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*Original Research Article*

# Anthropometric Indices as Predictors to Blood Gases Changes among Infantry Military Personnel

Ainsah Omar[1], Mohd Rawi Mohd Norddin[2], Osman Che Bakar[3], Ahmad Hakim Osman[4], Arina Amalina Osman[5], Maslinda Mohd Kasim[6], Ahmad Zakuan Kamarudin[7], Zul Azlin Razali[8]

[1]Professor of Psychiatry, Faculty of Medicine and Defence Health, National Defence University of Malaysia, Sungai Besi, Wilayah Persekutuan Kuala Lumpur, Malaysia,
[2]Brig Gen (Military Medical Doctor, Specialist), Military Hospital, Camp Terendak, Melaka, Malaysia,
[3]Professor of Psychiatry, Faculty of Medicine, University Teknologi MARA, Sungai Buloh, Selangor, Malaysia,
[4]Medical Doctor, Sungai Buloh Hospital, Selangor Malaysia
[5]Medical Student, Faculty of Medicine, Management Science University, Shah Alam, Selangor
[6]Kol Dr /Pathologist, Department of Pathology, Tuanku Mizan Military Hospital, Wilayah Persekutuan Kuala Lumpur, Malaysia,
[7]Brig Gen/Pathologist, Faculty of Medicine, International Islamic University, Pandan Utama Kuala Lumpur, Malaysia
[8]Psychiatrist, Faculty of Medicine, Islamic Science University of Malaysia, Pandan Utama Kuala Lumpur, Malaysia

Corresponding Author: Ainsah Omar

## ABSTRACT

**Background:** Obesity induced pulmonary dysfunctions has been well documented but little is known about the relationship between obesity and blood gases. This study examined the association between obesity related anthropometric measurements and blood gases changes among military personnel.
**Methods:** A total of 103 healthy military personnel were recruited, their anthropometric indices namely Body Mass Index (BMI), waist circumference (WC), hip circumference (HC), waist-hip-ratio (WHR) and percentage of body fat (PBF) were obtained. 1 ml of arterial blood was withdrawn from the radial artery for arterial blood gases analysis.
**Results:** 75.2% (n=79) and 24.8% (n=26) of subjects with and without obesity, respectively. PaO2 was significantly inversely correlated with BMI, (r = -0.435, p = 0.000), WC (r = -0.345, p = 0.000), WHR (r = -0.227, p = 0.021) and PBF(r = -0.418, p = 0.000). The $pCO_2$ was significantly correlated with BMI (r = -0.226, p=0.022), WC (r=0.256, p=0.000), HC (r=0.432, p=0.000), WHR (0.225, p=0.022) and PBF (0.319, p=0.001). The BMI, WC, WHR and PBF (except HR), were also significantly inversely correlated with low Pa $HCO_3$- (r = -0.275, p = 0.005), (r = -0.291, p=0.003), (r = -0.3, p=0.002) and (r= -0.319, p=0.001) respectively. Conclusion: All the anthropometric measurements studied except HC were predictors for blood gases changes in individuals with obesity. Both overall and central obesity were associated with hypoxemia, hypercapnia and low bicarbonate suggesting that blood gases changes could be due to combination of obesity-induced physical mechanical respiratory changes, fat contents and obesity related biochemical.
***Key words:*** obesity, anthropometric indices and blood gases

## INTRODUCTION

Physical fitness, as well as high alert levels, is paramount important for those involved in military services due to their nature of work requiring quick swift response and decision making. Obesity poses a serious medical problem which could result with high morbidity and mortality. [1,2] It increases risk of contracting chronic medical diseases i.e. hypertension, diabetes, heart diseases, cancers, heat related illnesses, sleep apnoea, obesity hypoventilation syndrome (OHS), depression and blood gases abnormalities. [1,2] Obesity is now becoming highly prevalent among military personnel. [3]

