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Red cell distribution width is inversely associated with body mass index in late adolescents

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Abstract. – OBJECTIVE: There are no studies that investigated the association between red blood cell (RBC) and platelet (PLT) indices in relation to obesity in a cohort of exclusively late adolescents. Hence, we aimed to explore this potential relationship.

PATIENTS AND METHODS: A cohort of adolescents (n=156) aged between 16-19 years was included. Iron homeostasis parameters [i.e. RBC, hemoglobin (HGB), hematocrit (HCT), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) and red cell distribution width (RDW)] and platelet indices [i.e., PLT, mean platelet volume (MPV), plateletcrit (PCT) and platelet distribution width (PDW)] were determined on the automatic hematology analyzer. Their indexes (i.e., MCV/RBC, MCH/RBC, RDW/MCV, MPV/PLT and PDW/PCT) were calculated.

RESULTS: Univariate binary regression analysis showed negative associations between body mass index (BMI) and RDW, PDW, and PDW/PCT, respectively, and positive associations between BMI and MPV and PCT, respectively. However, only RDW kept the independent negative association with BMI in multivariate binary regression analysis [Odds Ratio (95% Confidence Interval)=0.734 (0.548-0.983); *p*=0.038].

CONCLUSIONS: Lower RDW values are the independent predictor of higher BMI in the adolescent population. As a low-cost and simply measured parameter, RDW could be a useful diagnostic biomarker in young populations with overweight/obesity.

Key Words:
Adolescents, Iron homeostasis, Obesity, Platelets.

Introduction

As a major risk factor for cardiometabolic diseases, obesity in children and adolescents still represents a serious public health concern[1,2]. Its prevalence is increasing worldwide[3,4].

Enlarged adipose tissue exerts prothrombotic and proatherogenic properties with oxidative stress and inflammation as the key underlying features which may influence the physiological functions, size, and morphology of hematological parameters[5,6].

During the last decades, a lot of researchers[7-12] have investigated the utility of hematological parameters in various cardiometabolic diseases in the adult population. These parameters are low-cost and simply measured diagnostic biomarkers. However, discrepant results were demonstrated for the majority of these parameters in the adult population with metabolic syndrome[7,8], type 2 diabetes mellitus[9,10], obesity[11,12], etc.

No consensus exists either concerning the relationship between obesity and iron homeostasis biomarkers and platelet indices in children and adolescents[13-16].

We have recently shown[17] higher levels of several iron homeostasis indices (i.e., serum transferrin, soluble transferrin receptors, and ferritin) in a small cohort of overweight/obese girls [i.e., with body mass index (BMI) $\geq$25 kg/m^2] and with homeostasis model assessment of insulin resistance (HOMA-IR) $\geq$2.5. It was also shown[18] that white blood cell count (WBC) and some of their indices (i.e. neutrophils and eosinophils) were independently associated with increased cardiovascular risk in adolescents. Hence, we hypothesized that obesity may also be related to the altered platelets and their indices, as well as red blood cell parameters in overweight/obese adolescents. In line with this, we aimed to further explore the association between iron homeostasis parameters [i.e. Red blood cell (RBC), hemoglobin (HGB), hematocrit (HCT), mean corpuscular volume

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(MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) and red cell distribution width (RDW)] and platelet indices [i.e. platelet count (PLT), mean platelet volume (MPV), plateletcrit (PCT) and platelet distribution width (PDW)] and several their indexes (i.e. MCV/RBC, MCH/RBC, RDW/MCV, MPV/PLT and PDW/PCT) in relation with obesity in a cohort of adolescents.

Patients and Methods

Study Population

The present cross-sectional cohort study is derived from the previous one[18] that examined the utility of white blood cell indices in relation to cardiovascular risk in a young population. The study was conducted in a period between April to June 2019. As previously described[18], a total of 156 adolescents were encompassed.

The criteria for adolescents' inclusion in the research were their voluntary acceptance if they were older than 15 and younger than 20 years of age, and if they kept their body weight unchanged during the last 3 months. Adolescents with hematological, inflammatory [i.e., with high sensitivity C-reactive protein (hsCRP) higher than 10 mg/L, also] and metabolic diseases were excluded from the investigation. The use of medications during the last 3 months, cigarette smoking and alcohol consumption were exclusion criteria, as well.

