Physiology and Pharmacology

Physiol Pharmacol 20 (2016) 137-146 **www.phypha.ir/ppj**

Original Article

Does anthropometric measurements correlate with hematological parameters after the adolescent growth period?

Mehnaaz Sameera Arifuddin*, Mohammed Abdul Hannan Hazari

Department of Physiology, Deccan College of Medical Sciences, Hyderabad, Telangana, India

Abstract

Introduction: Musculoskeletal growth is variable during adolescent period and reaches its maximum by 18 years, whereas hemopoietic parameters reach adult values by 15 years. After adolescence period, the blood parameters may vary with nutrition and built of the individual. The purpose of this study was to find out any correlation between anthropometric and hematological parameters after the adolescent growth period.

Methods: Total of 81 subjects (males: 20; females: 61), 18-22 years were analyzed for 4 anthropometric measures and 19 hematological markers. Blood was collected in citrate tubes and analyzed for hematological parameters.

Results: Difference between BMI sub-groups with respect to hemoglobin (Hb), red cell distribution width-standard deviation (RDW-SD) and red cell distribution width-coefficient of variation (RDW-CV) in males and females was not significant. In males, height showed negative correlation with mean corpuscular hemoglobin concentration (MCHC) and weight showed positive correlation with hematocrit. BMI positively correlated with Hb. Body surface area (BSA) correlated with red blood cell count (RBC) and hematocrit. In females, height, weight and BSA did not show significant correlation with any of the blood parameters. BMI correlated positively with mid-cell fraction and negatively with mean platelet volume. RDW-SD and RDW-CV did not reveal any statistically significant correlation with height, weight, BMI and BSA in both males and females.

Conclusion: In male subjects, hemoglobin concentration positively correlated with BMI whereas RBC count and hematocrit correlated with BSA. In females no such association was noted. RDW did not show any correlation with anthropometric measures in both genders.

Email: mehnaaz@deccancollegeofmedicalsciences.com

Keywords:
BMI;
Body surface area;
Hematological parameters;
RDW;
Anthropometry

Received: 9 Mar 2016
Accepted: 13 Aug 2016

***Correspondence to:**
M. Sameera Arifuddin

Tel: +914024340225
Fax: +914024340235

Introduction

The period between 13-18 years of age is characterized by growth spurts and puberty changes in boys and girls and is called as adolescent period. During this period growth rate is variable; with initial fast growth followed by a period of slow growth and

then another spurt in growth. Sexual maturation or pubertal changes occur gradually over a period of time (Stanford Children's Health, 2016). In humans, growth spurt during adolescence is noticed primarily in long bones and other skeletal elements and continue till 18 years of age (Bogin B, 2016). Post-pubertal changes are seen not only in skeletal growth velocity and in muscle mass, but also in hemopoietic tissues. Many studies have shown that there are hematological variations at different stages of life. The level of hemoglobin, red blood cell count, packed cell volume are higher at birth and decrease thereafter, and attain adult values by the age of 15 years. However, levels in females are found to be less as compared to males owing to the effect of sex hormones on hemopoiesis (El-Hazmi and Warsy, 2001).

Anthropometric parameters like weight, height, body mass index (BMI) are frequently used as markers for assessment of nutritional status. Risk of mortality in seriously ill or hospitalized patients is increased if associated with low BMI. On the contrary, there is a decline in cognitive abilities and increased risk of many chronic diseases in patients with increased BMI (Housman et al., 2011). Body growth and development are also affected by malnutrition especially during adolescent period. The most common presentation seen in young adolescents is anemia, with iron deficiency being the most common underlying cause (Peter et al., 2012). Red cell distribution width (RDW), is a measure of the variability in size of circulating red blood corpuscles i.e. anisocytosis which is an indirect evidence of various factors affecting hemopoiesis including the nutritional status (Montagnana et al., 2011). An increase in RDW can also result from conditions that alter the shape of red blood cells due to the premature release of immature cells into the bloodstream, hemoglobinopathies or other hematological diseases (Skjelbakken et al., 2014). Increased RDW is also known to be a predictor of cardiovascular mortality in general population (Chen et al., 2010; Perlstein et al., 2009; Patel et al., 2009; Söderholm et al., 2015) and is also associated with increased mortality and adverse outcomes in renal and infectious diseases. Therefore, RDW is now considered as a new marker for estimating the risk of morbidity and mortality in various disease conditions (Li et al., 2015). Studies have been carried out to determine reference intervals for complete blood count and stratification based on age and sex in North America (Cheng et al., 2004), Europe (Nordin et al., 2004) and China (Qiao et al., 2014). Attempts have been made to find association of blood cell counts and anthropometry measures in pediatric age group (Kelishadi et al., 2010; Aypak et al., 2014). Available studies in general population cohorts especially young healthy adults correlating blood parameters with anthropometric measures are however limited, particularly in the Indian sub-continent. We hypothesize that after the adolescence growth period the nutritional status of an individual as assessed by anthropometry may majorly influence functioning of hemopoietic tissue as well as being reflected in peripheral blood parameters. The purpose of this study was to find out any correlation between anthropometric and hematological parameters including red cell distribution width in young adults.

