International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 3 Issue 6, October 2019 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Influence of Basal Metabolic Rate and Obesity on Lung Function Test

Okonkwo, C. O. J; Maduka, S. O; Ameh Priscilla Nkiruka; Mmaju Chidimma Ifenyinwa

Department of Human Physiology, Faculty of Basic Medical Sciences, College of Medicine, Nnamdi, Azikiwe University, Nnewi Campus, Okofia Anambra, Nigeria

ABSTRACT

Basal Metabolic Rate (BMR)is the rate of energy utilization in the body during absolute rest when the Person is awake. This study is aimed to ascertain the effect of BMR and obesity on lung function test among male and female medical students of 20-26 years of age. in Nnamdi Azikiwe University College of Health Science Nnewi. On average, 90(50 male, 40 female) medical students took part in this study and their lung function was measured using a Spirometer. Whereas students BMR was calculated using two different predicted Basal metabolic rate equation Harris –Benedict equation (Harris and Benedict equation: BMR (kcal/day) for men P = (13.7516 wt/1 kg + 5.0033 ht/1 cm − 6.7550 age/1 year + 66.4730) and for women P = (9.5634 wt/1 kg + 1.8496 ht/1 cm − 4.6756 age/1 year + 655.0955) and also . Henry and Rees equation (Henry and Rees, 1991): BMR (kcal/day) for men (18–30 years old) = (0.0560 wt + 2.800) × 238.85, and for women (18–38 years old) = (0.0480wt + 2.562) × 238.85. Where p = Total heat production at complete restWt= weight in KgHt=height in cm. The values are constants) Roza AM, Shizgal HM (1984). BMR is the amount of energy per unit time that a person needs to keep the body functioning at rest. Some of those processes are breathing, blood circulation, controlling body temperature, cell growth, brain and nerve function, and muscle contraindications. Lung functions was measured using the spirometer and the height and weight was measured using the standiometer and weighing balance respectively.

From the result obtained when comparing among male and female subjects there is no significant value in male BMR, when comparing between obese and non-obese between male and female subjects weight, height and BMI has significant value. In conclusion this study showed that the relation between predicted basal metabolic rate and indicators of lung function tests was statistically insignificant

***How to cite this paper**:* Okonkwo, C. O. J | Maduka, S. O | Ameh Priscilla Nkiruka | Mmaju Chidimma Ifenyinwa "Influence of Basal Metabolic Rate and Obesity on Lung Function Test" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-3 | Issue-6, October 2019, pp.1353-1363, URL: www.ijtsrd.com/papers/ijtsrd29523.pdf

IJTSRD29523

1.1. BACKGROUND

Basal metabolic rate is the amount of energy per unit time that a person needs to keep the body functioning at rest. Some of those processes are breathing, blood circulation, controlling body temperature, cell growth, brain and nerve function, and muscle contraindications (*McNab, 1997*). Basal metabolic rate (BMR) affects the rate that a person burns calories and ultimately whether that individual maintains, gains, or loses weight. The basal metabolic rate accounts for about 60 to 75% of the daily calorie expenditure by individuals. It is influenced by several factors. BMR typically declines by 1–2% per decade after age 20, mostly due to loss of fat-free mass, (*Manini, 2010).*although the variability between individuals is high (McMurray*et al., 2014).* It is reported in energy units per unit time ranging from watt (joule/second) to ml O_2/min or joule per hour per kg body mass J/(h·kg). Proper measurement requires a strict set of criteria be met. These criteria include being in a physically and psychologically undisturbed state, in a thermally neutral environment, while in the post-absorptive state (i.e., not actively digesting food) (*McNab BK 1997).*

BMR is measured under very restrictive circumstances when a person is awake. An accurate BMR measurement requires that the person's sympathetic nervous system not be stimulated, a condition which requires complete rest (*Stiegler and Cunliffe, 2006).*

BMR may be measured by gas analysis through either direct or indirect calorimetry, though a rough estimation can be acquired through an equation using age, sex, height, and weight. Studies of energy using both methods provide convincing evidence for the validity of the respiratory quotient (RQ), which measures the inherent composition and utilization of carbohydrates, fats and proteins as they are converted to energy substrate units that can be used by the body as energy.

Metabolism comprises the processes that the body needs to function (*Ballesteros et al., 2018).*

Lung function tests

Lung function tests (LFTs) are widely used to measure the performance of lungs during physiological and pathological conditions. LFTs determine lungs capability of holding air, amount of air moving in and out and how well lungs take in oxygen and remove carbon dioxide from blood. These tests also measure pathology in lungs if any present and hence used as diagnostic tests for lung diseases. There are a number of diagnostic tests such as Residual volume, Inhalation challenge tests, Body plethysmography, Gas diffusion tests, and exercise stress tests, which help in defining status of lung functions. But spirometry being the most commonly performed lung function test, is considered as first choice in diagnosis of lung pathology. Spirometry is a technique used to measure amount and flow of air inhaled and exhaled and the lung function. It measures amount of air that can be moved in and out of one's lungs (*McNab BK 1997).*

Most measured entity of lung function is Vital Capacity; Change in volume of lung after taking maximal inhalation followed by maximal exhalation is called Vital Capacity of lungs. It is the sum of tidal volume, inspiratory reserve volume and expiratory reserve volume. Vital capacity of normal adults ranges between 3 to 5 litres. A number of physiological factors like age, gender, height and ethnicity show variations in pulmonary functions.

1.2. STATEMENT OF PROBLEM

Obesity is a leading cause of mortality. Its prevalence has been on the increase worldwide. Because of the direct influence on metabolic rate, measurement of how obese subjects expend energy is important for estimation of their energy need and weight control interventions.

1.3. AIM OF STUDY

The aim of this study is to investigate the effect of obesity on lung function test and also to investigate the effect of BMR on lung function test.

1.4. OBJECTIVES OF STUDY

The objectives of this study include:

- To determine the FEV1, FVC, VC and TV of obese and non-obese subjects.
- To estimate BMR between obese and non-obese female subjects.
- To estimate BMR between obese and non-obese male subjects.

1.5. SIGNIFICANCE OF STUDY

There will better understanding of physiology lung function test on obese patients and the possibility of using BMR to maintain body weight.

2.1. OVERVIEW OF BASAL METABOLIC RATE

Basal metabolic rate (BMR) or basal energy expenditure (BEE) represents the amount of energy utilized by a body in physical and psychological resting state, after a night sleep, awake, without any previous physical activity, in postabsorbative state (more than 10 hours after last meal) and neutral environment. Resting energy expenditure (REE) is defined as basal metabolic rate, in which one of the conditions excepting the resting state is not fulfilled: less than 10 hours after meal intake, after a low intensity physical activity; other small modification from basal conditions. It is very similar with resting metabolic rate (RMR) which necessitate only 2–4 hours of fasting and is 10% higher than BMR. BMR it is not the lowest level of energy required for maintaining life. Lower levels of energy could be found during sleep, coma, hypothermia, under nutrition. Total energy expenditure includes BMR (which represent 35–70% of total energy expenditure), dietaryinduced thermogenesis (which represent about 10% of BMR) and energy used in volitional or non-volitional physical activity. Regularly the BMR is measured by indirect calorimetry, but can be also computed using some predictive equations. Predictive equations are a necessity in clinical practice secondary to difficulties and resources in calorimetry devices. For their computation, different variables as individual organ BMR, free fat mass (FFM) BMR, fat body mass, body surface, age, gender, height, weight, various biomarkers are used Predictive equations diversity is the result of the attempt of obtaining accurate data in different physiological and pathological conditions (Elia, M.1992).

