American Journal of Theoretical and Applied Statistics
2022; 11(1): 19-26
http://www.sciencepublishinggroup.com/j/ajtas
doi: 10.11648/j.ajtas.20221101.13
ISSN: 2326-8999 (Print); ISSN: 2326-9006 (Online)

Control Chart and Its Applicationin Modelling Body Mass Index (BMI) of Students in Delta State Polytechnic, Oghara

Akpojaro Ogheneochuko Owens, Agbogidi Bess Rioborue

Mathematics Unit, School of Basic Science, Nigeria Maritime University, Okerenkoko, Nigeria

Email address:
owenssmith@gmail.com (A. O. Owens)

To cite this article:
Akpojaro Ogheneochuko Owens, Agbogidi Bess Rioborue. Control Chart and Its Applicationin Modelling Body Mass Index (BMI) of Students in Delta State Polytechnic, Oghara. *American Journal of Theoretical and Applied Statistics*. Vol. 11, No. 1, 2022, pp. 19-26.
doi: 10.11648/j.ajtas.20221101.13

Received: December 2, 2021; **Accepted**: January 7, 2022; **Published**: January 25, 2022

Abstract: This study aimed to examine the health status of students as a function of the body mass index (BMI) using control chart. The utility of body mass index has proven very useful in helping managers to estimate the weight normality of individuals as a measure of healthy living among them. This study evaluated the reported BMI of students and problems associated with abnormal BMI among students. Stratified sampling was adopted since there are three faculties or schools in the polytechnic with each school having several departments, therefore, A simple random sample of 150 students was selected from the three schools of study in the Delta State Polytechnic, Otefe-Oghara and their BMI were examined through data on weight and height. The result of the study revealed that the students BMI are statistically in control for X-chat and out of control for MR-chat in engineering, both X-chart and MR-chart are out of control for Applied sciences but for school of business, both chats are in statistical control. The fact that the test for randomness proved to be false; it implies that the sample result is evident enough to infer on the general population that their current measures of body mass index are not random. Consequent to the study findings, it was concluded that quality control tools: (control chart for individual unit) is a veritable too for student BMI diagnostics. The study also concludes that most students' BMI was classified according to the World Health Organization (WHO) standard to be obese, which indicates a huge health risk of various obese-related diseases like diabetes, cardiac issues and even stroke especially for school of engineering and applied sciences.

Keywords: Health Status, Control Chart, Runs Test, Risk Assessment, Body Mass Index (BMI)

1. Introduction

Research has found a link between BMI and more direct measures of body fat, such as underwater weighing and dual-energy x-ray absorptiometry. The current metric for determining anthropometric height/weight features in adults and classifying (categorizing) them into groups is the body mass index (BMI). The most popular interpretation is that it is a measure of a person's fatness. It's also commonly used as a risk factor for the onset or prevalence of a variety of health problems. Furthermore, it is commonly employed in the formulation of public health policies.

A person's body mass index (BMI) is a number derived from their weight and height. For most people, BMI is a fairly accurate predictor of body fatness. Adults' BMI is used as a screening technique to identify potential weight concerns. BMI, on the other hand, is not a diagnostic tool [2].

A person's body mass index is generated from their weight and height. The BMI is calculated by dividing the body mass by the square of the body height. It is universally stated in kilograms per square meter, with mass in kilograms and height in metres. BMI should not be utilized as a diagnostic tool because it does not directly assess body fat. Instead, BMI should be used as a tool to track population weight status and as a screening tool to identify individuals with prospective weight problems. It is simply based on height and weight, and anyone with access to the right equipment can have their BMI measured and calculated with fair precision on a regular basis [11].

Because of its widespread acceptance in defining specific categories of body mass as a health issue, the BMI has been useful in population-based studies. A figure that measures

body weight adjusted for height is known as the body mass index. The normal range is 18.5-24.9. Overweight is defined as a value of 25-29.9, while obesity is defined as a value of 30 or higher. More than 2 in every 3 adults in the US are overweight or obese. She further added that public health experts are sounding the alarm, too, recognizing it as one of the driving forces behind many diseases [15].

The most appropriate simple indicator for relating weight and height to a health outcome is BMI. BMI is calculated by dividing weight (kg) by height squared (m^2). Both children and adults' height and weight are crude measures of the impact of various environmental factors (such as diet and infections) on an individual's genetic development potential over short and long periods of time, and they influence a variety of health consequences. As a result, the WHO recommended that BMI be used to track both undernutrition and obesity [12].

