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# Overweight and Obesity and the Immune System, Lipids and C-reactive Protein in Young and Middle-aged Saudi Female University Workers

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## Abstract

Saudi Arabia is one of the Middle Eastern countries with the highest prevalence of overweight and obesity in adults and especially in females. Overweight and obesity affect many systems in the body leading to increased mortality, morbidity, and risk for many diseases. This study aimed to determine the effects of overweight and obesity on the immune system cells, hematology, lipid profile, and C-reactive protein (CRP) concentration in 62 randomly chosen Saudi female university employees with an age range of 24-52 years. Blood samples were collected from the subjects and they were categorized using the body mass index (BMI), Waist-to-hip ratio (WHR), and waist circumference (WC) as adiposity measures. All results were compared to the controls. The lymphocyte count for the obese BMI group and eosinophil percent for the overweight BMI group were significantly higher. The total leucocyte and neutrophil counts, and triglyceride concentration were significantly higher for the WHR high-risk group. The total leucocyte, neutrophil, red blood cell counts, and concentrations of CRP and triglyceride were significantly higher for the WC high risk; the neutrophil percent was significantly lower for the WC moderate-risk group, and the basophil percent was significantly lower for the WC high-risk group. The remaining parameters and comparisons were not significantly different between the groups of each adiposity measure. In conclusion, overweight and obesity lead to some effects on the immune system and higher inflammation as evidenced by the higher total and some types of leucocytes and CRP concentrations. The effects on hematology and lipids were minimal. Finally, the WC is the best measure of adiposity for the subjects of the study since it resulted in more significant differences between groups compared to the BMI and WHR.

**Key words:** Obesity, CRP, BMI, Immune System.

## Introduction

Overweight and obesity are major health problems worldwide. Up to recent years, overweight and obesity were widespread mainly in rich developed countries, but now even poor and developing countries are experiencing increased rates of overweight and obesity. It is expected that, according to estimates of the World Obesity Federation (WOF 2018), 2.7 billion adults worldwide will be overweight or obese by the year 2025. Worldwide, the increased and excessive weight causes the death of at least 2.8 million people yearly (WHO 2017). Saudi Arabia is one of the Middle Eastern countries with the highest prevalence of overweight and obesity in adults. In 2016, it was estimated by the WHO (WHO 2020) that 69.7% of adults were overweight and 35.4% were obese. Also, the trend of adult obesity in Saudi Arabia has been increasing for the last two or three decades and is expected to continue to increase in the future (WHO 2018). In 2016 Saudi Arabia ranked 14th worldwide and 3rd in the Middle East for the prevalence of adult obesity (Central Intelligence Agency 2016)

Overweight and obesity lead to a reduced quality of life and increased mortality, morbidity, and risk for many non-communicable diseases such as cardiovascular diseases, stroke, hypertension, diabetes, hypercholesterolemia, several types of cancer, liver disease, inflammatory diseases, and musculoskeletal disorders. These diseases are the result of the effects of overweight and obesity on many different organs and systems in the body, such as the cardiovascular, respiratory, musculoskeletal, and immune system.

Anthropometric adiposity measures are used to determine the level of overweight and obesity easily and without any specialized equipment or instruments. The body mass index (BMI), Waist-to-hip ratio (WHR), and waist circumference (WC) are the most common adiposity measures used in clinical and research settings. The WHR and WC also help determine whether excess weight is in the upper part of the body, which carries an increased risk for overweight and obesity-related diseases, or in the lower part of the body, which confers protection against some overweight and obesity-related diseases.

Previous studies on overweight and obesity in Saudis and their effects on immune system cells and hematology (leucocytes and their types) (Al-Sufyani and Mahassni 2011; Mahassni and Sebaa 2012; Mahassni and Bashanfar 2019; Mahassni 2019) and the lipid profile (Mahassni and Sebaa 2013; Mahassni and Bashanfar 2016) and CRP (Mahassni and Sebaa 2013; Mahassni and Bashanfar 2019) although the age ranges of the subjects are different and not all age groups were studied.

Most studies done on the effects of overweight and obesity on the cardiovascular and immune systems in Saudi Arabia are epidemiological while there are some non-epidemiological studies but they are mostly on subjects with diseases, such as diabetes, asthma, and others. Therefore, there is a need for studies on the effects of overweight and obesity on blood immune system cells,

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hematology, lipids profile, and inflammation (C-reactive protein). It is important to study these parameters since they are related to many of the diseases that are prevalent in overweight and obesity.

