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An Analysis of Crude Death Rate in Malaysia

Ilyana Najihah Mohd Ruzi, Zarina Mohd Khalid*
Department of Mathematical Sciences, Faculty of Science, Universiti Teknologi Malaysia
*Corresponding author: zarinamkhalid@utm.my

Abstract
The purpose of this study is to analyse the crude death rate in Malaysia by evaluating and comparing the two models of Analysis of Variance (ANOVA), which are the one-way ANOVA and the two-way ANOVA tests. The one-way ANOVA test is a technique that generalises the two-sample t-test to three or more samples. The hypotheses about the population mean that the test is based on the observed sample mean. Two-way ANOVA is used to estimate how the mean of a quantitative variable changes according to the levels of two categorical variables. It is compared to the gender and crude death rate in certain Malaysian states in this study. These models are fitted to Malaysia's mortality data for genders and crude death rates in every state in Malaysia from 2018 until 2021. The result showed that all the assumptions of ANOVA for both tests were satisfied. The null hypothesis can be rejected, indicating that differences in population means exist. However, both tests need to undergo transformation since the homogeneity of variances rule has been violated. To check the equality of the variances for both ANOVA tests, an independent-sample T test has been used for one-way ANOVA and Weighted Least Square regression for two-way ANOVA.

Keywords: Analysis of Variance; One-way ANOVA; Two-way ANOVA; populations mean;

1. Introduction

As the world's population keeps growing, it is important for the application of mortality modelling. The death rate of a nation is one of the most important determinants of its relative well-being [1]. Human mortality rates begin to increase with advancing age, starting around 20. 85 years has been suggested as the biological limit of human life expectancy [2]. Mortality tables were created in the United Kingdom to help insurers predict changes in death rates, to protect insurers against losses. Concepts related to mortality, annuities, and adverse risk selection were already mentioned in the empirical and theoretical literature of the 19th century [3]. Gompertz (1825) noted that adult mortality increases exponentially as a function of age. The study of the death rate led to the development of graduation models [4]. These models have been used to soften the crude death rate and to analyse the behaviour of the dying.

The main objective of this study is to analyse female and male mortality rates within districts within states in Malaysia. Two models of analysis of variance are applied to the Malaysian data between 2018 and 2020. A comparison is then made by population means for each state in Malaysia, using the ANOVA models.

The crude death rate in every district in each state in Malaysia varies. Being in a rural area or an urban area shows a different pattern of death rates. Understanding the fundamental reasons that influence mortality is helpful for wellbeing strategy and intercession plan. This study will present the reasons why, in particular, districts and states have high death rates or low death rates respectively.

An ANOVA is a measurement tool that divides an observed total changeability found within an informational collection into two sections: deliberate elements and arbitrary variables. Examiners utilise the ANOVA test to decide the impact that free factors have on the dependent variable in a relapse

review. Using the ANOVA approach, it makes it easier to observe a problem involving comparing samples from a population by assuming that all the samples are independent.

2. Literature Review

2.1. Statistical Crude Death Rate

The death rate can be obtained by dividing the total number of deaths in a year by the number of thousands in the population. There are plenty of methods for analysing the mortality model, such as stochastics, regression, and more. It depends on two independent variables in order to be able to compare these fractions [10].

The population standard of population in England and Wales was introduced in 1901 by Dr. Stevenson and his co-workers. They used data for males and females in each of the twelve age groups among the white British population. They calculated the number of deaths that would occur among each group in a year at the standard death rate [11].

This is significant on the grounds that the projections of a marker over the long run will be comprised of corresponding qualities, which requires either the utilisation of longitudinal information strategies or useful information techniques to examine definitively. In a previous study, Letizia et al. (2021) looked at the anticipated mortality markers utilising practical ANOVA [12].

2.2. The cohort effects

The life table is the most important tool for studying mortality. It shows the chances of dying for a population based on gender, age, education, ethnicity, occupation, and lifestyle variables such as smoking or non-smoking status. The cohort life table depicts the death experience of a given cohort (born in the same year).

Death rates have been connected to explicit age or year of birth [13] The birth accomplice fulfils the presumption that individuals brought into the world around the same time or time span encounter comparable wellbeing impacts. This has been confirmed in the UK in examinations [14,15].

The cohort effect has been taken on from different areas of exploration, including the study of disease transmission and sociology [15]. The extended period of birth essentially influences the death rate through a mix of variables. Richards et al. 2006, found that the greatest improvement in death rates in England and Wales was made possible by individuals brought into the world in or around 1930 [13].

