



RESEARCH ARTICLE

WHITE BLOOD CELLS AND ITS RELATION WITH OBESITY, LIPID PROFILE AND INFLAMMATORY MARKERS IN INDIAN WOMEN

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ABSTRACT

Introduction: Non-communicable diseases (NCDs) are on rise in developed and developing countries and inflammation is one of the root causes for most of these NCDs. In obesity, diabetes and other diseases with underlying insulin resistance, persistent leucocytosis, reflects underlying inflammation. Therefore, the objective of present study was to study the association between white blood cells (WBC), obesity and inflammation and also study whether WBC is associated with pro-inflammatory markers independent of obesity and body fat distribution.

Methods: A cross-sectional study was conducted in 200 apparently healthy women aged 21-45 years living in urban slums of Mumbai. They were assessed for complete blood count, lipid profile and inflammatory markers. Weight, height, waist circumference, hip circumference and skinfolds were measured and body mass index (BMI), waist to hip ratio (WHR), waist to height ratio (WHtR) and percent body fat (PBF) were calculated.

Results: A little more than three-fourth of the women (n=170) had WBC<11000 cells/cu mm whereas thirty women had leucocytosis with WBC≥11000 cells/cu mm. Sixty percent of women with leucocytosis were obese with BMI≥25kg/m². Mean hs-CRP levels were significantly higher in overweight/obese women having leucocytosis (7.7±3.5mg/L) compared to those women who had normal BMI and having leucocytosis (5.0±3.3mg/L) or women with normal BMI and WBC counts both together (3.6±3.3mg/L).

Conclusion: Leucocytosis can form a simple marker of underlying inflammation in obesity and obesity-associated NCD's. It can be used as a simple measure for biochemical investigation in obese individuals to detect and prevent adults who are at risk of developing non-communicable diseases.

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INTRODUCTION

In recent years, the prevalence of metabolic syndromes and other non-communicable diseases (NCD's) has increased dramatically in both developed and developing countries. Inflammation is the root cause of a number of diseases including non-communicable diseases (Hunter, 2012). Chronic inflammation is a condition in which there is a protective response towards injury leading to tissue remodelling (Kumar *et al.*, 2009). Konstam *et al.* (2011) stated that the severity of tissue remodelling determines the prognosis of non-communicable diseases. Studies in literature reveal a positive association between diabetes, cardiovascular disease and inflammatory markers (Paiet *et al.*, 2004; Wang *et al.*, 2013). Obesity is a state of low grade inflammation (Castro *et al.*, 2017). Adipose tissue is a great source of markers of systemic

inflammation such as interleukin-6 (IL-6) and C-reactive protein (CRP) (Castro *et al.*, 2017). Pro-inflammatory cytokines such as IL-6 and interleukin 8 (IL-8), are important inducers of WBC production (Lasselín *et al.*, 2014). White blood counts (WBC) can provide useful information regarding the risk for various health conditions and is an objective marker of acute infection, tissue damage, and other inflammatory conditions (Blumenreich, 1990; Margolis *et al.*, 2005). WBC count, is one of the major components of inflammatory process and plays an important role in the pathogenesis of insulin resistance and cardiovascular disease (Ohshita *et al.*, 2004; Lasselín *et al.*, 2014) and can independently predict the development of coronary heart disease (Muniret *et al.*, 2009; Dehghani *et al.*, 2016). Therefore, leukocyte count has been proposed as an emerging biomarker for predicting future cardiovascular events. Several investigators have observed a positive relationship between WBC count and insulin resistance, hypertension, and cardiovascular disease (Ohshita *et al.*, 2004; Tamakoshi *et al.*, 2007; Lasselín *et al.*,

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2014), however, it needs to be investigated whether these associations are observed within healthy individuals with or without obesity. The World Health Organisation (2014) stated that non-communicable diseases (NCDs) contribute to around 5.87 million deaths and India shares more than two-third of the total deaths due to NCDs in the South-East Asia Region (SEAR) of WHO. Cardiovascular diseases (coronary heart disease, stroke, and hypertension) contributed to 45% of all NCD deaths. Therefore, with rising NCDs in India and strong association between WBC and cardiovascular diseases as reported in the literature, there is a need to study the association between WBC, obesity and inflammation in healthy Indian women and also study whether WBC is associated with pro-inflammatory markers independent of obesity and body fat distribution.