A dietary shift toward increased intake of energy-dense foods high in fat and sugars, as well as decreased physical activity levels due to increasing sedentary behavior, such as television viewing, changes in transportation, and increasing urbanization, are all factors that contribute to overweight or abnormal BMI [6]. [16] added that SPC monitors processes as they are carried out in order to regulate quality in a near-real-time manner rather than testing or inspecting later. This enables operators to bring operations under tighter control and decrease deviations right away, resulting in less waste and better quality.

BMI is a useful clinical technique for assessing overweight and obesity in the early stages. However, because BMI does not distinguish between fat and lean mass, it has significant drawbacks. Body mass index may overstate body fat in those who have more muscle mass, such as athletes, and underestimate it in people who have lost muscle mass [1]

Secondary lifestyle, attitude, environmental variables, and other factors can all contribute to a high BMI (overweight) and obesity among school children. The most significant elements that may influence a child's BMI are parental feeding attitudes, styles, and environmental influences (BMI). In general, the higher your BMI, the greater your chance of acquiring diabetes, arthritis, liver disease, numerous types of cancer (such as breast and prostate cancer), high blood pressure (hypertension), high cholesterol, sleep apnea, and other illnesses associated to excess weight [8].

Globally, about 3 million individuals die each year as a result of being overweight or obese. Furthermore, people with high BMIs frequently report feeling better, both physically and psychologically, once they reduce excess weight, regardless of disease. BMI is an estimate of body fat and a good gauge of your risk for diseases that can occur with more body fat. The greater your BMI, the more likely you are to have heart disease, high blood pressure, type 2 diabetes, gallstones, breathing issues, and some malignancies [14].

Overweight or obesity kills nearly 3 million people every year around the world. Furthermore, people with high BMIs frequently report feeling better, both physically and psychologically, once they lose excess weight, regardless of any particular disease. BMI is a measurement of body fat and a good predictor of disease risk. Heart disease, high blood pressure, type 2 diabetes, gallstones, breathing problems, and certain cancers are all linked to a higher BMI [4].

It's vital to remember that BMI isn't the only factor that determines risk. Other factors that influence an individual's risk of disease include what they eat, how much they exercise, and whether or not they have a family history of disease. Overweight and obese people, on the other hand, have a higher risk of several diseases as a group. They have a higher risk of Type 2 Diabetes, Gallbladder illness, Hypertension, Dyslipidaemia, Insulin Resistance, Atherosclerosis, Sleep Apnea, Breathlessness, Asthma, Social Isolation, and Depression, as well as daytime drowsiness and lethargy. Cardiovascular disorders (stroke, heart attack); Gout/hyperuricaemia; Osteoarthritis; Respiratory disease; Hernia; Psychological difficulties are all moderately increased risks [7].

The most appropriate basic indicator for relating weight and height to a health outcome is BMI. BMI is computed by dividing weight (kg) by height squared (m^2). Both children and adults' height and weight are crude measures of the impact of various environmental factors (such as diet and infections) on an individual's genetic development potential over short and long periods of time, and they influence a variety of health consequences. As a result, the WHO recommended that BMI be used to track both undernutrition and obesity [10].

Obesity is also no longer a condition that just affects older people, although the likelihood does Obesity is no longer a disease that just affects the elderly, despite the fact that the risk increases with age, and a growing number of young individuals are being diagnosed with obesity. Globally, almost 3 million individuals die each year as a result of being overweight or obese. Furthermore, people with high BMIs frequently report feeling better, both physically and psychologically, once they reduce excess weight, regardless of disease. The BMI was created in the 1800s by Belgian polymath AdolpheQuetelet, and is frequently referred to as the Quetelet index. Your BMI is determined by multiplying your weight in kilograms (kg) by your height in metres squared (m^2). It's measured in kilograms per square meter. Body mass index (BMI) is an indirect measure of body fatness. You may be underweight, healthy weight, overweight, or obese, depending on your BMI [11].

Statistical quality control is the field of activities presented by the application of statistical technique (method), which include both chart technique (process control) and acceptance sampling (product control) to save the problem of manufacturing goods. He was of the view that manufacturing industries embark on the techniques of sampling analysis in statistical quality control. There will be more sill since higher liable will be employed to tabulated complete any analyze the production data of the production process. Statistical

quality control is a technique of measuring items produced by manufacturing industries in his book; various advantages were analyzed both to customers as well as manufactures regarding quality control [10].

Because of its widespread acceptability in categorizing certain categories of body mass as a health issue, the BMI has been valuable in population-based investigations. The body mass index has proven to be quite beneficial in estimating an individual's weight normalcy in relation to their health. Being overweight (BMI of 25 or higher) or underweight (BMI of less than 18.5) can affect your health, according to the risk associated with extreme BMI. Obesity is highly likely to result from an unregulated BMI, according to health professionals.

