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Studying the Immune Profile and Susceptibility to Microbial Infections in Obese Adults

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Authors' contributions

This work was carried out in collaboration between all authors. Author MAKAS designed the study, wrote the protocol and wrote the first draft of the manuscript. Author HFF designed the study, managed the literature searches, analyses of the study and performed the spectroscopy analysis. Author FQJAZ managed the experimental process. All authors read and approved the final manuscript.

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ABSTRACT

Objectives: This study aims at studying the effect of adult obesity on immunologic profile and susceptibility to microbial infections.
Materials and Methods: This work was applied on 50 obese subjects visited to the Nutrition Center of Marjan hospital in Babylon province-Iraq from October 2014 to January 2015. The samples were consisted of 39 females and 11 males with age range 20-60 years. This study involved also 30 apparently health subjects with normal weight as controls consisted of 21 males and 9 females with age range 22-50 years. Body mass index for each subject was estimated as obesity determinant, then blood samples were collected from obese and control to estimate the concentrations of interleukin-2 (IL-2), interferon-gamma (IFN-γ), C3 & C4 complement components, and phagocytic index. Also, estimation of anti-streptolysin-O (ASO) & anti-measles-IgG concentrations were used as indicators for microbial infections.
Results: The result of IL-2 was significantly ($p < 0.05$) lower in obese subjects than controls, while

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IFN-γ was not significant decreased in obese group, while concentrations of C3 & C4 were a highly significant increased ($p<0.001$) in obese group, phagocytic index was a highly significant decreased in obese subjects ($p<0.001$). Regarding the susceptibility to microbial infections the concentrations of ASO & anti-measles virus IgG in obese group were a highly significant more than controls.

Conclusions: This result may provide clear evidence that obese subjects are more susceptible to microbial infections than normal subjects.

Keywords: Obesity; immunity; measles; ASO.

1. INTRODUCTION

Several epidemiological data have been reported that obese subjects have increased susceptibility to microbial infection, especially community-acquired infections, postoperative infections, and nosocomial infection as a result of impairment of the immune system [1].

Study the impact of obesity on the vulnerability to infection was started with *Influenza* H1N1 pandemic, demonstrated by increasing the course and mortality rate of this infection in obese individuals [2]. Louie et al. [3] indicate that obese adults are very susceptible to microbial infection, focused on respiratory infection of pandemic strain of *Influenza* A virus (H1N1), were obese subjects showed as a predictor for a worse outcome of this infection. A study has been done by Kwong et al. [4] on more 12 influenza seasons, examined the relationship between obesity and respiratory hospitalizations during the period of seasonal influenza epidemics, and the severely obese patients were at increased risk for respiratory hospitalization. Moreover, another study proved that obese children are more susceptible to infection with respiratory Syncytial virus than normal weight as a result of impairment of immune response to this virus [5].

An evidence has shown that obesity can be related to an increased risk of hepatic fibrosis and steatosis in non-diabetic patients with chronic hepatitis C infection and it has been shown to have an adverse effect on the progression of chronic HCV liver disease, and diminished response to antiviral therapy [6]. Moreover, study was performed by Bressler et al. [7] using standard statistical techniques in a retrospective analysis of patients with hepatitis C virus infection, was reported that body fat mass affects the response to antiviral treatment and eradication of this virus. Also, Obesity proved to be exacerbating the liver injury in patients with hepatitis C infection and other chronic liver diseases, it is represented that regeneration of hepatocytes which occur in responding to viral hepatitis infection may be impaired in patients who have fat deposition in hepatocytes, and obese patients with hepatitis C had increased levels of fibrosis in comparing with that non-obese [8].

In cutaneous infection, Obesity can cause changes in skin barrier function, the lymphatic system, structure and function of collagen. Also, suggested that the vascular supply is impaired in obese persons and affects both macrocirculation and microcirculation [9]. Study of invasive *Streptococcus pyogenes* disease in New Caledonia represented that (29%) of patients were obese, and consider obesity as one of the commodities of this infection [10].

Mycosis also come in infections that result from obesity, there is an indication to that obese subjects and diabetic patients present in two thirds of mucormycosis [11]. Individuals with obesity have more fat folds and thick layers of subcutaneous fat leading to sweat more frequency, especially in the sub maxillary area, abdominal skin folds, perineal area, and axillae. Scrubbing between these surfaces lead to maceration of the skin, and this condition facilitates incidence of fungal infection such as yeast dermatitis, fissures, and intertrigo, commonly caused by yeast [12].

