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A New Statistical Perspective to Life Expectancy Data for the Countries Having Longest Lifetimes as an Indicator of Public Health by Multivariate General Linear Model Approach

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Abstract: ***The aim of this study is to evaluate life expectancy data as an indicator of public health for the countries reported by World Health Organization (WHO) as having the longest lifetimes such as Iceland, Switzerland, Australia, Israel, Singapore, New Zealand, Italy, Japan, Sweden, Luxemburg, Spain, France, Republic of Korea, and Portugal by multivariate general linear model (GLM) approach. In this study life expectancy at birth, life expectancy at age 60, and healthy life expectancy at birth data of these countries are taken as multiple dependent variables measures. In this study, statistically significant risk factors that affect life expectancy for these countries having the longest lifetimes are determined by using multivariate GLM approach. After conducting this technique, average longest lifetimes belonging to these multiple dependent variables are computed in the aspect of the statistically significant risk factors for these countries. Average longest lifetimes for life exp., life exp. at 60, and healthy life exp. of the countries taken into the study are determined as 84.7, 26.7, and 74 years for prevalence of raised fasting blood glucose; 84.27, 26.36, and 74.27 years for prevalence of raisedblood pressure; 82.7, 25.1, and 73.6 years for prevalence of obesity; 84.85, 26.92, and 74.76 years for mortality rate from cardiovascular diseases; 85.1, 27.2, and 74.9 years for mortality rate from cancer; 83.58, 25.74, and 73.53 years for alcohol consumption, respectively, as the main findings of this study.***

Keywords: Life expectancy, public health, World Health Organization, multivariate general linear model

1. Introduction

Life expectancy at birth and life expectancy at age 60 are the indicators for the overall mortality level of a population and the overall mortality level of a population over 60 years, respectively. Healthy life expectancy at birth is another indicator to compute the equivalent number of years of life expected to be lived in full health [32].

World Health Organization (WHO) reported that Iceland, Switzerland, Australia, Israel, Singapore, New Zealand, Italy, Japan, Sweden, Luxemburg, Spain, France, Republic of Korea, and Portugal are the countries having the longest life expectancy at birth by gender in Table 1 [32]. On the other hand, Turkish female and male life expectancies in 2012 are 78.1 and 71.6 years, respectively, according to the WHO data repository [30].

Table 1: The countries having the longest life expectancy at birth by gender in 2012[32]

MEN			WOMEN		
Rank	Country	Life expectancy	Rank	Country	Life expectancy
1	Iceland	81.2	1	Japan	87.0
2	Switzerland	80.7	2	Spain	85.1
3	Australia	80.5	3	Switzerland	85.1
4	Israel	80.2	4	Singapore	85.1
5	Singapore	80.2	5	Italy	85.0
6	New Zealand	80.2	6	France	84.9
7	Italy	80.2	7	Australia	84.6
8	Japan	80.0	8	Rep. of Korea	84.6
9	Sweden	80.0	9	Luxembourg	84.1
10	Luxembourg	79.7	10	Portugal	84.0

In the literature, Wilkinson (1992) investigated the association between income distribution and life expectancy for Britain and 15 developed countries taken from the World Development Reports. Olshansky et al. (2005) discussed potential decline in the US life expectancy in the 21st century, especially in terms of obesity. Peeters et al. (2003) emphasized the relationship between obesity/overweight in adulthood and large decreases in life expectancy/increases in early mortality. Salomon et al. (2012) focused on healthy life expectancy for 187 countries between 1990 and 2010. Becker et al. (2005) investigated the changes in life expectancy according to 13 broad groups of causes of death and three age groups. They showed that mortality from infectious, respiratory, and digestive diseases, congenital, perinatal, and "ill-defined" conditions are the most important causes of death in the reduction of life expectancy before age 20 and between ages 20 and 50 in the aspect of public health. Salkeld et al. (2000) concluded that falls and hip fractures are serious hazards for older women who have exceeded average life expectancy in their life quality. Fontaine et al. (2003) estimated the life expectancy of an adult according to over-weight and obesity in the aspect of life quality. They emphasized that younger adults generally had greater years of life lost than did older adults.