## Materials and Methods

*Subjects, Categorizations, and Blood Samples Collection*

This study was carried out on 62 randomly chosen Saudi female employees, ranging in age from 24 to 52 years, from King Abdulaziz University, Jeddah, Saudi Arabia. All subjects gave consent to participate in this study on a consent form. None of the subjects were expectant or during menses at the time of blood sample collection. Also, none of the subjects had any chronic diseases, such as diabetes, high blood pressure, or heart diseases, nor were on any medications.

Blood samples were collected from all subjects into ethylenediaminetetraacetic acid vacutainer tubes for the determination of the differential complete blood count (CBC). Blood samples were also collected in plain vacutainer tubes, which were centrifuged for the separation of serum to use in the determination of C-reactive protein (CRP) concentration and the lipid profile.

*Anthropometric Measurements and Categorizations of the Subjects*

At the same time of blood collection, anthropometric measurements (weight, height, and waist and hips circumferences) were obtained for all subjects. Weight was measured on a household scale. The height, waist, and hips circumferences were measured using a tape measure.

The subjects were categorized using BMI, WHR, and WC. The BMI ranges that were used were underweight (below 18.5 $kg/m^2$), healthy (18.5-24.9 $kg/m^2$), overweight (25-29.9 $kg/m^2$), and obese (30-39.9 $kg/m^2$). The WHR groups were the low risk (below or equal to 0.8), moderate risk (0.81-0.85), and the high risk (above 0.85). Finally, the WC groups were the low risk (below 82.5 cm), moderate risk (82.5-88.9), and high risk (above 88.9).

*Determination of the Differential CBC, Lipid Profile, and CRP Concentration*

The differential CBC was determined for all subjects using an LH755 Beckman Coulter Counter (Miami, FL, USA). CRP concentrations were determined by nephelometry on a Siemens nephelometer II (BN II System, Germany) using a high-sensitivity C-reactive protein assay (Siemens, Marburg, Germany).

Cholesterol, triglycerol, high-density lipoprotein (HDL), and low-density lipoprotein (LDL) concentrations were measured on a Dimension Vista System (Siemens, Germany) using the Dimension Flex reagent cartridges (Siemens, Newark, DE, USA).

*Statistical Analysis*

Statistical analyses of the results were done using the SPSS statistical program. The mean, standard deviation (± SD), standard error (SE) and P value were calculated for the parameters. To test for the significance of the differences between the groups, the ANOVA one-way test was used for the homogeneous and normally distributed parameters, while the Kruskal-Wallis test was used for the non-normally distributed parameters. For the post hoc testing, the statistical tests used were as recommended by the SPSS program. The P values indicate a statistically significant difference (S) when $P \leq 0.05$ and a statistically none significant difference (NS) when $P > 0.05$.

## Results

*Subjects and categorizations*

The subjects of the study were used in a previous study (Mahassni 2019). The subjects had a mean age of 32.9 years. Upon categorizing the subjects into the three adiposity measures, it was found that most of the subjects were in the healthy BMI and low-risk WHR and WC groups. The number of subjects in the BMI groups was 7 for the underweight, 20 for the healthy, 18 for the overweight, and 17 for the obese. The number of subjects for the WHR risk groups was 34 for the low, 12 for the intermediate, and 16 for the high. The number of subjects for the WC risk groups was 28 for the low, 13 for the intermediate, and 21 for the high.

*Total and Differential Leukocyte Counts and Percents*

The mean counts and percents of serum leucocytes and their types for the BMI groups (Table 1) showed significant differences between the groups for the mean lymphocyte counts and eosinophil percent. For the WHR groups (Table 2), the mean total leukocyte and neutrophil counts were significantly different between the groups. Finally, there were significant differences between the WC groups (Table 3) for the mean total leucocyte and neutrophil counts, and mean neutrophil and basophil percent. The remaining cells for each adiposity measure were not significantly different between the respective groups.