The internal organs (liver, heart, brain, kidney), which have 7% on body weight, are responsible for 60% of BMR in comparison with muscle mass, which has 40% of body weight and is responsible for 18% of BMR (Lazzer, et al., 2010).Energy processes involved are mitochondrial proton leak (Jastroch, M.2010 et al) protein synthesis and degradation, ion pumps as Na K ATPase, biochemical reaction. BMR is increased in young age, males with increasing of body weight and free fat mass (Johnstone, et al., 2005). BMR is modified by genetic factors, ethnicity, normal physiological state or co morbidities, nutritional factor, sympathetic activity and stress (Gora et al., 1994). BMR increases with the development of body mass from early childhood to maturity, remains almost stable between 20 an 40 years of age and than decreases with age. BMR decreases with 23% per decade after 50 years of age. (Roberts, S. D., D.E., 2001). The mechanisms incriminated for decreasing of BMR with age were reduction in mass and function of internal organs and muscle mass (Roubenoff et al., 2000). Decreasing of organ mass is between 10–20% at 80 years in comparison with 20 years, excepting for heart. Heart mass increases with age in a similar proportion (He and Heshka,2009).Because BMR is mainly composed by internal organ metabolic rate, an organ reduced activity as in brain neural degenerative disorders, significantly decreases the BMR (Poehlman et al., 1997).Reduction of muscle skeletal mass is also an aging feature.

BMR remained different for older people in comparison with young people (Kremset al., 2005). Renal failure and malnutrition are associated with decrease BMR. Chronic brohopneumopathy, diabetes and lung cancer are associated with increased BMR. In humans, BMR declines with age, especially after 30 years, with ~0,69Mj/day/decade for man and with 0.43 Mj/day/decade for woman26. The decline in BMR with age has been related to the progressive lost of the fat free mass (sarcopenia), heat producing tissues and the decrease in fitness level (Kenney and Buskirk, 1997). The BMR increase with higher level of plasma norephrinefrine concentration found in highly fit, physically active adult subjects but not in sedentary elderly persons (Poehlman, E. T.; Horton, E. S1990). The relation of BMR with gender even after free fat mass correction is not very well sustained by latest data. The difference between male and female using Harris Benedict initial calculation was 8%

(Frankenfield, Muth and Rowe, 1998). Though some authors considered that the regression equation could be similar regardless of gender when free-fat mass is used as variable. (Frankenfield et al., 1998; Klausenet al., 1997). For other authors, gender is important in predicting BMR in children and teenagers but not in adults (Lazzer, 2010). No influence on BMR from fat distribution and consequently abdominal/hip circumference ratio was found (Owen et al., 1986). The most significant hormonal influence is supported by thyroid hormones which increase oxygen consume, heat production and BMR of all internal organs excepting the brain. BMR depends of body structure, metabolic alteration and psychological disturbances. The basal metabolic rate (BMR) is the main component of daily energy expenditure, accounting for 60–70 % of total energy expenditure in most individuals. Its measurement is essential in nutritional assessment and weight management programs.

2.2. A BRIEF HISTORY OF BASAL METABOLIC RATE

A Brief History of Basal Metabolic Rate: From Where Did BMR Come? The first recognition by a human that breathing was necessary for life certainly precedes recorded history. The scientific study Physiological and Biochemical Zoology of animal respiration blossomed with the emergence of physiology in the eighteenth century and coincided with the investigation of chemical combustion. In 1766, Karl Scheele discovered oxygen gas and named it fire air; 2 years later, Joseph Priestley independently isolated the same gas, calling it dephlogisticated air. Antoine Lavoisier, regarded as the founder of modern chemistry, was born 10 years after the birth of Priestley and was guillotined 10 years before Priestley's death. Lavoisier disproved the phlogiston theory and showed that air was a mixture of nitrogen and the gas he named oxygen in 1777. Lavoisier should be regarded as the father of the basal metabolic rate (BMR). With his wife as a major collaborator, Lavoisier showed that animal respiration is the combination of oxygen from air with carbon and hydrogen from the animal's body (which he recognized came from the food) to produce water, fixed air (carbon dioxide), and heat. He showed that the rate of oxygen consumption was influenced by the consumption of food, environmental temperature, and the performance of muscular work. Lavoisier measured the minimal metabolic rate in a resting postabsorptive state, which was probably the first measurement of BMR (Blaxter 1989; Lutz 2002). In the twentieth century, the measurement of metabolic rate became an important part of the examination of bioenergetics and growth. The rate of metabolism of animals can be assessed by measuring a number of variables, including consumption of oxygen, production of carbon dioxide, and heat produced, as well as the difference between food consumed and wastes excreted. Because metabolic rate varies in response to a wide range of factors, to facilitate scientific comparisons, it became necessary to define a set of conditions for its measurement. This is the reason for the origin of the concept of BMR, which was believed to represent the minimum energy cost of living. BMR is the metabolic rate of an adult animal at rest in a thermoneutral environment and a postabsorptive state. Although it can be determined by measuring a number of variables, it is most commonly measured as the rate of oxygen consumption. BMR represents the minimal cost of living rather than the heat required to maintain body temperature. This is most obvious from the fact that it is only at the lower critical temperature that BMR represents the heat required to maintain body temperature. At ambient temperatures greater than the lower critical temperature for a particular species, the heat produced from BMR is greater than that required for maintenance of an animal's body temperature, and this excess heat must be removed from the body by vasomotor-mediated increases in the thermal conductance. In 1895, Magnus-Levy showed that secretions from the thyroid gland stimulated the metabolic rate of humans. Until the development of radioimmunoassays in the 1960s for the measurement of blood thyroid hormone concentrations, the measurement of BMR was an important clinical measurement used to assess thyroid status of individual humans. This clinical context was a major influence on the development of strict conditions for the measurement of metabolic rate and the ref inement of the BMR concept during the twentieth century. During this period, BMR was also increasingly used to compare metabolic activity among various mammals and birds. However, the detailed conditions prescribed for the correct measurement of BMR of humans were not easily translated to the measurement of BMR in animals. Indeed, as pointed out by Blaxter (1989), in practice it is often easier to define the precise conditions for measurement of an animal's BMR than to achieve them. The concept of standard metabolic rate (SMR) was also developed to analyze the bioenergetics of ectotherms. It is related to BMR and includes the specification of the temperature at which metabolic rate is measured, which is important information when comparing the metabolic rate of ectothermic animal.

2.3. PHYSIOLOGY OF BASAL METABOLIC RATE

The early work of the scientists J. Arthur Harris and Francis G. Benedict showed that approximate values for BMR could be derived using body surface area (computed from height and weight), age, and sex, along with the oxygen and carbon dioxide measures taken from calorimetry. Studies also showed that by eliminating the sex differences that occur with the accumulation of adipose tissueby expressing metabolic rate per unit of "fat-free" or lean body mass, the values between sexes for basal metabolism are essentially the same. Exercise physiology textbooks have tables to show the conversion of height and body surface area as they relate to weight and basal metabolic values.