Materials and methods

An observational study was conducted in Department of Physiology after obtaining approval from Institutional Review Board. A total of 81 subjects (males: 20; females: 61) within the age range of 18-22 years were included in this study. Informed consent was taken from all subjects.

Exclusion criteria

Subjects already on iron supplementation; with any chronic disorder like asthma, tuberculosis, etc.; with any acute infection at the time of study were excluded. Pregnant and lactating women were also excluded.

Anthropometry

Subjects' height was measured to the nearest centimeter, while standing on a leveled ground. Subjects' weight was recorded using the Krups weighing machine to the nearest 0.1 kg, while standing straight with minimal clothing and without footwear. Body mass index (BMI) was calculated as below.

$$BMI\ \left(\frac{kg}{m^2}\right) = \frac{Weight\ (Kg)}{Height\ (m^2)}$$

Table 1: Classification of anemia based on hemoglobin (g/dL) values (WHO, 2011)

	Male (≥15 years)	Female (≥15 years, Non-pregnant)
Normal	≥13	≥12
Mild	12.9-11.0	11.9-11.0
Moderate	10.9-8.0	10.9-8.0
Severe	<8.0	<8.0

BMI categories were as follows (CDC, 2016):

1. Underweight : < 18.5 kg/m^2
2. Normal Range: 18.5-24.9 kg/m^2
3. Overweight: > 25-29.9 kg/m^2
4. Obese: > 30 kg/m^2

Subjects' body surface area (BSA) was calculated using Du Bois and Du Bois formula (Halls, 2016).

$$BSA\ (m^2) = 0.007184 \times Height\ (cm)^{0.725} \times Weight\ (Kg)^{0.425}$$

Hematological parameters

Blood collection: Venous blood was drawn from antecubital vein under aseptic precautions in 2 ml tubes containing 3.2% buffered tri sodium citrate (J. K. Diagnostics, Rajkot, India). Blood samples were analyzed in an automated cell counter (BC-2800, Mindray Medical International Limited, Shenzhen, China) within 24 hours of collection for hemoglobin (Hb), red blood cell (RBC) count, mean corpuscular volume (MCV), hematocrit (Hct), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red cell distribution width (RDW), total white blood cell (WBC) count, granulocytes (both absolute and percentage), lymphocytes (both absolute and percentage), mid cell fraction which is comprised of eosinophils, basophils, monocytes, and precursors of WBCs (both absolute and percentage), platelets, mean platelet volume (MPV) and platelet crit.

The values of Hb, RBC, Hct, total WBC, granulocytes, lymphocytes, mid-cell fraction, platelets, were multiplied by a factor of 1.1 to correct for sample dilution (1:9) which occurs by the use of citrate anticoagulant. However, the percent granulocytes and lymphocytes were recalculated by a simple percentage ratio of absolute granulocyte or lymphocyte to total WBC multiplied by 100. Sized parameters (MCV, RDW and MPV) and proportional parameters (MCH and MCHC) required no correction because these measurements were unaffected by dilution (Hanson, 2002; Perrotta et al., 1998).

The reference range for red cell distribution width-standard deviation (RDW-SD) is 39-46 fL (Briggs and Bain, 2012) and for red cell distribution width-coefficient of variation (RDW-CV) is 11.6-14.6% (Vajpayee et al., 2011).