2.3. Analysis of Variances (ANOVA)

2.2.1 One-way ANOVA test

Rice and Gains (1989) broadened Barnard's argument in order to obtain an accurate answer for the single direction ANOVA problem [5,6]. Welch (1951) provided an estimated response to the question, which works beautifully with large examples [7]. Krutchkoff (1988) proposes a reproduction-based method for estimating an arrangement that works well even with small instances [8].

2.2.2 Two-way ANOVA test

In the importance testing of hypotheses in the two-way ANOVA model, each summed up F-test proposed is definite as it depends on a p-value, which is the specific likelihood of a clear-cut subset of the example space (outrageous area). Krutchkoffs (1989) work, which describes a reenactment-based method for obtaining an estimated exam, is highly compelling. The test is unprejudiced as to the likelihood of the outrageous locale increments for any deviation from the valid hypothesis. This implies that if the probability of the extreme area is processed expecting that the invalid hypothesis is valid, it will be brought down to what it should be, along these lines, bringing about more modest probabilities when the invalid hypothesis is not true [9].

2.4. Review of the death rates by gender

Women live longer than men in both affluent and poor countries, it is now widely known [16]. The reasons for this divergence have been attributed to a variety of organic, sociological, monetary, and

societal factors. Paleo-demographers think that these distinctions were linked to the emergence of agiculture in early social hierarchies [17].

One of the primary elements accepted to impact life-range is the female-explicit chemical, oestrogen [18]. This chemical is known to secure the mind and focal sensory system from degenerative issues. It protects women against ischemic heart disease and coronary infection with a similar device [19]. The occurrence of heart attacks in postmenopausal women is lower than that of men in a similar age group [16]. Excessive testosterone levels can lead to risky and violent behaviour. Men are more prone to social influences than women [20]. Excessive strain and weakness might lead to undesired behaviours such as cigarette smoking and excessive alcohol consumption. Women are more conscious of the importance of seeking therapeutic advice for medical concerns [19].

The distinction in death rates between the sexes has been expanding since 1860, with an abundance of male deaths across most age groups. The special case was between the ages of 5–15, preceding 1930, when a particular female drawback was seen [21]. For a long time, between 18 and 25 years, male death rates were the most noteworthy. There was also a peak around the age of 60, owing to an increase in cardiovascular diseases (CVD) [22].

3. Methodology

3.1. Research Data

The purpose of this study is to use the ANOVA approach to explain trends in the crude death rates of the male and female populations in Malaysia. There will be two stages involved, which are the sampling and analysis stages. At the sampling stage, samples will be extracted from data that is sourced from the Department of Statistics Malaysia (DOSM) and for the analysis stage, the mean outcome and variance component associated with each source of the data are estimated.

3.2 Normality Test

ANOVA is a parametric test that assumes that the data fit the normal distribution. Simulation studies have shown that p-values from F-tests are highly sensitive to deviations from normality. The null hypothesis is that the sample distribution is normal. If the test is significant, the distribution is non-normal.

$$H_0 : \mu = \mu_0 \; and \; \sigma = {\sigma_0}^2, \tag{1}$$

$$H_1 : p_Y(y) \neq p_{N(\mu,\sigma^2)}(y), for \; all \; \mu \in \mathbb{R} \; and \; \sigma^2 > 0 \tag{2}$$

3.3 Homogeneity Test

The assumption of homogeneity of variance (HOV) in an ANOVA process is that treatment variances are identical. Therefore, the null hypothesis is;

$$H_0 : {\sigma_1}^2 = {\sigma_2}^2 = \cdots {\sigma_k}^2, \tag{3}$$

where *k* denotes the number of groups compared in a study.

3.4. ANOVA test

The stages in the analysis the crude death rates for Malaysian population using ANOVA are as follows:

1) Setup the null and alternate hypothesis.
2) Select the appropriate test statistic
3) Set up decision rule
4) Compute the test statistic
5) Conclusion

3.4.1. One-way ANOVA test

There are three primary assumptions of one-way ANOVA:

a) The responses for each factor level have a normal population.
b) These distributions have the same variances.

c) The data are independent.