Obesity is a major health issue, and the number of overweight and obese people is rising in emerging countries. As a result, the purpose of this study is to use the BMI indicator to assess the health state of students. Examining the body mass index of diverse students across the three faculties; evaluating the discrepancies in the reporting body mass index of students across the Departments; using the x-chart to monitor the BMI; and determining if these BMI are random are the specific aims.

For people who are considered obese (BMI greater than or equal to 30) or those who are overweight (BMI of 25 to 29.9) and have two or more risk factors, it is recommended that they lose weight. Even a small weight loss (between 5 and 10 percent of your current weight) will help lower their risk of developing diseases associated with obesity. People who are overweight, do not have a high waist measurement, and have fewer than two risk factors may need to prevent further weight gain rather than lose weight [9].

A recent study examined body mass index of individuals using statistical quality control charts (SQCCs) the mean Body Mass Index (BMI) values as the only indicator to assess the weight status of populations might be misleading in clinical weight management studies; and to introduce a powerful tool, SQCCs, to keep fluctuations in BMIs within acceptable limits in a given population for healthy aging using a sample of 829 random individuals. The mean BMI increased in both genders by age. In some groups, although a significant number of people were outside the normal weight BMI limits the mean BMI values were within the normal limits (18.5< 24.9). In addition, although the number of overweight individuals was greater in some groups, their mean BMIs were lower compared to the groups with fewer overweight individuals. Capability tests clearly show that each group, even the groups with a mean BMI in the normal weight ranges and also the groups which are referred as being "under control" according to the X-charts, was not in energy balance. The results clearly indicated that using the mean BMIs as the only indicator might be misleading in weight management studies. His study introduced SQCCs as a potential tool for clinical nutrition studies to maintain the fluctuations of individual BMIs within acceptable limits for healthy aging populations [5].

Another study examined the use of process control in the monitoring controlling of diabetes amongst patients. The study sourced data from the General Hospital Oghara, Delta State which were examined using the control chart for variables, specifically the use of X-bar and R-chart through the use of SPSS package. The findings of the study reveal that an average of 130mg/dL blood sugar level is expected for every diabetic patient health profile examined. However, the result indicated that for controlled diabetic patients' health, the blood sugar level of the patients is expected to reduce to 127mg/dL while uncontrolled health status will vary up to about 133mg/dL (allowable random variation). The result further pointed that the patient in sample 10 has an extreme condition of diabetes which requires a critical medical examination since the patient's blood sugar level profile is way higher that the expected upper allowable limit [5].

2. Material and Methodology

2.1. Population of the Studyand Sampling Technique

The populations of the study are the students of the Delta State Polytechnic, Otefe-Oghara in the 2019/2020 academic session. The polytechnic has three faculties or school, school of business, engineering and applied sciences. Business has five departments; Applied Sciences has three departments and Engineering four departments. In this design, the three faculties were regarded as the strata from which we employed the use of the simple random sampling technique in obtaining the samples needed for the study from each stratum. The sample for the study included a total of 150 students being 50 random students from each faculty/stratum.

2.2. Method of Data Collection

The study used direct observation in obtaining the required data useful for satisfying the aim of the study. The weight and height were directly observed. The height was measured using a measuring tape, while the weight was obtained using the health scale. The study will employ a primary source of data in achieving the set objectives.

2.3. Model Specification

Consider the control chart for individual units and the control limit given below;

2.3.1. $\bar{X}$-CHART (MEAN)

This shows the process variability by the mean measurement.

$$\bar{X}_i = \frac{\sum_{i=1}^{k} X_i}{k} \tag{1}$$

$$\text{Central line} = \bar{\bar{X}} = \frac{\sum_{i=1}^{n} \bar{X}_i}{n} \tag{2}$$

$$\text{Upper control limit} = \bar{\bar{X}} + 3\frac{\overline{MR}}{d_2} \tag{3}$$

$$\text{But } \overline{MR} = \frac{\sum_{i=1}^{n} MR_i}{k} \quad (4)$$

$$\text{Lower control limit} = \bar{\bar{X}} - +3\frac{\overline{MR}}{d_2} \quad (5)$$

2.3.2. Moving Range Control Limit

$$\text{Central line} = \overline{MR} = \frac{\sum_{i=1}^{n} MR_i}{k} \quad (6)$$

$$\text{Upper control limit} = D_4\overline{MR} \quad (7)$$

$$\text{Lower control limit} = D_3\overline{MR} \quad (8)$$

Where;
$\bar{\bar{X}}$ is the grand mean of BMI of all the observations
$\bar{X}_i$ is the mean of BMI for the ith patient
K is the number of observation per student
n is the number of students observed
D_3 and D_4 are statistical process control constants obtainable from the statistical table.