Studies had demonstrated that obesity impaired respiratory function through reduction of chest expansion, lung compliance and volume and movement of the diaphragm due to an excessive accumulation of fats in the chest and abdomen. [4-11] Obesity reduces total lung capacity, forced expiratory volume (FEV), functional residual capacity (FRC), vital capacity (VC) and particularly expiratory reserve volume (ERV). [12,-16] Studies had demonstrated that reduction of BMI improved respiratory function [7,18-19] and PaO2. [5,17] The impairment of respiratory function is reflected by abnormal arterial blood gases which measure the degree of pulmonary gas exchange and the indices include, pH, $PaO_2$, Pa $CO_2$, Pa $HCO_3^-$ [8,20-21] Low $PaO_2$ levels in the blood can cause shortness of breath and result in a bluish coloration to the skin (cyanosis). Low $PaO_2$, high Pa $CO_2$ and acidity of the blood could cause respiratory failure resulting in a reduction in alertness level, confusion and sleepiness. Eventually, these would lead to brain and heart malfunction, sometimes resulting in unconsciousness and abnormal heart rhythms (arrhythmias), both of which can lead to death.

The effects of obesity on pulmonary function have been well studied and documented. [5,7,8,10,12,14,22-26] However, the literatures on its effects on arterial blood gases levels which are more detrimental and have important clinical implications are sparse. [18,27-30] Hence our study aims to examine the association between obesity and arterial blood gases and investigate whether the anthropometric indices could be predictors for the abnormalities of arterial blood gases.

## MATERIALS AND METHODS

**Study location, study design and subjects:**

This study was conducted at a Military Camp, Kuala Lumpur, Malaysia from April 2016 to July 2016. A total of 103 consecutive healthy military personnel with no pre-existing respiratory illness who meet the criteria from various ranks (aged between 19 to 44 years old) were recruited. All subjects underwent routine medical check-up and gave informed consent prior to the study. Subjects' demographic profile and anthropometric measurements were recorded. 1ml of arterial blood was withdrawn for blood gases analysis. All subjects were examined by physicians and informed consents were obtained from all subjects before entering the study. All subjects were examined by a physician (medical check-up as a routine prior to training exercise). This study was approved by the Director of Defence Health, Ministry of Defence, Malaysia and Ethical approval was obtained from Malaysian Medical Research and Ethics Committee (MREC), NMRR-13-1265-18660.

**Anthropometric and body composition measurements:**

The anthropometrics measurements were done based on standard procedures which included height, body weight, waist circumference, hip circumference and percentage of body fat. The height, body weight and percentage of body fat were assessed, using the Body Composition Analyzer System. These measurements were done with subjects wearing light clothes and without shoes. BMI was calculated as weight in kilograms divided by the height squared (in kg/m2). Overweight and obese were defined as BMI $\geq$ 25 Kg/m2 and BMI $\geq$ 30 Kg/m2 respectively, based on World Health Organization (WHO) criteria (WHO, 2000). [31]

High percentage of body fat is defined as $\geq$ 25% of body fat. Waist circumference (WC) was measured at when there was no natural waistline, the smallest crest to the nearest 0.1 cm or when the measurement was taken across umbilical, in a circumference between the ribs and the iliac the smallest circumference between the ribs and the iliac crest to the nearest 0.1 cm or there was no natural waistline, the measurement was taken across umbilical, in a standing position with the abdomen relax at the end of a normal respiration and recorded to the nearest 0.1 cm using a flexible, not stretchable plastic measuring tape. Hip circumference was measured at the maximum circumference.

The waist-to-hip ratio was calculated based on WC divided by HC. The normal range of normal WC, HC, and WHR are 83-98 cm, 94-105 cm and 0.87-0.99, respectively.