RDW-SD is an actual measurement of the width of the RBC size distribution histogram and is measured by calculating the width (in fL) at the 20% height level of the RBC size distribution histogram. This parameter is therefore not influenced by the average RBC size (MCV). Whereas, RDW-CV is calculated using standard deviation and MCV by below mentioned equation. Since RDW-CV is mathematically derived from MCV, it is therefore affected by the average RBC size (MCV) (Curry et al., 2016). We used citrate as the EDTA coagulated blood gives false high RDW (Wikipedia, 2016).

$$RDW - CV\ (\%) = \frac{1\ \text{standard deviation of RBC volume}}{\text{MCV}} \times 100\%$$

Statistical analysis

Data obtained was analyzed using SPSS 17.0 (SPSS Inc., Chicago, USA). For differences in mean, either Student's t test or one-way analysis of variance (ANOVA) or Welch test was done depending on the significance of Levene's test of homogeneity of variances. LSD (Equal variances assumed) and Tamhane's (Equal variances not assumed) Post-Hoc tests were performed for statistical significance. Correlation statistics using Pearson's correlation coefficient was done. Statistical significance was fixed at $p<0.05$. Continuous variables are presented as mean ± standard deviation.

Table 2: Participant data and gender differences

	Gender		t-test, p value
	Male (n=20)	**Female (n=61)**	
Age (years)	19.90±0.85	19.70±0.99	t = 0.790, p = 0.432
Height (cm)	171.20±5.24	157.61±4.67	t = 10.962, p = 0.000*
Weight (kg)	69.25±10.97	56.39±10.33	t = 4.756, p = 0.000*
BMI (kg/m^2)	23.65±3.74	22.67±3.83	t = 1.002, p = 0.319
BSA (m^2)	1.81±0.13	1.56±0.14	t = 7.017, p = 0.000*
Hemoglobin# (g/dl)	13.54±1.38	10.54±1.44	t = 8.157, p = 0.000*
RBC# (million/mm^3)	5.44±0.58	4.73±0.53	t = 5.007, p = 0.000*
WBC# (/mm^3)	6056±1371	7040±1806	t = -2.233, p = 0.028*
Lymphocytes# (/mm^3)	2448±450	2593±622	t = -0.965, p = 0.337
Mid cell fraction# (/mm^3)	380±140	451±247	t = -1.227, p = 0.224
Granulocyte# (/mm^3)	3229±1177	3991±1358	t = -2.246, p = 0.027*
Lymphocyte# (%)	41.70±9.50	37.83±7.63	t = 1.848, p = 0.068
Mid-cell fraction# (%)	6.25±1.64	6.42±2.94	t = -0.239, p = 0.811
Granulocyte# (%)	52.04±9.52	55.69±8.35	t = -1.638, p = 0.105
Hematocrit# (%)	46.11±4.58	38.11±4.73	t = 6.610, p = 0.000*
MCV (fL)	85.21±6.39	81.01±8.92	t = 1.944, p = 0.055
MCH (pg)	25.02±2.76	22.35±2.96	t = 3.555, p = 0.001*
MCHC (g/dl)	29.36±2.01	27.74±1.69	t = 3.551, p = 0.001*
RDW-CV (%)	13.62±1.06	14.86±1.66	t = -3.886, p = 0.000*
RDW-SD (fL)	43.88±3.30	45.62±4.78	t = -1.519, p = 0.133
Platelet# (/mm^3)	160435±52344	212805±53536	t = -3.817, p = 0.000*
MPV (fL)	9.24±0.61	9.22±0.61	t = 0.129, p = 0.897
PDW (%)	14.88±0.31	14.80±0.37	t = 0.820, p = 0.415
Plateletcrit# (%)	0.15±0.05	0.20±0.05	t = -3.640, p = 0.000*

#corrected values for dilution, *Level of significance: p<0.05

Results

The mean age of the study group was 19.75±0.10 years. Because of the known physiological effect of sex hormones on the erythropoiesis, analysis was carried out separately for either of the gender. The mean weight of males and females is 69.25±10.97 and 56.39±10.33 kg, respectively. The mean height of males and females is 171.2±5.2 and 157.6±4.6 cm, respectively (Table 2). The mean RDW-SD and RDW-CV in males and RDW-SD in females was within normal range, whereas RDW-CV in females was slightly above normal range (Briggs and Bain, 2012; Vajpayee et al., 2011). Figure 1 shows that 5 out of 20 (25.0%) male participants were anemic and figure 2 shows that 56 out of 61 (91.8%) female participants were anemic. Mean body mass index in underweight, normal and overweight participants is given in Table 3. The mean RDW-SD and RDW-CV in both males and females is given in Table 4.