MATERIALS AND METHODS

The study was approved by the Independent Ethics Committee (IEC/39/13), Navi Mumbai, Maharashtra, India. This cross-sectional study was carried out in selected urban slums of Mumbai city, Maharashtra, India. Based on 2005-2006 National Family Health Survey-3 (NFHS-3, 2005-06) reports of Maharashtra on prevalence of overweight or obesity in urban women, the prevalence of obesity was assumed as 30% with $\pm 10\%$ (10% of 30% = 3%) error in the estimation with 95% level of confidence the sample was calculated to be 1500. One-third ($n=8$) of the wards from Mumbai city (total wards=24) were selected by simple random sampling. A list of slums was made within each ward. Two slums were selected randomly from each ward. Among the 1500 women, biochemical analysis was done on serum obtained from a sub-sample of two hundred women who consented to give blood and these women constituted the present study sample. Women who were pregnant, lactating or physically challenged or suffering from any non-communicable disease or cancer and AIDS (self-reported) were excluded. Also, who had diarrhoea or fever in the past two months or who experienced weight loss in the past 15 days or those who were on any medication were also excluded.

Anthropometric measurements

Weight was taken using a calibrated digital weighing scale (Equinox, Model EB6171) with an accuracy of 0.1kg. The scale was zeroed before every measurement and it was ensured that the woman was wearing a light gown and no footwear at the time of measurement. Height was measured thrice using a non-extensible, flexible measuring tape which was calibrated against a standard anthropometric rod (accuracy of 0.1cm). Height was measured with back of the head (occipital lobe), shoulder blades, buttocks and heels in contact with the wall surface and care was taken that there was no skirting on the wall against which height was measured. Body Mass Index (BMI) was calculated as $\text{weight}/\text{height}^2$ (kg/m^2). Waist circumference (WC) was measured at a level midway between the bottom of the rib cage and superior margin of iliac crests during inspiration and hip circumference (HC) was measured at maximal diameter of the buttocks. Waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) was calculated. Skin-folds were measured at four sites: biceps, triceps, subscapular and suprailiac on the right side of the body using Harpenden skin-fold callipers (Harpenden's calliper- Baty International; RH159LB, England). Skinfold thickness was measured to the nearest millimetres (mm). Percent body fat (PBF) was calculated based on the equation given by Siri (1956):

$$\text{Body Fat (\%)} = [(4.95/\text{density}) - 4.5] \times 100.$$

Body density was calculated using Durnin and Rahaman's equation for women (1967) (Durnin and Rahaman, 1967). For percent body fat, subjects were compared with cut off values for desirable fat ($\leq 30\%$) (Misra *et al.*, 2003).

Biochemical Investigations

For biochemical analysis, 10 ml of venous blood was collected in the morning after an overnight fast of twelve hours by a trained phlebotomist from which two mL of blood sample was immediately transferred to a BD vacutainer (spray-coated K2EDTA Tubes) for measurement of complete blood count (CBC) and the remaining eight ml of blood was transferred into a BD vacutainer plus plastic serum tubes for separation of serum. The vacutainers were kept in a closed ice box and were transported to a laboratory where blood was centrifuged and serum was separated which was then transported to the Department's laboratory where it was stored at -80 degree Celsius until analysis. Complete blood count was done using a fully automated random access clinical chemistry analyser (cCobas 111, Roche Diagnostics). Using the semi-automated enzymatic analyser (Transasia: ErbaSmartlab Automatic Biochemistry Analyser) and ERBA Mannheim test kits, Total cholesterol (TC), triglycerides (TG), HDL-C and LDL-C were analysed within a week of blood collection. Classification of lipid profile was done according to NCEP ATP III guidelines. High sensitivity CRP (hs-CRP) was measured by enzyme linked immunosorbent assay (ELISA) (Diagnostic Biochem Canada Inc human ELISA kit). Interleukin-6 (IL-6) and Interleukin-10 (IL-10) was measured by ELISA using human ELISA kit (DIASource IL-6 EASIA kit, Belgium and Krishgen Bio Systems Cat. No: KB1072, India respectively).