From a total of n=187 adolescents that were primarily screened, n=31 were excluded (n=23 with hsCRP>10 mg/L, n=2 with diabetes type 1, and n=6 who were smokers) (Figure 1).

Anthropometric measurements[17], [i.e., body mass index (BMI) and waist circumference (WC)] and blood pressure[19] were taken as previously described.

Hematological Analyses

Blood samples were obtained in the morning hours, after at least 8 hours of fasting as described previously[18]. For hematological parameters, whole blood K_2EDTA tubes were used, whereas serum separator and clot activator tubes were used for hsCRP measurement (i.e., after 30 minutes of being left to clot and thereafter centrifuged). The Sysmex XT-4000i analyzer (Sysmex Corporation, Kobe, Japan) was used for the determination of hematological analyses, whereas Roche Cobas c501 chemistry analyzer (Roche Diagnostics GmbH, Mannheim, Germany) measured serum hsCRP levels.

Statistical Analysis

All statistical analyses were performed using SPSS software version 21.0 (IBM Corp., Armonk, NY, USA). The data distribution was assessed by the Kolmogorov-Smirnov test. Normally distributed data were given as the arithmetic mean ± standard deviation and compared by Student's *t*-test. Skewed distributed variables were given as median (25^{th} percentile - 75^{th} percentile) and compared by Mann-Whitney *U* test. Differences between groups for categorical data were tested by the Chi-square test for contingency tables. Trend in relations between BMI and examined data were determined by the Spearman's rank-order correlation analysis and Spearman's correlation coefficients (ρ) were obtained. The binary regression analysis was performed to predict the odds for hematological parameters (RBC and PLT counts and indexes) as continuous, independent variables to fall into the category of the dependent variable (0 - normal weight and 1-overweight/obese participants). Multivariate binary regression models were developed by entering hematological parameters and the data significantly related to BMI and gender as predictors for the dependent dichotomous variable. The data from binary logistic regression analyses were given as odds ratio (OR) and 95% Confidence Interval (CI). Explained variations in BMI were presented as Nagelkerke R^2. All the analyses were considered statistically significant if the *p*-value was≤0.05.

Results

The clinical data with erythrocytes and thrombocytes counts, and indexes of the examined cohorts were provided in Table I. Overweight/obese participants had significantly higher BMI, WC, SBP, DBP, MPV, PCT than normal weight counterparts. However, overweight/obese participants had significantly lower RDW, RDW/MCV, PDW and PDW/PCT.

Spearman's rank-order correlation analysis was performed to determine the trend in correlation between BMI and tested variables (Table II). Higher BMI was related to higher WC, SBP, DBP, hsCRP, PLT, MPV and PCT. However, negative correlations were evident between BMI and the following markers: MCHC, RDW, PDW and PDW/PCT. This analysis presented the first step for in-depth association using binary regression analysis.

To achieve this, we first performed univariate binary regression analysis. Markers that correlated significantly with BMI in Spearman's correlation analysis were further tested for their potential

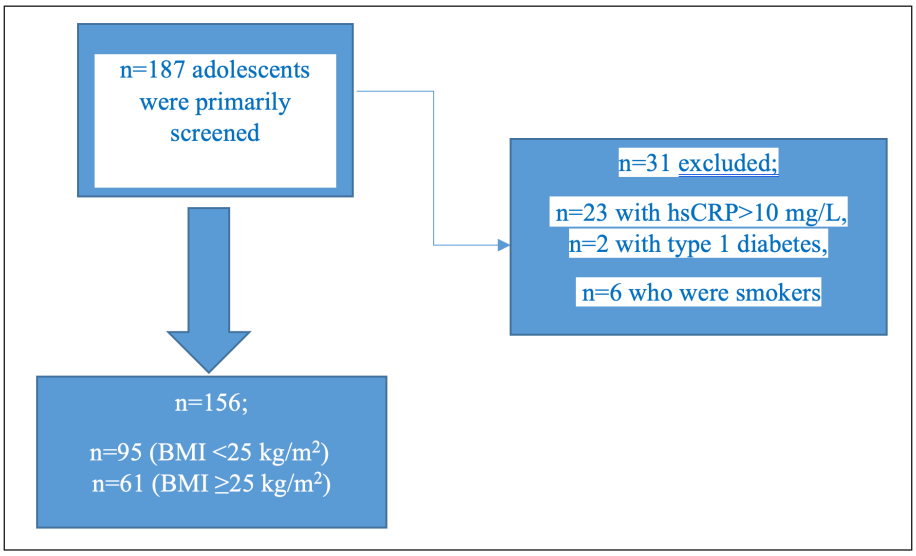

Figure 1. Participant flow chart.

