IMPACT: International Journal of Research in Applied, Natural and Social Sciences (IMPACT: IJRANSS)
ISSN (P): 2347-4580; ISSN (E): 2321-8851
Vol. 6, Issue 3, Mar 2018, 117-130

OBESITY IN SAUDI FEMALE POPULATION

Adil Omar Bahathiq

Associate Professor, Department of Physiology, Faculty of Medicine,

Um-Alqura University, Saudi Arabia

Received: 26 Feb 2018 **Accepted:** 08 Mar 2018 **Published:** 29 Mar 2018

ABSTRACT

An interaction of genotype and environment results in obesity which leads to a complex multifactorial chronic disease. Obesity also involves the integration of various factors such as social, behavioral, cultural, physiological, metabolic and genetic. Contributing to the significant increase in morbidity and mortality, a prevalence of obesity is becoming an important public health problem.

The aim of this study is to understand obesity among Saudi female population belonging to Makkah community. Obesity has been studied by measuring leptin concentration, and other measurements like body mass index (BMI) and waist circumference (WC).

This study included 240 women aged between 18 and 65and the participants were divided into three groups. The normal or control group whose BMI ranged from 18 to 29.9 comprised the first group, the obese characterized by the BMI ≥30 formed the second group and the obese diabetic group with body mass index (BMI) ≥30 formed the third group. The parameters collected included height, weight, and waist circumference and blood samples. Blood samples were later thawed.

Serum leptin levels in all the groups were detected using ELISA and their means found to be 8.4±1.4 in normal56.3±18.8 in obese and 42±19.3 in a diabetic obese group. In the normal group, the leptin levels were directly associated with BMI ($r = 0.152$, $p = 0.178$), and leptin levels showed strong positive correlation in obese and diabetic obese groups as the follow: $r = 0.350$, $p = 0.001$ and $r = 0.355$, $p = 0.001$. Also, leptin concentrations were positively correlated with BMI and WC in obese and diabetic obese groups, showing high leptin concentration in both the groups.

It is understood that leptin hormone influences appetite and body weight, causing obesity. However, fasting, hypertension, practice physical activity, smoking or following special diet results in changes to serum leptin concentration.

KEYWORDS: *Obesity, Leptin, Genotype*

INTRODUCTION

An abnormal or excessive accumulation of body fat in adipose tissue leads to obesity, impairing health (1). It is unhealthy to have excess weight. Hypertension, hypertriglyceridemia, hypercholesterolemia and high glucose level are all due to obesity. The interaction between genotype and the environment develops into obesity, a complex of multifactorial disease, involving the integration of various factors such as social, behavioral, cultural, physiological, metabolic, and genetic (2). Being a risk factor for metabolic syndrome, obesity is associated with T2DM,

hypertension, hypertriglyceridemia, hypercholesterolemia, which lead to heart disease (2). Therefore, obesity poses a real threat to health (3).

Among the Saudi population, obesity is considered a major health threat. According to a study, in an overall population aged 14-70 years, 13.05% of males and 20.26% of females were obese, which is higher than that reported in the United Kingdom, Australian, Americans and Italian populations (4).

Physiology of Obesity and Weight Loss Therapies

The interaction of the feeding center, located in the lateral hypothalamic nucleus, and the satiety center, located in the ventromedial nucleus of the hypothalamus is key to the regulation of appetite. In response to signals from both adipose tissue and the gastrointestinal tract, the brain regulates energy homeostasis. It is necessary to arrive at a balance between the urge to eat and energy expenditure overtime so that the body weight remains stable (6). It is essential to understand the cause of obesity, the role of appetite as it relates to energy intake and weight gain so that efficacious weight-loss therapies are developed. Several compounds appear to play important role in the regulation of food intake, circulating nutrients (eg, glucose, amino acids, and fatty acids), metabolic compounds (eg, lactate, pyruvate, and ketone bodies), and hormones (eg, insulin, glucagon, cholecystokinin, leptin, and ghrelin) (7).

A peptide hormone secreted by adipose tissue, leptin (from the Greek word leptos, meaning thin) influences energy homeostasis, immune and neuroendocrine functions (8). It has been well established in humans that plasma leptin levels are directly proportional to body fat percentage. High concentration of leptin is very common among obese individuals, especially in their serum and plasma, exhibiting leptin resistance because of either decreased leptin transport into the central nervous system or downregulation of leptin receptors (9,10).

Waist circumference (WC) was not included in Preliminary data analysis of leptin concentration across the range of BMI. Furthermore, the relationship between leptin level and WC have not been assessed in a sample of adults with differences in age, fasting, physical activity and hypertension (12, 13).