This work aimed at the illustration the relation between obesity and susceptibility to microbial infections by evaluation immune parameters associated with infections.

2. MATERIALS AND METHODS

2.1 Samples

This study involves a total of (50) obese adults consists of (43) females and (7) males, athletes and diabetic subjects were excluded. Their ages ranged from (20-60) years. These patients were

visited the center of nutrition in Marjan hospital in Babylon province–Iraq during the period November 2014_January 2015. The controls were a total of 30 healthy subjects with a normal weight consisting of (21) male and (9) female were involved in control group their ages ranged wads approximately similar to that of obese group.

2.2 Ethical Approval

This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki). Agreement of all subjects in case & control groups has been taken prior the study. Moreover, the study design was approved by Research Ethical Committee in College of Medicine/ Babylon University.

2.3 Estimation of Body Mass Index (BMI)

BMI of all case and control subjects was measured, the weight of each subject has been taken by personal balance without shoes and heavy clothes, and the standing height also was measured by tap measure, then body mass index estimated according to [13]. BMI for control (non obese) was 18.5-24.9) kg/m^2, whereas for obese was more than or equal to 30 kg/m^2.

2.4 Estimation of Immune Parameters

Phagocytic activity for neutrophils was carried out according to [14]. The levels of IL -2 and IFN-γ were determined according to the instructions of company (Elabscince-China**)** by using ELISA technique. Also, the concentrations of complement components C3 and C4 were estimated by ELISA technique (Elabscince-China).

2.5 Indicators of Microbial Infections

The anti-streptolysin-O (ASO) and anti-measles-IgG antibodies were used as indicators for bacterial and viral infections respectively by using ELISA technique (SunLong Biotech Co., LTD-China).

3. RESULTS

3.1 Cytokine Profile

In this study, the mean concentration of interleukine-2 (IL-2) in obese adults was (149.19) pg/ml which was statistically significant (p<0.05) lower than that of controls (412.45) pg/ml (Table 3.1). While the mean concentration of interferon gamma (IFN-γ) in obese adults and control groups were (757.91, 820.41) pg/ml respectively. Statistically, there is no significant difference between two groups (p>0.05), (Table 3.2).

3.2 Complement Components

In this study, the mean concentration of complement component (C3) in obese adults was a highly significant (p<0.001) more than controls (Table 3.3). The mean of C3 concentrations in obese adult group was (882.56) pg/ml, while in controls was (370.9) pg/ml. Regarding C4, the concentration in obese adults was a highly significant (p<0.001) more than that of controls (Table 3.4). The mean concentration of C4 in obese adults group was (192.77) pg/ml, while in control group was (32.02) pg/ml.

3.3 Phagocytic Index

The mean values of phagocytic index for obese subjects and controls were 6.1% and 10.6% respectively (Table 3.5). It is statistically clear that phagocytic index in obese adults is highly significant lower than that controls (p<0.001).

Table 3.1. Concentration of Interleukine-2 (IL-2) pg/ml for obese and control subjects

The subjects	Interleukine-2 (IL-2)		
	Mean	*SD	Significance between two groups
Obese subjects (n=50)	149.19	209.23	Significant P<0.05
Control subjects (n=30)	412.45	465.68	

*Standard deviation

Table 3.2. Concentration of interferon gamma (IFN-γ) pg/ml for obese and control subjects

The subjects	Interferon gamma (IFN-γ)		
	Mean	*SD	Significance between two groups
Obese subjects (n=50)	757.91	353.07	No significant P>0.05
Control subjects (n=30)	820.41	208.23	

*Standard deviation

3.4 Susceptibility for Microbial Infections

In this study the mean concentration of anti-streptolysin-O (ASO) in obese adult group was (1.174) IU, while in controls (0.3) IU, and

statistically the difference is a highly significant between two groups (p<0.001) (Table 3.6).

Table 3.3. Concentration of complement (C3) pg/ml in obese and control groups

The subjects	C3 complement component		
	Mean	*SD	Significance between two groups
Obese subjects (n=50)	882.56	592.2	Highly significant
Control subjects (n=30)	370.9	502.74	P<0.001

*Standard deviation

Regarding to measles infection, this study showed the mean concentration of anti-measles-IgG (MV-IgG) antibody in obese adults sera was (1.1) IU, while in controls sera was (0.15) IU, reported that concentration in obese subjects was statistically a highly significant higher than that of non-obese subjects, (Table 3.7).