Statistical Analysis

Data was analysed using SPSS software (version 20, SPSS Inc., Chicago, IL, USA). Descriptive statistics such as mean, standard deviation, and range were computed for quantitative variables. Continuous variables were tested using Kolmogorov-Smirnov test for normality of the data. Since the data was normally distributed, analysis of variance (ANOVA) and Pearson's correlation were used to examine differences in anthropometric and biochemical measurements within quintiles of WBC. Chi-square test was done to measure the associations. p values less than 0.05 was considered statistically significant.

RESULTS

BMI, PBF and WC showed a significant association with WBC count (Table 1). A little more than three-fourth of the women ($n=170$) had $\text{WBC} < 11000$ cells/cu mm whereas thirty women had leucocytosis with $\text{WBC} \geq 11000$ cells/cu mm. A higher percentage of women (60%) of women with leucocytosis were obese with $\text{BMI} \geq 25$ kg/m^2 compared to women with normal WBC count (31.8%). Similarly, a significantly higher percentage of women (60%) with leucocytosis had $\text{PBF} > 30\%$ and $\text{WC} \geq 80$ cm (53.3%) compared to women with normal WBC count. The percentage of women with high WHR and WHtR was also high in those having leucocytosis however, the difference was not significant (Table 1).

Table 1. Distribution of women with overall and central adiposity by WBC

Indicators of Obesity	Classification	WBC (cells/cu mm) %(n)		χ^2	P
		<11000 (n=170)	\geq 11000 (n=30)		
BMI (kg/m ²)	Underweight (<18.50)	12.5(21)	10.0(3)	9.094	0.028
	Normal (18.50-22.99)	41.2(70)	23.3(7)		
	Overweight (23-24.99)	14.7(25)	6.7(2)		
	Obese (\geq 25)	31.8(54)	60.0(18)		
PBF (%)	Non- obese (\leq 30)	70.0(119)	40.0(12)	10.156	0.002
	Obese (>30)	30.0(51)	60.0(18)		
WC (cm)	Normal (<79.99)	70.6(120)	46.7(14)	6.600	0.010
	Obese (\geq 80)	29.4(50)	53.3(16)		
WHR	Normal (<0.79)	69.4(118)	60.0(18)	1.038	0.208
	Obese (\geq 0.80)	30.6(52)	40.0(12)		
WHtR	Normal (<0.50)	56.5(96)	43.3(13)	1.775	0.129
	Obese (\geq 0.50)	43.5(74)	56.7(17)		