independent associations with BMI. Significant negative associations remained between BMI and RDW, PDW, and PDW/PCT, respectively (Table III) in univariate analysis. Overweight/obese adolescents were 31.9%, 11.5%, and 17.9% more likely to have lower RDW, PDW, and PDW/PCT, re-

Table I. Comparison of general clinical data, erythrocytes and thrombocytes numbers and hematological indices in normal weight vs. overweight/obese adolescents.

	Normal weight (BMI <25 kg/m²)	Overweight/obese (BMI ≥25 kg/m²)	*p*
N (female/male)	95 (77/18)	61 (49/12)	0.911
Age (years)	18 (17-19)	17 (16-19)	0.055
BMI (kg/m²)	21.3 (20.1-22.7)	27.7 (26.0-30.7)	**<0.001**
WC (cm)	78 (74-80)	94 (88-100)	**<0.001**
SBP (mmHg)	110 (94-120)	120 (106-130)	**<0.001**
DBP (mmHg)	70 (61-76)	78 (70-80)	**<0.001**
hsCRP (mg/L)	0.38 (0.30-0.63)	0.91 (0.52-2.35)	**<0.001**
RBC (x10¹²/L)	4.74±0.35	4.83±0.38	0.139
Hgb (g/L)	137 (129-145)	138 (132-145)	0.513
HCT (L/L)	0.41±0.03	0.42±0.03	0.062
MCV (fL)	86.7 (84.0-88.8)	87.0 (83.8-88.8)	0.986
MCH (pg)	29.40 (28.05-30.10)	28.70 (27.50-29.60)	0.208
MCHC (g/L)	333.77±10.77	332.03±9.73	0.309
RDW (%)	14.76±2.27	13.90±1.32	**0.008**
MCV/RBC	18.07 (16.98-19.33)	18.00 (16.76-19.08)	0.565
MCH/RBC	6.08±0.64	5.99±0.62	0.378
RDW/MCV	0.17±0.04	0.16±0.02	**0.018**
PLT (x10⁹/L)	268.72±51.15	283.51±49.73	0.077
MPV (fL)	9.11 (7.93-10.10)	10.00 (8.57-10.70)	**0.010**
PCT (mL/L)	2.36 (2.05-2.67)	2.70 (2.21-3.20)	**0.001**
PDW (fL)	15.80±2.91	14.74±2.95	**0.029**
MPV/PLT	0.034 (0.028-0.041)	0.033 (0.029-0.041)	0.829
PDW/PCT	6.89±2.28	5.86±2.30	**0.007**

BMI-body mass index; WC-waist circumference; SBP-systolic blood pressure; DBP-diastolic blood pressure; hsCRP-high sensitivity C-reactive protein; RBC-red blood cells; Hgb-hemoglobin; HCT-hematocrit; MCV-mean corpuscular volume; MCH-mean corpuscular hemoglobin; MCHC-mean corpuscular hemoglobin concentration; RDW-red cell distribution width; PLT-plateletes; MPV-mean platelet volume; PCT-plateletcrit, PDW-platelet distribution width.

spectively, than their normal-weight counterparts. On the other hand, MPV and PCT were 1.336 and 2.769 times, respectively, higher in overweight/obese than in normal-weight participants. Furthermore, these predictors were adjusted for other markers related to BMI in Spearman's correlation analysis [systolic blood pressure (SBP) and hsCRP]. Although there was statistically equal gender distribution between BMI subgroups, gender was included as a covariate in the multivariate binary regression model due to the generally small number of boys in examined cohorts. After performing multivariate binary regression analysis, of all tested markers only RDW kept the independent negative association with BMI. The odds of having lower RDW is 26.6% more likely in overweight/obese than in normal-weight participants (Table III). Nagelkerke R^2 of 0.336 indicated that the multivariate regression model (including RDW, gender, hsCRP, and SBP) could explain 33.6% variation in BMI.