The aim of this study was to evaluate the relationship of leptin with BMI and waist circumference in a random sample of adult women ranging from normal weight to severely obese. Through this study, a direct relationship of leptin with BMI and waist circumference was anticipated. The relationship of these hormones with diabetes, hypertension, and fasting was also studied.

MATERIALS AND METHODS

Approved by the University of Umm-Alqura Institutional Review Board, this study obtained signed an informed consent form. The study was carried out at Umm AL-Quran University, AL-Noor Specialist Hospital (Diabetic Centre) and King Abdul-Aziz Hospital (AL-Zaher). All blood analyses were carried out in the University Physiology Department and Professor Sultan research laboratory at Umm AL-Qura University.

Subjects

The study participant included 240 women aged 18-65 and was divided into three groups (see below).

First Group: The Control Group (normal) Comprised 80 volunteers, with the BMI ranging from 18 to 29.99.

Second Group: The obese Group Comprised 80 volunteers with the BMI of ≥30.

First and Second Groups Met the Following Criteria

- Should not be on any diet or use any medication that can interfere with the result.
- Should not perform any physical activity interfering with the result.

Third group: The Diabetic Obese Group Comprised 80 volunteers with the BMI of ≥30.

Anthropometric Measurements

BMI is calculated as kg/m^2. Height was measured to the nearest centimeter using a Harpenden anthropometer (Holtain, Ltd, Crymych, UK). Weight was measured to the nearest 0.1 kg using a Scaletronix scale (Sharp Corp, Wheaton, IL, model 695, weighing to 364 kg). Subjects were divided based on five BMI categories as follows (2): normal weight, <25; overweight, 25 to 29.9; obese I, 30 to 34.9; obese II, 35 to 39.9; severely obese, >40. The BMI of participants were not <18.5. Waist circumference was measured by locating the upper hip bone and placing a measuring tape around the abdomen (ensuring that the tape measure is horizontal) (14).

Hormone Levels

Plasma obtained by centrifugation of blood samples collected after an overnight fast was stored at -70°C in the Microbiology Department.

Using the enzyme-linked immunosorbent assay kit and once the samples thawed, leptin levels were measured in duplicate. Leptin kits were purchased from the Millipore Corporation Research Inc (St Charles, MO, U.SA) and were used to test hormone levels at Professor Sultan Research Laboratory.

Statistical Analysis

The SPSS software (version 11.5, 2002) was used for descriptive statistical analyses. For all analyses, the statistical significance was set at P = 0.05. The relationship of BMI, waist circumference with leptin concentrations in these subjects groups (normal, obese and obese diabetic) were determined using Pearson correlation coefficients. Correlation is defined as a measure of the strength of a linear relationship between two variables. The statistical measure of linear association is known as the correlation coefficient, denoted by the symbol r, which measures how close the points lie on a straight line, whose values always lie between –1 and +1. The value +1 indicates a perfect positive relationship between the two variables and–1 indicates a perfect negative relationship. In addition, a p-value is the probability of getting the observed difference. If the p-value is greater than 0.05, then it can be concluded that the observed difference could have occurred by chance and there is no statistically significant evidence (at the 5% level) for a difference between the groups in the population.

Result

The study samples were 240 women aged between 17 and 65 years, with a mean age of 32.7 ± 13.75 years, height 1.54 ± 6.3 m, and weight 74.9 ± 17.5 kg (see table 1).

Table 1: Summary of Characteristic Feature of All Volunteers in All Groups Such as Age, BMI, WC, Weight, Height, and Leptin Concentration

Character		Normal	Obese	Obese Diabetic
Age	Range	18-38	18-55	20-58
BMI		18-29.9	30-53	30-53.6
WC		60-100	77-149	90-192
Age (years)	mean±std	20.1±2.3	31.4±12.1	46.6±7.9
Height (m)		1.55±6.4	1.556±6.4	1.529±6.00
Weight (Kg)		55.61±7.9	86.5±13.7	82.7±10.2
BMI		22.7±2.6	35.7±5.2	35.4±4.3
WC (cm)		72.9±7.5	101.6±12	106.6±12.4
Leptin Concentration (ng/mL)		8.4±1.4	56.3±18.8	42 ±19.3
	Max.	10.99	99.60	97.27
	Min.	5.12	8.21	12.71