2.3.3. Runs Analysis

Test Statistics:

$$Z_r = \frac{r-\mu}{\sigma_r} \quad (9)$$

where,

$$\mu_r = \frac{2n_An_B}{n_A+n_B} + 1 \quad (10)$$

$$\sigma_r = \sqrt{\frac{2n_An_B(2n_An_B-n_A-n_B)}{(n_A+n_B)^2(n_A+n_B-1)}} \quad (11)$$

r is the number of runs, μ_r is the test value, n_A= number of samples above the center line
n_B = number of samples below the center line
H_0: The process is random
H_1: The process is not random
Decision Rule
Reject H_0 if p-value < α = 0.05,
Otherwise, accept H_0. process is not random.

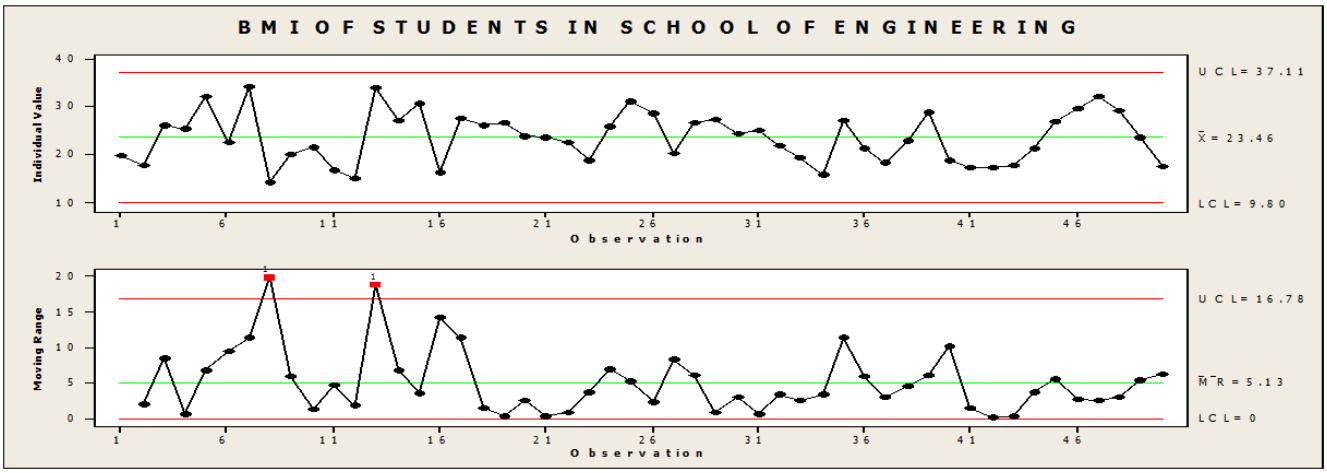

Figure 1. *Individual moving range chart for students BMI in school of Engineering.*