For the post hoc comparisons between the BMI groups (Table 4), the mean lymphocyte count for the obese BMI group was significantly higher than the mean count for the healthy (control) group. For the eosinophil %, the mean percents for the healthy and overweight groups were significantly higher than the mean percentage for the underweight group. There were no significant differences between the healthy BMI group (control) and the remaining BMI groups. The post hoc comparisons for the WHR groups showed that the mean leucocyte and neutrophil counts for the high-risk group were significantly higher than the respective counts for the low-risk group (control). The remaining cells showed no significant differences between the groups. Lastly, for the post hoc comparisons for the WC groups (Table 4), the leucocyte and neutrophil counts for the high-risk group were significantly higher, whereas the neutrophil % for the moderate group and basophil % for the high-risk group were significantly lower comparing each to the respective count/percent for the low

risk (control) group. There were no significant differences between the remaining comparisons and cells.

*CRP, Red Blood Cells, Hemoglobin, and Lipid Profile Concentrations*

The mean serum CRP concentrations (Table 5) were significantly different between the BMI and WC groups each, while they were not significantly different between the WHR groups. The mean red blood cell counts were significantly different between the WC groups but not significantly different between each of the BMI and WHR groups. There were no significant differences between each of the BMI, WHR, and WC groups for the mean hemoglobin concentrations and platelet counts.

The post hoc analysis (Table 4) shows that the mean CRP concentration was significantly lower for the underweight BMI group and significantly higher for the high-risk WC group compared to the mean CRP concentrations for the respective control groups. The mean RBC count for the high-risk WC group was significantly higher compared to the mean count for the control group. The mean CRP concentrations and RBC counts for the other groups were not significantly different from the respective controls.

For the lipid profile (Table 5), the mean cholesterol, HDL, and LDL were not significantly different between the groups of each of the adiposity measures. Whereas, the mean triglyceride concentrations were significantly different between the WHR and WC groups but not between the BMI groups. For the post hoc analysis (Table 4), the mean triglyceride concentrations for the high-risk WHR and WC groups were significantly higher than the mean concentrations for the respective controls. The mean triglyceride concentrations for the moderate risk groups for the WHR and WC were not significantly different from the mean concentrations for the respective controls.

Table 1: Statistical analysis for the total and differential leukocyte counts and percents for the BMI groups.

| Cell | BMI Group | Cell count (x$10^3$ cell/µL) | | | Cell % | | |
|---|---|---|---|---|---|---|---|
| | | Mean | ± SD | P value | Mean | ± SD | P value |
| Leucocyte | Underweight | 5.96 | 2.80 | $0.260^{NS*}$ | | | |
| | Healthy | 7.07 | 1.82 | | | | |
| | Overweight | 7.42 | 2.04 | | | | |
| | Obese | 7.79 | 2.13 | | | | |
| Neutrophil | Underweight | 3.27 | 1.66 | $0.645^{NS*}$ | 52.4 | 9.6 | $0.308^{NS*}$ |
| | Healthy | 4.06 | 1.39 | | 56.7 | 8.1 | |
| | Overweight | 4.01 | 1.57 | | 52.4 | 10.3 | |
| | Obese | 4.15 | 1.76 | | 51.4 | 9.6 | |
| Lymphocyte | Underweight | 2.19 | 1.01 | $0.033^{S*}$ | 39.1 | 8.7 | $0.134^{NS*}$ |
| | Healthy | 2.27 | 0.63 | | 32.8 | 7.6 | |
| | Overweight | 2.64 | 0.66 | | 36.9 | 8.4 | |
| | Obese | 2.86 | 0.67 | | 38.0 | 7.7 | |
| Monocyte | Underweight | 0.40 | 0.20 | $0.560^{NS*}$ | 6.6 | 2.0 | $0.506^{NS**}$ |
| | Healthy | 0.51 | 0.22 | | 7.3 | 2.2 | |
| | Overweight | 0.50 | 0.16 | | 6.9 | 1.4 | |
| | Obese | 0.52 | 0.20 | | 7.0 | 2.8 | |
| Eosinophil | Underweight | 0.09 | 0.07 | $0.066^{NS**}$ | 1.3 | 0.6 | $0.038^{S**}$ |
| | Healthy | 0.18 | 0.13 | | 2.5 | 1.4 | |
| | Overweight | 0.23 | 0.14 | | 3.2 | 2.2 | |
| | Obese | 0.22 | 0.30 | | 3.0 | 4.3 | |
| Basophil | Underweight | 0.01 | 0.04 | $0.581^{NS**}$ | 0.7 | 0.5 | $0.892^{NS*}$ |
| | Healthy | 0.02 | 0.04 | | 0.7 | 0.2 | |
| | Overweight | 0.04 | 0.05 | | 0.6 | 0.4 | |
| | Obese | 0.03 | 0.05 | | 0.6 | 0.2 | |