Table 3.4. Concentration of complement C4 in obese and control groups

The subjects	C4 complement component		
	Mean	*SD	Significance between two groups
Obese subjects (n=50)	192.77	132.79	Highly significant
Control subjects (n=30)	32.02	49.38	P<0.001

*Standard deviation

Table 3.5. Phagocytic index for obese adults and controls

The subjects	Phagocytic index		
	Mean (%)	*SD (%)	Significance between two groups
Obese subjects (n=50)	10.6	1.429	Highly significant
Control subjects (n=30)	6.1	0.994	P<0.001

*Standard deviation

Table 3.6. Concentration of anti-streptolysin-O in obese adult group and control group

The subjects	Anti-streptolysin-O (IU)		
	Mean	*SD	Significance between two groups
Obese subjects (n=50)	1.174	0.013	Highly significant
Control subjects (n=30)	0.3	0.017	P< 0.001

*Standard deviation

Table 3.7. Concentration of anti-measles virus-IgG antibody IU in obese adults and controls

The subjects	Anti-measles virus Ab (Anti-MV-Ab)		
	Mean	*SD	Significance between two groups
Obese subjects (n=50)	1.1	0.191	Highly significant
Control subjects (n=30)	0.15	0.035	P<0.001

*Standard deviation

4. DISCUSSION

The finding of significant decreasing of IL-2 in obese adults agree with Aygun et al. [15] who showed that IL-2 concentration in obese subjects was lower than that of control (non-obese) subjects, with statistically significant difference. Another study showed the low number of T cells in obese individuals as a result of lacking IL-2 that considered as a key in growth and activation of these cells, suggested obese subjects were more susceptible to be infected with microbial infections, and demonstrated that by adding of IL-2 to isolated infected cells reestablish the growth and activity of T cells [16].

Morita et al. [17] illustrated that IL-2 has important functions in regulation of T cells proliferation & survival, in addition to enhance IFN-γ production and prevent autoimmunity [17,18]. Moreover, IL-2 play a direct role in the enhancement of antimicrobial immunity [19-21]. This cytokine is a component of antituberculosis immunity [22]. IL-2 deficiency considered as risk for autoimmune diseases which can be treated by administering of interleukine-2 as activating and expanding factor for T reg. cells [23].

The finding of interferon-gamma (IFN-γ)agrees with Delgado-Borregoa et al. [6] who mentioned that there is no significant association between increasing BMI and levels of IFN-γ.

In spite of high susceptibility of obese adults to infections, the lowering of IFN-γ may be attributed to suppressed effect of obesity on TH1 response. Viral infections may cause immune anergy by shifting the immune response from TH1 to TH2 response [24,25].

In regards to complements component (C3) the finding matched with that showed by Hernández-Mijares et al. [26] who mentioned that the level of

C3 concentration in obese individuals was a highly significant higher than that of normal-weighted subjects. Moreover, they showed that obese individuals were more predisposed to cardiovascular diseases (CVDs) by considering that high levels of C3 as one of the risk factors, and predictor for these diseases. The association between adipose tissue and C3 levels, where adipocytes secrete C3 complement component and the elevation of concentration was related to weight increasing, and reduced by reduction of weight [27,28]. During the activation of the complement it is cleaved to C3a & C3b, where C3a has a significant role as anaphylatoxin, responsible for chemotaxis, histamine releasing by mast cells, smooth muscle contraction, and increasing vascular permeability. Therefore, increasing of C3 complement expression in obese individuals considered as a risk factor for shock in these subjects [29].

The C3a receptor (C3aR) as a signaling pathway of C3 complement factor has a main role for enhancement of C3 complement in the incidence of insulin resistance in obese subjects, proved the C3a receptor was high in white adipose tissue (WAT), and intensely up regulated after high fatty diet (HFD) [30,31].

The finding of a highly significant increasing of complement (C4) component agrees with Wärnberg et al. [32] who indicate that the complement C4 concentration in obese subjects was a significant higher than that of non-obese group, suggested this elevation could be due to increase of adipocyte cells and adipose tissue that considered as another complement producing part.

Trayhurn and Wood, study [33] mentioned that C4 have a role in systemic low-grad inflammations that predispose obese individuals to chronic diseases such as type 2 diabetic mellitus (T2DM) and cardiovascular disease. C4 as a component for classical pathway of complement system may enhance the incidence of urticaria and activate acute phase responses (APR) that increase the severity of this disease [34].

