How to Cite:
Shauri, A., Varghese, J., Zainab, U., Dawoud, O., Bagchi, S., & Diab, F. (2022). The association between obesity and the functions of the autonomic nervous system in young adults. *International Journal of Health Sciences*, *6*(S4), 11353–11376.
https://doi.org/10.53730/ijhs.v6nS4.11048

The association between obesity and the functions of the autonomic nervous system in young adults

Aashti Shauriq
Department of Biomedical Sciences, College of Medicine, Gulf Medical University, Ajman, UAE

Joel Varghese
Department of Biomedical Sciences, College of Medicine, Gulf Medical University, Ajman, UAE

Ummu Zainab
Department of Biomedical Sciences, College of Medicine, Gulf Medical University, Ajman, UAE

Omama Dawoud
Department of Biomedical Sciences, College of Medicine, Gulf Medical University, Ajman, UAE

Sovan Bagchi
Department of Biomedical Sciences, College of Medicine, Gulf Medical University, Ajman, UAE
Corresponding author email: dr.sovan@gmu.ac.ae

Faten Diab
Department of Biomedical Sciences, College of Medicine, Gulf Medical University, Ajman, UAE

***Abstract*---**Obesity is one of the most prevalent public health issues. Excess weight has been associated with autonomic dysfunction, but the evidence in young adults is scarce. Therefore, this study aims to assess the relationship between the body mass index (BMI) and the autonomic nervous system (ANS) function in young adults. Males are known to have higher sympathetic nervous system activity as compared to females, who are known to have a greater parasympathetic function. Hence, it is critical to assess the differences in ANS activity based on gender. This study was done on 120 university students aged 18 - 25 years, categorized based on BMI as normal (18kg/m2-24kg/m2) and obese (>25kg/m2). The ANS function

Manuscript submitted: 9 April 2022, Manuscript revised: 27 June 2022, Accepted for publication: 18 July 2022

was assessed by performing the Isometric Handgrip Test (IHGT), Deep Breathing Test (DBT), and Cold Pressor Test (CPT). Our study revealed that obese individuals exhibited an increase in the blood pressure and heart rate as compared to normal individuals, indicating that the former might be at greater risk for the development of ANS dysfunction. Our study also revealed that obese males exhibited a greater change in their blood pressure as compared to their obese counterparts.

***Keywords*---**autonomic nervous system, obesity, isometric handgrip test, deep breathing test, cold pressor test.

Introduction

Obesity has been called “New World syndrome” and is a reflection of the massive economic, social, and cultural problems currently being faced by developing and developed countries. It occurs when there is an imbalance between energy intake and energy expenditure resulting from a complex interaction of genetic, physiological, behavioral, and environmental factors (Grewal et al., 2011). More than 1 billion people worldwide are obese, amongst whom 340 million are adolescents and around 650 million are adults (WHO, 2022). This number is still increasing. WHO estimates that by 2025, approximately 167 million people, both adults, and children, will become less healthy because they are overweight or obese (WHO, 2022) As obesity arises from multifactorial interactions, it is considered a complex disease. Obesity is one of the most prevalent chronic diseases amongst young adults and is an important public health concern. Our body is maintained by a crucial system known as the autonomic nervous system. It tends to control all involuntary movements and actions that take place in our body. Examples of involuntary actions include respiration, heartbeat, blood pressure, and digestion (Waxenbaum et al. 2019). Many research studies (Grewal et al., 2011; Edwards et al., 2011) have been conducted to understand more about the autonomic nervous system and its functions. This system is further divided into the sympathetic nervous system and the parasympathetic nervous system. The sympathetic nervous system (SNS) prepares the body for intense physical activity and is often referred to as the fight-or-flight response, whereas the parasympathetic nervous system generally has the opposite effect and relaxes the body, which in turn inhibits or slows many high-energy functions. This is referred to as the rest-and-digest. The term used to define the condition that leads to the dysfunction of the autonomic nervous system is known as dysautonomia. Due to this, multiple involuntary responses will be affected, including heart rate, digestion, bladder function, sweating, and blood pressure. Dysautonomia has been featured in multiple inherited diseases, including Parkinson’s disease, multiple system atrophy, and autonomic neuropathy (Rastović et al., 2019). To diagnose dysautonomia, functional testing of the ANS is done with special focus on the organ systems affected. Tests such as the cold pressor test, deep breathing, isometric handgrip test, nerve biopsy, and many more are adopted in order to evaluate its functioning (NYU Langone, 2022). Dysautonomia may lead to the development or stabilization of obesity and is also related to cardiovascular mortality (Hofmann et al., 2000), so the study of ANS function in obesity is of significant clinical interest. These studies have generally revealed a reduced parasympathetic activity (Jain et al., 2016), since ANS is involved in energy metabolism and regulation of the cardiovascular system. Exercise and diet-based weight loss are the mainstay therapies for obesity, but there is a paucity of data regarding the effect of weight changes on autonomic nervous system (ANS) activity. Diet and exercise-based weight loss appear to increase parasympathetic activity and decrease sympathetic activity. The opposite effects are observed with weight gain (Costa et al., 2019). The autonomic nervous system (ANS) dysfunction has a bi-directional relationship with obesity. Alterations of the ANS might be involved in the development of obesity, which has effects on various pathways. However, excess weight is also known to induce ANS dysfunction, which may be involved in the hemodynamic and metabolic alterations that increase the cardiovascular risk in obese individuals (Guarino et al., 2017). It is also seen that the ANS plays a huge role in the systematic synchronization of food intake, which consists of signals involving satiety and energy expenditure. Thus, it can be inferred that ANS dysregulation might favor body weight gain. Contrarily, obesity might trigger sympathetic regulation of cardiovascular function, thus favoring the development of cardiovascular complications and events (Guarino et al., 2017). Sympathetic overactivity contributes to blood pressure (BP) elevation both directly and indirectly within the obese participants, including the stimulation of the renin-angiotensin-aldosterone system (RAAS), the adipocyte-derived peptide leptin suppresses appetite, and increases thermogenesis, but also raises SNS activity and BP (Guarino et al., 2017). Many studies (Grewal et al., 2011; Fidan-Yaylali, 2016) have been conducted in which there has been an association made between the dysfunction of the autonomic nervous system and an increase in the body mass index to unhealthy levels, leading to overweight and obesity. But these studies have not focused on the young adults that lie in the age group of 18–24 years. A BMI that falls between 18 kg/m2 and 24 kg/m2 is considered to be within the healthy range (Center for Disease Control and Prevention, 2019). However, a BMI that falls above 25 kg/m2 could have a negative impact on the functioning of the ANS (Grewal et al., 2011). Most research studies (Teixeira et al., 2020) came to the common conclusion that obesity plays an important role in disrupting the function of the ANS along with increasing the risk of developing neurodegenerative diseases with time. In healthy individuals, increasing BMI is correlated to increased sympathetic and lower parasympathetic activity. It has been reported in various studies (Molfino et al., 2009) that there is an increased sympathetic activity demonstrated in patients who are classified as obese based on their BMI, particularly in the muscle vasculature and in the kidneys, which could be contributing to the increased risk of cardiovascular diseases. This sympathetic activation can lead to selective leptin resistance (Mark et al., 2002), which results in a decrease in the ability of leptin to suppress appetite. This can also explain how hyperleptinemia could result in increased sympathetic activity in obese patients in which there is resistance to the metabolic actions of the hormone. Sympathetic activation can lead to obstructive sleep apnea syndrome in obese patients having an accumulation of fatty tissues, which leads to the narrowing of the upper respiratory muscles. This causes an obstruction in breathing and a significant increase in the intrathoracic pressure, which in turn triggers sleep apnea and hypoxia (McFarlane et al., 2017). A study has also shown (Tschop et al., 2001) how hyperinsulinemia causes a downregulation of the ghrelin hormone, leading to low ghrelin levels in obese patients. These can also be the possible mechanisms underlying sympathetic activation in these patients. Weight loss is able to reverse metabolic and autonomic alterations associated with obesity. Acknowledging the critical role of autonomic dysfunction in the pathophysiology of obesity and vice versa, the vagal nerves are the main nerves of the parasympathetic nervous system, which oversees specific body functions such as digestion, heart rate, and the immune system. Therefore, vagal nerve modulation and sympathetic inhibition may serve as therapeutic targets in this condition (Guarino et al., 2017). It is also observed that gender is thought to affect the functioning of the autonomic nervous system. An appreciation of gender differences in the structure and function of the autonomic nervous system (ANS) is crucial. It has been found that males have higher sympathetic nervous system activity with a loss of function in parasympathetic activity as they grow older. Females were found to have higher functioning in the parasympathetic nervous system. Gender differences in the autonomic nervous system may be present because of developmental differences or due to the effects of prevailing levels of male and/or female sex hormones. Hence, it is critical to acknowledge the gender differences in the structure and function of the ANS so as to attain an understanding of a number of common and important clinical presentations, such as males being at a higher risk of developing ventricular arrhythmias than females. Females are more prone to diseases, including coronary heart disease and Raynaud's syndrome (Dart et al., 2002). In this research, three different tests were used for the assessment of the autonomic nervous system: the hand grip test, the cold pressor test, and deep breathing. The first test was an isometric handgrip test. It is a non-invasive test that is done using a handgrip dynamometer. BP is taken before and after the HGT. This test is used to determine dysfunctions of autonomic nervous system activity which can be seen in people who have a BMI that is above 25kg/m2. Isometric handgrip exercise activates sympathetic nervous system activity and the cardiovascular system. When the muscle contracts, it evokes a significant increase in heart rate, mean arterial blood pressure, and muscle sympathetic nervous system activity with a minor increase in central hemodynamics. The baseline blood pressure (SBP and DBP) was compared with the post-experiment blood pressure (SBP and DBP). Moreover, HGT is influenced by many factors, for example, gender, age, physical activity, BMI, and smoking habits. Deep breathing evaluates the cardiac parasympathetic functions. Since the heart's responses to deep breathing are governed by the vagus nerve, the test is also known as cardiovagal testing. Deep breathing measures the changes in the heart rate and blood pressure that are provoked by "deep" breathing at 6 breaths per minute (Novak et al., 2011). The test begins with a rest period that gives the patient ample time to relax. The baseline BP and heart rate are measured before proceeding with the deep breathing test. The subject is instructed to inhale for 5 seconds and exhale for 5 seconds. This 10-second respiratory cycle is repeated six times. This test is based on the respiratory arrhythmia phenomenon, which relates to the increase in heart rate with inspiration and a decrease during expiration. Measuring this variability in heart rate is a reliable way to assess the parasympathetic innervation of the heart mediated by the vagus nerve (Phillips, 2015). The last test is the cold pressor test, which is used to evaluate cardiovascular reactivity to stress by measuring blood pressure response to an external cold stimulus. The CPT results in significant arteriolar vasoconstriction with a subsequent increase in BP. A previous study (Grewal et al., 2011) showed that there is a significant increase in