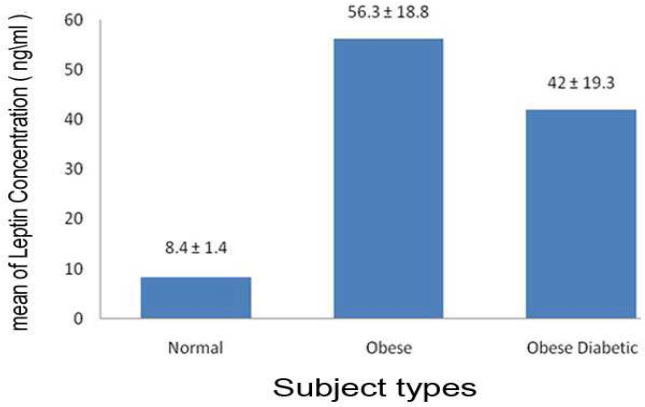

Figure 1: Mean ± Standard Deviation for Leptin Concentration

Leptin Concentration

In all three groups, the Mean of leptin concentrations was 8.4 ng/ml (±1.4) in normal, 56.3 (±18.8) in obese and 42 (±19.3) in the diabetic obese group (see table 1 and figure 1).

BMI and Weight

Directly associated with weight, BMI showed a strong positive relation (r = 0.935, P = 0.000) (See figure 2).

BMI and Waist Circumference

Directly associated with waist circumference, BMI demonstrated a strong positive relation (r = 0.840, P = 0.000) (See figure 3).

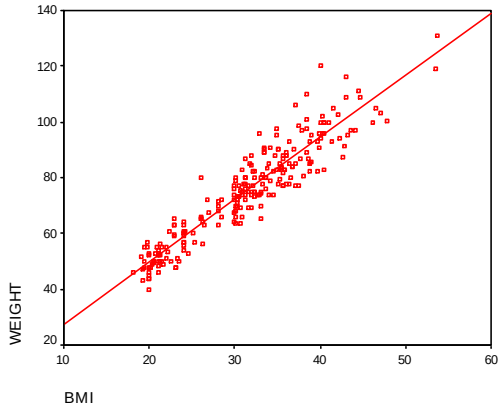

Figure 2: Correlation between Weight and BMI

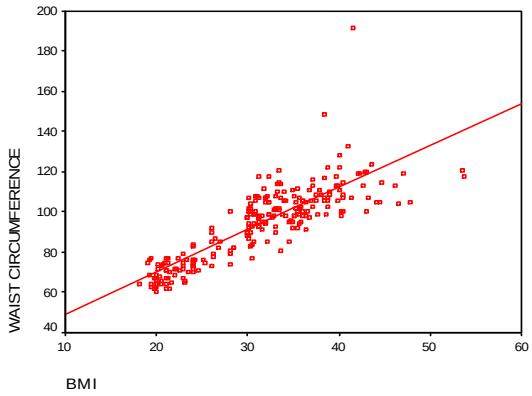

Figure 3: Correlation between Waist Circumference and BMI

Leptin Concentration and BMI in Various Groups

In Normal Subjects

Leptin concentration and BMI showed a linear correlation (r = 0.152, p = 0.178) (data not shown).

In Obese Subjects

Directly associated with BMI, demonstrating a strong positive relation (r = 0.350, p = 0.001) (See figure 4).

In Diabetic Obese Subjects

Directly associated with body mass index, leptin concentration showed a strong positive correlation (r = 0.355, p = 0.001) (See figure 5).

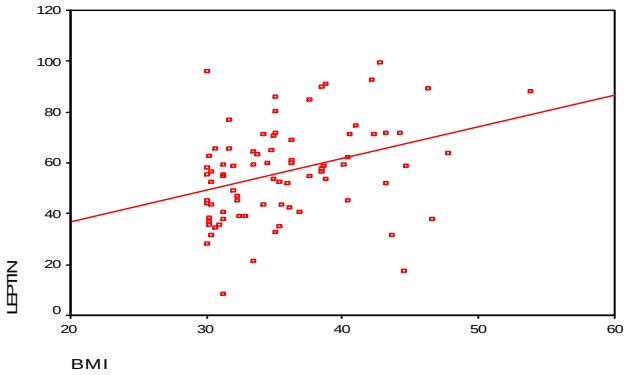

Figure 4: Correlation between Leptin Concentration and BMI in Obese Subjects

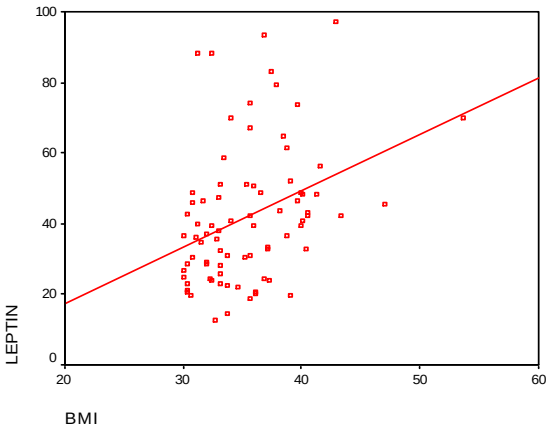

Figure 5: Correlation between Leptin Concentration and BMI in Obese Diabetic Subjects

Leptin Concentration and WC in Various Subject Groups

In Normal Subjects, No obvious correlation between leptin concentration and WC (r = 0.115, p = 0.310) (data not shown) was found.