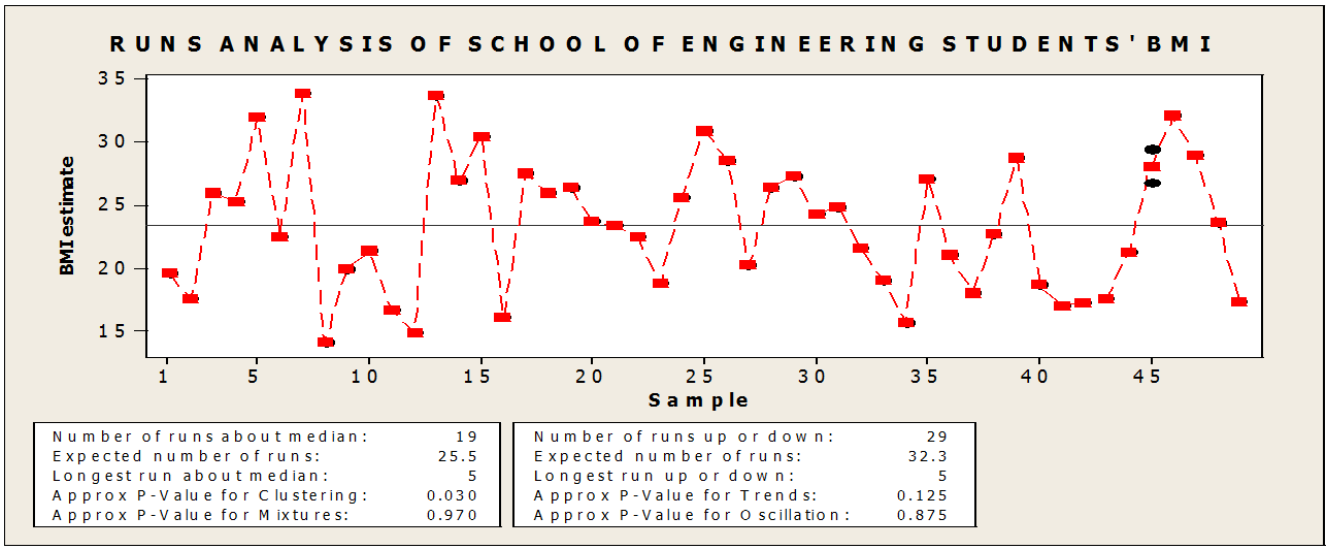

Figure 2. *Runs analysis for School of Engineering.*

3. Results and Discussion

Summary of the result from the analysis were presented follows:

The result presented in Figure 1 indicates that the BMI of students tends to be in statistical control for the X-chart and out of control for the moving range chart when the expected BMI of each student is normal indicates that the students are healthy in terms of their BMI measure. In Figure 2, the randomness test of the students' BMI was tested and the result yields a p-value greater than 5% level of significance and this implies that the BMI reported is not random. From the control charts fitted above, it was found that most of the reporting BMI of students are of normal expectation and thus student's health is indicated by the BMI's shows that students BMI is currently under control.

The results presented in Figure 3 assessed the actual BMI of students in Applied Sciences which indicated a process-out of control status. Two individuals who were found to be out of expectation of normal BMI. This result was able to detect those students in this category of out-of-control need medical evaluation and proper attention to restore normal health and avoid obese-related complications.

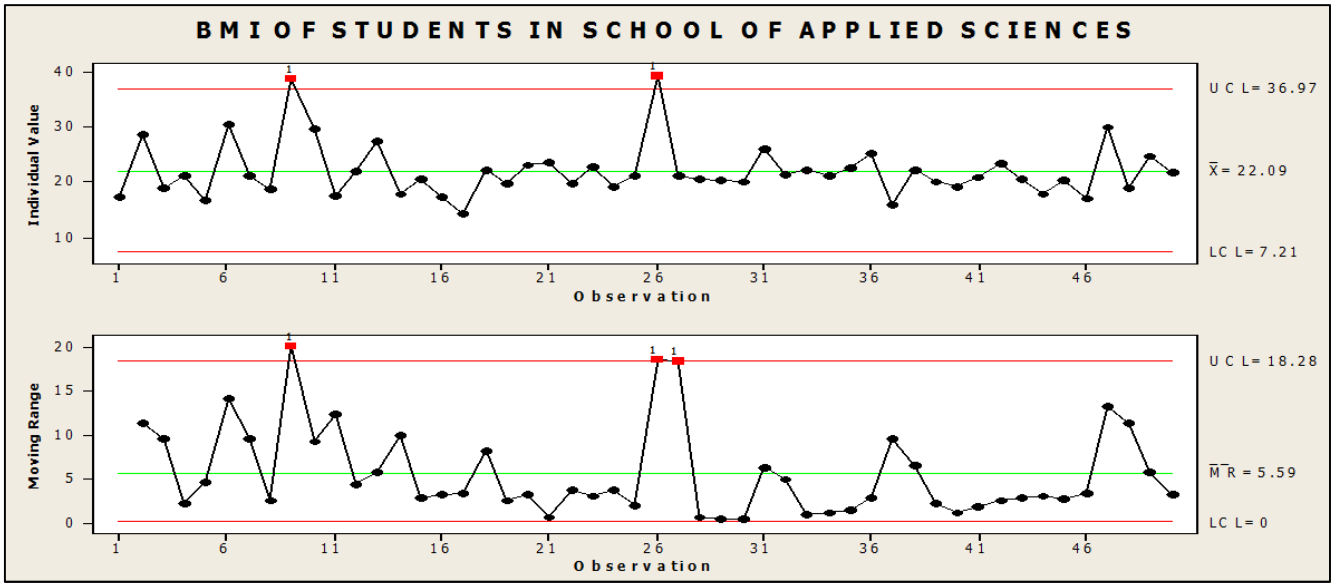

Figure 3. *Individual moving range chart for students BMI in school of Applied Sciences.*

The chart presented in Figure 4 shows the randomness of the students' BMI was tested and yield a p-value for the trend is greater than a 5% level of significance which implies that the BMI reported is also not randomly for students in Applied Sciences.