**Arterial blood gases (ABG):**

1 mL arterial blood was withdrawn from the radial artery after 5 minutes of rest with subjects sitting upright using the 1 mL arterial blood collection syringe (BD A-LineTM). The samplings were carried out by an anaesthetist. Blood gases were measured immediately, using blood gases analyser GEMTM Premier 3000 and 3500 Analyzer calibrated in accordance with the manufacturer's specification. The normal range for blood gases indices is as follows (Table 1).

**Table 1: The normal range of arterial blood gases**

| *Categories* | *Normal reading for analysis of blood gases* |
|---|---|
| pH | 7.38 mmHg – 7.42 mmHg |
| $PaCO_2$ | 38 mmHg – 42 mmHg |
| $PaO_2$ | 75 mmHg – 100 mmHg |
| $HCO_3^-$ | 22 mmol/L – 28 mmol/L |

**Statistical analysis**

All statistical analyses were performed using Statistical Package for the Social Science 20 (SPSS). The independent sample t test was used to compare the differences between means. The chi-square test was used to measure categorical data. P-values below 0.05 were considered statistically significant. All of the r values were determined by Pearson's and Spearman's correlation test to examine the bivariate relationships between anthropometric measurements and blood gases indices. The sample size calculation was based on the previous study at 95% level of confidence.

## RESULTS

**Demographic and anthropometric characteristics:**

The demographic profiles of subjects were shown in Table 2. 53.4% (n=50) of the subjects were aged below than 30 years old (< 30) and the mean was 28.7 ± 5.79 years old. Subjects with lower rank (corporal, a lance corporal and private) were 84.5% (n=87). 60.2% (n=62) were married and majority (97.1%, n=100) had no tertiary level education. The lowest income of subjects was RM700.00 and the highest was RM12, 000.00. 59.2% (n=61) had a family income less than RM2000 and the mean was RM 2154.01 ± RM 1317.22. 68.0% (n=70) were smoking.

**Table 2: The demographic characteristics and anthropometric indices of the total subject (n=103)**

| DEMOGRAPHIC CHARACTERISTICS | *No. of subjects (n)* |
|---|---|
| Age Of Subjects, *Mean ± SD* | 28.7 ± 5.79 |
| *< 30 Years Old* | 50 (53.4) |
| *≥ 30 Years Old* | 48 (46.6) |
| Rank | |
| *Lower Rank* | 87 (84.5) |
| *Higher Rank* | 16 (15.5) |
| Marital Status | |
| *Single* | 41 (39.8) |
| *Married* | 62 (60.2) |
| Educational Level | |
| *Lower Level* | 100 (97.1) |
| *Higher Level* | 3 (2.9) |
| Family Income, *Mean ± SD* | 2154.01 ± 1317.22 |
| *< RM2000.00* | 61 (59.2) |
| *≥ RM2000.00* | 42 (40.8) |
| Smoking | |
| *No* | 33 (32.0) |
| *Yes* | 70 (68.0) |

**The anthropometric characteristics of subjects:**

The anthropometric characteristics of subjects were shown in Table 3.

75.2% (n=79) and 24.8% (n=26) of subjects with non-obese and obese, respectively.

The mean body mass index (BMI), waist circumference (WC), hip circumference (HC), waist to hip ratio (WHR) and percentage of body fat (PBF) of the subjects were 25.6 kg/m2 ± 4.29 kg/m2, 89.1cm ± 11.03cm, 98.93cm ± 7.97cm, 0.88 ± 0.05 and 20.96 % ± 7.28 %, respectively. 19.4% (n=20), 26.2% (n=27), 40.8% (n=42) and 29.1% (n=30) of subjects had abnormally high waist circumference, hip circumference, waist-to-hip ratio and had ≥ 25% of body fat percentage respectively.