In Obese Subjects, leptin concentrations were directly associated with WC with a positive correlation (r = 0.299, p = 0.007) (See figure 7).

In Diabetic Obese Subjects, leptin concentrations were directly associated with WC and demonstrated a strong positive correlation (r =0.316, p=.0.004) (See figure 8).

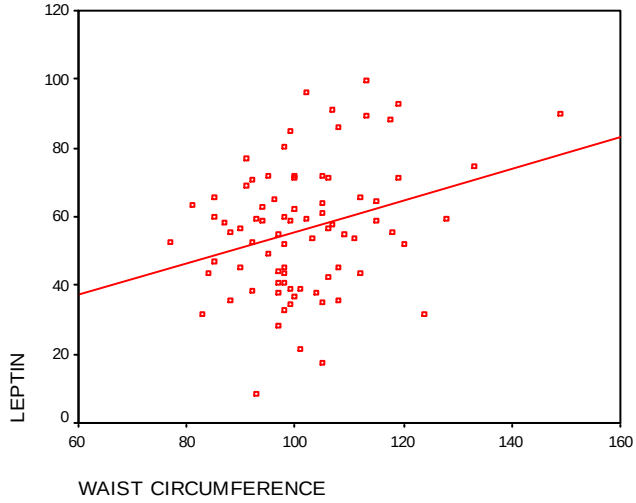

Figure 7: Correlation between Leptin Concentrations with WC in Obese Subjects

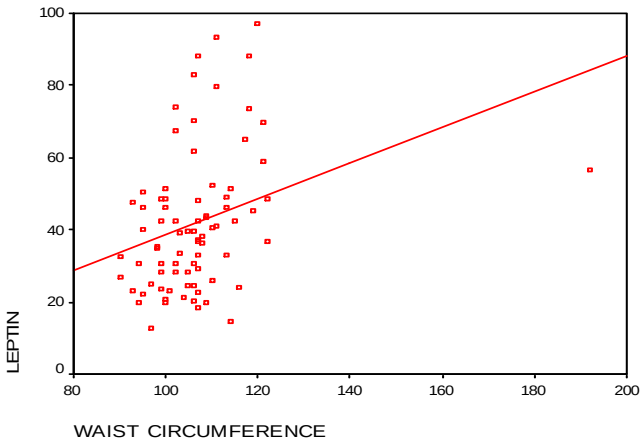

Figure 8: Correlation between Leptin Concentrations and WC in Obese Diabetics

Effect of fasting, practice physical activity and follow special diet on leptin concentration in diabetic obese Subjects

While there was no significant relation between leptin concentration and fasting, practice physical activity and follow special diet in diabetic obese group but we observed that there was a significant effect of this factors on leptin concentration in diabetic obese group (See figure 9).

Table (2): Relation between leptin concentration and other factor (fasting, special diet, Hypertension, and physical activity) in diabetic obese group:

Table 2

		Pearson Correlation	P. Value
Subjects Types		**O.D.**	**O.D.**
Factors	Fasting	0.136	0.231
	Special diet	-0.061	0.589
	Physical activity	-0.277	0.013
	Hypertension	-0.282	0.011
O.D.=Obese Diabetic			

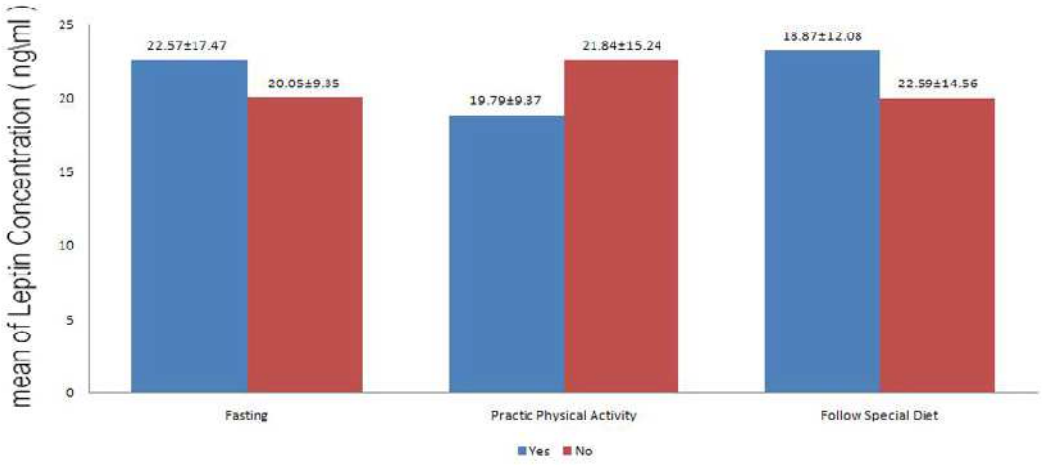

Figure (9): Effect of Fasting, Practice Physical Activity and Follow' Special Diet on Leptin Concentration in Diabetic Obese Subjects