In addition to the life expectancy studies in the literature, life expectancy at age 60, and healthy life expectancy data are also statistically evaluated besides the life expectancy at birth data in this study. A new statistical evaluation to the life expectancy data for the countries having the longest lifetimes in the aspect of public health is tried to be developed by conducting analysis of variance techniques used in multivariate general linear model (GLM) approach.

Multivariate GLM approach provides regression analysis and analysis of variance for multiple dependent variables by factors or covariates. Factors are categorical variables whose each level has a different linear effect on the values of the dependent variable. Covariates are continuous variables that may affect the values of the dependent variable. Also interactions between factors can be investigated as well as the main effects of the factors. In addition, the effects of the covariates and covariate interactions with the factors can be included into the model [5], [13]. In this study, it is only interested in the univariate and multivariate analysis of variance techniques used in the multivariate GLM approach with main effects of the factors.

In this study, gender, prevalence of raised fasting blood glucose, prevalence of raised blood pressure, prevalence of obesity, mortality rates from cardiovascular and cancer diseases, and also alcohol consumption are taken as several potential risk factors and behaviours thought to be effective on life expectancy in the aspect of public health. For the aim of determining statistically significant risk factors that affect life expectancy for the countries having the longest lifetimes, multivariate GLM approach will be used to conduct analysis of variance techniques for more than one normally distributed dependent variables assumed to have linear relationship with these potential risk factors. After conducting the univariate and multivariate analysis of variance techniques, average longest lifetimes belonging to life expectancy at birth, life expectancy at age 60, and healthy life expectancy at birth of the countries given in Table 1 will be computed in the aspect of the statistically significant risk factors.

2. Materials and Method

In this section, the data used in this study are clearly described and the *multivariate GLM* approach is given in details.

2.1. Data description

The data used in this study are taken from WHO data repository (2016) and the statistical data analyses are performed by using IBM SPSS 22.0. The countries having the longest life expectancy at birth by gender given in Table 1 are taken as subjects into the study. These countries are investigated in the aspect of life expectancy at birth (life exp.), life expectancy at age 60 (life exp. at 60) and healthy life expectancy at birth (healthy life exp.) as measures of the multiple dependent variables. Possible risk factors and behaviours called as between-subjects factors thought to be effective on these multiple dependent variables are given in Table 2. Between-subject factor levels are assigned for each factor by converting the covariates to the categorical ones with determining cut-off values as given in Table 2.

Table 2: Possible between-subjects factors thought to be effective on the *life exp.*, *life exp. at 60* and *healthy life exp*. multiple dependent variables [22]

Factor names	Factor definitions	Factor levels
Gender	Gender types	1=Male, 2=Female
Prevalence of raised fasting blood glucose among adults aged 18+ years	Percent of defined population with fasting blood glucose ≥126 mg/dl (7.0 mmol/L)	1=per.of.pop.rais.glucose<6% 2=6%<per.of.pop.rais.glucose<10% 3=per.of.pop.rais.glucose>10%
Prevalence of raised blood pressure among adults aged 18+ years	Percent of defined population with raised blood pressure(systolic blood pressure≥140 or diastolic blood pressure ≥ 90)	1=per.of.pop.rais.pressure<15% 2=15%<per.of.pop.rais.pressure<25% 3=per.of.pop.rais.pressure >25%
Prevalence of obesity among adults aged 18+ years	Percent of defined population with a body mass index (BMI) of 30 kg/m^2 or higher	1=per.of.pop.BMI≥30<15% 2=15%<per.of.pop.BMI≥30<25% 3=per.of.pop.BMI≥30>25%
Cardiovascular disease death	Mortality rate from cardiovascular diseases per 100.000 population	1=mor.rate from c.d.d<100 2=mor.rate from c.d.d >100
Cancer disease death	Mortality rate from cancer diseases per 100.000 population	1=mor.rate from ca.d.d<100 2=100<mor.rate from ca.d.d <150 3= mor.rate from ca.d.d >150
Total alcohol per capita consumption among adults aged 15+ years	Total amount of alcohol consumed per adult (15+ years) over a calendar year, in litres of pure alcohol	1=alcohol consumption<10 litres 2=alcohol consumption>10 litres

2.2 Multivariate general linear model (*GLM*) approach

In this study, the focus is especially on the *multivariate GLM* approach providing analysis of variance techniques for the *life exp., life exp. at 60* and *healthy life exp.*multiple dependent variables by possible risk factors and behaviours taken as the between-subjectsfactors.

