An Extended Framework on the Dynamics of Human Vital Signs of Overweight and Underweight Joggers.

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Abstract. For a number of decades, healthcare professions and organizations have utilized the recording of vital signs as a means to evaluate the physiological status of an individual. In this study, an extended framework in the analysis of the dynamics of human vital signs of individuals performing strenuous activities specifically jogging on overweight and underweight individuals with the use of deterministic approach of chaos theory in the human vital signs is presented. With the use of the Largest Lyapunov Exponent test, it was recognized in a previous study that the chaotic properties of vital signs during physical exercises of individuals with normal body mass index is present. To further examine, this study focused on the health risk of overweight and underweight individuals in their jogging sessions. The Largest Lyapunov Exponent test was used to measure the risk according to the degree of chaos in each vital sign (blood pressure, respiratory rate & heart rate). The Body Mass Index are correlated to the occurrence of chaotic patterns to evaluate whether being overweight or underweight can be considered as a risk factor. This research aims to present a guideline in the reduction of risks that is associated with the irregularities in jogging patterns of overweight and underweight individuals.

1. Introduction
Weight irregularity can have an effect on the health status or general well-being of a person. Various health problems have been linked with weight disorders [1]. Significant deviation from normal weight (overweight and underweight) and lack of physical exercise have been identified as three of the most significant global behavioral risks to health [2,3]. Being obese and overweight are prone to many health problems such as diabetes, different types of cancer, high blood pressure, and heart diseases [4]. A gradual loss in weight and achieving the normal one prevents the risks of an individual to certain diseases and prolong each of their lives [5].

It is highly recommended that overweight and underweight individuals should engage in doing various physical activities and exercises which will greatly benefit their well-being [6]. One of the simplest and affordable ways in subscribing to a healthy lifestyle is jogging. Jogging aids in building stronger bones and improve cardiovascular fitness. However, overexerting too much in this activity may pose serious threats to the health of joggers especially starters who are overweight and underweight [7].

For various decades, medicinal services callings and associations have used the account of vital signs as a way to assess the physiological status of a person. This data, which customarily has comprised of circulatory strain, temperature, beat rate, respiratory rate and oxygen immersion
Thus, this study presents a mathematical framework in the determination of health risk of joggers which may be manifested through irregularities in their human vital signs. The researchers considered joggers who are then categorized into two groups: 1) overweight individuals and 2) underweight individuals. This study further aims to determine using the dynamics of the human vital signs the risk involved among joggers and to present a framework that can be used to assess the physical state of the individuals through the level of chaos in the human vital signs. The study will be of help to determine the risk factors and/or benefits of doing strenuous physical exercises specifically jogging therefore will be first-hand useful to overweight and underweight individuals in providing them knowledge regarding their health maintenance.

2. Methodology

2.1. Research Design
The study is classified as a quantitative research due to the reason that statistical and mathematical methods are used in the analysis of the data that were collected using a survey. The result of this research shows a mathematical framework in evaluating health risk for overweight and underweight joggers by using a test for chaos in human vital signs. iCare Health monitor mobile application was used in directing measurements of human vital signs. To show the certainty of the degree of chaos, the Largest Lyapunov Exponent Test was used.

2.2. Data Gathering
The research model contains overweight and underweight individuals who were randomly selected around Manila and Quezon City. These individuals were then categorized according to their BMI as either overweight or underweight. The demographic variable of the participant was collected through random sampling. The participants were grouped according to their genders: 1) Male and 2) Female. Each category includes 20 individuals. The number of participants has a total of 80. The researchers randomly selected individuals who were qualified to participate in the study based on the BMI category stated in this study. The researchers secured the consent of the participants to gather pertinent data through a survey form which were used for data analysis. Monitoring and recording of vital signs during the physical activity was done with the use of iCare Health Monitor Application, a mobile application. The Largest Lyapunov Test was utilized to determine the degree of chaos.