DISCUSSIONS

The objective of this study was to measure the relation between BMI, WC and leptin concentration to understand obesity in the Saudi female population. BMI and WC were directly associated with leptin levels, showing a significant positive correlation between leptin and BMI categories.

Due to both increased fat cell number (hyperplasia) and increased fat cell size (15), obesity is characterized by increased adipose tissue mass. As the most significant contributor to ill health, obesity is now very common in the world's population, which is also replacing under nutrition and infectious diseases. In the United States, obesity currently affects 30% of the adult population and in KSA it affects 35.5% (16).

As the anthropometric measurement for obesity and fat content, the current study used BMI and WC. Many studies confirmed the association of BMI and WC with obesity and fat content. Correlating strongly with fat mass measurement is BMI, though it is unable to distinguish to fat mass from lean mass (17). On the contrary, a patient's abdominal fat content can be measured based on waist circumference, which is clinically acceptable (18).

Obesity and leptin Concentration

The uniqueness of this study is that in adult Saudi women leptin concentrations were assessed for all BMI range, considering various risk factors such as waist circumference, age diabetes, and physical activity.

According to previous studies, in the healthy communities, based on the nationality, there is only little variation in leptin concentrations. A recent study indicated that leptin concentrations in Omani control subjects were 10.6 (± 4.2) ng/ml (19) and in American control subjects, it was 7.8 (± 0.7) ng/ml (20). Based on this study, the normal mean leptin concentration was 8.4 (±1.4) ng/ml in Saudi women.

Various studies reported leptin levels were higher in obese individuals compared to normal weight individuals (21,22). In both obese and non-obese subjects, leptin seems to correlate better with subcutaneous fat compared with visceral fat, irrespective of the weight (23, 24). It has been understood that leptin concentrations are higher in obese subjects (see table 1), mainly because of a diminished response by the leptin receptor signaling pathway,

leptin's poor penetration of the blood-brain barrier, or the presence of less active molecular forms of leptin (25). Leptin deficiency in normal subjects compared to obese subjects can be a likely target for leptin therapy, but an obese subject with high levels of leptin are likely to be resistant to leptin therapy (26). Obesity can lead to leptin resistance, which may also be due to a lack of sensitivity to circulating leptin contributing to the etiology of obesity (27).

There is an increased concentration of serum leptin -based on increased body fat content. The increased release of leptin from large fat cells is the proof for the positive correlation between body fat and serum leptin. In addition, fat content can be assessed based on the serum leptin levels, whose level may decrease by reduction of body fat, maintaining the BMI values (28).

Although insulin levels are not assessed, previous studies proved that leptin is directly associated with insulin resistance (29,30). However, in the diabetic obese group(table 2), leptin concentrations were lower compared to those in the obese group but still higher compared to the normal group (31). The differences in fat distribution between the obese diabetic and the obese nondiabetic groups may be the reason for this. Studies have demonstrated that subcutaneous fat produces more leptin compared to visceral fat. diabetic subjects (Figure 9) have more visceral fat and less subcutaneous fat because insulin is an important stimulator of leptin production (31).

Profound insulin deficiency leads to uncontrolled diabetes which in turn is realized by behavioral markers and metabolic concerns, such as severe hyperglycemia, depletion of body fat mass, and reduced circulating leptin levels that stimulate food intake (32). It is essential to understand whether the subcellular and tissue distribution of leptin are different in human adipocytes obtained from lean and diabetic obese individuals and whether it can be altered by effectors such as insulin (33).

The present study indicated that in diabetic obese volunteers there were no obvious relation between fasting, smoking, physical activity and follow special diet with leptin concentration. The same finding was conducted in other studies,(Klein et al., 2004). But in obese group we observed a negative correlation between diet and leptin concentration (see table 2). This suggests that leptin is involved in the regulation of energy balance by inhibiting dietary intake in healthy humans. Our findings could imply that when body weight is increased, there is simultaneously increased in leptin levels, which would influence the subject to decrease energy intake, and thus reduce body weight. Such scenario where low leptin levels predicted weight gain in healthy subjects is supported by recent studies (Ravussin et al., 1997)

In the present stud the diabetic obese subjects have a high leptin concentration than those whom not fasting (see figure 9). Similar study conducts and finds that plasma leptin started to increase in the first 6 hour, during which none of the patients consumed any food (Hathout et al., 1999).