**Table 3: The anthropometric characteristics of total subjects**

| Anthropometric Characteristics | *No. of subjects, n (%)* | *Mean ± SD/ Median (IQR)* |
|---|---|---|
| BMI,*Total*<br>*Non-Obese*<br>*Obese* | 103 (100)<br>79 (75.2)<br>26 (24.8) | 25.58 ± 4.29<br>24.19 ± 3.25<br>32.13 ± 1.94 |
| WC, *Total*<br>*Non-Obese*<br>*Obese* | 103 (100)<br>83 (80.6)<br>20 (19.4) | 89.0 ± (79.0-98.0)<br>84.0 ± (78.0-94.0)<br>103.0 ± (100.0-108.75) |
| HC,*Total*<br>*Non-Obese*<br>*Obese* | 103 (100)<br>76 (73.8)<br>27 (26.2) | 100.16 ± 8.72<br>96.18 ± 5.719<br>111.33 ± 5.299 |
| WHR,*Total*<br>*Non-Obese*<br>*Obese* | 103 (100)<br>61 (59.2)<br>42 (40.8) | 0.88 ± 0.05<br>0.85 ± 0.036<br>0.94 ± 0.025 |
| PBF, *Total*<br>*< 25%*<br>*≥ 25%* | 103 (100)<br>73 (70.9)<br>30 (29.1) | 21.6 ± (15.3-26.0)<br>17.6 ± (13.15-22.1)<br>28.5 ± (27.23-33.18) |

**Demographic characteristics of subject with non-obese and obese**

Demographic characteristics of subjects with non-obese and obese were shown in Table 4.

66.7% (n=12) of subjects with obesity were 30 years old and above from lower rank (77.8%, n=14), married (72.2%, n=13), had low educational level (94.4%, n=17), low family income (72.2%, n=13) and smoking (77.8%, n=14). There were no significant differences between demographic profile of subjects with non-obese and obese (p >0.05).

**Table 4: Demographic characteristics of subjects with and without obesity.**

| DEMOGRAPHIC CHARACTERISTICS | BMI | | *Chi-Square ($\chi^2$)* | *P-Value* |
|---|---|---|---|---|
| | *Non-Obese, n (%)* | *Obese, n (%)* | | |
| Age Of Subjects<br>< 30 Years Old<br>≥ 30 Years Old | <br>49 (57.6)<br>36 (42.4) | <br>6 (33.3)<br>12 (66.7) | 3.529 | .050 |
| Rank<br>Lower Rank<br>Higher Rank | <br>73 (85.9)<br>12 (14.1) | <br>14 (77.8)<br>4 (22.2) | 0.744 | .389 |
| Marital Status<br>Single<br>Married | <br>36 (42.4)<br>49 (57.6) | <br>5 (27.8)<br>13 (72.2) | 1.317 | .251 |
| Educational Level<br>Lower Level<br>Higher Level | <br>83 (97.6)<br>2 (2.4) | <br>17 (94.4)<br>1 (5.6) | 0.539 | .463 |
| Family Income<br>< RM2000.00<br>≥ RM2000.00 | <br>48 (56.5)<br>37 (43.5) | <br>13 (72.2)<br>5 (27.8) | 1.526 | .217 |
| Smoking<br>Yes<br>No | <br>29 (34.1)<br>56 (65.9) | <br>4 (22.2)<br>14 (77.8) | 0.965 | .326 |

**Pearson Chi-Square*
*** Fisher's Exact Test*

**The correlation between obesity related anthropometric measurements and blood gases**

The correlation between obesity related anthropometric measurements and blood gases were shown in Table 5.