By considering neutrophils as important part of innate immune system cells that perform immediate immunity against microbial infection in nonspecific way. The result of this study refers to reduction of neutrophils activity in obese group. The low percent of phagocytic index in obese group may be resulted from low level of IL-2 concentration as mentioned above. Kogut et al. [35] confirmed that interleukin-2 has an important role in activation of phagocytosis through induction of IL-8 and T helper type 1 cytokine secretion that work as agonist for phagocytosis. Another study by Hellmann et al. [36] indicated to that low level of phagocytic activity resulted from increased saturated fatty acids in obese subjects. The major role of neutrophils is immune defense against microbial infections and inflammatory stimuli, considered as essential part of innate immunity, by having toll-like receptors (TLRs) for recognition of antigenic elements of opsonized microbe [37].

ASO considered as an indicator for bacterial infection with *Streptococcus pyogenes*. As illustrated previously the low level of IL-2 associated with high susceptibility to microbial infections especially those associated with autoimmune diseases. Therefore, the high level of ASO measured in this study may attributed to the IL-2 deficiency, high concentration complement components (C3 & C4) over the normal values, in addition to the low levels of phagocytic index. Thus, obese adults may predispose to infection with *S. pyogenes* with their complication of autoimmune disease. Obesity considered as one of the risk factors that facilitate infection with *Streptococcus pyogenes* with no difference in residence and season in the incidence of *S. pyogenes* infection [38]. Moreover, obese subjects predisposed to *S. pyogenes* and other infections [39,40].

Depending on the fact that anti-measles-IgG elevates and persists for a long time considered as an indicator for chronic or previous infection [41] this result indicates that elevation of anti-measles-IgG antibody may be resulted from past infections with measles virus in obese adults in compared with non-obese group. This finding agrees with Kimura et al. [42] who showed the high body mass index (BMI) was associated with elevation of previous measles infections. This elevation of viral infection in obese adults may be resulted from impaired immune system, where low levels of IL-2 concentration and phagocytic index in obese group may facilitate viral infection in obese subjects. Al-Saadi et al. [43] illustrated that measles previous infections may predispose for M. tuberculosis and other bacterial infections by inducing immune anergy that increases the severity of microbial diseases. Obese subjects are more predisposed to respiratory viral infection than non-obese subjects suggested that this susceptibility to this infection is resulted from

impairing of immune system in obese individuals, where adipose tissues secrete adipokine and adiponectin that have a role in decline activity of macrophage and cytokines secretion [44].

5. CONCLUSION

This study showed that obese subjects have significant decreasing levels of immunological profile and more predisposed to be infected with microbial infections.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Falagas ME, Kompoti M. Obesity and infection. Lancet Infect. Dis. 2007;6:438–446.
2. Fuhrman C, Bonmarin I, Bitar D, Cardoso T, Duport N, Herida M, Isnard H, Guidet B, Mimoz O, Richard JC, Brun-Buisson C, Brochard L, Mailles A, Paty AC, Saura C, Lévy-Bruhl D. Adult intensive-care patients with 2009 pandemic influenza A(H1N1) infection. Epidemiol Infect. 2011;139: 1202–1209.
3. Louie JK, Acosta M, Samuel MC, Schechter R, Vugia DJ, Harriman K, Matyas BT. A novel risk factor for a novel virus: Obesity and 2009 pandemic influenza A (H1N1). Clin Infect Dis. 2011; 52:301–312.
4. Kwong JC, Campitelli MA, Rosella LC. Obesity and respiratory hospitalizations during influenza seasons in Ontario, Canada: A cohort study. Clin Infect Dis. 2011;53:413–421.
5. Akiyama N, Segawa T, Ida H, Mezawa H, Noya M, Tamez S, Urashima M. Bimodal effects of obesity ratio on disease duration of respiratory syncytial virus infection in children. Allergol Int. 2011;60:305–308.
6. Delgado-Borrego A, Healey D, Negre B, Christofi M, Sabharwal S, Ludwig DA, Chung RT, Jonas MM. The influence of body mass index on outcome of pediatric chronic hepatitis C virus infection. J Pediatr Gastroenterol Nutr. 2010;51(2): 191–197.
7. Bressler BL, Guindi M, Tomlinson G, Heathcote J. High body mass index is an independent risk factor for non-response to antiviral treatment in chronic hepatitis C. Hepatology. 2003;38:639-644.
8. Chalasani N, Younossi Z, Lavine JE, Diehl AM, Brunt EM, Cusi K, Charlton M, Sanyal AJ. The diagnosis and management of non-alcoholic fatty liver disease: Practice guideline by the American Association for the study of liver diseases. American College of Gastroenterology and the American Gastroenterological Association. 2012;55(6):2005-2023.
9. Yosipovitch G, DeVore A, Dawn A. Obesity and the skin: Skin physiology and skin manifestations of obesity. J Am Acad Dermatol. 2007;56:901–916quiz 917-20.
10. Le Hello S, Doloy A, Baumann F, Roques N, Coudene P, Rouchon B, Lacassin F, Bouvet A. Clinical and microbial characteristics of invasive *Streptococcus pyogenes* disease in new caledonia, a region in oceania with a high incidence of acute rheumatic fever. Journal of Clinical Microbiology. 2010;48(2):526–530.
11. Gleissner B, Schilling A, Anagnostopolous I, Siehl I, Thiel E. Improved outcome of zygomycosis in patients with hematological diseases? Leukemia Lymphoma. 2004; 45(7):1351–1360.
12. Garcia-Hidalgo L. Dermatological complications of obesity. Am J Clin Dermatol. 2002;3(6):497–506.
13. World Health Organization. Physical status: The use and interpretation of anthropometry. Report of a WHO Expert Committee. WHO Technical Report Series 854. Geneva; 1995.
14. Furth RV, Theda L, Liejilt PC. *In vetro* determination of phagocytosis. Handbook of experimental immunology. Black well scientific publication, Oxford. 1985;(2): 125.
15. Aygun AD, Gungor S, Ustundag B, Gurgoze MK, Sen Y. Proinflammatory cytokines and leptin are increased in serum of prepubertal obese children. Mediators of Inflammation. 2005;3:180–183.
16. Costanzo AE, Taylor KR, Shelley Dutt, Han PP, Ken Fujioka, Jameson JM. Obesity impairs γδ T cell homeostasis and antiviral function in humans. PLoS One. 2015;18;10(3):e0120918.
17. Morita CT, Jin C, Sarikonda G, Wang H. Nonpeptide antigens, presentation mechanisms and immunological memory of human Vγ9Vδ2 T cells: Discriminating