*ANOVA one-way test

**Kruskal-Wallis test

Table 2: Statistical analysis for the total and differential leukocyte counts and percents for the WHR groups.

| Cell | WHR Group | Cell count (x$10^3$ cell/µL) | | | Cell % | | |
|---|---|---|---|---|---|---|---|
| | | Mean | ± SD | P value | Mean | ± SD | P value |
| Leucocyte | Low | 6.90 | 1.85 | $0.021^{S*}$ | | | |
| | Moderate | 6.28 | 1.55 | | | | |
| | High | 8.25 | 2.29 | | | | |
| Neutrophil | Low | 3.79 | 1.33 | $0.009^{S*}$ | 53.5 | 9.3 | $0.120^{NS*}$ |
| | Moderate | 3.05 | 0.86 | | 48.7 | 9.2 | |
| | High | 4.73 | 1.79 | | 56.0 | 8.6 | |
| Lymphocyte | Low | 2.44 | 0.68 | $0.417^{NS*}$ | 36.5 | 7.9 | $0.323^{NS*}$ |
| | Moderate | 2.48 | 0.93 | | 39.0 | 8.0 | |
| | High | 2.73 | 0.68 | | 34.4 | 8.2 | |
| Monocyte | Low | 0.46 | 0.17 | $0.558^{NS*}$ | 6.9 | 2.4 | $0.066^{NS**}$ |
| | Moderate | 0.49 | 0.12 | | 7.9 | 1.2 | |
| | High | 0.52 | 0.21 | | 6.4 | 2.0 | |
| Eosinophil | Low | 0.17 | 0.17 | $0.456^{NS**}$ | 2.4 | 2.8 | $0.105^{NS**}$ |
| | Moderate | 0.22 | 0.16 | | 3.7 | 2.5 | |
| | High | 0.23 | 0.26 | | 2.7 | 2.7 | |
| Basophil | Low | 0.04 | 0.05 | $0.093^{NS**}$ | 0.7 | 0.3 | $0.079^{NS*}$ |
| | Moderate | 0.01 | 0.03 | | 0.7 | 0.4 | |
| | High | 0.03 | 0.04 | | 0.5 | 0.2 | |

*ANOVA one-way test
**Kruskal-Wallis test

Table 3: Statistical analysis for the total and differential leukocyte counts and percents for the WC groups.

| Cell | WC Group | Cell count (x$10^3$ cell/µL) | | | Cell % | | |
|---|---|---|---|---|---|---|---|
| | | Mean | ± SD | P value | Mean | ± SD | P value |
| Leucocyte | Low | 6.71 | 1.87 | $0.017^{S*}$ | | | |
| | Moderate | 6.41 | 1.44 | | | | |
| | High | 8.12 | 2.21 | | | | |
| Neutrophil | Low | 3.75 | 1.25 | $0.015^{S*}$ | 54.9 | 8.1 | $0.032^{S*}$ |
| | Moderate | 3.11 | 1.22 | | 47.3 | 10.5 | |
| | High | 4.55 | 1.68 | | 54.7 | 9.0 | |
| Lymphocyte | Low | 2.30 | 0.72 | $0.055^{NS*}$ | 35.4 | 7.8 | $0.184^{NS*}$ |
| | Moderate | 2.53 | 0.54 | | 40.1 | 7.9 | |
| | High | 2.81 | 0.78 | | 35.6 | 8.1 | |
| Monocyte | Low | 0.46 | 0.18 | $0.593^{NS*}$ | 7.0 | 2.0 | $0.158^{NS**}$ |
| | Moderate | 0.47 | 0.14 | | 7.5 | 1.6 | |
| | High | 0.51 | 0.19 | | 6.7 | 2.7 | |
| Eosinophil | Low | 0.15 | 0.11 | $0.383^{NS**}$ | 2.1 | 1.3 | $0.451^{NS**}$ |
| | Moderate | 0.27 | 0.25 | | 4.4 | 4.5 | |
| | High | 0.21 | 0.23 | | 2.5 | 2.4 | |
| Basophil | Low | 0.03 | 0.05 | $0.792^{NS**}$ | 0.7 | 0.3 | $0.029^{S*}$ |
| | Moderate | 0.04 | 0.05 | | 0.8 | 0.4 | |
| | High | 0.03 | 0.05 | | 0.5 | 0.2 | |