Discussion

As far as we are informed, the present study is the first that investigated RBC and PLT indices and several of their indexes exclusively in a cohort of late adolescents.

Table II. Correlation analysis of BMI with tested markers.

	ρ	p
Age (years)	-0.079	0.325
WC (cm)	0.841	**<0.001**
SBP (mmHg)	0.402	**<0.001**
DBP (mmHg)	0.342	**<0.001**
hsCRP (mg/L)	0.474	**<0.001**
RBC ($x10^{12}$/L)	0.146	0.069
Hgb (g/L)	0.026	0.750
HCT (L/L)	0.129	0.109
MCV (fL)	-0.016	0.840
MCH (pg)	-0.149	0.063
MCHC (g/L)	-0.207	**0.009**
RDW (%)	-0.254	**0.001**
MCV/RBC	-0.081	0.317
MCH/RBC	-0.119	0.140
RDW/MCV	-0.157	0.050
PLT ($x10^9$/L)	0.242	**0.002**
MPV (fL)	0.192	**0.017**
PCT (mL/L)	0.331	**<0.001**
PDW (fL)	-0.220	**0.006**
MPV/PLT	-0.040	0.671
PDW/PCT (mg/μg)	-0.312	**<0.001**

WC-waist circumference; SBP-systolic blood pressure; DBP-diastolic blood pressure; hsCRP-high sensitivity C-reactive protein; RBC-red blood cells; Hgb-hemoglobin; HCT-hematocrit; MCV-mean corpuscular volume; MCH-mean corpuscular hemoglobin; MCHC-mean corpuscular hemoglobin concentration; RDW-red cell distribution width; PLT-plateletes; MPV-mean platelet volume; PCT-plateletcrit, PDW-platelet distribution width.

Table III. Univariate and multivariate binary logistic regression analysis for the associations of erythrocytes and thrombocytes and their indexes and BMI in adolescents.

Predictors	Unadjusted OR (95% CI)	p	R^2
MCHC (g/L)	0.984 (0.954- 1.015)	0.303	0.009
RDW (%)	0.681 (0.518-0.896)	**0.006**	0.084
PLT ($x10^9$/L)	1.006 (0.999-1.012)	0.079	0.027
MPV (fL)	1.336 (1.066-1.673)	**0.012**	0.057
PCT (mL/L)	2.769 (1.523-5.037)	**0.001**	0.101
PDW (fL)	0.885 (0.793-0.989)	**0.041**	0.041
PDW/PCT (mg/μg)	0.821 (0.709-0.950)	**0.008**	0.063
Each predictor adjusted for hsCRP, SBP (continuous variables) and gender (categorical variable)	**Adjusted OR (95% CI)**	**p**	**R^2**
RDW (%)	0.734 (0.548-0.983)	**0.038**	0.336
MPV (fL)	1.201 (0.929-1.551)	0.162	0.315
PCT (mL/L)	1.504 (0.709-3.192)	0.287	0.309
PDW (fL)	0.998 (0.863-1.154)	0.978	0.300
PDW/PCT (mg/μg)	0.961 (0.796-1.160)	0.676	0.303

MCHC-mean corpuscular hemoglobin concentration; RDW-red cell distribution width; PLT-plateletes; MPV-mean platelet volume; PCT-plateletcrit, PDW-platelet distribution width; hsCRP-high sensitivity C-reactive protein; SBP-systolic blood pressure.

Our results demonstrated higher MPV and PCT and lower RDW, RDW/MCV, PDW and PDW/PCT in overweight/obese participants, as compared to the normal-weight corresponding group. Univariate binary regression analysis showed negative associations between BMI and RDW, PDW and PDW/PCT, respectively, and positive associations between BMI and MPV and PCT, respectively. However, only RDW kept the independent negative association with BMI in multivariate binary regression analysis.

The majority of previous studies[7,10,12] included both adolescents and children or adults in whom a variety of confounding factors might be a source of biases. Previous studies[7,10,12] did not exclude comorbidities, a wide age range of the studied population, hormone variation, drugs use, alcohol and cigarette consumption.

RDW reflects the size variability of RBC in circulation, being increased in iron deficiency anemia, and for years it was regarded as of minor importance[20,21].