Our findings demonstrate that follow special diet lead to a decrease in plasma leptin levels (see figure 9). Because a decrease in BMI was observed after following special diet, it is most likely that this is responsible for decreased leptin levels after follow special diet. In support of our findings,(Ozata et al., 2001) weight loss in obese individuals with type 2 diabetes leads to a reduction in serum leptin levels, and elevated leptin levels after sulfonylurea treatment in type 2 diabetics, because their patients had gained weight after treatment.

In spite of controlling the glucose level, high levels of leptin are observed in diabetic obesity, as leptin antagonizes insulin's action in the liver, which is influenced by the changes in intrahepatic glucose with increased

gluconeogenesis and decreased glycogenolysis. It is likely that these leptin's metabolic effects regulate hepatic glucose metabolism under physiological conditions (34).

Obesity and Anthropometric Measurements

As demonstrated by this study, BMI and WC correlate well with leptin concentration in all subject groups. This is achieved by the close relation of BMI, WC and body fat content along with the role of visceral and subcutaneous fat for producing leptin (35,36).

In our study, the mean BMI in normal obese and diabetic obese groups were, respectively, 22.7 (± 2.8), 35.7 (± 5.2) and 35.4 (± 4.3)[AQ: three set of values are provided for two parameters. Please check and edit as necessary.]. BMI and body weight are correlated,. Based on the reported data, BMI and leptin concentrations were higher in obese women compared to other groups. The WC mean in the normal, obese and diabetic obese groups were 72.9 (± 7.5), 101.6 (±12) and 106.6 (±12.4), indicating that the high WC was found in the obese and diabetic obese compared to the normal group.

According to the findings of the current study, there is a positive relationship between BMI and WC, demonstrating that increase in BMI will in turn cause increase in WC and leptin concentration (See figure 3).

CONCLUSIONS

A Middle Eastern country with approximately 23 million populations, Saudi Arabia has shown significant economic and cultural changes over the past thirty years. Approximately 60% of the population is urbanized and have adopted lifestyle according to their diet and physical activity.

In today's world, obesity has become a major health issue as it is linked to hypertension, dyslipidemia, and diabetes and insulin resistance syndrome. Over the past several years, Data have shown a worldwide increase in the number of obese people. In Saudi Arabia, the prevalence of obesity among female and, to a lesser extent, male adults has reached epidemic proportions.

Based on the findings of this study and other studies, obesity and being overweight are the major public health issues of women in Saudi Arabia.

In Saudi Arabia, limited physical activity, limited availability of exercise facilities for women and limited awareness of obesity-related health risks among the population are the reasons for the prevalence of obesity among Saudi women.

REFERENCES

1. *Martin A, Saunders DH, Shenkin SD, Sproule J. (2014). Lifestyle intervention for improving school achievement in overweight or obese children and adolescents, Cochrane Database Syst Rev. 14;(3):159-163*
2. *Al-Quaiz, Al-Joharah M. (2001). "Current concepts in the management of obesity. An evidenced based review." Saudi Medical Journal 22:205-210.*
3. *Tyson N, Frank M . (2018) Childhood and adolescent obesity definitions as related to BMI, evaluation and management options. Best Pract Res Clin Obstet Gynaecol.48, 158-164.*