BP during CPT in obese participants as compared to normal participants. The major mechanism that mediates the cardiovascular response to CPT is the increase in sympathetic activity, which is stimulated by the skin's nerve fibers. Several studies (Silverthorn et al., 2013; Grewal et al., 2015)have shown that there are risk factors that might affect BP response to CPT, such as gender, age, and BMI. For example, BP response to the CPT is greater among people with hypertension and less physical activity. BP is measured before and after hand immersion in cold water for obese and normal participants. In this study, we aimed to investigate the role of obesity and the functions of the autonomic nervous system. We have also taken into consideration the factors of gender differences. A conclusion was deduced based on the results of the three tests that were conducted.

Subjects and Methods

Study population

A total of 120 students from Gulf Medical University aged 18–24 years were enrolled in this study. It was conducted in the Physiology Laboratory at Gulf Medical University.

Instrument used

Automatic Sphygmomanometer: Oscillatory devices generate a digital readout and function on the idea that blood flowing through an artery between systolic and diastolic pressures creates vibrations in the arterial wall that can be recognized and converted into electrical signals (Berger et al., 2001). Handgrip Dynamometer: A handgrip dynamometer is an effective tool for measuring hand grip strength as produced by the contraction of wrist and finger flexor muscles as well as muscles that flex the thumb (Skirven, 2021).

Consent

The Institutional Review Board (IRB) ethically approved the study. The subjects gave their written and informed consent. Only the students and supervisor conducting the study had access to the data collection.

Methods

The questionnaires were given to the subjects after they had given their written informed consent to ensure that they met the study's inclusion criteria. Isometric handgrip test (IHGT): The isometric handgrip test is a physiological test used to increase the arterial pressure. It provides pressor stimuli to the cardiovascular system via efferent sympathetic pathways, causing an increase in heart rate and blood pressure (Garg et al., 2013). This test measures the difference between the highest blood pressure during the experiment and the blood pressure at rest. Before the experiment, the subject was asked to rest for a duration of 10 minutes, during which the entire procedure was explained to them. The baseline readings were measured after the resting period. They were then asked to exert pressure on the handgrip. The subjects held a dynamometer in their dominant hand for 5–

10 seconds, and the blood pressure was simultaneously measured on the non-dominant arm. The blood pressure readings before and after the experiment were recorded and compared to the baseline measurements.