Table 2. Mean anthropometric measurements of women as per quintiles of WBC count

Anthropo- metric Measurement	WBC (per cu mm)					F	P
	Q1 5200-7600 (n=45)	Q2 7600-8700 (n=44)	Q3 8700-9500 (n=32)	Q4 9500-10500 (n=43)	Q5 10500-17700 (n=36)		
BMI (kg/m ²)	22.7 \pm 4.2 ^{abcd}	22.4 \pm 4.6 ^{abcd}	25.4 \pm 4.5 ^{abcde}	24.2 \pm 4.5 ^{abcde}	26.2 \pm 6.3 ^{cde}	4.691	0.001
WC(cm)	73.2 \pm 9.7	72.5 \pm 9.1	78.6 \pm 9.8	76.2 \pm 9.1	78.5 \pm 12.8	3.171	0.015
HC(cm)	94.3 \pm 9.2 ^{abcd}	94.9 \pm 10.5 ^{abcde}	99.8 \pm 8.2 ^{abcde}	96.6 \pm 8.5 ^{abcde}	100.5 \pm 12.2 ^{bcde}	3.169	0.015
WHR	0.77 \pm 0.05	0.76 \pm 0.05	0.79 \pm 0.05	0.79 \pm 0.05	0.78 \pm 0.06	1.306	0.269
WHtR	0.48 \pm 0.06 ^{abcd}	0.47 \pm 0.06 ^{abcd}	0.52 \pm 0.07 ^{ce}	0.40 \pm 0.06 ^{abcd}	0.52 \pm 0.09 ^{ce}	3.416	0.010
PBF (%)	27.9 \pm 5.3 ^{abcd}	29.1 \pm 5.0 ^{abcde}	30.9 \pm 5.3 ^{abcde}	29.0 \pm 5.5 ^{abcde}	31.4 \pm 6.3 ^{bcde}	2.789	0.028

*Values with different superscripts are significantly different from each other.

Table 3. Mean Biochemical measurements of women within quintiles of WBC count

Biochemical Measurements	WBC					F	P
	Q1 5200-7600 (n=45)	Q2 7600-8700 (n=44)	Q3 8700-9500 (n=32)	Q4 9500-10500 (n=43)	Q5 10500-17700 (n=36)		
TC (mg/dl)	168.3 \pm 35.0	173.3 \pm 36.8	173.3 \pm 43.0	168.8 \pm 43.8	167.6 \pm 34.4	0.202	0.937
TG (mg/dl)	103.9 \pm 54.6	127.0 \pm 66.2	123.6 \pm 67.4	120.9 \pm 68.1	114.1 \pm 68.2	0.858	0.490
HDL-C (mg/dl)	66.5 \pm 24.5	69.6 \pm 25.4	62.9 \pm 24.7	63.9 \pm 22.0	61.6 \pm 24.7	0.694	0.597
LDL-C (mg/dl)	84.8 \pm 30.2	90.1 \pm 33.3	97.4 \pm 36.7	96.3 \pm 29.8	91.7 \pm 40.5	0.920	0.453
Hs-CRP (mg/L)	3.6 \pm 3.1 ^{abcd}	3.5 \pm 3.4 ^{abcd}	5.1 \pm 3.5 ^{abcde}	5.0 \pm 3.4 ^{abcde}	6.6 \pm 3.7 ^{cde}	5.503	0.000
IL-6 (pg/ml)	25.5 \pm 25.4	28.3 \pm 34.4	25.3 \pm 24.6	31.9 \pm 24.1	25.7 \pm 19.5	0.472	0.756
IL-10 (pg/ml)	3.4 \pm 6.1	4.4 \pm 9.1	4.8 \pm 9.0	6.2 \pm 10.7	6.3 \pm 9.5	0.824	0.511

*Values with different superscripts are significantly different from each other

Table 4. Mean lipid levels and inflammatory markers in overweight/obese women with or without leucocytosis

Biochemical Measurements	Owt/Ob and Leucocytosis (n=20)	Normal and Leucocytosis (n=79)	Normal and normal WBC (n=91)	Owt/Ob and normal WBC (n=10)	F	P
TC(mg/dl)	171.9 \pm 34.4	173.3 \pm 40.7	169.1 \pm 37.2	151.7 \pm 36.4	0.993	0.397
TG(mg/dl)	134.9 \pm 70.8	122.8 \pm 67.1	112.4 \pm 60.4	89.7 \pm 66.3	1.476	0.222
HDL-C (mg/dl)	59.1 \pm 26.4	67.2 \pm 22.4	65.3 \pm 25.6	60.1 \pm 20.4	0.752	0.522
LDL-C(mg/dl)	92.6 \pm 42.0	96.0 \pm 36.5	89.9 \pm 29.5	72.0 \pm 28.3	1.666	0.176
Hs-CRP (mg/L)	7.7 \pm 3.5 ^{ad}	5.0 \pm 3.3 ^{bd}	3.6 \pm 3.3 ^{cd}	5.2 \pm 4.0 ^{abcd}	8.763	0.000
IL-6(mg/dl)	26.5 \pm 15.6	26.0 \pm 22.2	29.1 \pm 30.9	26.8 \pm 29.2	0.204	0.894
IL-10(mg/dl)	6.4 \pm 8.1	3.8 \pm 5.9	5.5 \pm 10.7	6.5 \pm 13.1	0.804	0.493