In this study, *s* represent states in Malaysia. Therefore, for the hyphotheses;

$H_0 : \mu_{s_i} = \mu_{s_j}$; $for\ at\ least\ one\ (s_i, s_j)\ where\ s_i \neq s_j\ for\ i^{th}\ state\ on\ j^{th}$ (4)

$H_1 : \mu_{s_i} \neq \mu_{s_j}$; $for\ at\ least\ one\ (s_i, s_j)\ where\ s_i \neq s_j\ for\ i^{th}\ state\ on\ j^{th}$ (5)

The total mean:

$$\mu = \frac{1}{n}\sum_{j=1}^{s} n_j \mu_j \, , n = \sum_{j=1}^{s} n_j \quad (6)$$

The grand mean:

$$\overline{X_J} = \frac{1}{n}\sum_{j=1}^{s} x_j$$

The mean of the samples under level *j*:

$$\overline{x_j} = \frac{1}{n}\sum_{i=1}^{n_j} x_{ij} \quad (7)$$

The total average $\bar{x}$:

$$\bar{x} = \frac{1}{n}\sum_{j=1}^{s}\sum_{i=1}^{n_j} x_{ij} \quad (8)$$

Sum of squared deviation within groups:

$$SSE = \sum_{j=1}^{s}\sum_{i=1}^{n_j}(x_{ij} - \bar{x}_i)^2 \quad (9)$$

Sum of squared between groups:

$$SSC = \sum_{j=1}^{s}\sum_{i=1}^{n_j}(\bar{x}_j - \bar{x})^2 \quad (10)$$

Total of sum squared:

$$SST = SSC + SSE \quad (11)$$

F-statistic formula

$$F = \frac{SSC/(s-1)}{SSE/(n-s)} = \frac{MSC}{MSE} \quad (12)$$

3.4.3. Two-way ANOVA test

There are four primary assumptions of two-way ANOVA:

a) The populations from which samples are obtained must be normally distributed
b) Sampling is done correctly. Observations for within and between groups must be independent.
c) The variances among populations must be equal (homoscedastic).
d) Data are interval or nominal.

The null hyphothesis of interest is ”no difference between treatments.”. Therefore, the hypotheses for two-way ANOVA ar stated as below;

$H_0 : \alpha_i = 0, i = 1,2,3, \dots, t$ (13)

$H_1 : \alpha_i \neq 0, i = 1,2,3 \dots, t$ (14)

For two-way ANOVA table, it is assumed that main effect A has a levels (A=a-1 df), main effect B has b levels (B=b-1 df), n is the sample size of each treatment, and N=abn is the total sample size. Notice that the overall degrees of freedom is once again one less than the total sample size. Table below shows a basic table for two-way ANOVA table.

4. Results and discussion

4.1. Analysis of Malaysian Male Crude Death Rate

Life expectancy in Malaysia has changed significantly for decades for both males and females. According to the latest data published by WHO (2018), the life expectancy for a male is 73.2, a female is 77.6 and the total life expectancy is 75.3. There is an increase in Malaysian male longevity from 58.84 years in 1960 to 74.08 years in 2018 [23].

4.1.1 One-way ANOVA Test for analysis of Malaysian male crude death rate

Table 1 ANOVA table for Malaysia male crude death rate for 2018-2020

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CDR_2018	Between Groups	169.168	13	13.013	5.860	<.001
	Within Groups	290.899	131	2.221		
	Total	460.066	144			
CDR_2019	Between Groups	136.840	13	10.526	5.573	<.001
	Within Groups	247.415	131	1.889		
	Total	384.256	144			
CDR_2020	Between Groups	119.669	13	9.205	4.164	<.001
	Within Groups	289.617	131	2.211		
	Total	409.286	144			

The f-value of the crude death rate for each state in Malaysia is 5.751, 5.481, and 4.081 for 2018, 2019, and 2020, according to Table 1. Because the p-values are smaller than the specified alpha value, it is significant because it was chosen for the test. However, the variances are intended to be the same, the assumptions of the one-way ANOVA test. When the significant p-value exceeds the 0.05 level of significance, equal variances are assumed, however the significant p-values clearly less than 0.05. As a result, the presumption has been disproved.

The equality of the variances can be confirmed by doing another independent test, the sample T-test. Johor and Malacca have been chosen as the t-test samples in this debate. The variations in either of these two states are equivalent.

Table 2 Independent Sample T-test for Johor and Malacca for Malaysian male crude death rate for 2018-2020

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
CDR_2018	Equal variances assumed	2.815	.122	.293	11	.775	.2400	.8189	-1.5624	2.0424
	Equal variances not assumed			.482	10.617	.640	.2400	.4983	-.8615	1.3415
CDR_2019	Equal variances assumed	2.366	.152	.647	11	.531	.4933	.7623	-1.1845	2.1711
	Equal variances not assumed			1.114	10.997	.289	.4933	.4428	-.4812	1.4679
CDR_2020	Equal variances assumed	1.861	.200	.427	11	.677	.2967	.6940	-1.2309	1.8242
	Equal variances not assumed			.687	10.175	.508	.2967	.4321	-.6638	1.2571

The significance value in Table 2 reveals an inconsequential value that is more than the 0.05 level of significance. As a result, the null hypothesis is not rejected. As a result, the equality of variances assumption has been met.