friend from foe through the recognition of prenyl pyrophosphate antigens. Immunol Rev. 2007;215:59–76.

18. Liao W, Lin JX, Leonard WJ. Interleukin-2 at the crossroads of effector responses, tolerance and immunotherapy. Immunity. 2013;38(1):13–25.
19. Budagian V, Bulanova E, Paus R, Bulfone-Paus S. IL-15/IL-15 receptor biology: A guided tour through an expanding universe. Cytokine Growth Factor Rev. 2005;17(4):259-80.
20. Spellberg B, Edwards JE. Type 1/Type 2 immunity in infectious diseases. Clin Infect Dis. 2001;2(1):76-102.
21. Sasaki Y, Yoshimoto T, Maruyama H, Tegoshi T, Ohta N, Arizono N, Nakanishi K. IL-18 with IL-2 protects against *Strongyloides venezuelensis* infection by activating mucosal mast cell–dependent type 2 innate immunity. J Exp Med. 2005; 202(5):607-16.
22. Millington KA, Innes JA, Hackforth S, Hinks TS, Deeks JJ, Dosanjh DP, Guyot-Revol V, Gunatheesan R, Klenerman P, Lalvani A. Dynamic relationship between IFN-gamma and IL-2 profile of Mycobacterium tuberculosis-specific T cells and antigen load. J Immunol. 2007;178(8):5217-26.
23. Zhang H, Chua KS, Guimond M, Kapoor V, Brown MV, Fleisher TA, Long LM, Bernstein D, Hill BJ, Douek DC, Berzofsky JA, Carter CS, Read EJ, Helman LJ, Mackall CL. Lymphopenia and interleukin-2 therapy alter homeostasis of CD4+CD25+ regulatory T cells. Nat Med. 2005;11(11):1238-43.
24. Brenndörfer ED, Brass A, Karthe J, Ahlén G, Bode JG, Sällberg M. Cleavage of the T cell protein tyrosine phosphatase by the hepatitis C virus nonstructural 3/4A protease induces a Th1 to Th2 shift reversible by ribavirin therapy. Journal of Immunology. 2014;192(4):1671-80.
25. O'Rourke RW, White AE, Metcalf MD, Winters BR, Diggs BS, Zhu X, Marks DL. Systemic inflammation and insulin sensitivity in obese IFN-γ knockout mice. Metabolism. 2012;61(8):1152-61.
26. Hernández-Mijares A, Bañuls C, Bellod L, Jover A, Solá E, Morillas C, Víctor VM, Rocha M. Effect of weight loss on C3 and C4 components of complement in obese patients. Eur J Clin Invest. 2012; 42(5):503-9.
27. Gabrielsson BG, Johansson JM, Lönn M, Jernås M, Olbers T, Peltonen M, Larsson I, Lönn L, Sjöström L, Carlsson B, Carlsson LM. High expression of complement components in omental adipose tissue in obese men. Obes Res. 2003;11(6):699-708.
28. Onat A, Can G, Rezvani R, Cianflone K. Complement C3 and cleavage products in cardiometabolic risk. Clin Chim Acta. 2011; 412:1171–1179.
29. Klos A, Tenner AJ, Johswich KO, Ager RR, Reis ES, Köhl J. The Role of the Anaphylatoxins in Health and Disease. MolImmunol. 2009;46(14):2753–2766.
30. Wlazlo N, van Greevenbroek MM, Ferreira I, Jansen EJ, Feskens EJ, van der Kallen CJ, Schalkwijk CG, Bravenboer B, Stehouwer CD. Low-grade inflammation and insulin resistance independently explain substantial parts of the association between body fat and serum C3: The CODAM Study. 2012;61(12):1787–1796.
