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ANALYSIS OF OBESITY RATES ON CALORIE CONSUMPTION OF SOME FOODS IN 40 ASIAN COUNTRIES

ENNY SUPARTINI, PUSPA FAYDIAN RAHMAH, FIRYA FATIN RAHMADANTI, MILA ANTIKASARI, RESA SEPTIANI PONTOH*

Department of Statistics, Padjadjaran University, Bandung, Indonesia

Abstract: Differences in culture, habits, and environment in different countries cause calorie intake consumed in other countries based on different types of food. This triggers an increase in obesity and malnutrition rates in different countries. The method used is a multivariate regression analysis with a sample of 40 countries located on the Asian continent and eleven independent variables. Obtained the form of a regression model to determine the level of obesity in a country. With a significance level of 5%, all assumptions of the multivariate regression model are fulfilled. Based on the results above, it can be concluded that the regression model is suitable model. Furthermore, the k-means analysis was carried out with the optimal number of k formed by the silhouette method as 4 clusters. Cluster 1 consists of 15 countries, cluster 2 consists of 10 countries, cluster 3 consists of 11 countries, and cluster 4 consists of 4 countries. It can be concluded that each country is expected to pay attention to calorie intake and the type of food consumed to decrease obesity rates in various countries.

Keywords: calories; obesity; k-means clustering.

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*Corresponding author

E-mail address: resa.septiani@unpad.ac.id

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1. INTRODUCTION

Obesity occurs when the body becomes obese caused by a buildup of adipose (*adipocytes,* i.e., particular fat tissue stored by the body), which is excessive and causes an imbalance of energy intake with the energy used over a long time [1]. A person can be declared obese [2] when the Body Mass Index (BMI) > 25 kg /m^2.

According to (P2TM Ministry of Health RI. 2018), the value of the Asia-Pacific BMI is based on the WHO classification:

Classification	Body Mass Index
Underweight	< 18.5 kg/m^2
Normal	18.5-22.9 kg/m^2
Overweight	≥23 kg/m^2
Risk	23-24.9 kg/m^2
Obesity I	25-29.9 kg/m^2
Obesity II	≥30 kg/m^2

Table 1. BMI Classification by Asia Pacific Criteria

Obesity is one of the factors causing the emergence of various degenerative diseases such as heart disease and stroke [3]. The disease is the most significant cause of death in the population in the world, especially for the elderly population. In addition, obesity is also one of the causes of increased risk of bone and joint damage. According to [4], three factors cause obesity, including:

1) Physiological Factors

   Physiological factors consist of 2 factors, namely internal factors such as heredity and external factors such as the type of food consumed and the level of activities carried out.

2) Psychological Factors

   Psychological factors that cause obesity include an unstable emotional condition.

3) Accident or brain injury factors

   One example of this factor is an accident that causes brain injury, especially at the center

of hunger regulation.

Calories are a group of macronutrient nutrients, with carbohydrates, proteins, and fats being the largest sources of calories [5]. The body's needs will be fulfilled if the nutrients are sufficient and used efficiently so that optimal nutritional needs. Calories can be burned using physical work, which means work that makes physical human muscles a source of energy [6]. There is energy consumption as a benchmark or determinant of the weight or lightness of physical work. In International Standards (SI), the energy consumed is expressed as a unified unit of Kilo Calories (Kcal) which is equivalent to 4.2 Kilo Joules (Kj) [7].

Everyone has different calorie needs - different depending on age, gender, and physical activity performed. Here is a table of average calorie needs depending on age, gender, and physical activity performed [8]:

Gender	Age (year)	Light activity, plenty of rest)	Moderate activity, quite active	Active	Kind genitals	Age (year)	Light activity, plenty of rest)	Moderate activity, quite active	Active
Children	2-3	1000	1000-1400	1000-1400		4-8	1400	1400-1600	1600-2200
Woman	4-8	1200	1400-1600	1400-1800	Man	9-13	1800	1800-2200	2000-2600
	9-13	1600	1600-2000	1800-2000		14-18	2200	2400-2800	2800-3200
	14-18	1800	2000	2400		19-30	2400	2600-2800	3000
	19-30	2000	2000-2200	2400		31-50	2200	2400-2600	2800-3000
	31-50	2000	2000	2200		51+	2000	2200-2400	2400-2800
	51+	1600	1800	2000-2200					

Table 2. Estimated Energy Requirements dari Institute of Medicine Dietary Reference Intakes, 2002.