4.2 Analysis of Malaysian female crude death rate

The Malaysian female lifespan has been increased, on average, from 62 years in 1960 to 79 years in 2018, and the mortality rate is decreasing [24].

4.2.1 One-way ANOVA Test for analysis of Malaysian male crude death rate

Table 3 ANOVA table for Malaysia female crude death rate for 2018-2020

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CDR_2018	Between Groups	111.832	13	8.602	6.134	<.001
	Within Groups	183.723	131	1.402		
	Total	295.555	144			
CDR_2019	Between Groups	92.994	13	7.153	4.861	<.001
	Within Groups	192.787	131	1.472		
	Total	285.781	144			
CDR_2020	Between Groups	103.560	13	7.966	5.995	<.001
	Within Groups	174.079	131	1.329		
	Total	277.639	144			

The f-value of the crude death rate for each state in Malaysia is 6.134, 4.861, and 5.995 for 2018, 2019, and 2020, respectively, according to Table 3. Because the p-values are less than the alpha value we specified for the test, the results are significant. Because there are disparities in the means, the null hypothesis is rejected. The assumptions must be examined before the conclusion can be accepted to see if they have been violated or not. The premise of equal variances has been broken in this circumstance. As a result, one-way ANOVA is not an option.

As a result, another test is required. An independent sample T-test must be used to verify variance equality. The equality of variances of these states can be validated by using Johor and Malacca as t-test samples.

Table 4 Independent Sample T-test for Johor and Malacca for Malaysian female crude death rate for 2018-2020

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
CDR_2018	Equal variances assumed	.495	.496	.202	11	.844	.1233	.6116	-1.2228	1.4695
	Equal variances not assumed			.250	4.965	.813	.1233	.4934	-1.1477	1.3943
CDR_2019	Equal variances assumed	.201	.663	.033	11	.974	.0233	.7050	-1.5283	1.5750
	Equal variances not assumed			.037	3.996	.972	.0233	.6295	-1.7253	1.7720
CDR_2020	Equal variances assumed	.000	.997	-.620	11	.548	-.4100	.6609	-1.8647	1.0447
	Equal variances not assumed			-.616	3.277	.578	-.4100	.6661	-2.4318	1.6118

4.3 Two-way ANOVA test for states and gender of crude death rate in 2018

Table 5 The result of test of between-subject effect of crude death rate in 2018

Tests of Between-Subjects Effects

Dependent Variable: CDR_2018

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	391.113[a]	27	14.486	7.937	<.001	.450	214.293	1.000
Intercept	4266.871	1	4266.871	2337.842	<.001	.899	2337.842	1.000
States	277.385	13	21.337	11.691	<.001	.367	151.981	1.000
Gender	47.407	1	47.407	25.974	<.001	.090	25.974	.999
States * Gender	12.780	13	.983	.539	.899	.026	7.002	.322
Error	478.185	262	1.825					
Total	10761.090	290						
Corrected Total	869.298	289						

a. R Squared = .450 (Adjusted R Squared = .393)

b. Computed using alpha = .05

Based on Table 5, a two-way ANOVA test revealed there was not a statistically significant interaction between the states and gender. Using the F-test, we have the interaction effect, F(13,262) = 0.539, p =0.539, $partial\,\eta^2 = 0.026$ and observed power = 0.322. There is insufficient evidence to reject the interaction effect null hypothesis since we have a significant p-value of 0.899, which is a huge number compared to the level of significant (α=0.05).

The error variance of the dependent variable is equal across the group. As a result, the null hypothesis must be rejected because the significant value is less than the level of significance 0.05, implying that the dependent variable's variance is not equal. As a result, the two-way ANOVA violates the criterion of equality of variance. This data does not allow for a two-way ANOVA test.

Instead, we planned to use Weighted Least Square regression. The significant value is less than the level of significance of 0.05, as shown in Table 6. As a result, there is enough evidence to rule out the null hypothesis. As a result, in 2018, there is a difference in the crude death rate by gender and state.