Table 1 shows significant differences on independent sample t test between genders with respect to height, weight, BSA, WBC, Hb, RBC, hematocrit, MCH, MCHC, RDW-CV, platelets, plateletcrit. No significant difference was seen between genders with respect to body mass index, MCV and RDW-SD.

Linear regression analysis done to find out relation between Hb, RDW-SD and RDW-CV with BMI and BSA did not show any significant results in both genders. Figure 1 and 2 depicts the scattering of data for hemoglobin with respect to BMI in males and females respectively. We sub-grouped the individuals according to the BMI category (Table 3). Overweight and obese individuals were included under one group as the number of individuals in obese group was only 3. Difference between BMI sub-groups with respect to Hb, RDW-SD and RDW-CV in males (Table 4) and females (Table 5) was also not significant.

Gender specific results

Bivariate correlation using Pearson's statistics was performed separately for males and females. Few of the hematological parameters significantly correlated with anthropometric measures.

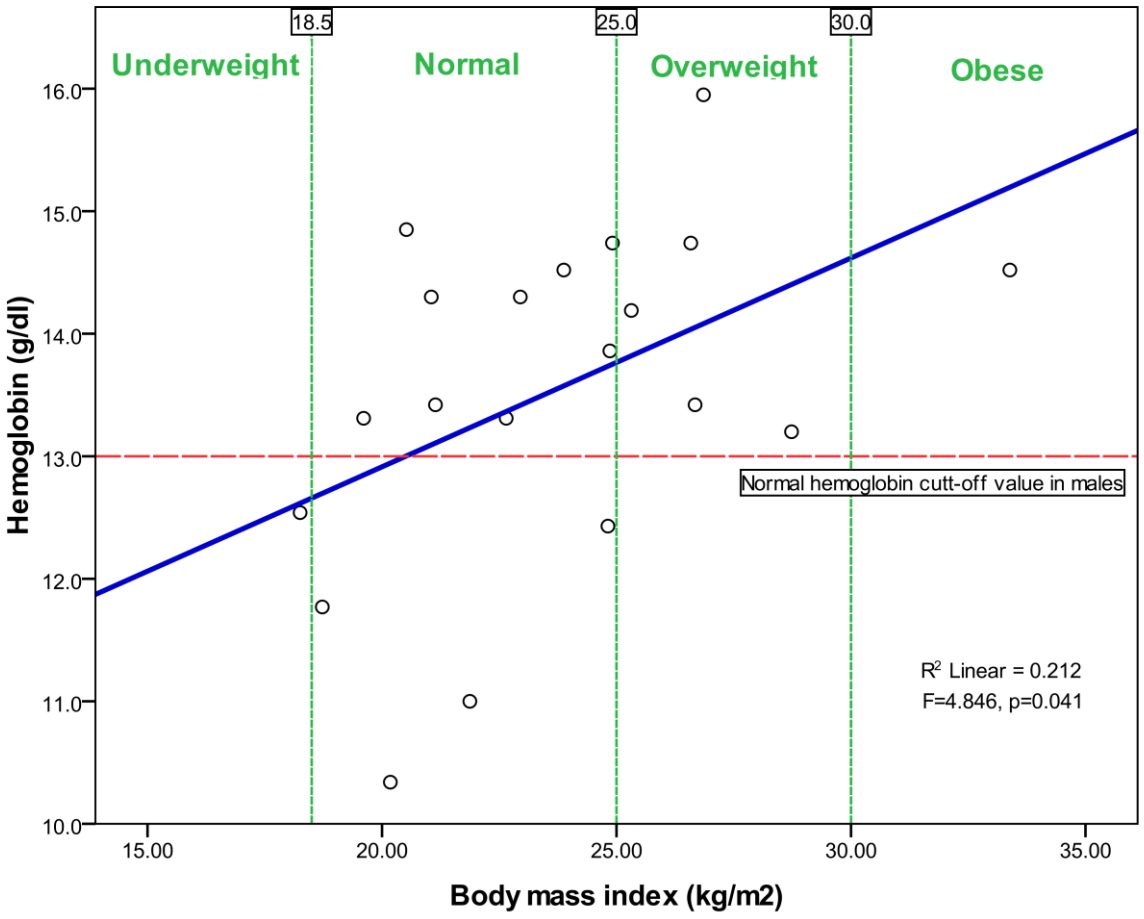

Fig.1. Variation in hemoglobin in relation to BMI in males with trend line

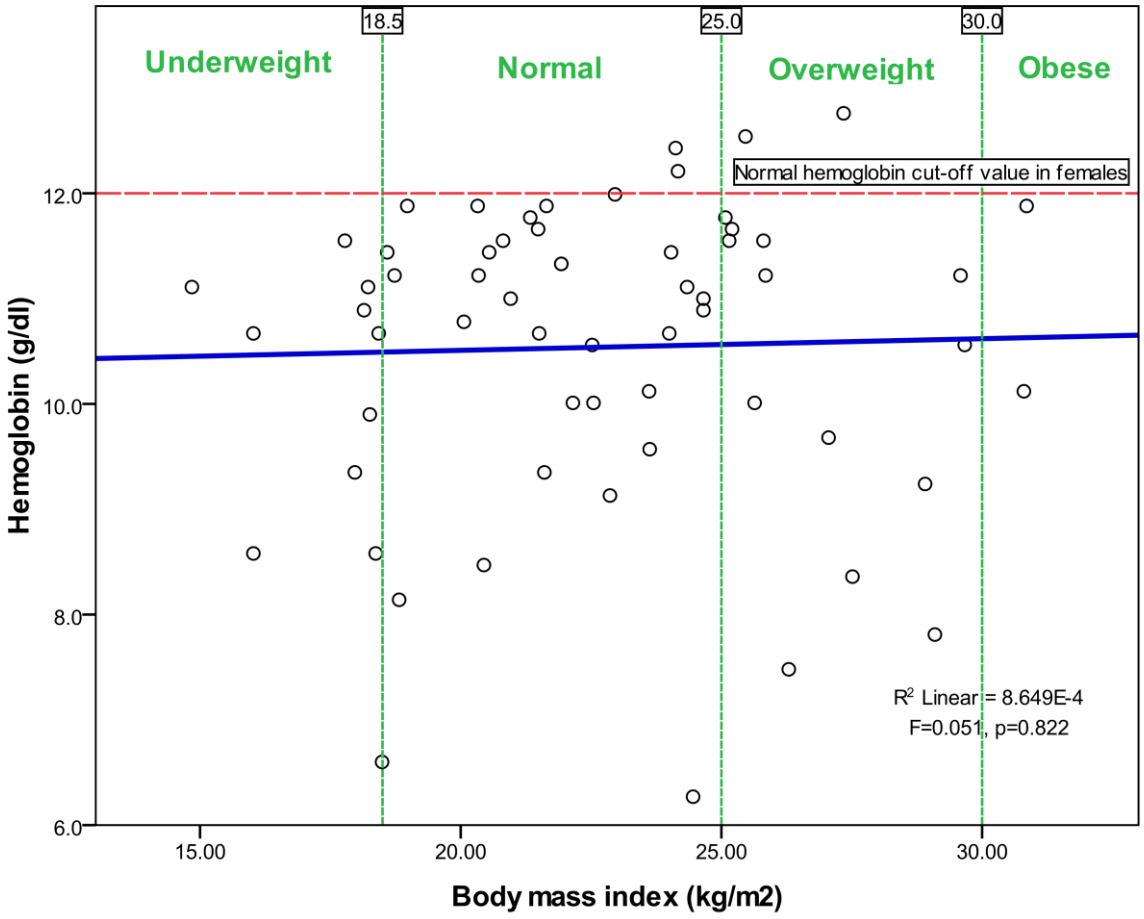

Fig.2. Variation in hemoglobin in relation to BMI in females with trend line

In males, height showed negative correlation with MCHC (r=-0.539, p=0.014). Weight was positively correlated with hematocrit (r=0.454, p=0.044). BMI positively correlated with Hb (r=0.461, p=0.041). BSA correlated with RBC (r=0.446, p=0.049) and hematocrit (r=0.451, p=0.046).

In females, height, weight and BSA did not show significant correlation with any of the blood parameters. BMI positively correlated with mid-cell fraction (r=0.260, p=0.043) and negatively correlated with mean platelet volume (r=-0.0257, p=0.045).

RDW-SD and RDW-CV did not reveal any statistically significant correlation with height, weight, BMI and BSA in both males and females.

Discussion

The current study was done to evaluate any correlation between the anthropometric measurements and hematological profile especially red cell distribution width in young adults who have just completed their adolescence period; a period when both growth and blood parameters have already reached adult values.

In current study, 25.0% male and 91.8% female participants were anemic which was in contrast to the result obtained in a study done on Chinese population with only 31.1% women over 20 years of age were anemic (Qin et al., 2013).