There is a difference between intake and energy expenditure which is suspected to be due to lifestyle modifications. A lifestyle that leads to westernization and a sedentary lifestyle is often found, especially in major cities in Indonesia [9]. Of course, this changes the diet to be high in calories, especially with ready meals that can impact obesity. Obesity can be measured from the thickness of the fat folds under the skin or subcutaneously because as much as 50% of the distribution of fat buildup is a lot in the subcutaneous area [10].

Obesity is a problem widely found in many countries. Shifting lifestyles in a less good direction causes obesity rates in many countries to increase. No exception for countries in Asia. Here is a comparison graph of the obesity rates of countries in Asia.

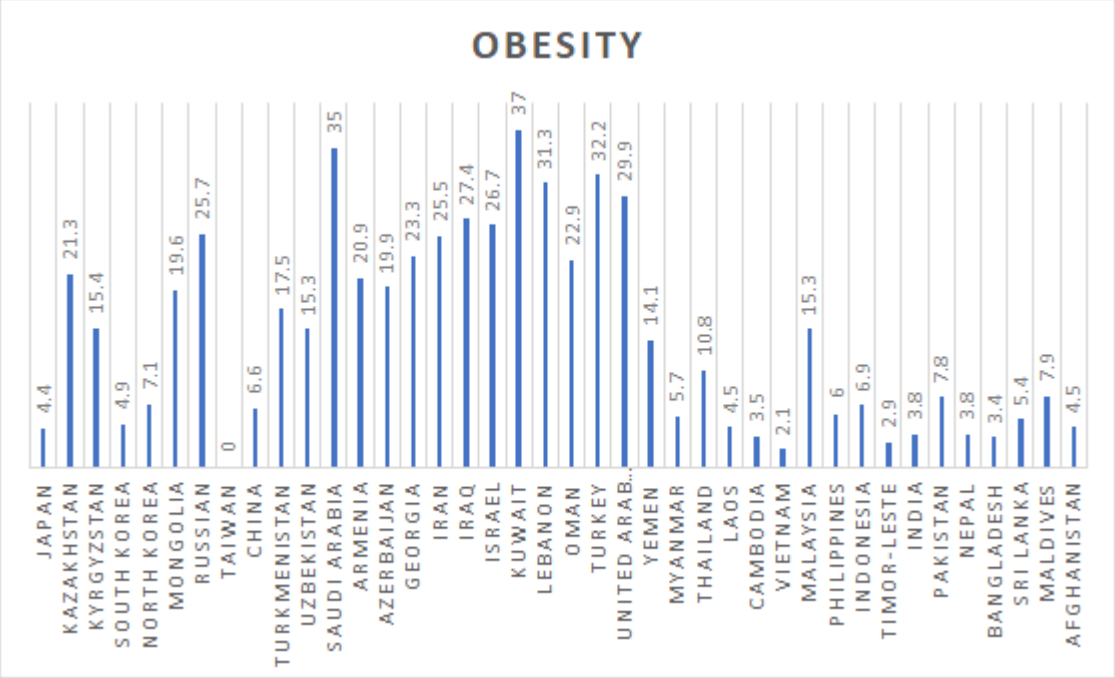

Figure 1 Diagram of obesity rates of 40 Asian countries

From the graph, it can be seen that Kuwait and Saudi Arabia are countries with high obesity rates compared to other countries in Asia. The high prevalence of overweight or obesity rates in Kuwait and some neighbouring countries are due to increased lifestyle behaviors, including nutrition education and exercise [11]. Some previous studies showed that the reasons for the increase in obesity among adolescents in these countries are high fast food consumption, low levels of physical activity, high sedentary behavior, and increased intake of high-fat foods [12]. Studies

show that intake of milk, fast food, sugary drinks, and sugar is significantly associated with sleep duration in boys. In contrast, in children, only fast food and potatoes are significantly associated with sleep duration [13]. Several studies say that short sleep duration significantly increases the risk of obesity in boys and girls [14].

2. RESEARCH METHODOLOGY

This study uses data taken from the site *Kaggle,* which is data on various food calories and obesity levels globally. However, this research will only take the variable of various food calories as variable X and obesity rate as variable Y. The data taken was only taken in the scope of the Asian Continent. The data was collected by a physicist who is experienced in the field of statistics and *programming* named Bruno V. Ribeiro.