Deep breathing (DB): This test is based on the respiratory arrhythmia phenomenon, which relates to the increase in heart rate with inspiration and a decrease during expiration. Measuring this variability in heart rate is a reliable way to assess the parasympathetic innervation of the heart is mediated by the vagus nerve. Deep breathing measures the changes in the heart rate and blood pressure that are provoked by "deep" breathing at 6 breaths per minute (Novak et al., 2011). The subject was given ample time to relax before beginning with the test. The baseline BP and heart rate were measured before proceeding with the deep breathing test. The subject was instructed to inhale for 5 seconds and exhale for 5 seconds. This 10 second respiratory cycle is repeated 6 times. The subjects were asked to breathe continuously and regularly. Care was taken in order to avoid any sudden inhalations and exhalations and prevent hyperventilation, and was instructed to do deep breathing through nostrils with closed mouth. The readings were recorded right after performing the test and were compared to the baseline measurements.

Cold pressor test (CPT): CPT is a classic test used for research purposes to investigate the relationship between cognition, stress, and emotions. It is a non-invasive test that can be performed easily in a controlled setting (Deuter et al., 2012). The cold stimulus triggers the afferent sensory pathway that in turn activates a sympathetic response, which will cause an increase in blood pressure. This activation is the result of the cold water activating the afferent pain and temperature fibers from the skin, as well as the emotional arousal. The baseline BP and heart rate were measured before proceeding with the test. The participant was asked to immerse his/her dominant hand in cold water during the cold pressor test for a duration of one minute, and the blood pressure was measured simultaneously on the non-dominant hand ten seconds after the test began. The results were then recorded and compared to the baseline measurements.

Data analysis

All the data collected was stored in the excel sheet. The data was analyzed using the SPSS software and was presented as mean ± SD and mean rank. The statistical test that was used to analyze the data was the Mann-Whitney-U-test. Based on the three methodologies that were used to assess the ANS, this nonparametric test was employed to analyze the independent variables (IHGT, DB, and CPT). The correlation between the variables tested was determined using mean rank.

Results

A total of one hundred and twenty (120) students aged between 18 - 25 years, of Gulf Medical University participated in the research, amongst which sixty (60) had the BMI within the range of 18 - 24 kg/m2, hence were classified as normal and the rest sixty (60) subjects had the BMI ranging from 25kg/m2 and above and hence were categorized as overweight and obese. Participants that were classified as everyday smokers and someday/occasional smokers, pregnant and lactating women, alcoholics, subjects undergoing any sort of hormonal replacement therapy and any other severe underlying health condition were excluded from our study.

Sample population

A total of 120 participants were included in the study. 60 participants (50%) were classified as normal, out of which 29 (24.2%) were males and 31 (25.8%) were females.60 (50%) participants were classified as overweight and obese, out of which 29 (24.2%) were males and 31 (25.8%) were females.

Table 1.1: Participants by BMI and gender

BMI/GENDER	NORMAL	OW/OB	TOTAL
MALE	29 (24.2%)	29 (24.2%)	58 (48.3%)
FEMALE	31 (25.8%)	31 (25.8%)	62 (51.7%)
TOTAL	60 (50%)	60 (50%)	120

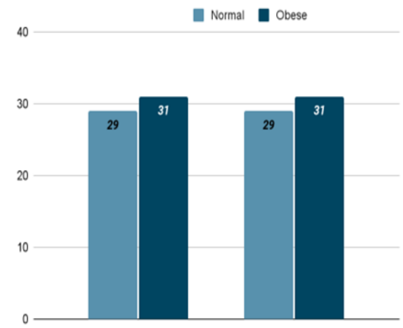

Fig 1.1: BMI Distribution

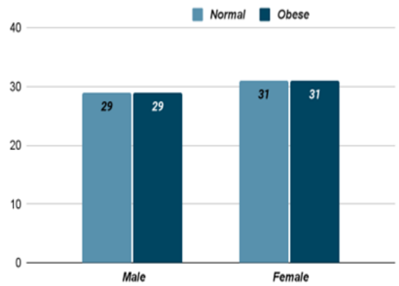

Fig 1.2: Gender Distribution

Results based on Body Mass Index (BMI)

Results for baseline BP and HR

Using the Mann-whitney test, the resting blood pressure and heart rate was compared between the two independent variables (normal and obese groups) and the mean rank was calculated. The *p* value for SBP and DBP is <0.001 which shows that it is statistically significant and hence it can be concluded that the resting systolic and diastolic blood pressure in the obese particpants is significantly higher in normal participants. The *p* value obtained for HR is 0.51, higher than p = <0.05, which shows that there is no statistical significance and, hence, it can be concluded that there is no significant difference in the resting HR between the obese and the normal participants.

Table 1.2: Results for baseline BP and HR based on BMI			
Baseline BMI	SBP Mean rank	DBP Mean rank	HR Mean rank
NORMAL	49.23	49.36	65.46
OBESE	71.78	71.64	55.54
p value	<0.001	<0.001	0.11

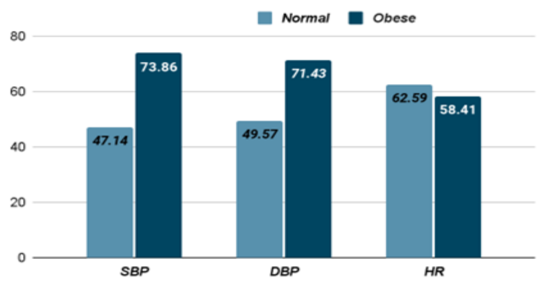

Fig 1.3: Results for baseline BP and HR based on BMI

Results for Isometric Handgrip Test BP

Using the Mann-Whitney test, the mean rank of the two independent variables (normal and obese groups) for post-handgrip systolic and diastolic blood pressure was compared and the mean rank was calculated. The p value obtained for SBP is <0.001 and DBP is 0.003, which is lesser than p= <0.05, hence shows that it is statistically significant and therefore it can be concluded that the post handgrip systolic and diastolic blood pressure are significantly higher in the obese participants than the normal participants.

Table 1.3: Results for IHGT BP based on BMI		
IHGT *BMI*	*SBP Mean rank*	*DBP Mean rank*
NORMAL	*49.08*	*51.03*

OBESE	*71.92*	*69.97*
p value	*<0.001*	*0.003*

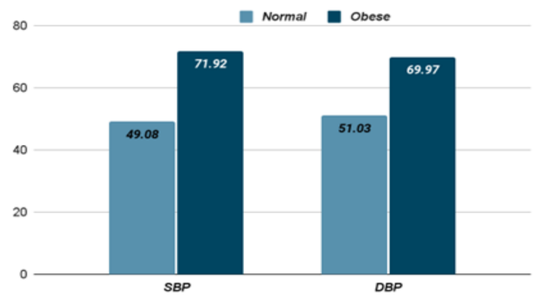

Fig. 1.4: Results for IHGT BP based on BMI

Results for Deep Breathing Test BP & HR

Using the Mann-whitney test, the resting blood pressure and heart rate was compared between the two independent variables (normal and obese groups) and the mean rank was calculated.The *p* value for SBP and DBP is <0.001 which shows that it is statistically significant and hence it can be concluded that the post-experiment systolic and diastolic blood pressure in the obese particpants is significantly higher in normal participants. The *p* value obtained for HR is 0.11, higher than *p* = <0.05, which shows that there is no statistical significance and, hence, it can be concluded that there is no significant difference in the post-experiment HR between the obese and the normal participants.