2.3. Data Analysis and Correlation
In the study, the data were separated in MS Excel® into time series of the participant within the range of 30 minutes. In obtaining the Largest Lyapunov Exponent (LLE), a positive value is considered to be chaotic and a negative value as non-chaotic. A higher value of the LLE has a higher degree of chaos. The statistical tools that were used in the correlation of data between the BMI and the degree of chaos were explained.

3. Result and Discussion
Box Plots are commonly used to compare single-value or range of values for easier and more effective decision making. It can summarize the data and display the results in a single graph. Based on Figure 1, and Table 1, for the overweight individuals, it is presented that the data ranges from -0.03 to 2.37 giving us a range of 2.37. The 50% of the data were concentrated on the range between 0.9652 to 1.3562. Even though the graph shows that the boxes were symmetrical, if the whiskers
will be considered, it presents that the data is negatively skewed meaning that the values of the LLE are more concentrated on the upper part of the graph. In the case of underweight individuals for the heart rate vital sign, it is shown that the ranges of the values of the LLE is from -0.06 to 2.02. The middle half of the data were concentrated on the range between 0.7223 to 1.7924. There were more values clumped together in the 2nd quartile or the range from the first quartile to the median as shown in the plot. Also, values are more skewed negatively meaning that the values of the LLE are more clumped together on the upper part of the graph.

In comparing the overweight individuals to underweights, it is displayed that the overweight LLE values has a wider range than the underweight LLE values. Also, for both BMI categories, the LLE values are more concentrated on the upper level of the plot and more distributed on the lower level.

![Boxplot of the heart Rate Largest Lyapunov Exponent vs BMI Category](image)

**Figure 1.** Boxplot of the heart Rate Largest Lyapunov Exponent vs BMI Category

| Statistic | OW       | UW       |
|-----------|----------|----------|
| N Valid   | 40       | 40       |
| Missing   | 0        | 0        |
| Mean      | 1.3104   | 1.1919   |
| Median    | 1.3562   | 1.1622   |
| Range     | 2.39     | 2.08     |
| Minimum   | -0.03    | -0.06    |
| Maximum   | 2.37     | 2.02     |
| Percentiles 25 | .9652 | .7223 |
| 50        | 1.3562   | 1.1622   |
| 75        | 1.7334   | 1.7924   |
| 100       | 2.3665   | 2.0204   |

**Table 1.** Boxplot of the heart Rate Largest Lyapunov Exponent vs BMI Category

Based on Figure 2 and Table 2, the boxplot for the overweight individuals of the Systolic Blood Pressure can imply that the LLE values variation are more skewed negatively meaning that the concentration of the values of the Largest Lyapunov Exponent of the Systolic Blood Pressure are on the upper level of the range -1.15 to 2.34. It has an outlier having a value of -1.15. The range of the 1st quartile to the 3rd quartile which represents the middle half of the data is 0.8721 to 1.9738.
For underweight individuals for the Systolic Blood Pressure LLE values, it can be seen in the boxplot that the distribution of the values is quite uniform, meaning that the values are spread equally within the range -0.06 to 2.02. It is slightly skewed to positively meaning that the concentration of the values of the LLE were slightly on the lower level of the range of its LLE. Same with the Heart Rate LLE values plot, the range is wider on the overweight individuals having a range equal to 3.50 for the Systolic Blood Pressure LLE values than the underweight individuals with a range of 2.08. Also, even though that the skewness of the plot is different, it is presented that the concentration of the 50% of both the boxplots are within the same range.