Assumptions underlying the multivariate *GLM* approach
Before constituting the*multivariate GLM*approach to the *life expectancy* multiple dependent variables data, "*normality"* assumption by *Kolmogorov-Smirnov goodness-of-fit test*, "*homogeneity of variances"* assumption by *Levene's test*, "*homogeneity of covariance matrices of the dependent variables"* assumption by *Box's M test*, and "*sphericity"* assumption by *Bartlett's test of sphericity* must be checked [11], [19].

Kolmogorov-Smirnov goodness-of-fit test
In this study, *Kolmogorov-Smirnov (K-S) test*[14] is used to decide if the sample comes from a population with normal distribution. The *K-S test statistic* is defined as;

$$D = \max \left| F_n(x) - F_0(x) \right| \quad (1)$$

where $F_n(x)$ is the empirical cumulative density function and $F_0(x)$ is the theoretical cumulative density function for

normal distribution, respectively. If the *K-S test statistic D* is greater than the critical value obtained from *K-S* table, it is decided that the sample doesn't come from a population with the normal distribution at α significance level[27].

Levene's homogeneity of variance test

Levene (1960)proposed a test statistic for testing the *homogeneity of variance* assumption called *Levene's test statistic* by using *F* distribution with *k-1* and *n-k* degrees of freedom, $F_{k-1,n-k,1-\alpha}$, at α significance level as follows;

$$L=\frac{(n-k)\sum_{i=1}^{k}n_i\left(\overline{Z}_{i.}-\overline{Z}_{..}\right)^2}{(k-1)\sum_{i=1}^{k}\sum_{j=1}^{n_i}\left(Z_{ij}-\overline{Z}_{i.}\right)^2} \quad (2)$$

where*n* is the total number of subjects, *k* is the number of groups, n_i is the number of subjects in the i^{th}group, $Z_{ij}=\left|y_{ij}-\overline{y}_{i.}\right|$, $\overline{Z}_{i.}$ are the group means of the Z_{ij}, $\overline{Z}_{..}$ is the overall mean of the Z_{ij}.

Box's M test

Box (1949) proposed a test statistic for testing the *homogeneity of covariance matrices of the dependent variables* assumption by using *Box's M test statistic* as follows;

$$M=(n-k)\ln|S|-\sum_{i=1}^{k}(n_i-1)\ln|S_i| \quad (3)$$

where $n=\sum_{i=1}^{k}n_i$, $S=\frac{\sum_{i=1}^{k}(n_i-1)S_i}{n-k}$, and S_i is the i^{th} within-group covariance. In this study, for the case $A_2-A_1^2>0$;

$$A_1=\frac{2p^2+3p-1}{6(p+1)(k-1)}\left[\sum_{i=1}^{k}\left(\frac{1}{n_i-1}\right)-\frac{1}{n-k}\right] \quad (4)$$

$$A_2=\frac{(p-1)(p+2)}{6(k-1)}\left[\sum_{i=1}^{k}\left(\frac{1}{n_i-1}\right)^2-\frac{1}{(n-k)^2}\right] \quad (5)$$

to test the significance of *Box's M test statistic*, $F_{v_1,v_2}=\frac{M}{b}$ distributionis used where $v_1=\frac{p(p+1)(k-1)}{2}$,

$v_2=\frac{v_1+2}{A_2-A_1^2}$, and $b=\frac{v_1}{1-A_1-(v_1/v_2)}$ [8].