Table 1.4: *Results for DBT BP and HR based on BMI*

Deep Breathing BMI	SBP Mean rank	DBP Mean rank	HR Mean rank
NORMAL	49.23	49.36	65.46
OBESE	71.78	71.64	55.54
p value	<0.001	<0.001	0.11

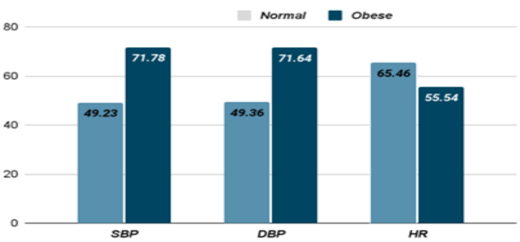

Fig. 1.5: Results for DBT BP and HR based on BMI

Results for Cold pressor Test BP & HR

Using the Mann-whitney test, the resting blood pressure and heart rate was compared between the two independent variables (normal and obese groups) and the mean rank was calculated. The *p* value for SBP is <0.001 and HR is 0.01 which shows that it is statistically significant and hence it can be concluded that the post-experiment SBP and HR are significantly higher in the obese participants than the normal participants. The *p* value obtained for DBP is 0.18, which shows that there is no statistical significance in the post-experiment DBP between the obese and the normal participants.

Table 1.5: *Results for CPT BP and HR based on BMI*

CPT BMI	SBP Mean rank	DBP Mean rank	HR Mean rank
NORMAL	48.59	56.31	68.32
OBESE	72.41	64.69	52.68
p value	<0.001	0.18	0.01

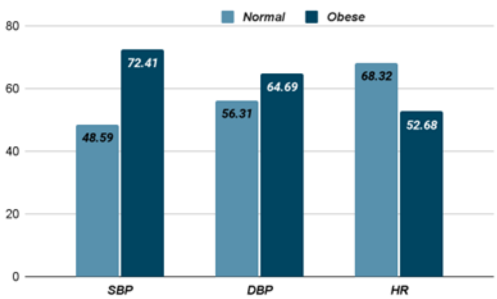

Fig 1.6: Results for CPT BP and HR based on BMI

Results based on Gender

Results for Baseline BP & HR in Normal Participants

Sixty participants that had the BMI range of 18-24 kg/m2 were categorized as normal. They were further analyzed based on their gender and their BP and HR was recorded while they were at rest. After which, using the Mann-Whitney test, the resting BP and HR were compared between the two independent variables (male and female groups) and the mean rank was calculated. The *p* value for SBP is 0.98, DBP is 0.49, and HR is 0.81, which is more than $p = <0.05$. Hence, there is no statistical significance in resting BP and HR amongst the normal participants based on gender.

Table 1.6: *Results for baseline BP and HR based on gender among normal participants*

Baseline Gender	SBP Mean rank	DBP Mean rank	HR Mean rank
N.MALE	30.45	28.90	31.05
N.FEMALE	30.55	32.00	29.98
p value	0.98	0.49	0.81

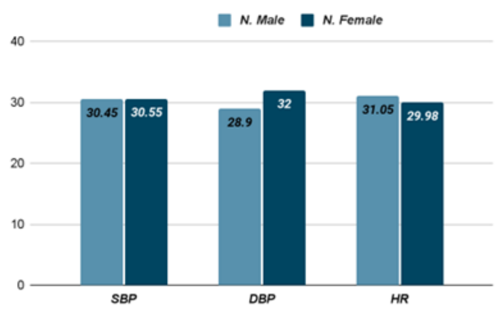

Fig 1.7: Results for baseline BP & HR based on gender among normal participants

Results for Baseline BP and HR in Obese participants

Sixty participants that had the BMI from 25kg/m2 and above were categorized as obese. They were further analyzed based on their gender and their BP and HR was recorded while they were at rest. After which, using the Mann-Whitney test, the resting BP and HR were compared between the two independent variables (male and female groups) and the mean rank was calculated. The *p* value for SBP is 0.03 and HR is 0.04, which is less than $p = <0.05$, indicating that these values are statistically significant. However, the *p* value for DBP is 0.07, which is more than *p* = <0.05, hence there is no statistical significance found.

Table 1.7: *Results for baseline BP and HR based on gender among obese participants*			
Baseline Gender	SBP Mean rank	DBP Mean rank	HR Mean rank
OB.MALE	35.43	34.69	25.91
OB.FEMALE	25.89	26.58	34.79
p value	0.03	0.07	0.04

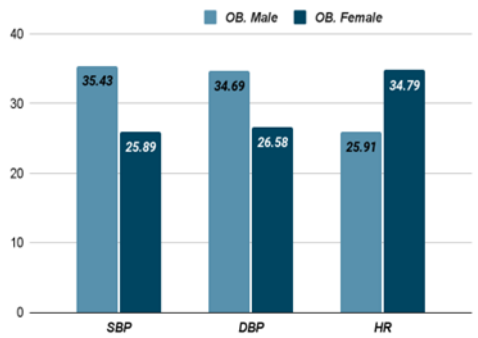

Fig 1.8: Results for baseline BP & HR based on gender among obese participants

Results for Isometric Handgrip Test BP in Normal Participants

Using the Mann-whitney test, the blood pressure taken after the handgrip experiment was compared between the two independent variables (normal male and female groups) and the mean rank was calculated. The *p* value for SBP is 0.72, DBP is 0.67, which is more than *p* = <0.05. Hence, there is no statistical significance in post-experiment BP amongst the normal participants based on gender.