There are 11 independent variables selected in this study, namely alcoholic drinks, animal products, cereals, fish and seafood, fruits, meat, milk, tubers, sugar and sweeteners, vegetable oil, and vegetable products. The overall independent variable is the percentage of energy intake (in kcal) from various food groups for 40 different Asian countries. In comparison, the dependent variable consists of the variables of the level of obesity in these 40 countries.

Data analysis was performed using univariate and multivariate methods. Univariate data analysis was carried out to see descriptive statistics of each research variable, such as the average, minimum value, maximum value, and quartile of each variable. Multivariate analysis was performed using a multivariate linear regression test because both the response variable and the predictor variable were more than one and were correlated between variables. The analysis was carried out using *software* R and various *packages* that facilitate the analysis test.

Regression Analysis

Multiple linear regression analysis is one of the data analysis methods used to see the influence of free variables on bound variables.

The general equation is [15]:

$$Y = \beta_{01} + \beta_{11}X_1 + \ \dots \ + \beta_{p1}X_p + \varepsilon_1$$

With

Y: dependent variable

Values matrix X: independent variable value

β : regression model parameter matrix:

ε values matrix: matrix value of error (error)

Testing the Residual Assumptions on the Multivariate Linear Regression Model

Normality Assumptions

The model's residuals must have a multivariate normal distribution, which is stated. The hypothesis used is as follows:$\varepsilon \sim N_p(0, \Sigma)$

H_0 : residuals are normally distributed

H_1 : residuals are generally not distributed multivariate

Tests are carried out using the multivariate normality statistical test of Shapiro Wilk with the formula [16]:

$$T_3 = \frac{1}{D}\left[\sum_{i=1}^{k} a_i (X_{n-i+1} - X_i)\right] \text{ with } D = \sum_{i=1}^{n} (X_i - \bar{X})^2$$

After the Shapiro Wilk value is obtained, a comparison is made between the probability value obtained with the specified significance level. If the probability value is less than the predetermined significance level, then $T_3 H_0$is rejected. Vice versa, accept if the probability value is more than the predetermined significance level H_0

Linearity Assumption Test Linearity

A linearity test determines whether there is a linear relationship between the dependent variable and each independent variable to be tested. The hypothesis used is as follows:

H_0 : linear model

H_1 : non-linear model The

According to Ramsey, the test is carried out using the statistical reset test introduced by Ramsey in 1969. Based on his idea that if there is no non-linearity in the model, the range of non-linear

transformation) is of no benefit. The reset test is formed with the formula: $f_t = (X'_t \hat{\theta} y_t)$ [17].

$$RESET = \frac{[(\hat{e}'\hat{e} - \hat{v}'\hat{v}) \ / \ (k-1)]}{[(\hat{v}'\hat{v}) \ / \ (nk)]}$$

After the reset value is obtained, a comparison is made between probability values obtained with a specified significance level. If the probability value is less than the predetermined significance level, it is rejected. Vice versa, accept if the probability value is more than the predetermined significance level.

Non-Autocorrelation Assumption Test The autocorrelation

The non-autocorrelation test aims to determine whether, in the linear regression model, there is a correlation between confounding error in the period and confounding error in period t-1 (previous). If there is autocorrelation, then there is a problem of autocorrelation that must be resolved.

The hypothesis used is as follows:

H_0 : there is non-autocorrelation

H_1 : there is autocorrelation

Testing is done using the Durbin Watson statistical test, which is formed with the formula [18]:

$$d = \frac{\sum_{t=2}^{n} (e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t^2}$$

After the reset value is obtained, a comparison is made between the probability value obtained with the specified significance level. If the probability value is less than the predetermined significance level, then $Durbin\ Watson\ H_0$ is rejected. Vice versa, accept H_0 if the probability value is more than the predetermined level of significance.

Homoscedasticity Assumption Test

The homoscedasticity test is used to determine whether or not there are deviations from the classic assumption of heteroscedasticity, namely the inequality of variants of the residuals for all observations in the regression model. The hypothesis used is as follows:

H_0 : there is homoscedasticity

H_1 : there is heteroscedasticity

The test is carried out using the statistical test *Breusch Pagan Godfrey* which is formed by the formula:

$$p_i = \frac{e_i^2}{\sigma^2} \quad \text{with} \quad \sigma^2 = \frac{\sum e_i}{n}$$

After the value is *breusch pagan* obtained, a comparison is made between the probability value obtained with the specified significance level. If the probability value is less than the predetermined significance level, then rejected. Vice versa, accept if the probability value is more than the predetermined significance level [19].