4. *El-Hazmi, M., and Warsy, A. (2000). "Prevalence of overweight and obesity in diabetic and non-diabetic Saudis." Eastern Mediterranean Health Journal 6 : 276-282.*
5. *Alsaif, M., Hakim, I., Harris, R., Alduwaihy, M., Al-Rubeaan, K., Al-Nuaim, A., Al-Attas, O. (2002). "Prevalence and risk factors of obesity and overweight in adult Saudi population." Nutrition Res 22: 1243-1252.*
6. *Stanley, S., Wynne K., McGowan B. and Bloom S. (2005). "Hormonal regulation of food intake." Physiol Rev 85: 1131-1158.*
7. *Nitin Sippy et al., A Study of Prevalence of Obesity in Adolescents of a Select Primary Urban Health Centre of Navi Mumbai, International Journal of Medicine and Pharmaceutical Sciences (IJMPS), Volume 5, Issue 6, November-December 2015, pp. 39-42*
8. *Havel PJ. (2001). Peripheral signals conveying metabolic information to the brain: Short-term and long-term regulation of food intake and energy homeostasis. Exp Biol Med.;226:963-977.*
9. *Al-Harithy, Rowyda N. (2004). "Relationship of leptin concentration to gender, body mass index and age in Saudi adults." Saudi Med J 25:1086-1090.*
10. *Caro JF, Kolaczynski JW, Nyce MR, Ohannesian JP, Opentanova I, Goldman WH, Lynn RB, Zhang PL, Sinha MK, Considine RV. (1996).Decreased cerebrospinal fluid/serum leptin ration in obesity: A possible mechanism for leptin resistance. Lancet;348:159-161.*
11. *Supriya Rana, Indira R. Samal & Ravjit Kaur Sabharwal, Diet, Obesity and Prostate Cancer in a Population of Northern India, International Journal of General Medicine and Pharmacy (IJGMP), Volume 7, Issue 1, December-January 2018, pp. 21-28*
12. *Bjorbaek C, El Haschimi K, Frantz JD, Flier JS. (1999)The role of SOCS-3 in leptin signaling and leptin resistance. J biol Chem.;274:30059-30065.*
13. *Hu FB, Chen C, Wang B, Stampfer MJ, Xu X.(2001).Leptin concentrations in relation to overall adiposity, fat distribution, and blood pressure in a rural Chinese population. Int J Obes Relat Metab Disord.;1:121-125.*
14. *Tschop M, Weyer C, Tataranni AP, Devanarayan V, Ravussin E, Heiman ML. (2001).Circulating ghrelin levels are decreased in human obesity. Diabetes.;50:707-709.*
15. *Rosicka M, Krsek M, Matoulek M, Jarkovska J, Marek J, Justova V, Lacinova Z. (2003).Serum ghrelin levels in obese patients: The relationship to serum leptin levels and soluble leptin receptor levels. Physiol Res.; 52:61-66.*
16. *National Institutes of Health and National Heart Lung and Blood Institute. (1998).Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. The evidence report. Obes Res.;6:51S-209S.*
17. *Camp, H. S.,Ren, D. and Leff, T. (2002).Adipogenesis and fat-cell function in obesity and diabetes. Trends Mol Med. 8:442-447.*
18. *Al-Nozha, M. M.,Al-Mazrou, Y. Y.,Al-Maatouq, M. A.,Arafah, M. R.,Khalil, M. Z.,Khan, N. B.,Al-Marzouki, K.,Abdullah, M. A.,Al-Khadra, A. H.,Al-Harthi, S. S.,Al-Shahid, M. S.,Al-Mobeireek, A. and Nouh,*

M. S. (2005).Obesity in Saudi Arabia. Saudi Med J. 26:824-89.

19. *Laura Stewart . (2015).Childhood obesity .Medicine, 43, 2. 108-111*
20. *Zeynep Atay, Abdullah Bereket. (2016) .Current status on obesity in childhood and adolescence: Prevalence, etiology, co-morbidities and management. Obesity Medicine, 3, 1-9*
21. *Almaskari, Y. Masoud, Alnaqdy A. Adel (2006). "Correlation between serum leptin levels, body mass index and obesity in omanis." Sultan Qaboos Med Journal. 6:28-31. be cosistent in spacing*
22. *Veronica, M., Carlson, J. Joseph, Hunt, C. Steven, Adams, D. Ted (2006). "Relationship of ghrelin and leptin hormones with body mass index and waist circumference in a random sample of adults." J Amer Diet Assoc 106: 822-828.*
23. *Considine RV, Sinha MK, Heiman ML, Kriauciunas A, Stephens TW, Nyce MR, Ohannesian JP, Marco CC, Mckee LJ, Bauer TL, Caro JF. (1996).Serum immunoreactive leptin concentrations in normal weight and obese humans. N Engl J Med.;334:292-295.*
24. *Ruhl CE, Everhart JE. (2001).Leptin concentrations in the United States: Relations with demographic and anthropometric measures. Am J Clin Nutr.;74: 295-301.*
25. *Cnop M, Landchild MJ, Vidal J, Havel PJ, Knowles NG, Carr DR, Wang F, Hull RL, Boyko EJ, Retzlaff BM, Walden CE, Knopp RH, Kahn SE. (2002).The concurrent accumulation of intra-abdominal and subcutaneous fat explains the association between insulin resistance and plasma leptin concentrations: Distinct metabolic effects of two fat compartments. Diabetes.;51:1005-1015.*
26. *Minocci A, Savia G, Lucantoni R, Berselli ME, Tagliaferri M, Calo G, Petroni ML, de Medici C, Viberti GC, Liuzzi A. (2000).Leptin plasma concentrations are dependent on body fat distribution in obese patients. Int J Obes Relat Metab Disord.;24:1139-1144.*
27. *Ostlund, R. E., Jr.,Yang, J. W.,Klein, S. and Gingerich, R. (1996).Relation between plasma leptin concentration and body fat, gender, diet, age, and metabolic covariates. J Clin Endocrinol Metab. 81:3909-13.*
28. *Adeyemi, E. and Abdulle, A. (2000).A comparison of plasma leptin levels in obese and lean individuals in the United Arab Emirates. Nutrition Research. 20:157-166.*
29. *Patrick Ip, Frederick Ka-Wing Ho, Lobo Hung-Tak Louie, Thomas Wai-Hung Chung, Yiu-Fai Cheung, So-Lun Lee, Stanley Sai-Chuen Hui, Walter King-Yan Ho, Daniel Sai-Yin Ho, Wilfred Hing-Sang Wong, Fan Jiang.(2017) Childhood Obesity and Physical Activity-Friendly School Environments .The Journal of Pediatrics, 191, 110-116*
30. *Almaskari, Y. Masoud, Alnaqdy A. Adel (2006). "Correlation between serum leptin levels, body mass index and obesity in Omanis." Sultan Qaboos Med J 6:28-31.*
31. *Donahue RP, Prineas RJ, Donahue RD, Zimmet P, Bean JA, De Courten M, Collier G, Goldberg RB, Skyler JS, Schneiderman N. (1999).Is fasting leptin associated with insulin resistance among non-diabetic individuals? The Miami Community Health Study. Diabetes Care.22:1092-1096.*