Higher RDW levels were found in children with essential hypertension and left ventricular hypertrophy[22] and overweight/obese children and adolescents[15,16,23] and metabolic syndrome in the adult women[7]. However, although a study[7] included more than a thousand participants there was no such increase in males, only in females with metabolic syndrome. Also, the increase is shown only if expressed as RDW-standard deviation (RDW-SD), but not as RDW-coefficient of variation (RDW-CV), although both RDW indices positively correlated with WC in the female population[7].

Our results show the opposite, i.e. lower RDW-CV in overweight/obese adolescents and the independent negative association with BMI. This is similar to the findings of Ebrahim et al[9,] who demonstrated that besides the other RBC indices, RDW-SD was inversely correlated with BMI in an adult population with type 2 diabetes mellitus. Similarly, higher RDW level was related to a lower incidence of metabolic syndrome among Chinese adults older than 60 years of age[8].

A study of participants aged between 45 and 73 years with a 14-year follow-up showed the relationship between low RDW and increased risk for diabetes mellitus development[24]. The authors of the latter study[24] suggested that low RDW might be an indicator of reduced survival of RBC. It was assumed that hyperglycemia-induced oxidative stress and inflammation could be associated with lower changes in RBC deformability, thus leading to diminished RBC survival and forming a cell population that is more homogenous, i.e. lower RDW[24]. The authors[8] proposed another potential explanation, such as gene deletions and polymorphisms of a gene in controlling metabolic disturbances in different ethnic groups, which can, at least in part, clarify the differences between RDW and metabolic disorders. In line with this, no difference in RDW in overweight/obese Brazilian youngsters older than 4 years[13], nor in Ethiopian adults with type 2 diabetes was found[10].

Interestingly, Kohsari et al[11] demonstrated that RDW was negatively correlated with BMI in normal-weight Iranian adults, whereas the opposite was observed in the overweight/obese group. The authors[11] explained the positive association between RDW and BMI in overweight/obese subjects by increased secretion of free radicals and proinflammatory cytokines by adipose tissue. These processes can change the morphology and size of RBC and lead to anisocytosis by the increased number of premature erythrocytes in circulation and a compensatory increase in new RBC[11,25].

A possible explanation for our results might be the different duration of obesity[26]. In case of a shorter duration of obese state, compensatory mechanisms might be involved in maintaining the redox balance, and hematology parameters could not have been altered yet[26]. Also, it was earlier reported[23] that nutritional changes rather than overweight *per se* have led to increased RDW.

Another potential explanation for divergent RDW findings might be attributed to preanalytical (e.g. the time between samples collection and their analysis, the temperature of storage and transportation, etc.) and analytical factors (e.g. neither there is consensus on whether to calculate RDW-CV or RDW-SD, nor there is consensus on universal reference range, variety in automatic hematology analyzers, etc.)[20,21].

Although PLT indices were not independently correlated with BMI in our study, we recorded higher MPV and PCT and lower PDW and PDW/PCT in overweight/obese participants, as compared to the normal-weight corresponding group. Our results are similar to the study of Ebrahim et al[9,] who found a positive correlation between PCT and BMI. Similarly, Çeçen[12] demonstrated a positive correlation between BMI and PLT and PCT, respectively, and negative with PDW. Also, Anık et al[27] demonstrated higher PCT in morbidly obese, obese and overweight subjects compared to the healthy group.

It was shown[28] that an obese inflammatory state promotes an increase in PLT by enhanced secretion of proinflammatory cytokines. Indeed, we demonstrated a positive correlation between PLT and BMI in the present cohort of adolescents. Another possible explanation is an increase in thrombopoietin synthesis by adipose tissue[29], enhanced platelet reactivity and diminished fibrinolysis[5]. Moreover, obesity-related insulin resistance contributes to PLT life shortening, which may cause an increase in PLT count[30].

Limitations

The present study has several limitations that should be stated. Its cross-sectional design showed correlation, but not causation between RDW and BMI. Also, our results cannot be extrapolated to non-Caucasians. Moreover, we were not able to assess the dietary intake which might influence the iron homeostasis and PLT indices[6,23]. Nevertheless, with the inclusion of normal weight and overweight/obese adolescents without other known comorbidities and with a limited age range, we have tried to eliminate many confounding factors that could enhance the inflammation.

Longitudinal, multicentric and multiethnic large sample studies are needed to validate our results.

