Regression Hb with each fitness variable.

Regression weight	Beta coefficient	R^2	F	p-value	Correlation coefficient (r)
Hb → VO2max	0.623	0.105	8.449	0.005	0.324
Hb → Reaction time	−1.541	0.014	1.346	0.249	−0.120
Hb → Flexibility	0.632	0.005	0.398	0.530	0.072
Hb → LHG	2.783	0.194	19.294	< 0.001	0.441
Hb → RHG	2.697	0.196	19.537	< 0.001	0.443
Hb → RHGS	0.087	0.143	13.046	0.001	0.379

Hb [31], micronutrient demand may outstrip the dietary intake to meet physiologic needs leading to an increased risk and the prevalence of anemia. The magnitude of anemia among the early adolescents in this study was significant enough to be classified as a moderate public health problem according to the WHO public health problem categorization [34]. The prevalence among the mid and late adolescents is however considered a mild public health problem similar to findings from an Ethiopian study on anemia among adolescents [31]. A study among adult amateur runners in Congo found that about 15.8% presented with mild anemia [35]. Although there are currently not enough representative estimates for anemia prevalence among male adolescents in Ghana [25], the relatively elevated prevalence among male adolescent athletes from this study, calls for attention to anemia among adolescent males. Anemia Prevalence among athletes in our study was higher than what was found among adolescent sports participants in a Finnish study [8]. The prevalence from our study was however a little lower than the 16% found among adolescent sports club members in a Japanese study [9]. The variation in prevalence from the various studies could be due to different racial backgrounds, dietary variety, socioeconomic conditions, intensity of exercise, and training weather conditions of the study participants from different geographic locations [36]. Adolescent athletes may have limited access to balanced diet, or even limit food consumption to regulate their weight, which could eventually affect the total dietary intake, and the dietary micronutrients. Iron and Vitamin B_{12} are important micronutrients for the maturation of red cells and Hb development [37] and therefore dietary intake, physiological losses and other factors that affect their levels could influence the prevalence of anemia.

The proportion of male adolescent athletes who were anemic from our study was more than nonathletic adolescent males (13%) from a study in Ghana [25]. Iron lost through sweat (2.5 mg of iron lost per liter of sweat) [38], exercise-induced inflammation, and hemolysis are thought to contribute to the generally lower Hb concentrations of athletes than the general population [18, 39]. In this study, we found that the Hb levels among the females were significantly lower than the males though the proportions who were anemic were similar among both genders. Menstruation among adolescent females could also contribute to low Hb levels observed in this study. Research and global estimates demonstrate that the prevalence of anemia is generally higher among females compared to males [4, 19, 40].

Anemia represents a decreased concentration of Hb and will limit the oxygen-carrying capacity of the blood, affecting its ability to meet physiologic responses adequately [17]. Our findings from this study suggest a significantly positive association between Hb levels and the magnitude of cardiorespiratory endurance. This was similar to studies by Kriswanto et al., and Zufrianingrum and Sukarmin, among young athletes, where they both found a positive correlation between Hb levels and cardiorespiratory endurance [24, 41]. A study by Astuti et al. among adolescent athletes in Indonesia also found similar results [42]. Nonanemic athletes also had significantly higher maximal oxygen uptake than their anemic counterparts. This further affirms the concept that anemia could impair aerobic endurance capacity, a physical measure of fitness [17]. Cardiorespiratory endurance increases with age from childhood to about 20 years [43]. From the study, we observed that athletes who had an 'excellent' level of cardiorespiratory endurance were mainly within the late adolescent group, and none of the early adolescents expressed an excellent endurance capacity. Rapid adolescent growth involves the structural and functional development of respiratory and cardiovascular organs. This development increases the overall cardiac output by an increment in the rate and amount of oxygen delivered to working muscles. We also believe that training over a period of time could improve stamina, and compared to early adolescents, late adolescent athletes must have had a few more years of training to improve their cardiorespiratory endurance. An earlier study study among healthy United states soldiers, 18 years and above, found that cardiorespiratory endurance declined with age but noted that for a particular age group those, those who trained more had higher endurance [44].

Nonanemic adolescents from our study had better reaction time. Reaction time is an indirect measure of sensorimotor function and a simpler means of measuring the processing speed of the central nervous system [45]. A higher reaction time means a longer time from detection of stimulus, signal processing and interpretation, motor planning and response [46–48]. From our study, reaction time was higher among anemic adolescents than those with no anemia, though not significant. Studies by Kahlon et al. and Sharma et al., among adolescents also found higher reaction time among those with anemia suggesting reduced sensorimotor function with anemia [45, 49]. Iron supplementation among anemic individuals led to improved motor skills and cognitive function [50]. The general weakness, poor concentration, and tiredness associated with anemia could probably have contributed to relatively increased reaction time among anemic adolescents.

Anemic adolescents had lower handgrip strength but not flexibility. Hand grip strength and relative hand grip strength (RHGS), a measure of muscular strength, have been used to predict mortality among middle-aged individuals [51], and linked to optimal cardiovascular health in adolescents and children [52]. It is used as an indicator of physical fitness [53] or physical performance [54]. Our study showed a significant positive association between hand grip strength and Hb. Research by Marzban et al. also showed a significant association between Hb levels and hand grip strength [36]. Other studies in Brazil [55] and Korea [56] also found a significant association between hand grip strength and anemia. Oxygen transport to the muscles declines with decreasing Hb levels which could cause hypoxia of the muscle tissues [36] resulting in reduced muscle strength and lower handgrip strength observed in our study, suggesting that anemia could account for some variation in the muscular strength of the athletes. We observed anemia was associated with muscular strength [57], aerobic capacity [58], and reaction time [45, 49] but bore no association with the flexibility of adolescents involved in sports.

5 | Conclusion

In conclusion, the study has given insight into the incidence of anemia, and the physical fitness level of adolescent Ghanaian athletes. Our findings suggest that anemia could independently predict cardiorespiratory endurance and muscular strength which are important components of physical fitness among sportsmen and women. Our study found anemia to be mild to moderate public health risk among adolescent athletes in Ghana and could be an independent risk factor for low levels of physical fitness. Adolescent athletes are still in an active growth phase and anemia of any form will impair growth, especially when there's an increased demand for exercise and rigorous training schedules. Whether the type of anemia could have varying measures of influence on performance and fitness variables, will require further studies.

6 | Limitations

In this study, a differential analysis was not done to determine the type of anemia that was prevalent. However. determination of anemia was based on WHO classification using age and Hb concentration [2]. Other factors that could have influenced anemia including the macro and micronutrient intake were not included in the analysis. The study design was cross-sectional, so we could not infer causality.

Author Contributions

Divine Eli-Cophie: conceptualization, investigation, funding acquisition, writing–original draft, methodology, validation, visualization, writing–review and editing, software, formal analysis, data curation, resources, project administration. **Charles Apprey:** conceptualization, investigation, writing–original draft, methodology, validation, writing–review and editing, formal analysis, project administration, supervision, data curation, software, visualization. **Reginald Adjetey Annan:** conceptualization, investigation, writing–original draft, methodology, validation, writing–review and editing, software, formal analysis, supervision, data curation, resources, project administration, visualization.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data is available on reasonable request to the author, through the chairman of the Committee of Human Research Publication and Ethics, of the Kwame Nkrumah University of Science and Technology, School of Medical Science, Ghana.

Transparency Statement

The lead author DIVINE ELI-COPHIE affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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