*ANOVA one-way test
**Kruskal-Wallis test

Table 4: Post hoc statistical analysis for the significantly different cells in Tables 1-3.

| Parameter | Test | G1 | G2 | Mean Difference (G1-G2) | SE | P value |
|---|---|---|---|---|---|---|
| BMI | | | | | | |
| Lymphocyte count | LSD | Healthy | Underweight | 0.08 | 0.30 | $0.790^{NS}$ |
| | | | Overweight | -0.38 | 0.22 | $0.095^{NS}$ |
| | | | Obese | -0.59 | 0.22 | $0.010^{S}$ |
| Eosinophil % | Tamhane | Underweight | Healthy | -1.2 | 1.2 | $0.022^{S}$ |
| | | | Overweight | -1.9 | 1.2 | $0.017^{S}$ |
| | | | Obese | -1.7 | 1.2 | $0.520^{NS}$ |
| CRP | Games-Howell | Healthy | Underweight | 0.62 | 2.21 | $0.048^{S}$ |
| | | | Overweight | -3.93 | 1.63 | $0.150^{NS}$ |
| | | | Obese | -3.84 | 1.66 | $0.062^{NS}$ |
| WHR | | | | | | |
| Leucocyte count | LSD | Low | Moderate | 0.62 | 0.65 | $0.339^{NS}$ |
| | | | High | -1.35 | 0.58 | $0.024^{S}$ |
| Neutrophil count | LSD | Low | Moderate | 0.74 | 0.47 | $0.121^{NS}$ |
| | | | High | -0.94 | 0.42 | $0.030^{S}$ |
| Triglyceride | Games-Howell | Low | Moderate | 0.10 | 0.17 | $0.823^{NS}$ |
| | | | High | -0.41 | 0.15 | $0.042^{S}$ |
| WC | | | | | | |
| Leucocyte count | LSD | Low | Moderate | 0.30 | 0.64 | $0.646^{NS}$ |
| | | | High | -1.41 | 0.55 | $0.013^{S}$ |
| Neutrophil count | Dunnett's | Low | Moderate | 0.64 | 0.47 | $0.094^{NS}$ |
| | | | High | -0.81 | 0.41 | $0.010^{S}$ |
| Neutrophil % | LSD | Low | Moderate | 7.6 | 3.0 | $0.014^{S}$ |
| | | | High | 0.1 | 2.6 | $0.957^{NS}$ |
| Basophil % | Dunnett's | Low | Moderate | -0.1 | 0.1 | $0.122^{NS}$ |
| | | | High | 0.2 | 0.1 | $0.019^{S}$ |
| CRP | Games-Howell | Low | Moderate | -2.72 | 1.73 | $0.427^{NS}$ |
| | | | High | -3.72 | 1.51 | $0.048^{S}$ |
| RBC | Tamhane | Low | Moderate | -0.10 | 0.15 | $0.882^{NS}$ |
| | | | High | -0.37 | 0.13 | $0.011^{S}$ |
| Triglyceride | Tamhane | Low | Moderate | -0.18 | 0.17 | $0.724^{NS}$ |
| | | | High | -0.40 | 0.15 | $0.024^{S}$ |

Table 5: Statistical analysis for the CRP, red blood cells, and lipid profile concentrations for the BMI, WHR, and WC groups.