Cluster Analysis

Analysis of grouping data for obesity case research in 40 ASEAN countries using the k-means cluster method with the number of clusters formed by four clusters using the help of R. Cluster Analysis software is clearing objects into some parts with the same characteristics. K-means is a non-hierarchical clustering method that divides data into one or more clusters [20]. This method divides the data into clusters so that the data with the characteristics are grouped into one group. Data with the characteristics are placed in the other cluster. Here is the K-means algorithm as follows.

1. Non-multicollinearity assumption test using VIF value ≤ 10
2. Determines the total cluster many k to be formed, and k is used as a randomly formed centroid
3. Calculate Euclidean Distance to find out the power distance to each centroid [21].

   $$min \sum_j^i - a_{ij} = \sqrt{\sum_{k=1}^{p} \left(x_{ik} - x_{jk} \right)^2}$$

   With

   d(i,j) = euclid squared distance between i-th object and to -j object

   X_{ik} *= data from the i-th object on the k-th variable*

   X_{jk} *= data from object to - j on variable to - k*

4. Group each data based on the closest distance between the data and its centroid. And determine the position of the new centroid (k)

$$X_{jk} = \frac{\sum_{j}^{i} x_{ik}}{p}$$

5. Repeat Step 3 if the position of the centroid is new with the old centroid is different

Silhouette Method

The Silhouette Coefficient method is often used to see how well an object is placed in a cluster. The silhouette method can also measure how close the relationship between objects in a cluster is. Here are the stages of calculating the Silhouette Coefficient [22].

1. Calculate the average distance from an object, e.g., with all other objects that are still in one cluster

$$a(i) = \frac{1}{|A| - 1} \sum j \in {}_{a}, j = 1 \; d(i,j)$$

2. Calculate the average distance from object I to all objects in the other cluster by taking the minimum value.

$$d(i,X) = min\, X = \frac{1}{|A|} \sum j \in X \; d(i,j)$$

3. Perform silhouette coefficient value calculations.

$$s(i) = \frac{b(i) - a(i)}{max\,(a(i), b(i))}$$

Multicollinearity Test

The multicollinearity test is an assumption test to determine the correlation or substantial relationship between two or more independent variables. Requirements must be met to avoid multicollinearity before carrying out cluster analysis. The multicollinearity test method is viewed using the VIF (Variance Inflation Factor) model. If the VIF value is less than 10, there is no need for multicollinearity and vice versa [23]. The hypothesis used in multicollinearity tests is:

H_0 = No multicollinearity

H_1 = There is multicollinearity

After the VIF value is obtained, a comparison between the VIG value obtained and the specified VIF value. In this case, the VIF value is used, which is 10. If the VIF value is more than 10, then H0 is rejected. Vice versa, receive H0 if the VIF value is less than 10.

3. RESULTS AND DISCUSSION

Data Sources

This data includes secondary data taken from the site *Kaggle* from an article entitled "*Project Healthy Diet (fighting COVID-19)"* written by Bruno Vieira Ribeiro. The data was collected after the pandemic, which is around 2020.

Descriptive

Statistics These descriptive statistics help explain the data. These descriptive statistics are obtained from calculations using the *software. Table* R

No.	Variable	Minimum	Quartile 1	Median	Average	Quartile 3	Maximum
1.	Obesity	0.00	4.80	12.45	14.46	23.00	37.00
2.	Alcoholic Beverage	0.0000	0.0961	0.3290	0.7084	1.2767	2.4472
3.	Animal Products	2369	4985	8798	8532	10 983	20 375
4.	Cereals	14.67	20.25	23.45	24.68	28.93	37.53
5.	Fish and *Seafood*	0.0000	0.1374	0.3963	0.7497	1.0663	4.4183
6.	Fruits	0.3375	1.1299	1.5626	1.8080	2.2351	6.8918
7.	Meat	0.298	1.981	3.193	3.571	4.499	10.567

8..	Milk	0.1169	0.8294	2.1051	2.6340	4.0059	6.9775
9..	Bulbs – crops	0.3152	0.7202	1.2423	1.4128	1.7553	3.2012
10.	Sugar and sweeteners	0.8619	3.2407	4.3806	4.1877	5.3170	7.7290
11.	Vegetable Oil	0.9325	2.9595	4.0640	4.4530	5.9948	9.8846
12.	Vegetable Products	29.64	39.04	41.21	41.47	45.04	47.64

Table 3. Descriptive Statistics of Calorie Data by Type of Food, Obesity Level, and Level of Undernutrition in 40 countries located on the continent of Asia

Regression Analysis

Regression analysis aims to determine which independent factors affect dependent variables. The regression analysis used is multiple linear regression analysis. Using regression analysis, the results obtained in the form of a linear model whose parameters are simultaneously significant to the model and testing the model's residual assumptions must be met.