*Values with different superscripts are significantly different from each other

Abbreviation: Owt-overweight ; Ob-Obese

Table 5. Correlation of WBC with Anthropometric and Biochemical

Anthropometric Parameter	WBC		Biochemical Parameter	WBC	
	R	P		R	p
Weight	0.229**	0.001	TC	-0.040	0.576
BMI	0.254**	0.000	TG	0.082	0.249
WC	0.203**	0.004	HDL-C	-0.148*	0.036
HC	0.205**	0.004	LDL-C	0.079	0.266
WHR	0.090	0.205	Hs-CRP	0.273**	0.000
WHtR	0.218**	0.002	IL-6	0.027	0.705
PBF	0.183**	0.010	IL-10	0.109	0.123

** . Pearson's Correlation is significant at the 0.01 level.

* . Pearson's Correlation is significant at the 0.05 level.

Further, WBC counts were divided into quintiles. Mean BMI, HC, WHtR and PBF were significantly higher in the fifth quintile of WBC. Mean WHtR was almost similar in third and fifth quintile of WBC. Mean WC and WHR did not show a significant difference within quintiles of WBC (Table 2). It was also evident that women with WBC count between 8700-9500 cells/cu mm had increased BMI, WC, HC, WHR, WHtR and PBF. Mean hs-CRP significantly increased with increasing quintiles of WBC, with the highest mean being in the fifth quintile of WBC with WBC ≥ 10500 cells/ cu mm. Those with high WBC counts also had higher anti-inflammatory marker i.e. IL-10 with a mean of 6.3 ± 9.5 pg/ml. Mean HDL-C levels were lowest in the fifth quintile of WBC however, the difference was not significant (Table 3). When overweight/obese women whose BMI exceeded 23 kg/m^2 with or without leucocytosis were studied, it was observed that mean hs-CRP levels were significantly higher in overweight/obese women having leucocytosis compared to those women who had normal BMI but still had leucocytosis or women with normal BMI and WBC counts both together (Table 4). Overweight/obese women with normal WBC levels had lower hs-CRP levels compared to overweight/obese women with leucocytosis however, the difference was not significant. Other parameters did not show a significant difference; however, mean TC and LDL-C were higher in women who had normal BMI but having leucocytosis. Mean HDL-C was lowest in overweight/obese women with leucocytosis whereas they had higher TG levels, compared to other three categories (Table 4). Pearson's correlation showed that WBC count correlated significantly and positively with weight, BMI, WC, HC, WHtR and PBF, although the highest correlation was with BMI ($r=0.254$, $p=0.000$). Among the biochemical parameter, WBC showed a significant negative correlation with HDL-C and a significant positive correlation with hs-CRP (Table 5).