The primary organ responsible for regulating metabolism is the hypothalamus. The hypothalamus is located on the diencephalonand forms the floor and part of the lateral walls of the third ventricle of the cerebrum. The chief functions of the hypothalamus are:

1. control and integration of activities of theautonomic nervous system (ANS)
   - The ANS regulates contraction of smooth muscle and cardiac muscle, along with secretions of many endocrine organs such as the thyroid gland (associated with many metabolic disorders).
   - Through the ANS, the hypothalamus is the main regulator of visceral activities, such as heart rate, movement of food through the gastrointestinal tract, and contraction of the urinary bladder.
2. production and regulation of feelings of rage and aggression

3. regulation of body temperature
4. regulation of food intake, through two centers:

- The feeding center or hunger center is responsible for the sensations that cause us to seek food. When sufficient food or substrates have been received and leptin is high, then the satiety center is stimulated and sends impulses that inhibit the feeding center. When insufficient food is present in the stomach and ghrelinlevels are high, receptors in the hypothalamus initiate the sense of hunger.
- The thirst center operates similarly when certain cells in the hypothalamus are stimulated by the rising osmotic pressure of the extracellular fluid. If thirst is satisfied, osmotic pressure decreases.

All of these functions taken together form a survival mechanism that causes us to sustain the body processes that BMR measures.

2.4. FACTORS THAT INFLUENCE BASAL METABOLIC RATE

- Body size: Metabolic rate increases as weight, height, and surface area increase.
- Body composition: Fat tissue has a lower metabolic activity than muscle tissue. As lean muscle mass increases, metabolic rate increases.
- Gender: The basal metabolic rate (BMR) averages 5 to 10 percent lower in women than in men. This is largely because women generally possess more body fat and less muscle mass than men of similar size.
- Age: A decrease in lean muscle mass during adulthood results in a slow, steady decline of roughly 0 3 percent per year in BMR after the age of about 30. This can be largely avoided by strength training throughout adulthood.
- Climate and body temperature: The BMR of people in tropical climates is generally 5 to 20 percent higher than their counterparts living in more temperate areas because it takes energy to keep the body cool. Exercise performed in hot weather also imposes an additional metabolic load. Body fat content and effectiveness of clothing determine the magnitude of increase in energy metabolism in cold environments; it takes energy to keep the body warm if you work or exercise in very cold weather.
- Hormonal levels: Thyroxine (T4), the key hormone released by the thyroid glands has a significant effect upon metabolic rate. Hypothyroidism is relatively common, especially in women near or after menopause. Everyone with a weight problem should have their thyroid function checked by their doctor and treated appropriately if it turns out to be low.
- Health: Fever, illness, or injury may increase resting metabolic rate two-fold.

2.5. BMR IN METABOLIC DISORDER

BMR IN OBESITY

Obesity is a state defined by a BMI over 30 and consists of accumulation of fat in subcutaneous and visceral region. The accumulation of fat in internal organ is a feature which reduces their caloric consumption of internal organs decreasing the number of metabolic active cells. The adipose tissue has a lower energetic expenditure than lean mass: 4.5kcal/kg/day in adipose tissue in comparison with 13 kcal/kg/day in skeletal muscle. Secondary to fat accumulation BMR augments in absolute value, but energy consumption per kilogram of body weight is reduced compared with energy consumption per free fat mass kilogram which is normal. However, BMR adjusted per weight is not similar to all obese patients. In morbid obesity, lower level of BMR/kg total weight were found in higher BMI and heavier subgroup. These patients are more energetically efficient and accumulate more adipose tissue.

In nutritional intervention with low caloric diets or in fasting, BMR is reduced, the patients did not lose the expected weight and are frequently suspected of non compliance. BMR reduction in fasting state is about 15% and explain weight preserving in these conditions. Leptin level modulates BMR, increases BMR in obesity and decrease it in fasting condition. Obese patients with higher BMR adjusted to weight are considered hypermetabolizer patients. These patients are considered to support metabolic adaptation for reduction of further gain weight. This category was often associated with more diabetes, but it could be also associated with different increassedblod glucose levels, but below the values diagnostic for diabetes (Rosales-Velderrain et al., 2014). The leptin resistant state with dysfunctional satiety and BMR reduction could be a cause of obesity. Leptin resistant state is produced by a defective regulator expression of leptin receptor gene (Sahu and Minireview, 2004).

BMR IN METABOLIC SYNDROME Metabolic syndrome with obesity has a lower energetic requirement in comparison with diabetes with associated obesity. BMR adjusted for free mass is decreased in metabolic syndrome (Buscemi et al., 2007). That induces the idea that more efficient energetically, metabolic syndrome is a particular state prone to accumulation of fat tissue. Some of the mechanisms considered involved are genetic modification for uncoupling proteins (UCP) with decreased mitochondrial function and lipotoxic mechanism.

BMR IN DIABETES MELLITUS

BMR in diabetes is increased and correlate with the level of glycemic imbalance. It is considered that BMR is increased in Caucasian diabetic patient with 6% (Fontvieille et al., 1992; Bitz et al., 2004). There are many mechanism implicated in increasing BMR in diabetes, such the increased oxidation's level for carbohydrates, augmentation of neoglucogenesis and hepatic glucose output, increased sympathetic activity and decreased capacity of glycogen synthesis.

2.6. OBESITY

Obesity is a medical condition in which excess body fat has accumulated to the extent that it may have a negative effect on health (WHO, 2015). People are generally considered obese when their body mass index (BMI), a measurement obtained by dividing a person's weight by the square of the person's height, is over 30 kg/m2, with the range 25–30 kg/m2 defined as overweight (WHO, 2015). Some East Asian countries use lower values (Kanazawa et al., 2005). Obesity increases the likelihood of various diseases and conditions, particularly cardiovascular diseases, type 2 diabetes, obstructive sleep apnea, certain types of cancer, osteoarthritis and depression (Haslam and James, 2005; Luppino et al., 2010).

Obesity is most commonly caused by a combination of excessive food intake, lack of physical activity, and genetic susceptibility (WHO, 2015; Yazdi, Clee and Meyre, 2015). A few cases are caused primarily by genes, endocrine disorders, medications, or mental disorder (Bleich et al., 2008). The view that obese people eat little yet gain weight due to a slow metabolism is not medically supported. On average, obese people have greater energy expenditure than their normal counterparts due to the energy required to maintain an increased body mass (Kushner, 2007).

Obesity is mostly preventable through a combination of social changes and personal choices (WHO, 2015). Changes to diet and exercising are the main treatments (Haslam and James, 2005). Diet quality can be improved by reducing the consumption of energy-dense foods, such as those high in fat or sugars, and by increasing the intake of dietary fiber (WHO, 2015). Medications can be used, along with a suitable diet, to reduce appetite or decrease fat absorption (Yanovski and Yanovski, 2014). If diet, exercise, and medication are not effective, a gastric balloon or surgery may be performed to reduce stomach volume or length of the intestines, leading to feeling full earlier or a reduced ability to absorb nutrients from food (Colquitt et al., 2014).