Table 1.8: *Results for IHGT BP based on gender among normal participants*		
IHGT Gender	SBP Mean rank	DBP Mean rank
N.MALE	29.69	29.53

N.FEMALE	31.26	31.40
p value	0.72	0.67

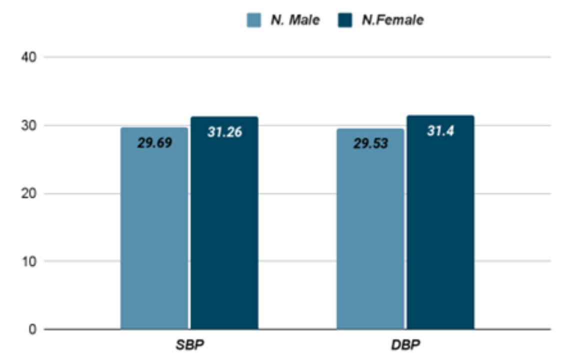

Fig 1.9 Results for IHGT BP based on gender among normal male and female participants

Results for Isometric Handgrip Test BP in Obese Participants

Using the Mann-whitney test, the blood pressure taken after the handgrip experiment was compared between the two independent variables (obese male and female groups) and the mean rank was calculated. The p value for SBP is 0.002, DBP is 0.02, which is less than $p = <0.05$. Hence, there is a statistical significance in post-experiment BP amongst the obese participants based on gender.

Table 1.9: *Results for IHGT BP based on gender among obese male and female participants*		
IHGT Gender	SBP Mean rank	DBP Mean rank
OB.MALE	37.83	35.76
OB.FEMALE	23.65	25.58
p value	0.002	0.02

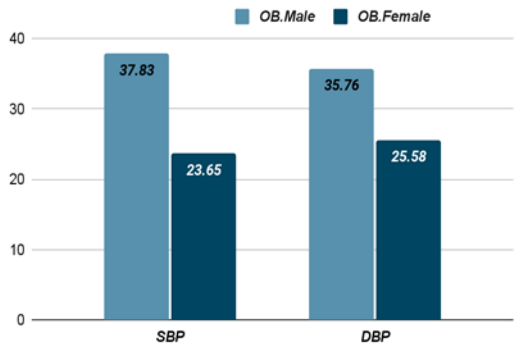

Fig 2.0: Results for IHGT BP based on gender among obese male and female participants

Results for Deep breathing Test BP & HR in Normal Participants

Using the Mann-Whitney test here, the BP and HR taken after deep breathing experiment was compared between the two independent variables (normal male and female groups) and the mean rank was calculated. The *p* value for SBP is 0.62, DBP is 0.87, and HR is 0.49 which is more than $p = <0.05$. Hence, there is no statistical significance in post-experiment BP and HR amongst the normal participants based on gender.

Table 2.0: *Results for DBT BP and HR based on gender among normal participants*

Deep Breathing Gender	SBP Mean rank	DBP Mean rank	HR Mean rank
N.MALE	29.36	30.12	32.09
N.FEMALE	31.56	30.85	29.02
p value	0.62	0.87	0.49

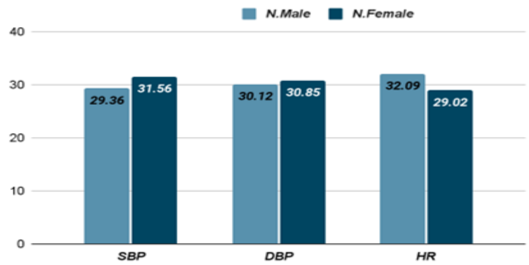

Fig 2.1: Results for DBT BP and HR based on gender among normal participants

Results for Deep breathing Test BP & HR in Obese Participants

Using the Mann-Whitney test, the BP and HR taken after deep breathing experiment was compared between the two independent variables (obese male and female groups) and the mean rank was calculated. The *p* value for SBP is 0.06, DBP is 0.03, and HR is 0.18, In which DBP is lesser than SBP and HR than *p* = <0.05. Hence, there is only a statistical significance in post-experiment DBP amongst the obese participants based on gender.

Table 2.1: *Results for DBT BP and HR based on gender among obese participants*

Deep Breathing Gender	SBP Mean rank	DBP Mean rank	HR Mean rank
OB.MALE	34.84	35.41	27.38
OB.FEMALE	26.44	25.90	33.42
p value	0.06	0.03	0.18

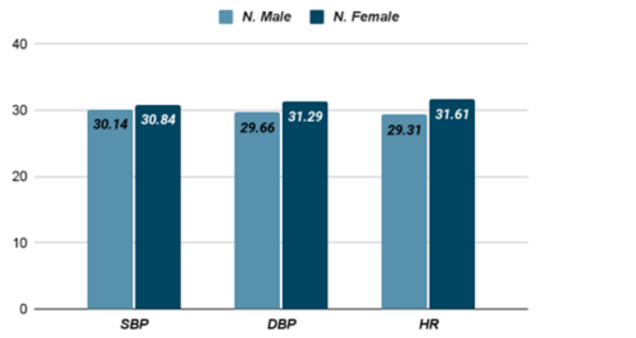

Fig 2.3: Results for CPT BP & HR based on gender among normal participants

Results for Cold Pressor Test BP & HR in Normal Participants

Using the Mann-Whitney test, the post-experiment BP and HR were compared between the two independent variables (normal male and normal female groups) and the mean rank was calculated. The *p* value for SBP is 0.87, DBP is 0.71, and HR is 0.61, which is more than *p* = <0.05. Hence, there is no statistical significance in post-experiment BP and HR amongst the normal participants based on gender.

Table 2.2: *Results for CPT BP and HR based on gender among normal participants*			
CPT Gender	SBP Mean rank	DBP Mean rank	HR Mean rank
N.MALE	30.14	29.66	29.31
N.FEMALE	30.84	31.29	31.61
p value	0.87	0.71	0.61

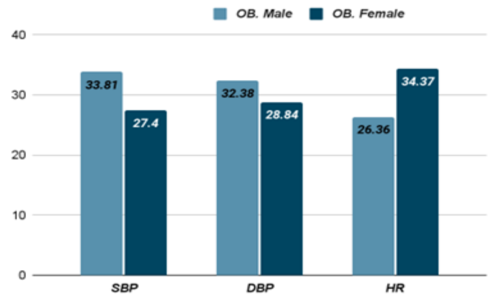

Fig 2.4: Results for CPT BP & HR based on gender among obese participants

Results for Cold Pressor Test BP & HR in Obese Participants

Using the Mann-Whitney test, the post-experiment BP and HR were compared between the two independent variables (obese male and obese female groups) and the mean rank was calculated. The p value for SBP is 0.15, DBP is 0.44, and HR is 0.07, which is more than $p = <0.05$. Hence, there is no statistical significance in post-experiment BP and HR amongst the obese participants based on gender.