4. MAIN RESULTS

No.	Variable	Estimate	Std. Error	t value	p-value of
1.	*Intercept*	4.8851538	1.5072729	3,241	0.003068
2.	Alcoholic beverages	-0.3587205	0.4232016	-0848	0.403829
3.	Animal products	0.0008575	0.0003269	2623	0.013935
4.	Cereal	10.2978392	5.2537015	1.960	0.060003

5.	Fish and *seafood*	1.0678250	0.7493246	1.425	0.165195
6.	Fruits	2.4443191	0.9361913	2611	0.014345
7.	Meat	2.9034086	1.0314382	2815	0.008832
8.	Milk	3.2805045	0.9950619	3,297	0.002662
9.	Tubers	1.0972652	0.5628523	1949	0.061319
10.	Sugar and sweetener	0.0527682	0.0137303	3843	0.000639
11.	The vegetable oil	8.9407809	3.8892591	2.299	0.029187
12.	Products vegetables	1.0657610	0.5173879	2.060	0.048814

Table 4. The final model of linear regression analysis of calories - food calories against obesity level

The table above shows the value of the coefficient in a multivariate linear regression equation of calories in calories contained in the food on the effects of the obesity rate. The value of the equation used is in the estimation column.

Output	
Residual Standard Error	0.001918 on 28 DF
Multiple R-Squared	0.7112
Adjusted R-squared	0.5977
F-statistics	6.268 on 11 and 28 DF
p-value	4.18E-05

Table 5. Summary Output

From the output obtained a calculated F value of 4.18E-05 with a p-value of 4,177e-05 so that it can be interpreted with a significant level of 5% simultaneously, variables have a significant impact on the model. The output also obtained an adjusted value of $R > 0.5$, so it can be said that

the model can already explain 59.7% of changes in dependent variables by independent variables, while other variables influence the rest.

Various Food Calories Affect the Level of Obesity

The average value of the dependent variable if the independent variable = 0

The average level of obesity when all calories of alcoholic beverages = calories of animal products = calories of cereals = calories of fish and seafood = calories of fruits = calories of meat = calories for milk = calories for tubers = calories for sugar and sweeteners = calories for vegetable oil = calories for vegetable products = 0 is 4.8851538.

The average value of obesity rate against alcoholic drink calories

The average obesity rate will decrease by 0.0532715 for each increase of one calorie alcoholic drink unit.

The average value of the obesity rate on the calories of animal products.

The average obesity rate will increase by 0.0008575 for each increase of one calorie unit for animal products.

The average value of the obesity rate on cereal calories

The average obesity rate will increase by 10.2978392 for each increase in one unit of cereal calories.

The average value of the obesity level on the calories of fish and seafood.

The average obesity rate will increase by 1.06782350 for each increase in one unit of calories for fish and seafood.

The average value of the obesity rate on fruit calories

The average obesity rate will increase by 2.4443191 for every increase of one unit of fruit calories.

The average obesity rate for meat calories

The average obesity rate will increase by 2.9034086 for every one unit increase in meat calories.

The average value of the obesity rate on the milk calories

The average obesity rate will increase by 3.2805045 for each increase in one unit of milk calories.

The average value of the obesity rate against the calories of tubers

The average obesity rate will increase by 1.0972652 for every one increment of one tuber calorie unit.

The average obesity rate for sugar and sweeteners calories

The average obesity rate will increase by 0.0527682 for each increase in one unit of calories for sugar and sweeteners.

The average value of obesity rate on vegetable oil calories

The average obesity rate will increase by 8.9407809 for every increase of one calorie of vegetable oil.

The average value of the obesity rate on the calories of vegetable products.

The average obesity rate will increase by 1.0657610 for each increase in one unit of calories for vegetable products.