Obesity is a leading preventable cause of death worldwide, with increasing rates in adults and children (Imaz et al., 2008). In 2015, 600 million adults (12%) and 100 million children were obese in 195 countries. Obesity is more common in women than men (WHO, 2015). Authorities view it as one of the most serious public health problems of the 21st century (Dibaise and Foxx-Orenstein, 2013). Obesity is stigmatized in much of the modern world (particularly in the Western world), though it was seen as a symbol of wealth and fertility at other times in history and still is in some parts of the world (Woodhouse, 2008).

Obesity is a medical condition in which excess body fat has accumulated to the extent that it may have an adverse effect on health (Sweeting, 2007). It is defined by body mass index (BMI) and further evaluated in terms of fat distribution via the waist–hip ratio and total cardiovascular risk factors (Gray and Fujioka, 1991). BMI is closely related to both percentage body fat and total body fat (Flegal et al., 2001). In children, a healthy weight varies with age and sex. Obesity in children and adolescents is defined not as an absolute number but in relation to a historical normal group, such that obesity is a BMI greater than the 95th percentile (Nikcevic, Kuczmierczyk and Bruch, 2009). The reference data on which these percentiles were based date from 1963 to 1994, and thus have not been affected by the recent increases in weight (Bei-Fan, 2002). BMI is defined as the subject's weight divided by the square of their height. BMI is usually expressed in kilograms of weight per metre squared of height. To convert from pounds per inch squared multiply by 703 (kg/m2)/(lb/sq in) (Nikcevic, Kuczmierczyk and Bruch, 2009).

Effects of obesity on health

Excessive body weight is associated with various diseases and conditions, particularly cardiovascular diseases, diabetes mellitus type 2, obstructive sleep apnea, certain types of cancer, osteoarthritis, and asthma (Haslam and James, 2005). As a result, obesity has been found to reduce life expectancy.

2.7. Lung Function Test

Lung function tests (LFTs) are a group of tests that measure how well your lungs work. This includes how well you're able to breathe and how effective your lungs are able to bring oxygen to the rest of your body.

It helps to test the following:
if you are having symptoms of lung problems, if you are regularly exposed to certain substances in the environment or workplace to monitor the course of chronic lung disease, such as asthma or chronic obstructive pulmonary disease (COPD) to assess how well your lungs are working before you have surgery. LFTs are also known as lung function tests.

LUNG VOLUME AND CAPACITY

Lung volumes and lung capacities refer to the volume of air associated with different phases of the respiratory cycle. The average total lung capacity of an adult human male is about 6 litres of air.. A lung's capacity consists of two or more lung volumes.

Total lung capacity (TLC): the volume in the lungs at maximal inflation, the sum of VC and RV. Tidal volume: that volume of air moved into or out of the lungs during quiet breathing (TV indicates a subdivision of the lung; when tidal volume is precisely measured, as in gas exchange calculation, the symbol TV or VT is used.) Residual volume (RV): the volume of air remaining in the lungs after a maximal exhalation. Expiratory reserve volume (ERV): the maximal volume of air that can be exhaled from the end-expiratory position. Inspiratory reserve volume (IRV): the maximal volume that can be inhaled from the end-inspiratory level. Inspiratory capacity (IC): the sum of IRV and TV. Inspiratory vital capacity (IVC): the maximum volume of air inhaled from the point of maximum expiration. Vital capacity (VC): the volume of air breathed out after the deepest inhalation. Tidal volume: that volume of air moved into or out of the lungs during quiet breathing (VT indicates a subdivision of the lung; when tidal volume is precisely measured, as in gas exchange calculation, the symbol TV or VT is used.) Functional residual capacity: the volume in the lungs at the end-expiratory position. Forced vital capacity (FVC): the determination of the vital capacity from a maximally forced expiratory effort. FEVtForced expiratory volume (time): a generic term indicating the volume of air exhaled under forced conditions in the first t seconds.FEV1 Volume that has been exhaled at the end of the first second of forced expiration.

Maximal voluntary ventilation (MVV): volume of air expired in a specified period during repetitive maximal effort.

Measurements

Lung function test is measured using spirometry. Spirometry includes tests of pulmonary mechanics –

measurements of FVC, FEV1, FEF values, forced inspiratory flow rates (FIFs), and MVV. Measuring pulmonary mechanics assesses the ability of the lungs to move huge volumes of air quickly through the airways to identify airway obstruction. The measurements taken by the spirometry device are used to generate a pneumotachograph that can help to assess lung conditions such as: asthma, pulmonary fibrosis, cystic fibrosis, and chronic obstructive pulmonary disease. Physicians may also use the test results to diagnose bronchial hyper responsiveness to exercise, cold air, or pharmaceutical agents (*McMurray et al., 2015).*

Lung volumes and capacity

There are four lung volumes and four lung capacities. A lung's capacity consists of two or more lung volumes. The lung volumes are tidal volume (VT), inspiratory reserve volume (IRV), expiratory reserve volume (ERV), and residual volume (RV). The four lung capacities are total lung capacity (TLC), inspiratory capacity (IC), functional residual capacity (FRC) and vital capacity (VC).

Factors affecting volumes

Several factors affect lung volumes; some can be controlled and some cannot be controlled. Lung volumes vary with different people as follows: Taller people, people who live at higher altitudes have larger lung volume, while shorter people, people who live at lower altitudes, people who are obese have smaller lung volume (Jones and Nzekwu, 2006).

A person who is born and lives at sea level will develop a slightly smaller lung capacity than a person who spends their life at a high altitude. This is because the partial pressure of oxygen is lower at higher altitude which, as a result means that oxygen less readily diffuses into the bloodstream. In response to higher altitude, the body's diffusing capacity increases in order to process more air. Also, due to the lower environmental air pressure at higher altitudes, the air pressure within the breathing system must be lower in order to inhale; in order to meet this requirement, the thoracic diaphragm has a tendency to lower to a greater extent during inhalation, which in turn causes an increase in lung volume.

MATERIALS AND METHOD

3.1. MATERIALS

Spirometer
Standiometer
Cotton wool
Spirit

SPIROMETER:

A spirometer is an apparatus used for measuring the volume of air inspired and expired by the lungs. A spirometer measures ventilation, the movement of air into and out of the lungs. It is the main piece of equipment used for basic Pulmonary Function Tests (PFTs). The spirometer used for this study was gotten from the Department of Human Physioligy, NnamdiAzikiwe University.

STANDIOMETER: A standiometer is an apparatus or equipment used for measuring height and weight and the same time. It is used in routine medical examinations and also clinical tests and experiments. The standiometer was gotten from the department of physiology NnamdiAzikiwe University.

COTTON WOOL: Cotton wool is a soft mass of cotton, used especially for applying liquids to the skin. It is socked in spirit to form swap.

SPIRIT: is a volatile liquid (alcohol) used in sterilizing or disinfecting surfaces or parts.

3.2. METHOD

3.2.1. Research design

This research is a cross sectional study conducted in college of Health Science NnamdiAzikiwe University Nnewi campus.