Table 6 ANOVA table of Weighted Least Square for crude death rate for 2018

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	96.791	2	48.395	31.952	<.001[c]
	Residual	434.695	287	1.515		
	Total	531.485	289			

a. Dependent Variable: CDR_2018

b. Weighted Least Squares Regression - Weighted by weight

c. Predictors: (Constant), Gender, States

4.4 Two-way ANOVA test for states and gender of crude death rate in 2019

Table 7 The result of test of between-subject effect of crude death rate in 2019

Tests of Between-Subjects Effects

Dependent Variable: CDR_2019

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	317.264[a]	27	11.751	6.981	<.001	.418	188.486	1.000
Intercept	4139.627	1	4139.627	2459.343	<.001	.904	2459.343	1.000
States	223.722	13	17.209	10.224	<.001	.337	132.913	1.000
Gender	40.444	1	40.444	24.028	<.001	.084	24.028	.998
States * Gender	9.947	13	.765	.455	.947	.022	5.909	.269
Error	441.005	262	1.683					
Total	10371.710	290						
Corrected Total	758.268	289						

a. R Squared = .418 (Adjusted R Squared = .358)

b. Computed using alpha = .05

According to Table 7, the two-way ANOVA test once again shows there is no statistically significant interaction between states and gender of the crude death rate in 2019. We can see that the p-value is 0.947, or 94.7%, more than 0.05, or 5% level of significance. Using the F-test, we have the interaction effect, F(13,262) = 0.455, p =0.455, $partial\ \eta^2 = 0.022$ and observed power = 0.269. Therefore, there is insufficient evidence to reject the interaction effect of the null hypothesis. Hence, we failed to reject the null hypothesis.

The significance p-values are smaller than the level of significance that we determined. As a result, the assumption of equal variances has been broken. Therefore, a two-way ANOVA could not be performed on this set of data.

Hence, a weighted least square regression was used. Take a look at Table 8, where the significant value is less than 0.05. As a result, there is enough evidence to rule out the null hypothesis. As a result, in 2019, there is a variance in the crude death rate by gender and state.

Table 8 ANOVA table of Weighted Least Square for crude death rate for 2019

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	85.996	2	42.998	31.312	<.001[c]
	Residual	394.108	287	1.373		
	Total	480.105	289			

a. Dependent Variable: CDR_2019

b. Weighted Least Squares Regression - Weighted by weight

c. Predictors: (Constant), Gender, States

4.5 Two-way ANOVA test for states and gender of crude death rate in 2020

Table 9 The result of test of between-subject effect of crude death rate in 2020

Tests of Between-Subjects Effects

Dependent Variable: CDR_2020

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	359.766[a]	27	13.325	7.465	<.001	.435	201.554	1.000
Intercept	4013.189	1	4013.189	2248.329	<.001	.896	2248.329	1.000
States	220.285	13	16.945	9.493	<.001	.320	123.411	1.000
Gender	50.250	1	50.250	28.152	<.001	.097	28.152	1.000
States * Gender	11.702	13	.900	.504	.921	.024	6.556	.300
Error	467.661	262	1.785					
Total	10305.470	290						
Corrected Total	827.427	289						

a. R Squared = .435 (Adjusted R Squared = .377)

b. Computed using alpha = .05

Table 10 ANOVA table of Weighted Least Square for crude death rate for 2020

ANOVA[a,b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	106.595	2	53.297	36.956	<.001[c]
	Residual	413.903	287	1.442		
	Total	520.497	289			

a. Dependent Variable: CDR_2020

b. Weighted Least Squares Regression - Weighted by weight

c. Predictors: (Constant), Gender, States

Refer to Table 19, the two-way ANOVA gives such a huge p-value, which is 0.921. Since the p-value is larger than our chosen level of significant, we failed to reject the null hypothesis. By using the F-test, we have the interaction effect of F(13,262) = 0.504, p =0.504, $partial\ \eta^2 = 0.024$ and observed

power = 0.3. Therefore, there is insufficient evidence to reject the null hypothesis. It is also shows significant p-values is smaller than significant level of $\alpha = 0.05$, which means the equality of variance is violated. Hence, we could not conduct a two-way ANOVA test. By using the Weighted Least Square regression, referred to in Table 10, we get the significant value to reject the null hypothesis since the p-value is less than 0.05. Therefore, there is a difference between the crude death rate in 2020 between the means of states and gender.

Conclusion

In conclusion, ANOVA's following assumptions have all been met. Both tests are capable of rejecting the null hypothesis and providing the proper basis for this investigation. Both tests must be transformed since they violate the homoscedastic requirement. The change is that in order to demonstrate homoscedasticity, both tests must undergo another test. Since the homoscedasticity of the data has been established, the data's normalcy has also been established, and all of the data is independent. As a result, all of ANOVA's assumptions were met, and ANOVA could be tested in this study. There is no other option than to accept the null hypothesis because all of the mean values have been provided and the existence of disparities between means has been demonstrated. As a result, ANOVA tests appear to provide the optimum model for analysing this problem across all scenarios.

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