**Table 5: The correlations between obesity related anthropometric measurements and blood gases**

| ARTERIAL BLOOD GASES ANALYSIS | Correlations | | | | |
|---|---|---|---|---|---|
| | BMI** | WC ** | HC* | WHR* | PBF** |
| pH | r = - .060 p = .549 | r = .006<br>p = .951 | r = .005<br>p = .961 | r = .025<br>p = .799 | r = - .095<br>p = .339 |
| $pCO_2$ | r = .345<br>p = .000 | r = .256<br>p = .009 | r = .184<br>p = .063 | r = .225<br>p = .022 | r = .345<br>p = .000 |
| $pO_2$ | r = - .435 p = .000 | r = - .349 p = .000 | r = - .142 p = .152 | r = - .227<br>p = .021 | r = - .418<br>p = .000 |
| $HCO_3^-$ | r = -0.275 p = .005 | r = -.291<br>p = .003 | r = - .183 p = .065 | r = - .300 p = .002 | r = - .319 p = .001 |

** Pearson's Correlation*
*** Spearman's Correlation*

There were significant inverse correlations between all anthropometric indices (except HC) i.e. BMI, (r = - 0.435, p = 0.000), WC(r = -0.349, p = 0.000), WHR (r = -0.227, p = 0.021), PBF(r = -0.418, p = 0.000) and blood arterial PaO2. Except HC all anthropometric measurements i.e. BMI ($r = -0.275$, $p = 0.005$), WC ($r = -0.291$, $p=0.003$), WHR ($r = -0.300$, $p=0.002$) and PBF ($r = -0.319$, $p=0.001$) were significant inversely correlated with low HCO3- concentrations. All the anthropometric indices (except HC) i.e. BMI ($r = 0.345$, $p = 0.000$), WC ($r = 0.256$, $p = 0.009$), HC ($r = 0.432$, $p=0.000$), WHR ($r = 0.225$, $p = 0.022$) and PBF ($r = 0.324$, $p = 0.001$) were significantly positively correlated with high Pa CO2, concentrations.

## DISCUSSION

Our study demonstrated that both overall and central obesity were associated with unfavourable blood gases levels in healthy subjects with no pre-existing respiratory problem. Subjects were healthy army personnel whom were in service and had undergone medical check-up prior to the study. There were no significant differences in demographic profiles of either obese or non-obese groups.

Subjects were, therefore, ensured not to have respiratory and cardiac problems. The anthropometric indices were significantly correlated with arterial blood gases levels indicating that they were good predictors for arterial blood gases changes. We found that with an exception of HC, all the other obesity related indices were significantly correlated with high $PaCO_2$, low $PaO_2$ and Pa $HCO_3$- suggesting obesity was related to hypoxia, hypercarbia and acidity respectively. Whilst previous studies examined the effects of obesity on few selected anthropometric and arterial blood gases indices. Our study to the best of our knowledge was the first to examine comprehensive anthropometric parameters ranging from BMI, WC, HC, WHR and PBF addressing both overall and central obesity and their relation to arterial blood gases parameters i.e. pH, $PaO_2$, Pa $CO_2$, Pa $HCO_3$-. A study by Zavorsky et al. (2007) solely examined the effects of WHR on $PaO_2$. Whilst Chiang et al. (2003), Zavorsky et al. (2008), Littleton and Tulaimat (2017) investigated the effects of BMI but did not examine the effect of central obesity on blood gases, $PaO_2$.

Our subjects with obesity were those with BMI≥30 and mean BMI of 32.13 ± 1.94. Most of the previous studies recruited obese subjects with BMI of ≥40. [1,18,28-30] We found significant relationships between all anthropometric indices (except HC) and unfavourable arterial blood gases parameters among non-morbid obesity subjects. These suggested that impaired arterial blood gases levels also presented in individuals with non-morbid obese. These findings were supported by Jenkins and Moxham (1991) and Mehari et al. (2015) who reported that mild obesity had a negative impact on lung functions. [13,23] Functional residual capacity (FRC), expiratory reserve volume (ERV) and arterial oxygen tension ($PaO_2$) were reduced in 91 of subjects with Grade I obesity and 28 subjects with normal weight. [9] Ray et al. (1983) and Weiner et al. (1998) however noted that only severe obesity impaired respiratory functions. [5,32] Based on these findings individuals with mild obesity should have a lung function test and arterial blood gases assessment particularly those with early signs and symptoms of hypoxia or hypercapnia such as low alertness level and sleepiness. The possibilities of hypoventilation syndrome (OHS) needed to be considered when non morbid obesity individuals presented with sleepiness and low alertness level.