3.2.2. Area of study

This study took place at the Old Physiology laboratory of the Department of Human Physiology, NnamdiAzikiwe University, Nnewi campus. This study involved ninety (90) students.

NnamdiAzikiwe University, Awka is a Federal university in Nigeria. Its main campus is located in Nigeria in Anambra State's capital, Awka, and two two other campuses located at Nnewi and Agulu. NnamdiAzikiwe University came into being as an offshoot of the defunct Anambra State University of Technology (ASUTECH). The university is named after Dr. NnamdiAzikiwe, the first president of Nigeria. The College of Health Sciences in which the department of Physiology is situated is located at Nnewi.

3.2.3. Population of study

The study population was made up of ninety (90) students (52 male and 38 female) which included both males and females from different departments.

3.2.4. Determination of sample size

The sample size for this study was determined by simple random selection. A total number of 90 Students (52 male and 38 female) participated in the study. Inclusion criteria were healthy student, and age 20- 26 years old. Exclusion criteria were age <20 or >26 years old, presence of skeletal deformity, current history of acute respiratory illness, and a history of a chronic disease.

3.2.5. Ethical consideration

Ethical clearance was obtained from the Faculty of Basic Medical Sciences before the commencement of this study. The students consent was gotten before data collection.

3.3. Experimental procedure for collection of data

The subjects used for this study were 90 in number. Each of the subjects was given detailed explanation of the procedures involved and why the experiment is done. Those who agreed were recruited for the experiment.

The subjects' weight and height were measured using a standiometer. Before climbing the standiometer the subject was asked to remove any weighty thing from their pockets and also their shoes or sandals so as to get their exact weight and height. After measuring their weight and height, each of the subjects was asked to put the mouth piece of the spirometer on the mouth and was asked to inhale maximally and exhale maximally. The reading on the spirometer was taken. After use by each subject, the mouthpiece of spirometer was cleaned with swap and the spirometer was reset so as to take another reading. This was done for each and every one of the subjects.

The body mass index (BMI) was calculated for each student as weight (in kilograms) divided by square of height (in meters). BMI less than 25.00 was classified as "non-obese" and 25.00 or higher as "overweight/obese". A portable All-flow spirometer was used for measurement of FVC, FEV1, VT and VC for each subject.

Spirometry measurements were carried out according to the guidelines of the American Thoracic Society (ATS). Four predictive equations were used for estimation of basal metabolic rate for all participants in the study as follows:

1. Harris and Benedict equation: BMR (kcal/day) for men = (13.7516 wt/1 kg + 5.0033 ht/1 cm − 6.7550 ag e/1 year + 66.4730) and for women = (9.5634 wt/ 1 kg + 1.8496 ht/1 cm − 4.6756 age/1 year + 655.0955) (Frankenfield, Roth-Yousey and Compher, 2005).
2. Henry and Rees equation (Henry and Rees, 1991): BMR (kcal/day) for men (18–30 years old) = (0.0560 wt + 2.800) × 238.85, and for women (18–38 years old) = (0.0480wt + 2.562) × 238.85.

3.3.1. Parameters used

Weight: the standiometer was used measure subjects' weight. The measurement of subjects' weight were in kilogram.

Height: standiometer was also used to measure subjects' height. Height is measured alongside weight using a standiometer.

FEV 1: is the volume that has been exhaled at the end of the first second of forced expiration.

FVC: force vital capacity (FVC) is the determination of the vital capacity from maximally forced expiratory effort.

VT: Tidal volume (VT) is the volume of air moved into and out of the lungs during quiet breathing.

VC: vital capacity (VC) is the volume of air breathed out after the deepest inhalation.

3.4. Statistical analysis

The data collected were entered into Microsoft Excel andanalyzed using statistical package for social sciences (SPSS) Version 20.0. The student's t-test was used for testing the statistical difference between the groups of male and female, and between the groups of 'overweight/obese' and 'non-obese' in relation to the demographic details, the spirometric indicators, and the predicted values of BMR for each equation. P value <0.05.

RESULT

Table4.1 Characteristics of male and female in the study group

	SEX	N	Mean	P-VALUE
AGE(YEAR)	MALE	50	22.98±1.51	.
	FEMALE	40	21.88±1.44	0.001*
WEIGHT(Kg)	MALE	50	69.87±7.53	
	FEMALE	40	62.39±8.45	0.00*
HEIGHT(CM)	MALE	50	176.32±15.45	
	FEMALE	40	164.05±12.09	0.00*
H(m)	MALE	50	1.76±0.16	
	FEMALE	40	1.64±0.12	0.00*
H2	MALE	50	3.13±0.64	
	FEMALE	40	2.71±0.38	0.00*
BMR	MALE	50	1722.59. ±121.47	
	FEMALE	40	16270.81±2094.94	0.00*
VC	MALE	50	1.22±0.50	
	FEMALE	40	1.16±0.35	0.47
MVV	MALE	49	1.35±0.53	
	FEMALE	40	1.27±0.49	0.48
FEVI	MALE	49	1.39±0.49	
	FEMALE	40	1.23±0.36	0.07
VT	MALE	49	1.45±0.52	
	FEMALE	40	1.42±0.48	0.82
BMI	MALE	49	22.78±3.75	
	FEMALE	40	23.55±5.11	0.43

Table 4.1 shows characteristics of males and females in the study group. Males were significantly taller ($p < 0.05$) and heavier ($p < 0.05$) than females. Lung function test indicators were significantly higher ($p < 0.05$) among males compared to Mean BMR values predicted with the two equations were significantly higher in males compared to females ($p < 0.05$).

Table4.2.Comparison between obese/non-obese formale and female subjects in study group

		FEMALE			MALE		
	NUTRITION STATUS	N	Mean	P-Value	N	Mean	P-VALUE
AGE(YEAR)	NON OBESE	27	21.89±1.42		39	23.00±1.43	
	OBESE	13	21.85±1.52	0.93	10	22.90±1.91	0.88
WEIGHT(Kg)	NON OBESE	27	60.28±8.91		39	68.04±7.18	
	OBESE	13	66.77±5.41	0.00	10	76.00±4.78	0.00
H(m)	NON OBESE	27	1.68±0.09		39	1.79±0.16	
	OBESE	13	1.55±0.14	0.00	10	1.66±0.08	0.001
BMR	NON OBESE	27	15762.75±45		39	1711.02±12	7.33
	OBESE	13	17326.02±13	0.00	10	1754.55±90	0.231
VC	NON OBESE	27	1.23±0.38		39	1.23±0.49	
	OBESE	13	1.018±0.20	0.02	10	1.32±0.40	0.576
MVV	NON OBESE	27	1.33±0.53		39	1.35±0.54	
	OBESE	13	1.14±0.39	0.20	10	1.35±0.48	0.968
FEVI	NON OBESE	27	1.26±0.36		39	1.37±0.50	
	OBESE	13	1.15±0.37	0.40	10	1.47±0.45	0.565
VT	NON OBESE	27	1.50±0.52		39	1.46±0.53	
	OBESE	13	1.28±0.36	0.13	10	1.41±0.49	0.780
BMI	NON OBESE	27	21.26±2.48		39	21.48	
	OBESE	13	28.29±5.96	0.00	10	27.85±2.56	0.000

Table 4.2 shows insignificant statistical difference in age, height and lung function indicators (but not in weight and BMI) between overweight/obese and non-obese males and females of the study population.