Some of our study participants were underweight (Total: 16.04%, Males: 5.0%, Females: 19.7%) in contrast to Moafi et al (2011) study in which 19.4% of the total enrolled university going students (18.2% male, 20% female) were underweight. Major portion (55.55%) of our participants was in normal BMI category (Males: 65.0%, Females: 52.5%). The percentage of combined overweight and obese individuals was 30.0% in males and 27.9% in females (Total: 28.39%). Iranian study (Fujita et al., 2013) showed that 32.2% of total subjects were having normal weight and 37.7% and 30.1% were overweight and obese, respectively. In the study by Qin et al (2013) the prevalence of overweight/obese

Table 3: Mean body mass index in underweight, normal and overweight participants

	Underweight (n=13)	Normal (n=45)	Overweight/obese (n=23)
BMI (kg/m^2)	17.65±1.20	22.07±1.85	27.51±2.24

Table 4: Mean values of Hb, RDW-SD and RDW-CV in male participants with respect to body mass index

	Underweight (n=1)	Normal (n=13)	Overweight/Obese (n=6)	ANOVA
Hb (g/dl)	12.5±0.0	13.2±1.5	14.3±1.0	F=1.669, p=0.218
RDW-SD (fL)	49.1±0.0	43.7±3.5	43.5±2.4	F=1.382, p=0.278
RDW-CV (%)	13.8±0.0	13.8±1.3	13.3±0.3	F=0.452, p=0.644

Table 5: Mean values of Hb, RDW-SD and RDW-CV in female participants with respect to body mass index

	Underweight (n=12)	Normal (n=32)	Overweight/Obese (n=17)	ANOVA
Hb (g/dl)	10.0±1.5	10.7±1.3	10.6±1.6	F=0.976, p=0.383
RDW-SD (fL)	46.9±4.3	45.0±4.9	46.0±4.9	F=0.721, p=0.490
RDW-CV (%)	15.4±2.0	14.6±1.6	14.9±1.9	F=0.945, p=0.395

status was 40.0% in females.

In our study, BMI positively correlated only with Hb but a European study showed a positive correlation of BMI with Hb, RBC, and Hct (Barazzoni et al., 2014). Our study comprised of participants with ages between 18 and 22 years whereas this European study recruited subjects across a wider age group (18-69 years). Analysis of differences in Hb concentration among BMI categories revealed no significant result (Table 4 and 5) and this is consistent with the findings of Ghadiri-Anari et al. (2014) and Ausk et al. (2008) whereas Saxena et al. (2011) and Peter et al. (2012) reported an inverse relation of Hb with BMI in females.

Body surface area correlated with RBC count and hematocrit only in males and not in females in our study. On pubmed search we did not find any study which explored such relationship. Blood indices like MCV, MCH and MCHC did not show any association with BMI or BSA.

Most of the studies have shown correlation between RDW and various disease states (Chen et al., 2010; Perlstein et al., 2009; Patel et al., 2009; Söderholm et al., 2015; Li et al., 2015) but only a few have reported correlation with anthropometry in healthy individuals. To the best of our knowledge no study has so far specifically explored the relation between red cell distribution width, body mass index and body surface area in young healthy adults. Findings of our study suggest that there is no association between RDW (both RDW-SD and RDW-CV) and anthropometric measures like height, weight, BMI and BSA. A study done in adolescent subjects by Fujita et al (2013) showed that increased RDW associated with overweight/obesity is the marker of inflammation.

A Brazilian study (Oliveira et al., 2014) showed that total WBC count positively correlates with BMI but we did not find any correlation between total WBC or granulocytes or lymphocytes with BMI in both genders. Marzullo et al. (2014) concluded that neutrophils, monocytes and lymphocytes are raised in morbid obesity (BMI>40) when compared to normal BMI group which reflects the inflammatory process in these patients. None of our subjects belonged to morbid obesity group.

A population based study in United States (Vuong et

al., 2014) concluded that waist circumference rather than BMI (which is a widely used tool for assessing obesity in clinical practice) is the strong predictor for many blood parameters.

A Study by Charles et al. (2007) on individuals between 26 to 61 years found that there is no association of BMI with WBC and platelet count. Our study also did not yield any significant relationships between platelet count / platelet crit / platelet distribution width and BMI / BSA.

Conclusion

We conclude that there is no association between most of the hematological parameters and anthropometric parameters like height, weight, BMI and BSA. In male subjects, hemoglobin concentration positively correlated with BMI whereas RBC count and hematocrit correlated with BSA. In females no such association was noted. RDW did not show any relationship with anthropometric measures in both genders.