DISCUSSION

This study demonstrates that WBC is strongly and significantly associated with overall and central obesity. Adipose tissue may strongly influence inflammatory cytokines and WBC levels (Greenberg and Obin, 2006). In the present study, WBC strongly and positively correlated with BMI, WC, WHtR and PBF which emphasises the possibility that these correlations might be mediated by inflammatory pathways. It was observed that mean hs-CRP was significantly higher in the highest quintile for WBC count and WBC count correlated significantly with hs-CRP. CRP is a strong predictor for cardiovascular diseases (Ridker *et al.*, 2000). Adipose tissue is the main site of production of some of the inflammatory markers (Gregor and Hotamisligil, 2011). IL-6 produced in adipose tissue upregulates production of CRP in liver (Schmidt-Arras and Rose-John, 2016). Increased CRP level is parallel to elevated WBC levels (Farhangi *et al.*, 2013) and same could be observed in the present study. It was further observed that obese individuals with leucocytosis had higher hs-CRP compared to normal weight women with leucocytosis. Increase in leucocytosis alone, could be because of temporary infections, however, obesity accompanied with leucocytosis is of concern. Inflammation increases the tendency of WBC to adhere to vascular endothelium by altering the endothelial and rheological function. This may result in capillary leucocytosis. Thus, increased WBC count in obese may be due to subclinical inflammatory response which can progress into development of non-communicable diseases and metabolic syndrome (Lipowsky *et al.*, 1980; Memon *et al.*, 1997; Hingorani *et al.*,

2000; López-Jaramillo, 2000). Therefore these subjects should be further investigated for cardiovascular disease and well-being. HDL-C is an important risk factor for cardiovascular diseases and epidemiological studies have shown evidence that white blood cell (WBC) counts correlate well with cardiovascular risk factors (Kim *et al.*, 2017). Studies have reported the anti-inflammatory properties of HDL-C which helps in protection from atherosclerosis (De Nardo *et al.*, 2014). This was observed in the present study where WBC showed a significant negative correlation with HDL-C. These findings were similar to those reported in 1383 healthy participants from Thailand (Lohsoonthorn *et al.*, 2006) as well as in middle-aged Japanese men (Nagasawa *et al.*, 2004). In the present study, there were a considerable percentage of healthy women who were overweight or obese by measures of overall and central obesity, yet they had leucocytes within normal range. These women may be at risk of developing non-communicable diseases following the inflammatory pathway, because the mean IL-6 and hs-CRP were higher in these women following obese women with leucocytosis. It was reported that obesity associated leucocytosis is thus of clinical importance because if granulocytes and monocytes releases substances particularly free radicals and proteolytic enzyme then it is injurious to health (Nieman *et al.*, 1999). The limitation of the present study was that it was a cross-sectional study and thus did not permit the identification of causal relationship for raised WBC count. The study was limited to apparently healthy women from urban slums in Mumbai city and included only 200 women.

Conclusion

In conclusion, we noted that in healthy women WBC counts were associated with hs-CRP and HDL-C which is a risk factors for cardiovascular diseases. The present study suggests that WBC count can be used as a simple measure for biochemical investigation in obese individuals in order to design health intervention programs to detect and prevent adults who are at risk of developing non-communicable diseases. Further investigations would be beneficial even in low socioeconomic women especially in countries undergoing nutrition and epidemiological transition.

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REFERENCES

Blumenreich, MS. 1990. The White Blood Cell and Differential Count. In: Walker HK, Hall WD, Hurst JW, editors. Clinical Methods: The History, Physical, and Laboratory Examinations. 3rd edition. Boston: Butterworths;