| | BMI | | | | WHR | | | | | WC | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Group | Mean | ± SD | P value | Group | Mean | ± SD | P value | Group | Mean | ± SD | P value |
| CRP | Underweight | 0.10 | 0.26 | $0.000^{S**}$ | Low | 1.89 | 3.75 | $0.099^{NS**}$ | Low | 1.08 | 1.77 | $0.003^{S**}$ |
| mg/L | Healthy | 0.72 | 0.89 | | Moderate | 4.15 | 8.16 | | Moderate | 3.80 | 7.54 | |
| | Overweight | 4.65 | 7.39 | | High | 4.09 | 5.84 | | High | 4.80 | 6.38 | |
| | Obese | 4.56 | 5.73 | | | | | | | | | |
| Red blood cells | Underweight | 4.17 | 0.79 | $0.062^{NS*}$ | Low | 4.40 | 0.49 | $0.158^{NS*}$ | Low | 4.34 | 0.49 | $0.027^{S**}$ |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $x10^6$ cell/µL | Healthy | 4.37 | 0.33 | | Moderate | 4.48 | 0.35 | | Moderate | 4.44 | 0.43 | |
| | Overweight | 4.53 | 0.39 | | High | 4.67 | 0.46 | | High | 4.71 | 0.36 | |
| | Obese | 4.66 | 0.44 | | | | | | | | | |
| Hemoglobin | Underweight | 11.7 | 2.8 | $0.461^{NS*}$ | Low | 12.2 | 1.9 | $0.900^{NS**}$ | Low | 12.2 | 1.8 | $0.520N^{S**}$ |
| g/dL | Healthy | 12.1 | 1.4 | | Moderate | 12.5 | 1.2 | | Moderate | 12.3 | 1.5 | |
| | Overweight | 12.7 | 1.4 | | High | 12.5 | 1.3 | | High | 12.6 | 1.4 | |
| | Obese | 12.5 | 1.5 | | | | | | | | | |
| Platelet | Underweight | 245 | 111 | $0.532^{NS**}$ | Low | 267 | 79 | $0.131^{NS*}$ | Low | 253 | 82 | $0.077^{NS*}$ |
| $x10^3$ cell/µL | Healthy | 267 | 74 | | Moderate | 261 | 105 | | Moderate | 309 | 86 | |
| | Overweight | 306 | 89 | | High | 313 | 62 | | High | 292 | 73 | |
| | Obese | 276 | 65 | | | | | | | | | |
| Choesterol | Underweight | 4.58 | 0.98 | $0.545^{NS*}$ | Low | 4.83 | 0.92 | $0.053^{NS*}$ | Low | 4.81 | 0.95 | $0.664^{NS*}$ |
| mmol/L | Healthy | 5.08 | 0.97 | | Moderate | 4.49 | 0.72 | | Moderate | 4.90 | 0.98 | |
| | Overweight | 4.72 | 1.12 | | High | 5.41 | 1.28 | | High | 5.08 | 1.18 | |
| | Obese | 5.06 | 1.03 | | | | | | | | | |
| Triglyceride | Underweight | 0.73 | 0.19 | $0.093^{NS*}$ | Low | 1.04 | 0.46 | $0.004^{S**}$ | Low | 0.95 | 0.38 | $0.019^{S**}$ |
| mmol/L | Healthy | 1.06 | 0.50 | | Moderate | 0.94 | 0.48 | | Moderate | 1.13 | 0.60 | |
| | Overweight | 1.21 | 0.48 | | High | 1.45 | 0.55 | | High | 1.35 | 0.57 | |
| | Obese | 1.28 | 0.61 | | | | | | | | | |
| HDL | Underweight | 1.79 | 0.27 | $0.119^{NS**}$ | Low | 1.69 | 0.30 | $0.579^{NS*}$ | Low | 1.75 | 0.28 | $0.211^{NS*}$ |
| mmol/L | Healthy | 1.78 | 0.26 | | Moderate | 1.58 | 0.32 | | Moderate | 1.66 | 0.32 | |
| | Overweight | 1.61 | 0.31 | | High | 1.71 | 0.40 | | High | 1.58 | 0.39 | |
| | Obese | 1.55 | 0.40 | | | | | | | | | |
| LDL | Underweight | 2.64 | 0.91 | $0.441^{NS*}$ | Low | 2.92 | 0.83 | $0.066^{NS**}$ | Low | 2.87 | 0.85 | $0.164^{NS**}$ |
| mmol/L | Healthy | 3.12 | 0.83 | | Moderate | 2.74 | 0.61 | | Moderate | 3.04 | 0.88 | |
| | Overweight | 2.93 | 1.00 | | High | 3.56 | 1.00 | | High | 3.31 | 0.93 | |
| | Obese | 3.25 | 0.82 | | | | | | | | | |

*ANOVA one-way test

**Kruskal-Wallis test

## Discussion

This research study determined the total and differential leucocyte, RBC, and platelet counts, counts; lipid profile; and the concentrations of hemoglobin and C-reactive protein in subjects categorized into three different anthropometric adiposity measures. This was done to determine the effects of overweight and obesity on the immune system, lipids in the blood, hematology, and inflammation in Saudi female university workers.