Table 2.3: *Results for CPT BP and HR based on gender among obese participants*			
CPT Gender	SBP Mean rank	DBP Mean rank	HR Mean rank
OB.MALE	33.81	32.38	26.36
OB.FEMALE	27.40	28.84	34.37
p value	0.15	0.44	0.07

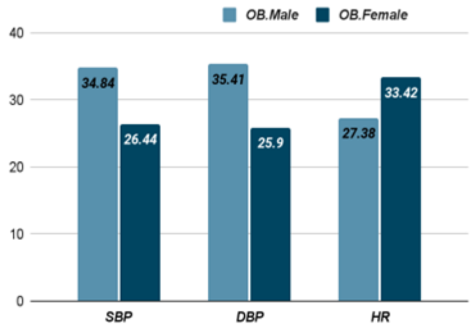

Fig 2.2: Results for DBT BP and HR based on gender among obese participants

Discussion

In the present study, the statistical analysis showed that the resting blood pressure was significantly higher in overweight or obese participants compared to normal participants (p= <0.001). Another study by Matteo Ottolini, MS et al. (Ottolini et al., 2020) suggested that a spatially restricted impairment of endothelial TRPV4 channels contributes to obesity-induced hypertension, which indicates that obesity causes impairment of Ca+ channel signaling pathways. Since intracellular calcium plays a crucial role in the regulation of cardiovascular functions, an increased influx of calcium into the vascular smooth muscle cells leads to an augmented muscular tone and, therefore, to increased vascular resistance and a rise in blood pressure (Simonetti et al., 2007). We also observed that although there was no statistical significance in resting blood pressure and heart rate amongst the normal participants based on gender, there was an increase in the resting systolic blood pressure and heart rate among the obese participants, in which the SBP was higher in the males compared to the females. However, the heart rate was significantly higher amongst the females. Similar results were shown in a study conducted by Prabhavathi et al. (Prabhavathi et al., 2014) in which the heart rate was significantly higher in females as compared to males. This difference is largely accounted for by the size of the heart, which is typically smaller in females than in males. The smaller female heart, pumping less blood with each beat, needs to beat at a faster rate to match the larger male heart's output. Furthermore, women have different intrinsic rhythmicity to the pacemaker of their hearts, which causes them to beat faster. In our study, we found no significant association in blood pressure (SBP and DBP) amongst the normal participants based on gender, but rather we found a significant association between obesity/overweight and blood pressure (SBP and DBP) changes in IHGT. Chao Ji et al.(Ji et al., 2018) conducted a cross-sectional study using a handgrip dynamometer on participants who were 18 years of age or older. They found that increased handgrip strength is associated with higher DBP in men and women. In men, especially overweight and obese men, strong handgrip strength may be associated with a higher risk of hypertension. This could be because obesity is associated with functional limitations in muscle performance and an increased likelihood of developing a functional disability such as mobility and strength. The consensus is that obese individuals have greater absolute maximum muscle strength compared to non-obese people, suggesting that increased adiposity acts as a chronic overload stimulus on the antigravity muscles (e.g., quadriceps and calf). An increase in muscle size and strength causes the blood pressure and heart rate to increase as well, in order to meet the greater demand for oxygen from the muscles (Tomlinson et al., 2015). We found no significant association in blood pressure (SBP and DBP) amongst the normal participants based on gender. We also noticed that obese males displayed a significantly higher BP response than obese females. Anjana and Reetu et al. (Anjana et al., 2014) conducted a study on the effect of gender differences in response to sustained isometric exercise using a handgrip dynamometer. They included 30 participants (16 males and 14 females) within the age group of 21–25 years. They found that males had a higher BP response than females, which proves that gender differences do exist in cardiovascular response to sustained isometric exercise. Thus, proving consistency with our results. The lower response in females could be due to less muscle mass and a lower target force with attenuated sympathetic neural outflow, which results in greater muscle perfusion, different substrate utilization, and lower metabolite production in females.

In our study, we found the post-experiment SBP to be significantly lower than the resting SBP amongst the normal participants. This is because deep breathing stimulates the stretch receptors in the walls of large blood vessels within the thoracic cavity. This activates nerve reflexes that lower the blood pressure (Herakova et al., 2017). However, we observed that the heart rate significantly increased post-experiment. This could be due to compensation being carried out for the decreased left ventricular output while breathing in. During inspiration, more blood gets pooled in the lungs so that the left ventricle gets less blood to pump out. By increasing the heart rate with a reflex mechanism, the body maintains the cardiac output (Mehlsen et al., 1987). Amongst the obese participants, there was no statistical significance between the resting and post-experiment blood pressure (systolic blood pressure and diastolic blood pressure).
When comparing the blood pressure (systolic blood pressure & diastolic blood pressure) between the two groups, it was found to be significantly higher in the overweight/obese participants as compared to the normal participants. Similarly, Hisao Mori and Hareaki Yamamoto et al.(Mori et al., 2005) conducted a study on the Japanese population in which they divided the subjects into two groups, where in one group the BP was measured before and after taking DBs over a period of 30 seconds and in the other group the BP was measured before and after a 30 second rest in a sitting position without DB. This study concluded that deep breathing lowers blood pressure. These results could be because the intra-abdominal and pleural pressures are increased slightly in obesity because the downward movement of the diaphragm and the outward movement of the chest wall are restricted when fat accumulates within the thoracic and abdominal cavities (Dixon et al., 2018). However, there was no significant association in the heart rate based on BMI and gender. Although in overweight/obese participants, we found the DBP is significantly higher in males compared to females. There was no statistical significance in systolic blood pressure and heart rate. A similar study reported by Hussein and Sameeha et al.(Alhawari et al., 2018) showed a significant gender difference in both systolic blood pressure with a mean

difference = 18.08 mmHg and diastolic blood pressure with a mean difference = 3.6 mmHg, higher in males than in females. This could be because in adolescence and puberty, when androgen and testosterone levels are increasing, they may play an important role in higher blood pressure in males as compared to females.
In this study, we found statistical significance in the blood pressure (systolic blood pressure & diastolic blood pressure) and heart rate amongst the normal and obese participants while performing the cold pressor test. Sara Sarris, Mona Youssef et al.(Sarris et al., 2021) conducted a similar study in which they recruited male and female university students aged 17–25 and performed the cold pressor test. Their results showed that in the case of both males and females, the mean basal pulse rate following CPT was statistically increased. We also observed that stress caused by CPT elevated the HR and blood pressure (SBP and DBP) because of the increase in vascular resistance and increase in muscular sympathetic activity, which is mediated by autonomic neural pathways. Moreover, the temperature is known to influence heart rate and blood pressure in individuals. Another reason may be that immersion in cold water will cause a pain sensation and activation of sympathetic noradrenergic fibers that leads to vasoconstriction and an elevation in the heart rate. Furthermore, we found that the systolic blood pressure was significantly higher in the overweight/obese participants as compared to the normal participants, but there was no significant difference found in the diastolic blood pressure based on BMI. A similar study was carried out by Simran Grewal, Vidushi Gupta et al. (Grewal et al., 2011) on 100 volunteers, of which 50 subjects with BMI > 30kg/m2 (taken from local obesity centers) were included in the study group and 50 subjects with BMI 30kg/m2 (nonobese) were included in the control group. The subjects in this study immersed their hands in cold water at a constant temperature. The mean change in systolic blood pressure before and after CPT was statistically significant in the study group as compared to the control group, which correlates with our results. The results of the cold pressor test in the obese participants could possibly be because of a hypofunctional sympathetic nervous system. As stated before, cold water immersion will cause a pain sensation and activation of sympathetic noradrenergic fibers that leads to vasoconstriction, thus elevating the blood pressure. It was also found that the heart rate was significantly higher in the normal compared to overweight/obese participants. This could be due to the increased insulation function served by the adipose tissue in obese compared to normal participants, which leads to a delayed response to the pain stimulus. However, we found no statistical significance in blood pressure (SBP & DBP) and heart rate amongst the normal and overweight/obese participants based on gender.