We found that subjects with obese had low $PaO_2$ and high $PaCO_2$, these findings were consistent with previous studies. [18,27-30,37] Our subjects' anthropometric parameters i.e. BMI, WC, WHR and percentage body fat with the exception of HR were inversely and positively correlated with $PaO_2$ and $PaCO_2$. These findings were also documented by Gabrielsan et al. (2011) who found that both central (WC, WHR) and overall (BMI) obesity were inversely and positively correlated to $PaO_2$ and $PaCO_2$. [17] Zavorsky et al. (2007) however reported that only central (WHR) and not overall obesity (BMI) was inversely correlated with $PaO_2$. Unlike ours, the study by Zavorsky et al. (2007) had a small sample size of 25 subjects with morbidly obese and 20 subjects with normal lung function whilst others had pre-existing lung impairments. Chiang et al. (2003) cross sectionally examined 76 subjects with morbid obesity and found that overall obesity (BMI) was inversely correlated to $PaO_2$. [14] Our findings not only demonstrated that overall and central obesity parameters were good predictors of obesity, the overall obesity parameters (BMI and percentage body fat) had a stronger correlation with the arterial blood parameters compared to central obesity related indices (WC, WHR).

Our findings suggested that the mechanisms underlying arterial blood gases changes in obesity were probably multifactorial, a combination of obesity induced physical changes in the respiratory system, the effects of fat contents and the obesity related biochemical i.e. inflammatory cytokines i.e. interleukin 6, tumour necrosis factor and leptin. [33-35] Phipps et al. (2002) and Ansarin et al. (2005) supported that the non-related obesity induced respiratory mechanical changes also played a role in causing unfavourable arterial blood gases changes among obese subjects. [36,37] Phipps et al. reported that leptin levels were higher in hypercapnic than eucapnic patients with similar adiposity and apnoea-hypopnoea index. [36] Ansarin et al. (2005) found that $PaO_2$ was significantly inversely correlated with body mass, BMI and percentage body fat) but not with lung function parameters i.e. FRC, TLC or FVC. [37]

The obesity induced respiratory mechanical changes had been well documented. [4-6, 22-24]

This conclusion was supported by the findings that central anthropometric measures i.e. WC and WHR had been found to be predictors for unfavourable blood changes, suggesting that android obesity (deposition of fat at the upper part of the body i.e. thorax and abdomen) were associated with unfavourable blood gases. Deposition of fat at these areas impaired respiratory functions through reducing chest wall compliance and an increase in mechanical ventilatory constraint and lower lung volumes due to a large amount of abdominal fat resulting in hypoventilation and retention of carbon dioxide. [5,18] Abnormal ventilation perfusion occurs among individuals with high WC and WHR were due to the substantial portion of fat mass surrounding the thorax, chest, abdomen and muscle which adversely affected the chest wall compliance. [4,18] Impairment of ventilation and perfusion affected the lung ability to dissolve oxygen ($O_2$) from lungs to blood and remove carbon dioxide ($CO_2$) from blood which would be reflected by the $PaO_2$ and $PaCO_2$ arterial blood levels. Our findings, however, suggested that other mechanisms may also contribute to the obesity induced changes in arterial blood gases changes.

## CONCLUSION

Overall and central obesity were significantly correlated with hypoxemia, hypercarbenemia and low hydrogen carbonate. Except for HR, all anthropometric indices are good predictors for blood gases changes. Unlike other studies which examined subjects with morbid obesity, our study demonstrated that unfavourable blood gases changes occurred among non-morbid obesity. A further study examining the obesity induced non-physical mechanical respiratory changes i.e. fat contents and biochemical related to obesity on arterial blood gases changes is worth exploring.

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