Table4.3 showing comparison between Non-obesed and obesed in male and female subjects

Nutritional Status	Mean	N	Std. deviation	P-value	Mean	N	Std. deviation	p-value
NON OBESBE	15762.75±2214.45	27	2214.45	.004*	1711.02±127.33	39	127.33	0.316
OBESE	10949.51±7911.278	22	7911.28		1754.55±90.76	10	90.76	
Total	13601.70±5990.79	49	5990.79		1719.90±121.22	49	121.22	

Mean BMR values for overweight/obese and non-obese subjects were presented in Table 4.3. A Significant statistical difference was found between the two groups for each equation ($p < 0.05$).

Table4.4 The estimated basal metabolic rate among obese and non-obese male and female subjects using the two different predictive equations.

		FEMALE			MALE		
BMR EQUATIONS	NUTRITIONAL STATUS	N	Mean±SD	P-VALUE	N	Mean±SD	P-VALUE
HARRIS AND BENEDIT	NON OBEESE	27	15762.75±2214.45	0.009	39	1711.02±127.32	0.14
	OVER WEIGHT	13	17326.02±1360.76		11	1763.62±91.21	
HENRY AND REES	NON OBEESE	27	1303.01±102.15	0.007	39	1578.84±96.07	0.00*
	OVER WEIGHT	13	1377.43±62.03		11	1690.19±62.74	

Tables 4.4 show the relation between mean BMR values and LFT indicators among males and females respectively. Although the majority of BMR values were lower among those who have low values of LFT, statistical analysis showed insignificant relation ($p > 0.05$).

DISCUSSION

Measurement of basal metabolic rate is needed for nutritional assessment, weight loss planning and care for various medical conditions. Because of the increasing awareness about its importance worldwide, a free metabolic rate calculator, based on Harris and Benedict's equation, was recently released as a new application for smart mobile phones (Merghani et al., 2015). In this study, I chose two commonly used predictive equations for estimation of BMR in my study. In general, predictive equations tend to overestimate the actual energy expenditure (Frankenfield, Roth-Yousey and Compher, 2005).

The finding that lung function test are significantly higher among the males compared to the females is a normal physiological finding. Other factors known to affect lung volumes and capacities are age, height and weight. The age range of the students who participated in our study is relatively narrow (from 20 to 26 years old). This decreases variation in their expected values of lung function test however, the range of height is wide. The negative effects of excessive weight gain on the respiratory system are well known (Koenig, 2001; Chinn, Jarvis and Burney, 2002; Weiss and Shore, 2004). Accordingly, l divided my subjects into overweight/obese and non-obese subjects. In the absence of extreme values, presentation of lung function test in the form of (mean ± SD) is representative for my findings in the study population. My finding that, there was an insignificant difference in lung ventilatory function between overweight/obese and non-obese subjects was similar to results of a study recently conducted in king Abdulaziz medical city in Riyadh, Saudi Arabia and researchers recommended searching for another diagnosis to explain abnormal lung function findings in obese subjects (Ghobain, 2012; Merghani et al., 2015). Basal metabolic rate is relatively constant but varies greatly between individuals depending on their age, gender, and free fat mass. Gender is a significant determinant of BMR, with men having a greater rate than women (Lazzer et al., 2010). However, this difference might be attributed to higher free fat mass in males compared to females. Since the estimation of BMR in this study was based on predictive equations, results were significantly higher among males compared to females. Higher BMR values among males were reported by Arciero and his colleagues in 1993 who conducted their study in the United States across a broad spectrum of age (Arciero, Goran and Poehlman, 1993). In Arciero study, the lower values in females persisted even after controlling for differences in body composition and aerobic fitness.

It is well known that patients who consume low amount of oxygen have lower rate of metabolism than those who consume higher amounts; however, patients with impaired lung function, have still higher BMR compared to those with normal lung function, due to the increased activity of their respiratory muscles as a compensation for the impaired lung function. A recent study has shown that patients with COPD and bronchial asthma have increased metabolic rate that is directly correlated to severity of the diseases (Agha and ElWahsh, 2013). On the other hand, the negative effect of abnormal metabolism on lung function was confirmed in many previous studies. For example, diabetic patients had FEV1 values lower than those without diabetes, and this effect is even greater in those with poorly controlled diabetes (McKeever et al., 2005). In contradistinction to these results, I found insignificant association between predicted BMR and abnormal values of lung function tests. However, a significant difference in predicted BMR between overweight/obese and non-obese subjects is an expected finding since BMR calculations are directly based on weights of the participants. It is worth noting that accurate BMR calculations should rely on free fat mass rather than total body weight; that is why many studies found that the predictive equations overestimate the BMR, especially in obese subjects (Foster and McGuckin, 2001).

CONCLUSION

In conclusion, this study showed that the relation between predicted basal metabolic rate and indicators of lung function tests was statistically insignificant. A practical estimation of BMR based on direct measurement of oxygen consumption is recommended to confirm the absence of this association.

REFERENCES

[1] Agha MA, ElWahsh RA (2013). “Basal metabolic rate in bronchial asthma and COPD patients”. *Egypt J Chest Dis Tuberc.*; 62 (1):39–44.

[2] American Thoracic Society (1995) Standardization of spirometry, 1994 update. Am J RespirCrit Care Med 152:1107–1136

[3] Arciero PJ, Goran MI, Poehlman ET. Resting metabolic rate is lower in women than in men. J Appl Physiol. 1993; 75(6):2514–2520.

[4] Ballesteros FJ, Martinez VJ, Luque B, Lacasa L, Valor E, Moya A (2018). "On the thermodynamic origin of metabolic scaling”. Scientific Reports. 8: 1448:1–1448:10. Bibcode: 2018NatSR...8.1448B. doi:10.1038/s41598-018-19853-6.

[5] Bei-Fan Z (December 2002). "Predictive values of body mass index and waist circumference for risk factors of certain related diseases in Chinese adults: study on optimal cut-off points of body mass index and waist circumference in Chinese adults". Asia Pac J ClinNutr. 11 (Suppl 8): S685–93. Originally printed as Zhou BF (March 2002). "Predictive values of body mass index and waist circumference for risk factors of certain related diseases in Chinese adults--study on optimal cut-off points of body mass index and waist circumference in Chinese adults". Biomedical and Environmental Sciences. 15 (1): 83–96.

[6] Bitz, C.; Toubro, S.; Larsen, T. M.; Harder, H.; Rennie, K. L.; Jebb, S. A.; Astrup, A., (2004) ‘Increased 24-h energy expenditure in type 2 diabetes’. Diabetes care, 27, 2416-2421.

[7] Blaxter K. 1989. Energy Metabolism in Animals and Man. Cambridge University Press, Cambridge

[8] Bleich S, Cutler D, Murray C, Adams A (2008). "Why is the developed world obese?" Annual Review of Public Health (Research Support). 29: 273–95.