Conclusion

In conclusion, obese individuals are at greater risk of the development of a wide spectrum of neurological and metabolic disorders due to dysfunction of the autonomic nervous system. Results of our study also concluded that obese males exhibited a greater change in their blood pressure as compared to obese females in response to various strenuous activities that stimulate the autonomic nervous system.

Additional research is needed to identify the specific autonomic nervous system pathways that are affected as a result of obesity. Also, there is a need for the development of specific treatment targets and combinations of approaches aimed towards individuals who are obese in order to obtain a sustainable health outcome. The most economical and highly accessible course of action could be a lifestyle intervention consisting of dietary changes and 45 to 60 min of moderate intensity exercise.

Acknowledgement

We are very grateful to Gulf Medical University and the Center for Advanced Simulation and Healthcare (CASH) department for providing a controlled environment and the necessary resources to conduct this research study.

List of Tables and Figures

References

1. Alhawari, H. H., Al-Shelleh, S., Alhawari, H. H., Al-Saudi, A., Aljbour Al-Majali, D., Al-Faris, L., & AlRyalat, S. A. (2018). Blood Pressure and Its Association with Gender, Body Mass Index, Smoking, and Family History among University Students. *International Journal of Hypertension*, *2018*(29 May 2018), 1–5. https://doi.org/10.1155/2018/4186496
2. Anjana, Y., & Reetu, K. (2014). EFFECT OF GENDER DIFFERENCE IN RESPONSE TO SUSTAINED ISOMETRIC EXERCISE USING HANDGRIP DYNAMOMETER. *Journal of Evolution of Medical and Dental Sciences*, *3*(22), 6043–6047. https://doi.org/10.14260/jemds/2014/2702
3. Berger, A. (2001). Oscillatory Blood Pressure Monitoring Devices. *BMJ : British Medical Journal*, *323*(7318), 919. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1121444/
4. Centers for Disease Control and Prevention. (2019). Adult BMI calculator. Retrieved from Centers for Disease Control and Prevention website: https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/english_bmi_calculator/bmi_calculator.html
5. Costa, J., Moreira, A., Moreira, P., Delgado, L., & Silva, D. (2019). Effects of weight changes in the autonomic nervous system: A systematic review and meta-analysis. *Clinical Nutrition*, *38*(1), 110–126. https://doi.org/10.1016/j.clnu.2018.01.006
6. Dart, A. (2002). Gender, sex hormones and autonomic nervous control of the cardiovascular system. *Cardiovascular Research*, *53*(3), 678–687. https://doi.org/10.1016/s0008-6363(01)00508-9
7. Deuter, C. E., Kuehl, L. K., Blumenthal, T. D., Schulz, A., Oitzl, M. S., & Schachinger, H. (2012). Effects of Cold Pressor Stress on the Human Startle Response. *PLoS ONE*, *7*(11), e49866. https://doi.org/10.1371/journal.pone.0049866
8. Dixon, A. E., & Peters, U. (2018). The effect of obesity on lung function. *Expert Review of Respiratory Medicine*, *12*(9), 755–767. https://doi.org/10.1080/17476348.2018.1506331
9. E.L. Phillips. (2009). Respiratory Sinus Arrhythmia - an overview | ScienceDirect Topics. Retrieved May 24, 2022, from www.sciencedirect.com website: https://www.sciencedirect.com/topics/psychology/respiratory-sinus-arrhythmia
10. Edwards, K. M., Wilson, K. L., Sadja, J., Ziegler, M. G., & Mills, P. J. (2011). Effects on blood pressure and autonomic nervous system function of a 12-week exercise or exercise plus DASH-diet intervention in individuals with elevated blood pressure. *Acta Physiologica*, *203*(3), 343–350. https://doi.org/10.1111/j.1748-1716.2011.02329.x
11. Fidan-Yaylali, G., Yaylali, Y. T., Erdogan, Ç., Can, B., Senol, H., Gedik-Topçu, B., & Topsakal, S. (2016). The Association between Central Adiposity and Autonomic Dysfunction in Obesity. *Medical Principles and Practice*, *25*(5), 442–448. https://doi.org/10.1159/000446915
12. Garg, R. (2013). The Isometric Handgrip Exercise As a Test for Unmasking Hypertension in the Offsprings of Hypertensive Parents. *JOURNAL of CLINICAL and DIAGNOSTIC RESEARCH*, *7(6)*(2013 Jun). https://doi.org/10.7860/jcdr/2013/5094.3043
13. Gonçalves Teixeira, B., Cavaleiro Rufo, J., Mendes, F., Farraia, M., Moreira,

P., & Moreira, A. (2020). Association between obesity and autonomic nervous system activity in children. *Journal of Health & Medical Informatics Extended Abstract 32nd European Pediatrics Congress*, *11*(2021-02-23). Retrieved from https://www.hilarispublisher.com/open-access/association-between-obesity-and-autonomic-nervous-system-activity-in-children.pdf