Limitations of the study

Since the normal range of different blood parameters is usually wide, our participant numbers were relatively less and require recruitment of more subjects. We suggest that a multi-centric study or a population based study be conducted to get a better understanding of variation in blood cell parameters with reference to age, sex, height, weight, BMI and BSA and to evolve reference intervals for the Indian population.

Acknowledgments

The authors thank all the participants who enrolled in this study.

Conflict of interest

The authors have no conflict of interest to declare.

References

Ausk KJ, Ioannou GN. Is obesity associated with anemia of chronic disease? A population-based study. Obesity (Silver Spring) 2008; 16: 2356-61.

Aypak C, Türedi O, Bircan MA, Yüce A. Could mean platelet volume among complete blood count parameters be a surrogate marker of metabolic syndrome in pre-pubertal children? Platelets 2014; 25: 393-8.

Barazzoni R, Gortan Cappellari G, Semolic A, Chendi E, Ius M, Situlin R, et al. The association between hematological parameters and insulin resistance is modified by body mass index - results from the North-East Italy MoMa population study. PLoS One 2014; 9: e101590.

Bogin B. Adolescent growth spurt. Center for academic research and training in anthropogeny. https://carta.anthropogeny.org/moca/topics/adolescent-growth-spurt. (Last accessed on 25th February, 2016).

Briggs C and Bain BJ. Basic haematological techniques, Chapter 3. In: Dacie and Lewis Practical Haematology, 11th ed., Bain BJ, Bates I, Laffan M, Lewis SM (Eds). Philadelphia, PA: Churchill Livingstone/Elsevier; 2012.

Centers for disease control and prevention (CDC). Available from http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/. (Last accessed on 25th February, 2016).

Charles LE, Fekedulegn D, McCall T, Burchfiel CM, Andrew ME, Violanti JM. Obesity, white blood cell counts, and platelet counts among police officers. Obesity (Silver Spring) 2007; 15: 2846-54.

Chen PC, Sung FC, Chien KL, Hsu HC, Su TC, Lee YT. Red blood cell distribution width and risk of cardiovascular events and mortality in a community cohort in Taiwan. Am J Epidemiol 2010; 171: 214-20.

Cheng CK, Chan J, Cembrowski GS, van Assendelft OW. Complete blood count reference interval diagrams derived from NHANES III: stratification by age, sex, and race. Lab Hematol 2004; 10: 42-53.

Curry CV and Staros EB. Red Cell Distribution Width (RDW). Available from http://emedicine.medscape.com/article/2098635-overview (Last accessed on 28th February 2016).

El-Hazmi MA and Warsy AS. Normal reference values for hematological parameters, red cell indices, HbA2 and HbF from early childhood through adolescence in Saudis. Ann Saudi Med 2001; 21: 165-9.

Fujita B, Strodthoff D, Fritzenwanger M, Pfeil A, Ferrari M, Goebel B, et al. Altered red blood cell distribution width in overweight adolescents and its association with markers of inflammation. Pediatr Obes 2013; 8: 385-91.

Ghadiri-Anari A, Nazemian N, Vahedian-Ardakani HA. Association of body mass index with hemoglobin concentration and iron parameters in Iranian

population. ISRN Hematol 2014; 2014: 525312.

Halls SB. Available from http://halls.md/body-surface-area/bsa.htm. (Last accessed on 20th February, 2016).

Hanson CA. Peripheral blood and bone marrow: Morphology, counts and differentials, and reactive disorders, Chapter 40, Section VII, Hematology. In: Clinical laboratory medicine, 2nd ed, McClatchey KD (Ed), Philadelphia, PA: Lippincott Williams & Wilkins, 2002, p.804.

Housman DB, Johnson MA, Davey A, Poon LW. Body mass index is associated with dietary patterns and health conditions in Georgia centenarians. J Aging Res 2011; 2011: 138015.

Kelishadi R, Hashemipour M, Ashtijou P, Mirmoghtadaee P, Poursafa P, Khavarian N, et al. Association of cell blood counts and cardiometabolic risk factors among young obese children. Saudi Med J 2010; 31: 406-12.

Li W, Li X, Wang M, Ge X, Li F, Huang B, et al. Association between red cell distribution width and the risk of heart events in patients with coronary artery disease. Exp Ther Med 2015; 9: 1508-14.