[9] Bonganha V, Libardi CA, Santos CF, De Souza GV, Conceicao MS, ChaconMikahil MPT, Madruga VA (2013) ‘Predictive equations overestimate the esting metabolic rate in postmenopausal women’. *J Nutr Health Aging* 17 (3):211–214

[10] Buscemi, S.; Verga, S.; Caimi, G.; Cerasola, G., (2007) ‘A low resting metabolic rate is associated with metabolic syndrome’. Clinical nutrition, 26, 806-809.

[11] Chinn S, Jarvis D, Burney P. (2002) ‘Relation of bronchial responsiveness to body mass index in the ECRHS. Eur Commun Resp Health Survey Thorax. 57:1028–1033.

[12] Colquitt JL, Pickett K, Loveman E, Frampton GK (2014). "Surgery for weight loss in adults". The Cochrane Database of Systematic Reviews (Meta-analysis, Review). 8 (8): CD003641

[13] Dibaise JK, Foxx-Orenstein AE (2013). "Role of the gastroenterologist in managing obesity". Expert Review of Gastroenterology & Hepatology (Review). 7 (5): 439–51.

[14] Du Bois D, Du Bois EF (1916) “A formula to estimate the approximate surface area if height and weight be known”. Archives of internal medicine, clinical calorimetry, tenth paper, pp. 863–871

[15] Elia, M., (1992) “Organ and tissue contribution to metabolic rate”; Raven Press New York,. pp. p. 61-80.

[16] Elia, M.; Ritz, P.; Stubbs, R. J., (2000) “Total energy expenditure in the elderly”. *European journal of clinical nutrition*, 54 Suppl 3, S92-103.

[17] Flegal KM, Ogden CL, Wei R, Kuczmarski RL, Johnson CL (2001). "Prevalence of overweight in US children: comparison of US growth charts from the Centers for Disease Control and Prevention with other reference

values for body mass index". *The American Journal of Clinical Nutrition*. 73 (6): 1086–93.

[18] Fontvieille, A. M.; Lillioja, S.; Ferraro, R. T.; Schulz, L. O.; Rising, R.; Ravussin, E., (1992) "Twenty-four-hour energy expenditure in Pima Indians with type 2 (non-insulin dependent) diabetes mellitus". Diabetologia, 35, 753-759.

[19] Food and Agricultural Organization/World Health Organization/United Nations University (1985) "Energy and protein requirements: report of a Joint FAO/WHO/UNU expert consultation world health organization technical report series 724". WHO, Geneva

[20] Foster GD, McGuckin BG. (2001) "Estimating resting energy expenditure in obesity". *Obes Res* ;9:367s–372s.

[21] Frankenfield D, Roth-Yousey L, Compher C (2005) "Comparison of predictive equations for resting metabolic rate in healthy non-obese and obese adults: a systematic review". *J Am Diet Assoc.* 105(5):775–789

[22] Frankenfield D, Roth-Yousey L, Compher C. (2005) "Comparison of predictive equations for resting metabolic rate in healthy non-obese and obese adults: a systematic review". *J Am Diet Assoc.*;105(5):775–789.

[23] Frankenfield, D. C.; Muth, E. R.; Rowe, W. A., (1998) "The Harris-Benedict studies of human basal metabolism: history and limitations". *Journal of the American Dietetic Association*, 98, 439-445.

[24] Ghobain Al (2012) "The effect of obesity on spirometry tests among healthy non- smoking adults". *BMC Pulm Med* 12:10.

[25] Goran, M. I.; Kaskoun, M.; Johnson, R., (1994) "Determinants of resting energy expenditure in young children". *The Journal of pediatrics*, 125, 362-367.

[26] Gougeon, R., (1996) "Thermic and metabolic responses to oral glucose in obese subjects with non-insulin-dependent diabetes mellitus treated with insulin or a very-low energy diet". *The American journal of clinical nutrition*, 64, 78- 86.

[27] Gray DS, Fujioka K (1991). "Use of relative weight and Body Mass Index for the determination of adiposity". *Journal of Clinical Epidemiology*. 44 (6): 545– 50.

[28] Haslam DW, James WP (2005). "Obesity". Lancet (Review). 366 (9492): 1197–209.

[29] He, Q.; Heshka, S.; Albu, J.; Boxt, L.; Krasnow, N.; Elia, M.; Gallagher, D., (2009) "Smaller organ mass with greater age, except for heart". *Journal of applied physiology*, 106, 1780-1784.

[30] Healthy Weight: Assessing Your Weight: BMI: About BMI for Children and Teens. Center for disease control and prevention. Retrieved 25 July 2018.

[31] Henry CJ, Rees DG (1991) "New predictive equations for the estimation of basal metabolic rate in tropical peoples". *Euro J ClinNutr* 45(4):177–185

[32] Hoag, S.; Marshall, J. A.; Jones, R. H.; Hamman, R. F., (1995) "High fasting insulin levels associated with lower rates of weight gain in persons with normal glucose tolerance: the San Luis Valley Diabetes Study". *International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity*, 19, 175-180.

[33] http://www.mmisoftware.co.uk/ipad/bodycal2/. A BMI and BMR calculator for the ipad. Accessed 15 Aug 2018

[34] Imaz I, Martínez-Cervell C, García-Alvarez EE, Sendra-Gutiérrez JM, González- Enríquez J (2008). "Safety and effectiveness of the intragastric balloon for obesity. A meta-analysis". *Obesity Surgery*. 18 (7): 841–6.

[35] Jastroch, M.; Divakaruni, A. S.; Mookerjee, S.; Treberg, J. R.; Brand, M. D., (2010) "Mitochondrial proton and electron leaks". Essays in biochemistry, 47, 53-67.

[36] Johnstone, A. M.; Murison, S. D.; Duncan, J. S.; Rance, K. A.; Speakman, J. R., (2005) "Factors influencing variation in basal metabolic rate include fat- free ass, fat mass, age, and circulating thyroxine but not sex, circulating leptin, or triiodothyronine". *The American journal of clinical nutrition*, 82, 941-948.

[37] Jones RL, Nzekwu MM. (2006). "The effects of body mass index on long volumes". Chest. 130 (3): 827-33.

[38] Kanazawa M, Yoshiike N, Osaka T, Numba Y, Zimmet P, Inoue S (2005). "Criteria and classification of obesity in Japan and Asia-Oceania". World Review of Nutrition and Dietetics. 94. pp. 1–12.

[39] Kenney, W. L.; Buskirk, E. R., (1995) "Functional consequences ofsarcopenia: effects on thermoregulation". *The journals of gerontology*. Series A, Biological sciences and medical sciences, 50 Spec No, 78-85.

[40] Klausen, B.; Toubro, S.; Astrup, A., (1997) 'Age and sex effects on energy expenditure'. *The American journal of clinical nutrition,* 65, 895-907.

[41] Koenig SM. (2001) "Pulmonary complications of obesity". *Am J Med Sci.*; 321:249–279.

[42] Krems, C.; Luhrmann, P. M.; Strassburg, A.; Hartmann, B.; Neuhauser-Berthold, M., (2005) "Lower resting metabolic rate in the elderly may not be entirely due to changes in body composition". *European journal of clinical nutrition*, 59, 255-262.