- Chapter, 153. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK261/>
- Burden of NCDs and their risk factors in India (Excerpted from Global Status Report on NCDs -2014) http://www.searo.who.int/india/topics/noncommunicable_diseases/ncd_situation_global_report_ncds_2014.pdf
- Castro, AM., Macedo-de la Concha, LE. and Pantoja-Meléndez, CA. 2017. Low-grade inflammation and its relation to obesity and chronic degenerative diseases. *Rev Med. Hosp Gen Méx.*, 80(2): 101-105. <https://doi.org/10.1016/j.hgmx.2016.06.011>
- De Nardo, D., Labzin, LI., Kono, H., Seki, R., Schmidt, S. V., Beyer, M. and Latz, E. 2014. High density lipoprotein mediates anti-inflammatory transcriptional reprogramming of macrophages via the transcriptional repressor ATF3. *Nature Immunology*, 15(2), 152–160. <http://doi.org/10.1038/ni.278>.
- Dehghani, M R., Rezaei, Y., Fakour, S. and Arjmand, N. 2016. White Blood Cell Count to Mean Platelet Volume Ratio Is a Prognostic Factor in Patients with Non-ST Elevation Acute Coronary Syndrome with or without Metabolic Syndrome. *Korean Circulation Journal*, 46(2):229–238. <http://doi.org/10.4070/kcj.2016.46.2.229>.
- Durnin, JV. and Rahaman, MM. 1967. The Assessment of the Amount of Fat in the Human Body from Measurements of Skinfold Thickness. *Br. J. Nutr.*, 21(3):681-9. doi: 10.1079/BJN19670070.
- Farhangi, M., Keshavarz, S., Eshraghian, M., Ostadrahimi, A. and Saboor-Yaraghi, A. 2013 White Blood Cell Count in Women: Relation to Inflammatory Biomarkers, Haematological Profiles, Visceral Adiposity, and Other Cardiovascular Risk Factors. *J Health Popul Nutr*, 31(1):58-64.
- Greenberg, A. and Obin, MS. 2006. Obesity and the role of adipose tissue in inflammation and metabolism. *Am J Clin Nutr*.83(2): 461S-465S.
- Gregor, M. and Hotamisligil, G. 2011. Inflammatory Mechanisms in Obesity. *Annu. Rev. Immunol.*, 29:415-445.
- Hingorani, AD., Cross, J., Kharbanda, RK., Mullen, MJ., Bhagat, K., Taylor, M., Donald, AE., Palacios, M., Griffin, GE., Deanfield, JE., MacAllister, RJ. and Vallance, P. 2000. Acute systemic inflammation impairs endothelium dependent dilatation in humans, 102: 994– 9.
- Hunter P. 2012. The inflammation theory of disease: The growing realization that chronic inflammation is crucial in many diseases opens new avenues for treatment. *EMBO Reports*, 13(11): 968–970. doi:10.1038/embor.2012.142.
- Kim, JH., Lim, S., Park, K. S., Jang, H. C. and Choi, SH. 2017. Total and differential WBC counts are related with coronary artery atherosclerosis and increase the risk for cardiovascular disease in Koreans. *PLoS ONE*, 12(7), e0180332. <http://doi.org/10.1371/journal.pone.0180332>
- Konstam, MA., Kramer, DG., Patel, AR., Maron, MS. and Udelson, JE. 2011. *Left ventricular remodeling in heart failure current concepts in clinical significance and assessment. JACC Cardiovasc. Imaging*, 4(1): 98–108.
- Kumar, V A.A., Fausto N. and Aster J. C. in Robbins and Cotran Pathologic Basis of Disease 8th edn 43–77 (Saunders, 2009).
- Lasselín, J., Magne, E., Beau, C., Ledaguenel, P., Dexpert, S., Aubert, A., Layé, S. and Capuron, L. 2014. Adipose Inflammation in Obesity: Relationship with Circulating Levels of Inflammatory Markers and Association with Surgery-Induced Weight Loss. *J ClinEndocrinolMetab.*, 99(1):E53–E61.
- Lipowsky, HH., Usami, S. and Chien, S. 1980. In Vivo Measurements of “Apparent Viscosity” And Microvessel hematocrit in the mesentery of the cat. *Microvasc Res.*, 19, 297–319