Bartlett's test of sphericity

Bartlett (1937) proposeda test statistic for testing the *sphericity of the residual covariance matrix* called *Bartlett's test statistic* by using the chi-square distribution with*k-1*degrees of freedom at α significance level as follows;

$$\chi^2=\frac{(n-k)\log\left(S_p^2\right)-\sum_{i=1}^{k}(n_i-1)\log\left(S_i^2\right)}{1+\frac{1}{3(k-1)}\left[\sum_{i=1}^{k}\left(\frac{1}{n_i-1}\right)-\frac{1}{n-k}\right]} \quad (6)$$

where $S_p^2=\frac{1}{n-k}\sum_{i=1}^{k}(n_i-1)S_i^2$ [2].

Multivariate analysis of variance (*MANOVA*) technique

After checking and providing these assumptions, *multivariate analysis of variance (MANOVA)* technique, by using *Pillai's trace*, *Wilks' lambda*, *Hotelling's trace*, and *Roy's largest root* test statistics with approximate *F* distribution [17], is performed based upon *sum-of-squares and cross-products (SSCP) matrices* in the *multivariate GLM*.

Let *T*, T_W and T_B be the *total*, *within-groups* and *between-groups sum–of-squares and cross-products (SSCP) matrices*, respectively. The four multivariate test statistics in terms of the eigen values $\lambda_1>\lambda_2>\ldots>\lambda_s$ of $T_W^{-1}T_B$ are defined in Table 3[6].

Table 3: Multivariate test statistics in the *MANOVA* technique [6]

Multivariate test statistics	Formulas
Pillai's trace	$V^{(s)}=\sum_{i=1}^{s}\frac{\lambda_i}{1+\lambda_i}$
Wilks' lambda	$\Lambda=\prod_{i=1}^{s}\frac{1}{1+\lambda_i}$
Lawley-Hotelling's trace	$U^{(s)}=\sum_{i=1}^{s}\lambda_i$
Roy's largest root	$\theta=\frac{\lambda_1}{1+\lambda_1}$

Univariate analysis of variance (*ANOVA*) technique

After an overall *F* test has shown statistical significance for the factors by using the *MANOVA* technique, univariate tests of significance for the *between-subjects factors* effects for each dependent variable are investigated by using *univariate analysis of variance (ANOVA)* technique [23]. In Table 4, an *ANOVA* table for a three-way crossed classification without any interaction term is demonstrated. Generalizations to higher-order classifications can be done easily by using this table.

In Table 4; *a*, *b*, and *c* are the levels of the fixed-effects factors as *A*, *B*, and *C*, *n* is the total number of observations, α_i is the effect of the i^{th} level of factor *A*, β_j is the effect of the j^{th} level of factor *B*, and γ_k is the effect of the k^{th} level of factor *C* on each dependent variable.

For statistically significant *between-subjects factors* by *ANOVA*, *Tukey's honest significant difference (HSD)*, *Fisher's least significant difference (LSD)*, *Duncan's multiple range*, *Student-Newman-Keuls (SNK)*, and *Scheffe* tests as post-hoc tests are performed to evaluate the

statistically significant pairs of means differences for each level of the factors separately[28].

Table 4: *ANOVA* table for the between-subjects factors effects in a three-way crossed classification without interaction [6]

Source of variation	Degrees of freedom	Sum of squares	Mean square	Test statistic	F-value
Due to A	a-1	SS_A	$MS_A = \sigma_e^2 + \frac{bcn}{a-1}\sum_{i=1}^{a}\alpha_i^2$	$F_A = \frac{MS_A}{MS_E}$	$F_{a-1,abc(n-1);1-\alpha}$
Due to B	b-1	SS_B	$MS_B = \sigma_e^2 + \frac{acn}{b-1}\sum_{j=1}^{b}\beta_j^2$	$F_B = \frac{MS_B}{MS_E}$	$F_{b-1,abc(n-1);1-\alpha}$
Due to C	c-1	SS_C	$MS_C = \sigma_e^2 + \frac{abn}{c-1}\sum_{k=1}^{c}\gamma_k^2$	$F_C = \frac{MS_C}{MS_E}$	$F_{c-1,abc(n-1);1-\alpha}$
Error	abc(n-1)	SS_E	$MS_E = \sigma_e^2$		
Total	abcn-1	SS_T			