[43] Kushner R (2007). "Treatment of the Obese Patient (Contemporary Endocrinology)". Totowa, NJ: Humana Press. p. 158. ISBN 978-1-59745- 400-1. Retrieved 5 September 2018.

[44] Lazzer S, Bedogni G, Lafortuna CL, Marazzi N, Busti C, Galli R,. Relationship between basal metabolic rate, gender, age, and body composition in 8,780 white obese subjects. Obesity. 2010;18(1):71–78.

[45] Lazzer, S.; Bedogni, G.; Lafortuna, C. L.; Marazzi, N.; Busti, C.; Galli, R.; De Col, A.; Agosti, F.; Sartorio, A., (2010) "Relationship between basal metabolic rate, gender, age, and body composition in 8,780 white obese subjects". *Obesity*, 18, 71-78.

[46] Luppino FS, de Wit LM, Bouvy PF, Stijnen T, Cuijpers P, Penninx BW, Zitman FG (2010). "Overweight, obesity, and depression: a systematic review and meta-analysis of longitudinal studies". Archives of General Psychiatry. 67 (3): 220–9.

[47] Lutz P.L. (2002). "The Rise of Experimental Biology: An Illustrated History". Humana, Totowa, N.J.

[48] Manini TM (2010). "Energy expenditure and aging". Ageing Research Reviews. 9 (1): 1–11.

[49] McKeever TM, Weston PJ, Hubbard R, Fogarty A. (2005) 'Lung function and glucose metabolism: an analysis of data from the third National Health and Nutrition Examination Survey'. *Am J Epidemiol*; 161(6):546–556.

[50] McMurray RG, Soares J, Caspersen CJ, McCurdy T (2014). "Examining variations of resting metabolic rate of adults: a public health perspective" Medicine & Science in Sports & Exercise. 46 (7): 1352– 1358.

[51] McNab BK (1997). "On the Utility of Uniformity in the Definition of Basal Rate of Metabolism". Physiological Zoology. 70 (6): 718–720.

[52] Merghani, T.H; Alawad, A.O; Ibrahim, R.M; Abdelmoniem A.M, (2015) 'Prediction of basal metabolic rate in overweight/obese and non-obese subjects and its relation to pulmonary function tests'.8: 353. Available at: www.ncbi.nlm.gov/pmc/article/PMC4536756/#!po=75.5814 Accessed on: 25 September, 2018.

[53] Mifflin MD, St Jeor ST, Hill LA, Scott BJ, Daugherty SA, Koh YO (1990) A new predictive equation for resting energy expenditure in healthy individuals. *Am J ClinNutr.* 51(2):241–247

[54] Nikcevic AV, Kuczmierczyk AR, Bruch M (2009). "Formulation and Treatment in Clinical Health Psychology". Routledge. ISBN 9781135452087.

[55] Obesity and overweight Fact sheet N°311. WHO. 2015. Retrieved 10 September 2018.

[56] Owen, O. E.; Kavle, E.; Owen, R. S.; Polansky, M.; Caprio, S.; Mozzoli, M. A.; Kendrick, Z. V.; Bushman, M. C.; Boden, G., (1986)'A reappraisal of caloric requirements in healthy women'. *The American journal of clinical nutrition*, 44, 1-19.

[57] P. M.; Strassburg, A.; Hartmann, B.; Neuhauser-Berthold, M., (2005) 'Lower resting metabolic rate in the elderly may not be entirely due to changes in body composition'. *European journal of clinical nutrition*, 59, 255-262. 25.

[58] Piaggi, P.; Thearle, M. S.; Bogardus, C.; Krakoff, J., (2015) 'Fasting hyperglycemia predicts lower rates of weight gain by increased energy expenditure and fat oxidation rate'. *The Journal of clinical endocrinology and metabolism*, 100, 1078-1087.

[59] Poehlman, E. T.; Dvorak, R. V., (1998) 'Energy expenditure in Alzheimer's disease'. *The journal of nutrition, health & aging*, 2, 115-118. 24. Krems, C.; Luhrmann,

[60] Poehlman, E. T.; Horton, E. S., (1990) 'Regulation of energy expenditure in aging humans'. Annual review of nutrition, 10, 255-275.

[61] Pollack A (2013). "A. M. A. Recognizes Obesity as a Disease". New York Times. Archived from the original on 23 June 2013.

[62] Roberts, S. D., D.E., (2001) 'Energy requirements and aging'. Energy working paper No.8R prepared for the joint FAO/WHO/UNU Expert Consultation on Energy in Human Nutrition,.2001.

[63] Rosales-Velderrain, A.; Goldberg, R. F.; Ames, G. E.; Stone, R. L.; Lynch, S. A.; Bowers, S. P., (2014). "Hypometabolizers: characteristics of obese patients with abnormally low resting energy expenditure". The American Surgeon, 80, 290-294.

[64] Roubenoff, R.; Hughes, V. A.; Dallal, G. E.; Nelson, M. E.; Morganti, C.; Kehayias, J. J.; Singh, M. A.; Roberts, S., (2000) 'The effect of gender and body composition method on the apparent decline in lean mass-adjusted resting metabolic rate with age'. The journals of gerontology. Series A, Biological sciences and medical sciences, 55, M757-760.

[65] Sahu, A., Minireview. (2004): 'A hypothalamic role in energy balance with special emphasis on leptin'. Endocrinology, 145, 2613-2620.

[66] Stiegler P, Cunliffe A (2006). "The role of diet and exercise for the maintenance of fat-free mass and resting metabolic rate during weight loss" (PDF). Sports Medicine. 36 (3): 239–262.

[67] Sweeting HN (October 2007). "Measurement and definitions of obesity in childhood and adolescence: a field guide for the uninitiated". *Nutrition Journal*. 6 (1): 32.

[68] Swinburn, B. A.; Nyomba, B. L.; Saad, M. F.; Zurlo, F.; Raz, I.; Knowler, W. C.; Lillioja, S.; Bogardus, C.; Ravussin, E., (1991) 'Insulin resistance associated with lower rates of weight gain in Pima Indians'. *The Journal of clinical investigation*, 88, 168-173.

[69] Weinstock, Matthew (2013). "The Facts About Obesity". H&HN. *American Hospital Association*. Retrieved 24 September 2018.

[70] Weiss ST, Shore S. (2004) 'Obesity and asthma: directions for research'. *Am J Respir Crit Care Med*; 169:963–968.

[71] Woodhouse R (2008). Obesity in art: a brief overview. Frontiers of Hormone Research. 36. pp. 271–86.

[72] World Health Organization (1997) "Obesity: preventing and managing the global epidemic". WHO, Geneva

[73] World Medical Association Medical Ethics Committee (1999) Updating the WMA Declaration of Helsinki. *Wld Med J* 45:11–13

[74] Yanovski SZ, Yanovski JA (January 2014). "Long-term drug treatment for obesity: a systematic and clinical review". *JAMA (Review)*. 311 (1): 74–86.

[75] Yazdi FT, Clee SM, Meyre D (2015). "Obesity genetics in mouse and human: Back and forth and back again". *PeerJ*. 3: e856.