**Figure 2.** Boxplot of the Systolic Blood Pressure Largest Lyapunov Exponent vs BMI Category

**Table 2.** Statistic Range Systolic Blood Pressure Largest Lyapunov Exponent vs BMI Category

| Statistic     | OW      | UW       |
|---------------|---------|----------|
| N             | 40      | 40       |
| Valid         | 40      | 40       |
| Missing       | 0       | 0        |
| Mean          | 1.2846  | 1.1919   |
| Median        | 1.3684  | 1.1622   |
| Range         | 3.50    | 2.08     |
| Minimum       | -1.15   | -0.6     |
| Maximum       | 2.34    | 2.02     |
| Percentage 25 | 0.8721  | 0.7223   |
| 50            | 1.3562  | 1.1622   |
| 75            | 1.7334  | 1.7924   |
| 100           | 2.3665  | 2.0204   |

Based on Figure 3 and Table 3, For Overweight individuals, it is shown that the values of the LLE are distributed uniformly on the range of the values. It has an extreme outlier with a value of -1.70. Its ranges id from -1.70 to 2.39. Same with the graph for the overweight individuals, for the underweight individuals, it shown that the boxplot is symmetric, meaning that the distribution of the values of the Largest Lyapunov Exponent of the Diastolic Blood Pressure is uniform all throughout the range which is from -0.85 to 2.31. There is an outlier with a value of -0.85.

Compared to the other box plots, for the Diastolic Blood Pressure LLE values, it is presented that it has a smaller range meaning that the LLE values are more concentrated on the upper level of the plots.
Figure 3. Boxplot of the Diastolic Blood Pressure Largest Lyapunov Exponent vs BMI Category

Table 3. Statistic Range Diastolic Blood Pressure Largest Lyapunov Exponent vs BMI Category

| Statistic | OW       | UW       |
|-----------|----------|----------|
| N Valid   | 40       | 40       |
| Missing   | 0        | 0        |
| Mean      | 1.2511   | 1.2523   |
| Median    | 1.3138   | 1.3306   |
| Range     | 4.09     | 3.16     |
| Minimum   | -1.70    | -0.85    |
| Maximum   | 2.39     | 2.31     |
| Percentage| 25.9256  | 25.9140  |
| 50        | 1.3138   | 1.3306   |
| 75        | 1.6759   | 1.7144   |
| 100       | 2.3909   | 2.3105   |

Based on Figure 4 and Table 4, for the overweight individual for the Respiratory Rate LLE, it is presented that the boxplot is skewed negatively or the values of the LLE were concentrated on the lower part of the plot which ranges from -0.26 to 1.70. The middle half of the data were presented by the values between the 1st and 3rd quartile which is from 0.1835 to 0.8037. It is also shown that the data were more concentrated on the 3rd quartile than on the 2nd quartile.

For underweight individuals, the plot is skewed negatively meaning that the data were more concentrated on the upper part of the plot. It can also be seen that more concentration of the values of the LLE were on the second quartile which ranges from the first quartile which is equal to 0.1835 to the 2nd quartile or median which is equal to 0.5736.

In comparison of the BMI categories for the LLE values of the Respiration Rate, it is shown in the ranges of the values that it is wider on the underweight individuals than on those who were overweight.

Even though the concentration of the values of the Largest Lyapunov Exponent of each of the vital signs were different, it is presented that the ranges of the values still overlaps when categorized by their BMI Categories, being Overweight or Underweight. Meaning that there are no difference on the ranges of the LLE for both the BMI Categories.
4. Conclusion
This paper focused on the health assessment of overweight and underweight individuals during jogging sessions. The results show that when the BMI Categories, Overweight and Underweight, are considered, the vital signs still show chaotic patterns. In studying the relationship of the BMI Category of the individuals and the chaotic behavior, it is proven that the variables are independent of each other. This means that being overweight or underweight does not affect the chaotic behavior of the vital signs. Since, the range of the values of the Largest Lyapunov Exponent shows the degree of chaos of the vital signs, it was investigated on whether each of the BMI Categories will have a specific range on the values of the LLE. It was shown in the results that the BMI Category does not affect the degree of chaos of the vital signs. This means that being overweight or underweight of the individual changes the range of the values of the Largest Lyapunov Exponent.

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