31. Mamane Y, Chung Chan C, Lavallee G, Morin N, Xu LJ, Huang J, Gordon R, Thomas W, Lamb J, Schadt EE, Kennedy BP, Mancini JA. The C3a anaphylatoxin receptor is a key mediator of insulin resistance and functions by modulating adipose tissue macrophage infiltration and activation. Diabetes. 2009;58:2006–2017.
32. Wärnberg J, Nova E, Moreno LA, Romeo J, Mesana MI, Ruiz JR, Ortega FB, Sjöström M, Bueno M, Marcos A. Inflammatory proteins are related to total and abdominal adiposity in a healthy adolescent population: The AVENA Study. Am J ClinNutr. 2006;84:505–512.
33. Trayhurn P, Wood IS. Adipokines: Inflammation and the pleiotropic role of white adipose tissue. Br J Nutr. 2004; 92:347–55.
34. Kasperska-Zajac A, Grzanka A, Machura E, Misiolek M, Mazur B, Jochem J. Increased serum complement C3 and C4 concentrations and their relation to severity of chronic spontaneous urticaria and CRP concentration. Journal of Inflammation 2013;10:22.
35. Kogut MH, Rothwell L, Kaiser P. Priming by recombinant chicken interleukin-2 induces selective expression of IL-8 and IL-18 mRNA in chicken heterophils during receptor-mediated phagocytosis of opsonized and nonopsonized *Salmonella enteric* serovarenteritidis. MolImmunol. 2003;40(9):603-10.

36. Hellmann J, Zhang MJ, Tang Y, Rane M, Bhatnagar A, Spite M. Increased saturated fatty acids in obesity alter resolution of inflammation in part by stimulating prostaglandin production. J Immunol. 2013;191(3):1383-92.
37. Futosi K, Fodor S, Mócsai A. Neutrophil cell surface receptors and their intracellular signal transduction pathways. Int. Immunopharmacol. 2013;17(3):638-50.
38. Concheiro J, Loureiro M, González-Vilas D, García-Gavín J, Sánchez-Aguilar D, Toribio J. Erysipelas and cellulitis: A retrospective study of 122 cases. Actas Dermosifiliogr. 2009;100(10):888-94.
39. Johnson DR, Kurlan R, Leckman J, Kaplan EL. The human immune response to streptococcal extracellular antigens: Clinical, diagnostic, and potential pathogenetic implications. Clinical Infectious Diseases. 2010;50(4):481-490.
40. Anaya DA, Dellinger EP. The obese surgical patient: A susceptible host for infection. Surg. Infect. (Larchmt). 2006;7: 473–480.
41. Narin R, Helbert M. Immunology for medical students, Second edition. Mosby. Elsevier, USA; 2007.
42. Kimura H, Konno S, Isada A, Maeda Y, Musashi M, Nishimura M. Allergy and Asthma Proceedings. 2015;36(4).
43. Al-Saadi MK, Muhsin MA, Ashwaq MS. Effect of measles infection on cellular immunity in tuberculosis patients. Journal of Clinical Immnunology and Immunopathology Research. 2011;3(2): 22-24.
44. Tsatsanis C, Margioris AN, Kontoyiannis DP. Association between H1N1 infection severity and obesity-adiponectin as a potential etiologic factor. J Infect Dis. 2010; 202(3):459-60.

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