- Lohsoonthorn, V., Dhanamun, B. and Williams, MA. 2006. Prevalence of Metabolic Syndrome and Its Relationship to White Blood Cell Count in a Population of Thai Men and Women Receiving Routine Health Examinations. *Am J Hypertens.*, 19 (4): 339-345. doi: 10.1016/j.amjhyper.2005.10.008
- López-Jaramillo, P. 2000. Calcium, nitric oxide, and preeclampsia. *Semin Perinatol.*, 24, 33–6.
- Margolis, KL, Manson, JE., Greenland, P. *et al.* 2005. Women’s Health Initiative Research Group: leukocyte count as a predictor of cardiovascular events and mortality in post-menopausal women: the Women’s Health Initiative Observational Study. *Arch Intern Med.*, 165:500–8.
- Memon, RA., Feingold, KR. and Grunfeld, C. 1997. Cytokines and intermediary metabolism. In: Cytokines in health and disease, 2nd ed, eds. by Remick DG, Friedland JS, 381–99, Marcel Dekker, New York.
- Misra, A., Pandey, RM., Sinha, S., Guleria, R., Sridhar, V. and Dudeja, V. 2003. Receiver Operating Characteristics Curve Analysis of Body Fat and Body Mass Index in Dyslipidemic Asian Indians. *Indian J Med Res*, 117:170-179.
- Munir, TA., Afzal, MN. and Habib-ur-Rehman, 2009. Baseline Leukocyte Count and acute Coronary Syndrome: Predictor of Adverse Cardiac Events, Long And Short Term Mortality And Association With Traditional Risk Factors, Cardiac Biomarkers And C-reactive Protein. *J Ayub Med Coll Abbottabad*, 21(3):46-50.
- Nagasawa, N., Tamakoshi, K., Yatsuya, H., Hori, Y., Ishikawa, M., Murata, C., Zhang, H., Wada, K., Otsuka, R., Mabuchi, T., Kondo, T. and Toyoshima, H. 2004. Association of white blood cell count and clustered components of metabolic syndrome in Japanese men. *Circ J.*, 68:892-897.
- National Family Health Survey- 3 (NFHS-3), India, 2005-06. *State Factsheet*. Maharashtra: International Institute for Population Sciences. <http://rchiips.org/nfhs/pdf/Maharashtra.pdf>. Accessed January 7, 2017.
- Nieman, DC., Henson, DA., Nehlsen-Cannarella, SL., Ekkens, M., Utter, AC., Butterworth DE and Fagoaga OR. 1999. Influence of obesity on immune function. *J Am Diet Assoc.*, 99(3):294-9.
- Ohshita, K., Yamane, K., Hanafusa, M., Mori, H., Mito, K., Okubo, M., Hara, H. and Kohno, N. 2004. Elevated white blood cell count in subjects with impaired glucose tolerance. *Diabetes Care*, 27(2):491-6.
- Pai, JK., Pischon, T., Ma, J., Manson, J., Hankinson, S., Joshipura, K., Curhan, G. *et al.* 2004. Inflammatory Markers and the Risk of Coronary Heart Disease in Men and Women. *N Engl J Med.*, 351:2599-2610 DOI: 10.1056/NEJMoa040967.
- Ridker, PM., Hennekens, CH., Buring, JE. and Rifai, N. 2000. C-Reactive Protein and Other Markers of Inflammation in the Prediction of Cardiovascular Disease in Women. *N Engl J Med.*, 342:836-843.
- Schmidt-Arras, D. and Rose-John, S. 2016. IL-6 pathway in the liver: From physiopathology to therapy. *Journal of Hepatology*, 64(6):1403-1415. <https://doi.org/10.1016/j.jhep.2016.02.004>
- Siri, WE. 1956. The Gross Composition of the Body. *Adv Biol Med Phys.*, 4: 239-280.

Tamakoshi, K., Toyoshima, H., Yatsuya, H., Matsushita, K., Okamura, T., Hayakawa, T., Okayama, A. and Ueshima, H. 2007. NIPPON DATA90 Research Group. White Blood Cell Count and Risk of All-Cause and Cardiovascular Mortality in Nationwide Sample of Japanese Results from the NIPPON DATA90. *Circ J*, 71: 479 – 485.

Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). *Circulation*. 2002; 106(25):3143-421.

Wang, X., Bao, W., Liu, J., OuYang, Y., Wang, D., Rong, S., Xiao, X. *et al.* 2013. Inflammatory Markers and Risk of Type 2 Diabetes: A systematic review and meta-analysis. *Diabetes Care*, 36(1): 166- 175. <https://doi.org/10.2337/dc12-0702>