Testing Assumptions Residual Model

Assumptions Normality Test

After calculating the statistical test multivariate normality *Shapiro Wilks Lambda*, a score *p-value* of 0.2757, it can be concluded that residual normal distribution models.

Linearity Assumption Test

After the statistical test is calculated *reset test* obtained *p-value* is 0.5411, and it can be concluded that the residual model is linear.

Non-Autocorrelation Assumption Test

After calculating using the Durbin Watson statistical test, the *p-value* is 0.124, so it can be concluded that there is no autocorrelation in the residual model.

Homoscedasticity Assumption Test

After calculating using the Breusch Pagan Godfrey statistical test, the p-value is 0.1416, so it can be concluded that there is no homoscedasticity in the residual model.

Cluster Analysis

Cluster analysis is used to group each data into one or more clusters based on the similarity of characteristics of each data. Before conducting a cluster analysis, it is necessary to fulfil the assumption of multicollinearity tests using VIF values.

Variable	Collinearity Statistics
	VIF
Animal Products	5.81643
Fruits	5.200415
Meat	2.964633
Milk	2.596004
Sugar and Sweetener	5.271156
The vegetable oil	4.449496
Products Vegetables	1.214201

Table 6. VIF Value

From the results of multicollinearity testing. It was found that all variables have a value of VIF money less than 10. Then it can be concluded that there is no non-multicollinearity. Furthermore, cluster analysis can be done.

Determination of Cluster K Using Silhouette Method

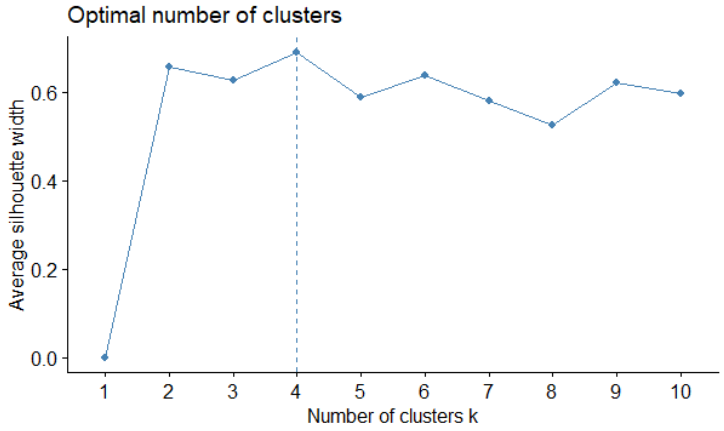

Figure 2. Optimal Number of Cluster

To determine the quality of the cluster that has been formed, all silhouette values of all data in the cluster will be added and then averaged. Here are the assessment criteria for a cluster [24].

Silhouette Coefficient Value	Quality
0,71 – 1,00	A strong structure has been formed.
0,51-0,70	A decent structure has been formed.
0,26-0,50	Weak structure
≤ 0,25	Poor structure

Table 7. Silhouette Coefficient Value

The K-cluster value formation graph of the Silhouette method shows that the optimum k value is negated at point 4 and shows that the average value of silhouette ranges above 0.6. This shows that by forming 4 clusters on data on various food calories against obesity rates in 40 ASEAN Countries, the cluster structure formed is feasible to represent each of the data characteristics.