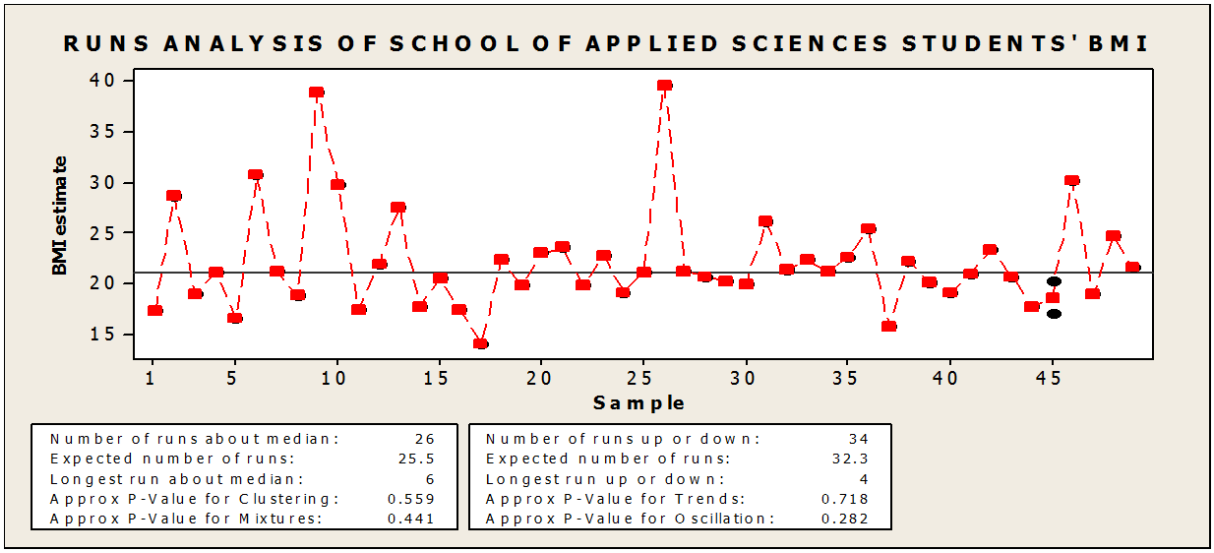

Figure 4. *Runs analysis for School of Applied Sciences students.*

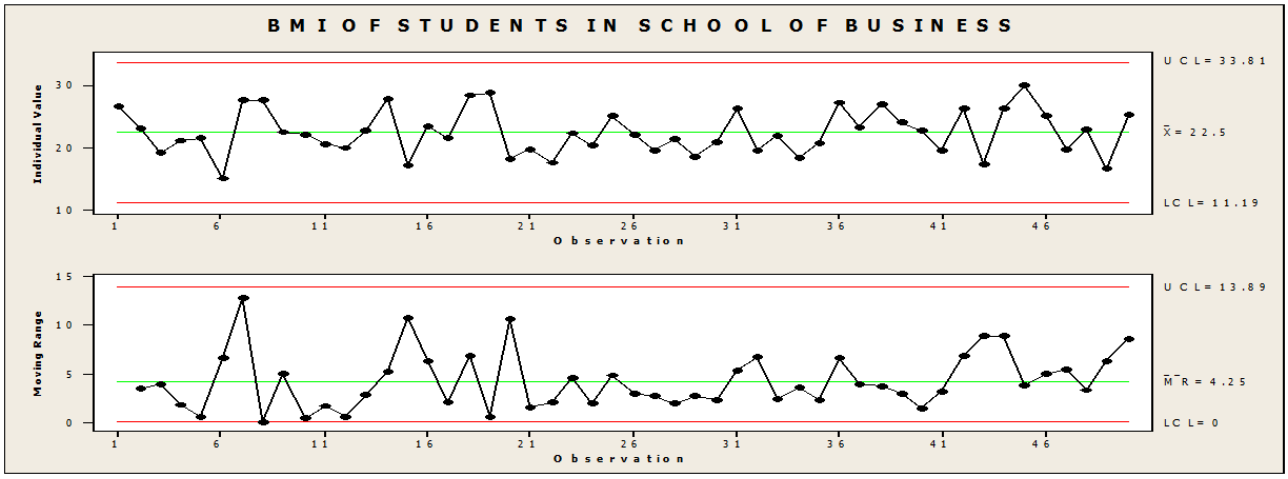

Figure 5. *Individual moving range chart for students BMI in school of Business.*