Conclusions

Although PLT, MPV and PCT correlated positively with BMI, whereas PDW and PDW/PCT correlated negatively with BMI, lower RDW values remained its independent predictor in the adolescent population. As a low-cost and simply measured parameter, RDW could be a useful diagnostic biomarker in young populations with overweigt/obesity.

Conflict of Interest

The Authors declare that they have no conflict of interests.

Ethics Approval

The Ethical Committee of thePrimary Health Care Center where the study was conducted gave the approval (05/01-E.K.-7143/1, date 13-02-2018).

Informed Consent

Besides the parental (i.e., for adolescents younger than 18 years), informed consent was signed by each adolescent.

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Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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References

1) Farello G, Iapadre G, Lizzi M, Gentile C, Altobelli E, Ciocca F, Verrotti A. Carotid intima media-thickness is increased in obese children metabolically healthy, metabolically unhealthy, and with metabolic syndrome, compared to the non-obese controls. Eur Rev Med Pharmacol Sci 2021; 25: 241-249.
2) Klisic A, Kavaric N, Bjelakovic B, Soldatovic I, Martinovic M, Kotur-Stevuljevic J. The association between retinol-binding protein 4 and cardiovascular risk score is mediated by waist circumference in overweight/obese adolescent girls. Acta Clin Croat 2017; 56: 92-98.
3) Kim MJ, Lee KH, Lee JS, Kim N, Song JY, Shin YH, Yang JM, Lee SW, Hwang J, Rhee SY, Yon DK, Shin JI, Choi YJ. Trends in body mass index changes among Korean adolescents between 2005-2020, including the COVID-19 pandemic period: a national representative survey of one million adolescents. Eur Rev Med Pharmacol Sci 2022; 26: 4082-4091.
4) Ban CY, Shin H, Eum S, Yon H, Lee SW, Choi YS, Shin YH, Shin JU, Koyanagi A, Jacob L, Smith L, Min C, Yeniova AÖ, Kim SY, Lee J, Yeo SG, Kwon R, Koo MJ, Fond G, Boyer L, Acharya KP, Kim S, Woo HG, Park S, Shin JI, Rhee SY, Yon DK. 17-year trends of body mass index, overweight, and obesity among adolescents from 2005 to 2021, including the COVID-19 pandemic: a Korean national representative study. Eur Rev Med Pharmacol Sci 2023; 27: 1565-1575.
5) Santilli F, Vazzana N, Liani R, Guagnano MT, Davì G. Platelet activation in obesity and metabolic syndrome. Obes Rev 2012; 13: 27-42.
6) Dandona P, Aljada A, Bandyopadhyay A. Inflammation: the link between insulin resistance, obesity and diabetes. Trends Immunol 2004; 25: 4-7.
7) Najafzadeh MJ, Baniasad A, Shahabinejad R, Mashrooteh M, Najafipour H, Gozashti MH. Inve-

stigating the relationship between haematological parameters and metabolic syndrome: A population-based study. Endocrinol Diabetes Metab 2023; 6: e407.