Marzullo P, Minocci A, Giarda P, Marconi C, Tagliaferri A, Walker GE, et al. Lymphocytes and immunoglobulin patterns across the threshold of severe obesity. Endocrine 2014; 45: 392-400.

Moafi A, Rahgozar S, Ghias M, Ahar EV, Borumand A, Sabbaghi A, et al. A study on body mass index, blood pressure, and red blood cell indices in new entering students of the University of Isfahan. Int J Prev Med 2011; 2: 280-5.

Montagnana M, Cervellin G, Meschi T, Lippi G. The role of red blood cell distribution width in cardiovascular and thrombotic disorders. Clin Chem Lab Med 2011; 50: 635-41.

Nordin G, Mårtensson A, Swolin B, Sandberg S, Christensen NJ, Thorsteinsson V, et al. A multicentre study of reference intervals for haemoglobin, basic blood cell counts and erythrocyte indices in the adult population of the Nordic countries. Scand J Clin Lab Invest 2004; 64: 385-98.

Oliveira TM, de Faria FR, de Faria ER, Pereira PF, Franceschini SC, Priore SE. Nutritional status, metabolic changes and white blood cells in adolescents. Rev Paul Pediatr 2014; 32: 351-9. [Article in Portuguese].

Patel KV, Ferrucci L, Ershler WB, Longo DL, Guralnik JM. Red blood cell distribution width and the risk of death in middle-aged and older adults. Arch Intern Med. 2009; 169: 515-23.

Perlstein TS, Weuve J, Pfeffer MA, Beckman JA. Red blood cell distribution width and mortality risk in a community-based prospective cohort. Arch Intern Med 2009; 169: 588-94.

Perrotta G, Roberts L, Glazier J, Schumacher HR. Use of sodium citrate anticoagulant for routine hematology analysis on the CELL-DYN® 4000: An opportunity to enhance efficiency in the clinical laboratory. Lab Hematol 1998; 4: 156-62.

Peter R, Kumar R, Sangwan L, Pandey S. Prevalence of anemia and its correlation to body mass index: study among unmarried girls. Int J Basic Appl Med Sci 2012; 2: 58-62.

Qiao R, Yang S, Yao B, Wang H, Zhang J, Shang H. Complete blood count reference intervals and age- and sex-related trends of North China Han population. Clin Chem Lab Med 2014; 52: 1025-32.

Qin Y, Melse-Boonstra A, Pan X, Yuan B, Dai Y, Zhao J, et al. Anemia in relation to body mass index and waist circumference among Chinese women. Nutr J 2013; 12:10.

Saxena Y, Shrivastava A, Saxena V. Effect of gender on correlation of anaemia with body mass index in medical students. Indian J Physiol Pharmacol 2011; 55: 364-9.

Skjelbakken T, Lappegård J, Ellingsen TS, Barrett-Connor E, Brox J, Løchen ML, et al. Red cell distribution width is associated with incident myocardial infarction in a general population: the Tromsø Study. J Am Heart Assoc 2014; 3. pii: e001109.

Söderholm M, Borné Y, Hedblad B, Persson M, Engström G. Red cell distribution width in relation to incidence of stroke and carotid atherosclerosis: a population-based cohort study. PLoS One 2015; 10: e0124957.

Stanford Children's Health. Available from http://www.stanfordchildrens.org/en/topic/default?id=the-growing-child-adolescent-13-to-18-years-90P02175. (Last accessed on 25th February 25, 2016).

Vajpayee N, Graham SS, Bem S. Basic examination of blood and bone marrow. In: Henry's Clinical Diagnosis and Management by Laboratory Methods, 22nd ed., McPherson RA, Pincus MR (Eds). Philadelphia, PA: Elsevier/Saunders; 2011.

Vuong J, Qiu Y, La M, Clarke G, Swinkels DW, Cembrowski G. Reference intervals of complete blood count constituents are highly correlated to waist circumference: should obese patients have their own "normal values?". Am J Hematol 2014; 89: 671-7.

WHO. Haemoglobin concentrations for the diagnosis of anaemia and assessment of severity.

WHO/NMH/NHD/MNM/11.1, 2011. Available from http://www.who.int/vmnis/indicators/haemoglobin.pdf (Last accessed on 28th February 2016)

Wikipedia. Red blood cell distribution width. Available from https://en.wikipedia.org/wiki/Red_blood_cell_distribution_width (Last accessed on 28th February 2016).