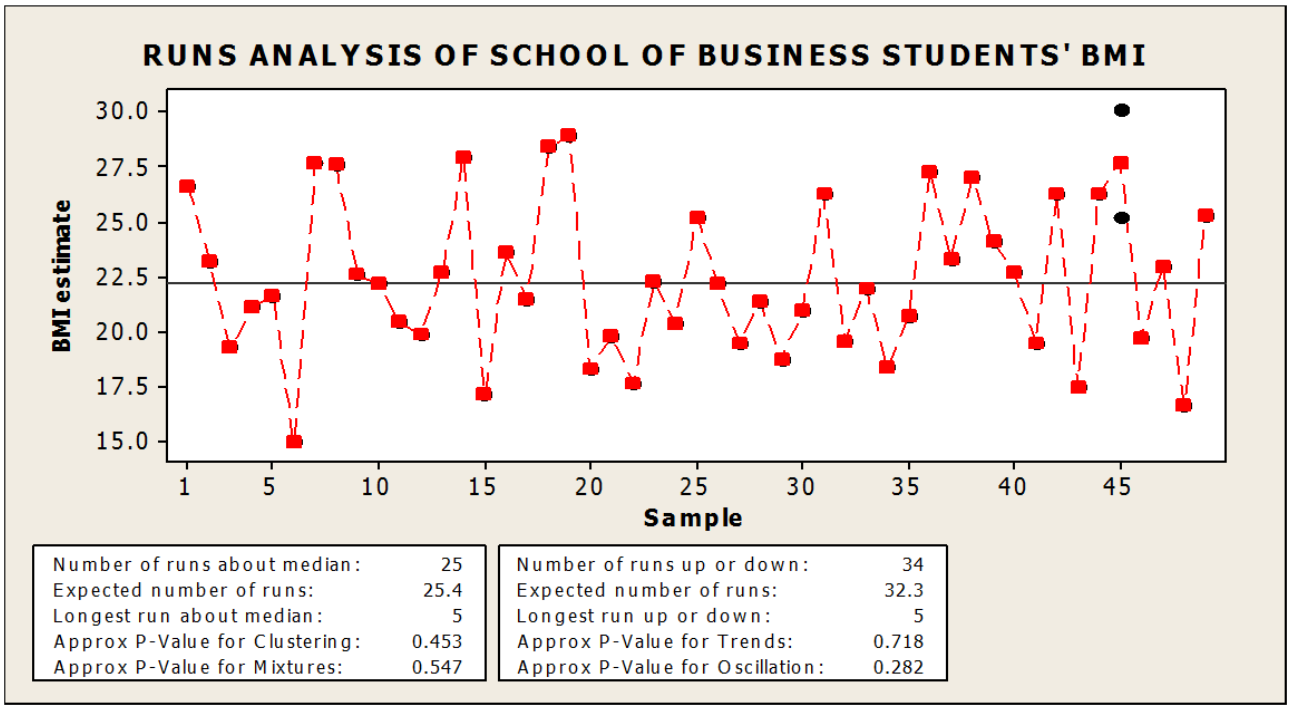

Figure 6. *Runs analysis for School of business students.*

The result presented in Figure 5 shows that the BMI of students tends to be in statistical control when the expected BMI of each student is overweight (22.5) which is optimally within the normal range of a healthy BMI. This result justifies that student BMI measure of health indicates that students in the school of business are healthy living. Notwithstanding, this BMI report also sounds like an alarming deviation in the control chart and this justifies the need to conduct a runs analysis which will help us investigate whether the BMI reported by the sample is randomly distributed across the students of the faculty.

The result presented in Figure 6 shows that the randomness of the students' BMI was tested and yield a p-value of both trend and oscillation reported values greater than 5% level of significance which implies that the BMI reported is not randomly in the population of students in the School of business.

Table 1. *Frequency distribution of risk assessment for School of Business.*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	MODERATELY OBESE	1	2.0	2.0	2.0
	NORMAL	28	56.0	56.0	58.0
	OVERWEIGHT	14	28.0	28.0	86.0
	UNDERWEIGHT	7	14.0	14.0	100.0
	Total	50	100.0	100.0	

The result presented in Table 1 shows that from the analysis, 56% of the students in School of Business included in this study have normal BMI, whereas, 28% are overweighted, 14% are underweight and 2% obese.

Table 2. *Frequency distribution of risk assessment for applied sciences.*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	MODERATELY OBESE	2	4.0	4.0	4.0
	NORMAL	32	64.0	64.0	68.0
	OVERWEIGHT	5	10.0	10.0	78.0
	SEVERELY OBESE	2	4.0	4.0	82.0
	UNDERWEIGHT	9	18.0	18.0	100.0
	Total	50	100.0	100.0	

The result presented in Table 2 shows that 64% of the students in Applied sciences included in the study are normal with BMI index. However, a combination of obesity indicated that 8% were obese, 10% overweight and 18% underweight.