The mean total leucocyte and neutrophil counts, each compared to its respective control, were significantly higher for the highest obesity WHR and WC (high risk) groups each, while they were not significantly different between the BMI groups. The mean lymphocyte counts were significantly higher for the obese BMI group compared to the control, while the counts were not significantly different between the WHR and WC groups. For the WC groups, compared to the respective controls, the mean neutrophil percent was significantly lower for the moderate group and the mean basophil percent was significantly lower for the high risk. Finally, the mean eosinophil percents for the healthy and overweight groups were significantly higher compared to the mean percent for the underweight group.

Therefore, nearly all the significant differences found for the mean total and differential leucocyte counts/percents were a higher count or percent than the mean counts/percents for the respective control group. Therefore, overweight and obesity led to changes in the mean counts and/or percents of immune system cells. Also, the higher cell counts/percents agree with previous findings (Al-Sufyani and Mahassni 2011; Mahassni and Sebaa 2012; Yoshimura et al. 2015; Sait et al. 2016; Mahassni and Bashanfar 2019). Also, the higher counts/percents of these cells may indicate an inflammatory state in the obese, which is confirmed by other researchers that found obesity to cause or be associated with an inflammatory state or that consider obesity to be an inflammatory

disease (Yoshimura et al. 2015; Castro, Macedo-de la Concha, and Pantoja-Meléndez 2017; Kumar 2019).

The mean CRP levels were significantly lower for the underweight BMI group and significantly higher for the high-risk WC group compared to the mean levels for the respective controls. The higher CRP concentration in the obese agrees with previous findings ((Mahassni and Sebaa 2013; Mahassni and Bashanfar 2019) and that overweight and obesity lead to high inflammation and that obesity is an inflammatory disease (Kumar 2019).

The mean platelet counts and hemoglobin concentrations were not significantly different between the groups of each one of the three adiposity measures. Mean RBC counts were significantly higher for the high-risk WC group but not different between the BMI and WHR groups compared to the respective mean control counts. These findings agree with previous findings for hemoglobin for the WHR and WC groups (Mahassni and Bashanfar 2019) and for platelet counts they agree with the previous findings for WHR and WC (Al-Sufyani and Mahassni 2011; Mahassni and Bashanfar 2019) but disagree with the previous findings (Al-Sufyani and Mahassni 2011; Mahassni and Bashanfar 2019) of higher platelet counts for the overweight and obese BMI groups compared to the control. The results for RBC counts agree partially with a previous study (Mahassni and Bashanfar 2019) that found significantly higher RBC counts for obese/morbidly obese BMI compared to the control but no significant differences between the WHR and WC groups.

Mean cholesterol, HDL, and LDL concentrations were not significantly different between the groups of the three adiposity measures. The mean triglyceride concentrations were significantly higher for the high-risk groups for both the WHR and WC compared to the mean concentrations for the respective control. The findings for the cholesterol concentration agree with previous findings (Mahassni and Sebaa 2013; Mahassni and Bashanfar 2016) while the findings for LDL and HDL disagree with the same previous studies that found significantly higher LDL concentrations and lower HDL concentrations for the obese BMI and high-risk WHR and WC groups compared to the controls. As for the triglyceride concentrations, they agree with findings of a previous study of significantly high triglyceride levels for the high-risk groups for the WHR (Mahassni and Sebaa 2013) and WC (Mahassni and Sebaa 2013; Mahassni and Bashanfar 2016) but disagree with the findings of high levels for the obese BMI group (Mahassni and Sebaa 2013) and no significant differences between the BMI and WHR groups (Mahassni and Bashanfar 2016).

## Conclusions

The overweight and obese subjects, compared to the controls, had higher counts/percents of total leucocyte, lymphocyte, neutrophil, basophil, and eosinophil cells, and higher CRP and triglyceride levels. Thus, it may be concluded that overweight and obese subjects had higher counts and levels of inflammatory markers and mediators putting at increased risk for inflammatory diseases and overweight obesity-related diseases. Finally, the WC is the best measure of adiposity for the subjects of the study since it resulted in more significant differences between groups compared to the BMI and WHR.

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