Cluster Results

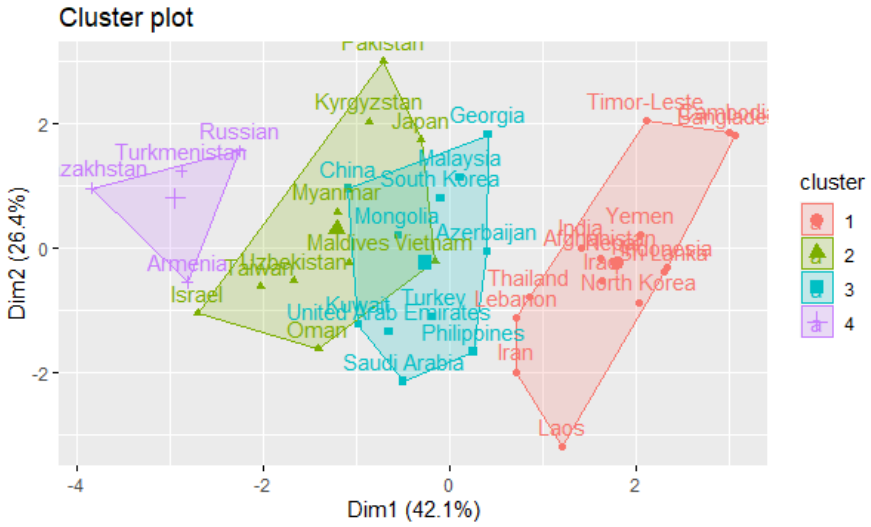

Figure 3. Clustering Analysis

From the above plot, 4 clusters were formed with each ASIAN Country. Cluster 1 consists of 15 countries, cluster 2 consists of 10 countries, cluster 3 consists of 11 countries, and cluster 4 consists of 4 countries.

Cluster 1	Klaster 2	Cluster 3	Cluster 4
North Korea, Iran, Iraq, Lebanon, Yemen, Thailand, Laos, Cambodia, Indonesia, Timor-Leste, India, Nepal, Bangladesh, Sri Lanka, Afghanistan	Japan, Kyrgyzstan, Taiwan, Uzbekistan, Israel, Oman, Myanmar, Vietnam, Pakistan, Maldives	South Korea, Mongolia, China, Saudi Arabia, Azerbaijan, Georgia, Kuwait, Turkey, United Arab Emirates, Malaysia, Philipines	Kazakhstan, Russian, Turkmenistan, Armenia

Table 8. Country Clustering

The data is formed into the original data to show the characteristics of each cluster using an average value.

Cluster	Animal Product	Fruits	Meat	Milk	Sugar and Sweetener	Vegetable Oil	Vegetable Products
1	4.39	1.64	1.74	1.11	3.78	45.6	3.85
2	11.0	2.16	4.39	3.70	3.98	39.0	4.80
3	10.2	1.77	4.75	2.79	4.85	39.8	4.78
4	13.2	1.65	5.15	5.24	4.39	36.8	4.94

Table 9. Characteristics of Each Cluster

Judging from the average number of animal products, fruits, meat, milk, sugar and sweetener, vegetable oil, and vegetable products in each cluster, it can be interpreted that:

Cluster 1 = contains countries with deficient average calorie consumption, including North Korea, Iran, Iraq, Lebanon, Yemen, Thailand, Laos, Cambodia, Indonesia, Timor-Leste, India, Nepal, Bangladesh, Sri Lanka, Afghanistan

Cluster 2 = contains countries with high average calorie consumption, including Japan, Kyrgyzstan, Taiwan, Uzbekistan, Israel, Oman, Myanmar, Vietnam, Pakistan, Maldives

Cluster 3 = contains countries with low average calorie consumption, including South Korea, Mongolia, China, Saudi Arabia, Azerbaijan, Georgia, Kuwait, Turkey, United Arab Emirates, Malaysia, Philippines

Cluster 4 = contains countries with very high average calorie consumption, including Kazakh, Russian, Turkmenistan, Armenian countries

According to [25], adult women in Kazakhstan Country have higher risk factors for blood sugar, blood pressure, and obesity than countries in other regions. In 2008, the average obesity rate for adult men was about 20.2, while the average obesity in adult women was about 27.4.

Nutritional imbalances also reflect that animal consumption is not fulfilled, and people prefer to eat foods that contain saturated fat. This is a risk factor for developing cardiovascular disease in-country Kazakhstan. In addition, the level of iodine in the water is insufficient and is found in parts of Kazakhstan [26]. This leads to high rates of prevalence of thyroid deficiency, especially in the southern and eastern regions of the country. Meanwhile, Timor-Leste is arguably the least developed country compared to the surrounding countries. Therefore, a relatively lower proportion of underweight or obese can be understandable [27].

5. CONCLUSION

Based on the results of the above analysis, information was obtained that independent variables that can have a significant effect are animal products, meats, milk, fruits, sugar and sweeteners, vegetable oils, vegetable products, and cluster formation using K-means with the Silhouette method to get the optimal K klister obtained as many as 4 clusters with a description cluster 1 is contains countries with an average of very-low-calorie consumption, cluster 2 contains countries with high average calorie consumption, cluster 3 contains countries with low average calorie consumption, cluster 4 contains countries with very high average calorie consumption. Each country is expected to pay attention to calorie intake and the type of food consumed to decrease obesity rates in various countries.

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CONFLICT OF INTERESTS

The author(s) declare that there is no conflict of interests.

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