Table 3. *Frequency distribution of risk assessment for School of Business.*

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	MODERATELY OBESE	6	12.0	12.0	12.0
	NORMAL	18	36.0	36.0	48.0
	OVERWEIGHT	14	28.0	28.0	76.0
	SEVERELY OBESE	1	2.0	2.0	78.0
	UNDERWEIGHT	9	18.0	18.0	96.0
	VERY SEVERELY UNDERWEIGHT	2	4.0	4.0	100.0
	Total	50	100.0	100.0	

The result presented in Table 3 shows that from the analysis, 36% of the students in the School of Business included in this study have normal BMI, whereas, 28% are overweighted, 18% are underweight and 14% obese.

4. Conclusion

This study examined the health status of students as a function of the body mass index. The utility of body mass index has proven very useful in helping to estimate the weight normality of students as a measure of healthy living among them. This study evaluated the reported BMI of students and problems associated with abnormal BMI among students. The result of the study revealed that the students BMI are statistically in control for school of business, out of control for school of applied sciences (both Xchart and MR-chart), in control for X-chart and out of control for MR-chart in school of engineering and as a result, the test proved to be false, it implies that the sample result is evident enough to infer on the general population that their current measures of body mass index are random.

It is hereby concluded that quality control is a veritable tool for BMI diagnostics.

The study also revealed that most students' BMI was classified according to WHO standard to be obese which indicates a huge health risk of various obese-related diseases like diabetes, cardiac issues and even stroke.

To effectively maintain healthy living, this study recommends the following:

(i). It is important for parents to understand this study in order to ensure their children having a better life with an ideal body mass index,

(ii). Parents and individuals can also take a class or counseling about nutrition or healthy eating pattern.

References

[1] Baumgartner, R. N., Heymsfield, S. B. & Roche, A. F. (2017): Human body composition and the epidemiology of chronic disease. *Obesity Research*, 3 (1): 73–95.

[2] Chukla, O. (2019). Impact of work-relatedfactors, lifestyle, and work ability on sickness absence among Dutch construction workers. *Environ. Health*, 35, 325–333.

[3] Eherevie, M. (2019). Application of statistical process control in monitoring blood sugar level. Independent Status Publishing Series, Ekewhan, 2 (9): 23-28.

[4] medicalnewstoday.com. What is obesity, and what causes it? Available at https://www.medicalnewstoday.com/articles/323551.

[5] Ozilgen, S (2011). Statistical quality control charts: new tools for studying the body mass index of populations from the young to the elderly. The Journal of Nutrition, Health & Aging 15 (5): 333-339.

[6] Popkin, B. M., Adair, L. S. and Ng. S. W. (2012): Global nutrition transition and the pandemic of obesity in developing countries. *Nutr Rev*. 70 (1): 3–21.

[7] Robert, R. E. (2020). Prospective association between obesity and depression: evidence from the Alameda County Study." *International journal of obesity* 27. 4: 514-521.

[8] Roswati, N., Norimah, S., Fatin, F. N. &Nurul, F. A. (2018). Factors Influence on Body Mass Index (BMI) among Overweight and Obese School Children. *Journal of ASIAN Behavioural Studies* (*jABs*), 3 (11).

[9] The US National Heart, Lung and Blood Institute (2019): Assessing Your Weight and Health Risk. Retrieved from the US-NHLBI portal on 19/6/2020 https://www.nhlbi.nih.gov/health/educational/lose_wt/risk.htm.

[10] Webster, U. (2019): Statistical process control (SPC) chart techniques to support data quality and information proficiency: the under-pinning structure of high, Quality Health Care. *Journal of Advanced Sciences*, 23 (2).

[11] Wikipedia (2018). Body mass index (BMI). Available at https://en.wikipedia.org/wiki/Body_mass_index.

[12] World Health Organization (2018): Obesity*: preventing and managing the global epidemic*. (WHO Obesity Technical Report Series No. 953.) World Health Organization, Geneva.

[13] World Health Organization (2019). Growth reference 5-19 years - BMI-for-age (5-19 years). Available at https://www.who.int/to-reference-data-for-5to19-years/indicators/bmi-for-age.

[14] World Health Organization (WHO, 2012): 2010 Fact Sheet on Obesity. Retrieved on 19/6/2020 from http://www.who.int/topics/obesity/en/.

[15] Yancy, P. (2018): Health Benefits of Having a NO RISK BMI. *International Journal of Behavioral Nutrition and Physical Activity*, 13 (4).