8) Yan Z, Fan Y, Meng Z, Huang C, Liu M, Zhang Q, Song K, Jia Q. The relationship between red blood cell distribution width and metabolic syndrome in elderly Chinese: a cross-sectional study. Lipids Health Dis 2019; 18: 34.
9) Ebrahim H, Fiseha T, Ebrahim Y, Bisetegn H. Comparison of hematological parameters between type 2 diabetes mellitus patients and healthy controls at Dessie comprehensive specialized hospital, Northeast Ethiopia: Comparative cross-sectional study. PLoS One 2022; 17: e0272145.
10) Adane T, Getaneh Z, Asrie F. Red blood cell parameters and their correlation with renal function tests among diabetes mellitus patients: a comparative cross-sectional study. Diabetes Metab Syndr Obes 2020; 13: 3937-3946.
11) Kohsari M, Moradinazar M, Rahimi Z, Najafi F, Pasdar Y, Moradi A, Shakiba E. Association between RBC Indices, Anemia, and Obesity-Related Diseases Affected by Body Mass Index in Iranian Kurdish Population: Results from a Cohort Study in Western Iran. Int J Endocrinol 2021; 2021: 9965728.
12) Çeçen S. Platelet Activation is a Risk Factor for Obesity. Turk J Endocrinol Metab 2020; 24: 132-137.
13) Yazaki LG, Faria JCP, Souza FIS, Sarni ROS. Neutrophil-to-lymphocyte and platelet-to-lymphocyte ratios of overweight children and adolescents. Rev Assoc Med Bras 2022; 68: 1006-1010.
14) Shen T, Wang J, Yang W, Li L, Qiao Y, Yan X, Chen M, Tang X, Zou J, Zhao Y. Hematological Parameters Characteristics in Children with Obstructive Sleep Apnea with Obesity. Risk Manag Healthc Policy 2021; 14: 1015-1023.
15) Christaki EV, Pervanidou P, Papassotiriou I, Bastaki D, Valavani E, Mantzou A, Giannakakis G, Boschiero D, Chrousos GP. Stress, Inflammation and Metabolic Biomarkers Are Associated with Body Composition Measures in Lean, Overweight, and Obese Children and Adolescents. Children (Basel) 2022; 9: 291.
16) Bala MM, Bala KA. Bone mineral density and complete blood count ratios in children and adolescents with obesity. Eur Rev Med Pharmacol Sci 2022; 26: 249-256.
17) Klisic A, Kavaric N, Kotur-Stevuljevic J, Ninic A. Serum soluble transferrin receptor levels are independently associated with homeostasis model assessment of insulin resistance in adolescent girls. Arch Med Sci 2021; 1-8.
18) Klisic A, Radoman Vujačić I, Vučković Lj, Ninic A. Total leukocyte count, leukocyte subsets and their indexes in relation to cardiovascular risk in adolescent population. Eur Rev Med Pharmacol Sci 2021; 25: 3038-3044.
19) Klisic A, Kavaric N, Soldatovic I, Bjelakovic B, Kotur-Stevuljevic J. Relationship between cardiovascular risk score and traditional and nontraditional cardiometabolic parameters in obese adolescent girls. J Med Biochem 2016; 35: 282-292.
20) Xanthopoulos A, Giamouzis G, Dimos A, Skoularigki E, Starling RC, Skoularigis J, Triposkiadis F. Red Blood Cell Distribution Width in Heart Failure: Pathophysiology, Prognostic Role, Controversies and Dilemmas. J Clin Med 2022; 11: 1951.
21) Frater JL. Red Blood Cell Distribution Width as a Biomarker in Type 2 Diabetes Mellitus: Technical Notes [Letter]. Diabetes Metab Syndr Obes 2023; 16: 479-481.
22) Sun X, Liu Y, Liu Y, Wang H, Liu B, Shi L. Association between red blood cell distribution width and left ventricular hypertrophy in pediatric essential hypertension. Front Pediatr 2023; 11: 1088535.
23) Fujita B, Strodthoff D, Fritzenwanger M, Pfeil A, Ferrari M, Goebel B, Figulla HR, Gerdes N, Jung C. Altered red blood cell distribution width in overweight adolescents and its association with markers of inflammation. Pediatr Obes 2013; 8: 385-391.
24) Engstrom G, Smith JG, Persson M, Nilsson PM, Melander O, Hedblad B. Red cell distribution width, haemoglobin A1c and incidence of diabetes mellitus. J Intern Med 2014; 276: 174-183.
25) Bissinger R, Bhuyan AAM, Qadri SM, Lang F. Oxidative stress, eryptosis and anemia: a pivotal mechanistic nexus in systemic diseases. FEBS J 2019; 286: 826-854.
26) Hildebrandt X, Ibrahim M, Peltzer N. Cell death and inflammation during obesity: "Know my methods, WAT(son)". Cell Death Differ 2023; 30: 279-292.
27) Anık A, Çelik E, Anık A.The Relation of Complete Blood Count Parameters with Metabolic and Clinical Parameters in Overweight and Obese Children. J Pediatr Res 2021; 8: 161-170.
28) Schafer AI. Thrombocytosis. N Engl J Med 2004; 350: 1211-1219.
29) Maury E, Brichard SM, Pataky Z, Carpentier A, Golay A, Bobbioni-Harsch E. Effect of obesity on growth-related oncogene factoralpha, thrombopoietin, and tissue inhibitor metalloproteinase-1 serum levels. Obesity (Silver Spring) 2010; 18: 1503-1509.
30) Jones RL, Paradise C, Peterson CM. Platelet survival in patients with diabetes mellitus. Diabetes 1981; 30: 486-489.