32. *Liuzzi A, Savia G, Tagliaferri M, Lucatoni R, Berselli ME, Petroni ML, De Medici C, Viberti GC. (1999).Serum leptin concentration in moderate and severe obesity: Relationship with clinical, anthropometric and metabolic factors. Int J Obes Relat Metab Disord.; 23:1066-1073.*

33. *Abdelgadir, M.,Elbagir, M.,Eltom, M.,Berne, C. and Ahren, B. (2002).Reduced leptin concentrations in subjects with type 2 diabetes mellitus in Sudan. Metabolism. 51:304-6*

34. *Gelling, W. R., Joost Overduin, Chistopher D. Morrison, Gregory J. Morton, R. Scott Frayo, David E. Cummings, Michael W. Schwartz (2004). "Effect of uncontrolled diabetes on plasma ghrelin concentration and ghrelin-induced feeding." Endocrinol. 145:4575-4582.*

35. *Russell, C. D., Ricci, M. R., Brolin, R. E., Magill, E., Fried, S. K. (2001). "Regulation of the leptin content of obese human adipose tissue." Amer J Physiol Endocrin and Metab.280:E399-404.*

36. *Liu, Lisen, George, B. Karkanias, Jose C. Morales, Meredith Hawkines, Nir Barziai, Jiali Wang, Luciano Rossetti (1998). "Intracerebroventricular leptin regulate hepatic but not peripheral glucose fluxes." J biolo Chem 273: 31160-31167.*

37. *Maugeri, D.,Bonanno, M. R.,Speciale, S.,Santangelo, A.,Lentini, A.,Russo, M.S.,Calanna, A.,Malaguarnera, M.,Motta, M.,Testai, M. and Panebianco, P.(2002). The leptin, a new hormone of adipose tissue: clinical findings and perspectives in geriatrics. Arch Gerontol Geriatr. 34:47-54.*

38. *Ostlund, R. E., Jr.,Yang, J. W.,Klein, S. and Gingerich, R. (1996).Relation between plasma leptin concentration and body fat, gender, diet, age, and metabolic covariates. J Clin Endocrinol Metab. 81:3909-13. Ref 37 is the same as Ref 20*

39. *Veronica, M., Carlson, J. Joseph, Hunt, C. Steven, Adams, D. Ted (2006). "Relationship of ghrelin and leptin hormones with body mass index and waist circumference in a random sample of adults." Journal of the American dietetic association 106: 822-828.*

40. *Klein , L.,Corwin, E. and Ceballos, R. (2004).Leptin, hunger, and body weight: Influence of gender, tobacco smoking, and smoking abstinence. Addict Behav. 29 (5):921-7.*

41. *Ravussin, E.,Pratley, R. E.,Maffei, M.,Wang, H.,Friedman, J. M.,Bennett, P. H. and Bogardus, C. (1997).Relatively low plasma leptin concentrations precede weight gain in Pima Indians. Nat Med. 3 (2):238-40.*

42. *Hathout, E. H.,Sharkey, J.,Racine, M.,Ahn, D.,Mace, J. W. and Saad, M. F. (1999).Changes in plasma leptin during the treatment of diabetic ketoacidosis. J Clin Endocrinol Metab. 84 (12):4545-8.*

43. *Ozata, M.,Oktenli, C.,Bingol, N. and Ozdemir, I. C. (2001).The effects of metformin and diet on plasma testosterone and leptin levels in obese men. Obes Res. 9 (11):662-7.*