14. Grewal, S., Sekhon, T., Walia, L., & Gambhir, R. (2015). Cardiovascular response to acute cold stress in non-obese and obese healthy adults. *Ethiopian Journal of Health Sciences*, *25*(1), 47. https://doi.org/10.4314/ejhs.v25i1.7
15. Guarino, D., Nannipieri, M., Iervasi, G., Taddei, S., & Bruno, R. M. (2017). The Role of the Autonomic Nervous System in the Pathophysiology of Obesity. *Frontiers in Physiology*, *8*(2017 Sep 14). https://doi.org/10.3389/fphys.2017.00665
16. Herakova, N., Nwobodo, N. H. N., Wang, Y., Chen, F., & Zheng, D. (2017). Effect of respiratory pattern on automated clinical blood pressure measurement: an observational study with normotensive subjects. *Clinical Hypertension*, *23*(1). https://doi.org/10.1186/s40885-017-0071-3
17. Herliah, A., Baso, Y. S., Hidayanty, H., Syarif, S., Aminuddin, A., & Bahar, B. (2022). Effect of web-based she smart education models on adolescent girl's knowledge, attitudes, and practice about obesity. *International Journal of Health & Medical Sciences*, *5*(1), 50-55. https://doi.org/10.21744/ijhms.v5n1.1832
18. Jain, A. (2016). Autonomic Reactivity Differs in Young Adults Classified using Revised Indian and WHO Guidelines for Obesity. *JOURNAL of CLINICAL and DIAGNOSTIC RESEARCH*, *10(9)*(2016 Sep). https://doi.org/10.7860/jcdr/2016/20611.8420
19. Ji, C., Zheng, L., Zhang, R., Wu, Q., & Zhao, Y. (2018). Handgrip strength is positively related to blood pressure and hypertension risk: results from the National Health and nutrition examination survey. *Lipids in Health and Disease*, *17*(1). https://doi.org/10.1186/s12944-018-0734-4
20. Laederach-Hofmann, K., Mussgay, L., & Ruddel, H. (2000). Autonomic cardiovascular regulation in obesity. *Journal of Endocrinology*, *164*(1), 59–66. https://doi.org/10.1677/joe.0.1640059
21. Mark, A. L., Correia, M. L. G., Rahmouni, K., & Haynes, W. G. (2002). Selective leptin resistance: a new concept in leptin physiology with cardiovascular implications. *Journal of Hypertension*, *20*(7), 1245–1250. https://doi.org/10.1097/00004872-200207000-00001
22. McFarlane, S. I. (2017). Obstructive sleep apnea and obesity: implications for public health. *Sleep Medicine and Disorders: International Journal*, *1*(4). https://doi.org/10.15406/smdij.2017.01.00019
23. Mehlsen, J., Pagh, K., Nielsen, J. S., Sestoft, L., & Nielsen, S. L. (1987). Heart rate response to breathing: dependency upon breathing pattern. *Clinical Physiology*, *7*(2), 115–124. https://doi.org/10.1111/j.1475-097x.1987.tb00153.x
24. Molfino, A., Fiorentini, A., Tubani, L., Martuscelli, M., Fanelli, F. R., & Laviano, A. (2009). Body mass index is related to autonomic nervous system activity as measured by heart rate variability. *European Journal of Clinical Nutrition*, *63*(10), 1263–1265. https://doi.org/10.1038/ejcn.2009.35
25. MORI, H., YAMAMOTO, H., KUWASHIMA, M., SAITO, S., UKAI, H., HIRAO, K., … UMEMURA, S. (2005). How Does Deep Breathing Affect Office Blood

Pressure and Pulse Rate? *Hypertension Research*, *28*(6), 499–504. https://doi.org/10.1291/hypres.28.499

26. Novak, P. (2011). Quantitative Autonomic Testing. *Journal of Visualized Experiments*, *(53); 2011*(53). https://doi.org/10.3791/2502
27. NYU Langone. (2022). Diagnosing Autonomic Disorders. Retrieved from nyulangone.org website: https://nyulangone.org/conditions/autonomic-disorders/diagnosis
28. Ottolini, M., Hong, K., Cope, E. L., Daneva, Z., DeLalio, L. J., Sokolowski, J. D., … Sonkusare, S. K. (2020). Local Peroxynitrite Impairs Endothelial TRPV4 Channels and Elevates Blood Pressure in Obesity. *Circulation*, *141(16)*(2020 Apr 21). https://doi.org/10.1161/circulationaha.119.043385
29. Prabhavathi, K. (2014). Role of Biological Sex in Normal Cardiac Function and in Its Disease Outcome – a Review. *Journal of Clinical and Diagnostic Research*, *8*(8). https://doi.org/10.7860/jcdr/2014/9635.4771
30. Rastović, M. (2019). AGING, HEART RATE VARIABILITY AND METABOLIC IMPACT OF OBESITY. *Acta Clinica Croatica*, *58(3)*(2019 Sep). https://doi.org/10.20471/acc.2019.58.03.05
31. Ratnawati, I. G. A. A., Suandayani, N. K. T., & Sutapa, G. N. (2019). The linearity of x-ray devices radiation output and its relationship with patient thickness. *International Journal of Physical Sciences and Engineering*, *3*(3), 1–6. https://doi.org/10.29332/ijpse.v3n3.351
32. Sara Sarris, Mona Youssef, Aya Alsheikh, Abdullah Fathi, & Sovan Bagchi. (2021, July). Assessment of autonomic nervous system function in university students using autonomic reflex tests. Retrieved June 28, 2022. *International Medical Journal* https://www.seronijihou.com/article/assessment-of-autonomic-nervous-system-function-in-university-students-using-autonomic-reflex-tests
33. Silverthorn, D. U., & Michael, J. (2013). Cold stress and the cold pressor test. *Advances in Physiology Education*, *37*(1), 93–96. https://doi.org/10.1152/advan.00002.2013
34. Simonetti, & Mohaupt. (2007). Kalzium und Blutdruck. *Therapeutische Umschau*, *64*(5), 249–252. https://doi.org/10.1024/0040-5930.64.5.249
35. Simran Grewal, V. G. (2011, April 30). Effect of obesity on autonomic nervous system. Retrieved from Int J Cur BioMed Sci. website: https://web-archive.southampton.ac.uk/cogprints.org/7314/
36. Suryasa, I. W., Rodríguez-Gámez, M., & Koldoris, T. (2021). Health and treatment of diabetes mellitus. *International Journal of Health Sciences*, *5*(1), i-v. https://doi.org/10.53730/ijhs.v5n1.2864
37. Terri M. Skirven. (2021). Dynamometer - an overview | ScienceDirect Topics. Retrieved April 10, 2022, from www.sciencedirect.com website: https://www.sciencedirect.com/topics/nursing-and-health-professions/dynamometer
38. Tomlinson, D. J., Erskine, R. M., Morse, C. I., Winwood, K., & Onambélé-Pearson, G. (2015). The impact of obesity on skeletal muscle strength and structure through adolescence to old age. *Biogerontology*, *17*(3), 467–483. https://doi.org/10.1007/s10522-015-9626-4\
39. Tschop, M., Weyer, C., Tataranni, P. A., Devanarayan, V., Ravussin, E., & Heiman, M. L. (2001). Circulating Ghrelin Levels Are Decreased in Human Obesity. *Diabetes*, *50*(4), 707–709. https://doi.org/10.2337/diabetes.50.4.707

40. Waxenbaum, J. A., Varacallo, M., & Reddy, V. (2019, March 9). Anatomy, Autonomic Nervous System. Retrieved from Nih.gov website: https://www.ncbi.nlm.nih.gov/books/NBK539845/
41. WHO. (2022, March 4). World Obesity Day 2022 – Accelerating action to stop obesity. Retrieved from www.who.int website: https://www.who.int/news/item/04-03-2022-world-obesity-day-2022-accelerating-action-to-stop-obesity