Tukey's honest significant difference (*HSD*) test

Tukey (1953) proposed a procedure for testing all pairwise comparisons of a factor's level means by using *studentized range statistic* as follows;

$$q = \frac{\bar{y}_{\max} - \bar{y}_{\min}}{\sqrt{MSE/n}} \quad (7)$$

where $\bar{y}_{\max}$ and $\bar{y}_{\min}$ are the largest and smallest factor level means, respectively, among the factor's all level means. If the absolute value of each pair of differences between the factor level means exceeds;

$$T_\alpha = q_\alpha(a, f)\sqrt{\frac{MSE}{n}} \quad (8)$$

where $q_\alpha(a, f)$ is the upper α percentage point of *q*, *a* is the number of factor levels and *f* is the number of degrees of freedom associated with the *MSE*, then from *Tukey's HSD test*, it is concluded that the two factor level means are statistically significantly different from each other[16].

Fisher's least significant difference (*LSD*) test

Fisher (1935) proposed a procedure for testing all pairwise comparisons of a factor's level means by using *least significant difference* as follows;

$$LSD = t_{\alpha/2,n-a}\sqrt{2MSE/n} \quad (9)$$

If the absolute value of each pair of differences between the factor level means exceeds *Fisher's LSD* value given in Eq.(9), then *Fisher's test* declares that the two factor level means are statistically significantly different [16].

Duncan's multiple range test

Duncan (1955) proposed a widely used procedure for comparing all pairs of a factor's level means first by determining the standard error of each factor level mean in ascending order as follows;

$$S_{\bar{y}_i} = \sqrt{MSE/n} \quad (10)$$

and then by obtaining $r_\alpha(p, f)$ for $p = 2,\ldots,a$ values from Duncan's table of significant ranges [16]. Finally, least significant ranges are constituted as follows;

$$R_p = r_\alpha(p, f)S_{\bar{y}_i} \text{ for } p = 2,\ldots,a \quad (11)$$

If an observed difference between factor level means is greater than the corresponding least significant range, *Duncan's multiple range test* declares that the pair of factor level means is statistically significantly different [16].

Student-Newman-Keuls (*SNK*) test

This test was devised by Newman (1939) and generated by Keuls (1952) by computing a set of critical values as follows;

$$K_p = q_\alpha(p, f)S_{\bar{y}_i} \text{ for } p = 2,\ldots,a \quad (12)$$

where $q_\alpha(p, f)$ is the upper α percentage point of the studentized range. The procedure is the same as in Duncan's multiple range test[16].

Scheffe's test

Scheffe (1953) proposed a method for comparing possible contrasts between a factor's level means. Suppose that a set of *m* contrasts in the factor level means is determined as follows;

$$\Gamma_u = c_{1u}\mu_1 + \ldots + c_{au}\mu_a \quad ; \quad u = 1,\ldots,m \quad (13)$$

The corresponding contrast in the factor level means $\bar{y}_i$ is as follows;

$$C_u = c_{1u}\bar{y}_1 + \ldots + c_{au}\bar{y}_a \quad ; \quad u = 1,\ldots,m \quad (14)$$

and the standard error of this contrast is;

$$S_{C_u} = \sqrt{MSE\left(\sum_{i=1}^{a} c_{iu}^2 \Big/ n\right)} \quad (15)$$

The critical value C_u given in Eq.(14) is compared with $S_{\alpha,u} = S_{C_u}\sqrt{(a-1)F_{a-1,n-a;1-\alpha}}$. If $|C_u| > S_{\alpha,u}$, then the null hypothesis that the contrast Γ_u equals zero is rejected at α significance level [16].

3. Results and Discussion

Before constituting *multivariate GLM* to the *life exp.*, *life exp. at 60* and *healthy life exp.* multiple dependent variables by possible risk factors and behaviours, assumptions underlying the multivariate *GLM* approach are satisfied as follows;

The data for the multiple dependent variables *life exp.*, *life exp. at 60*, and *healthy life exp.* come from the normal distribution as a result of *Kolmogorov-Smirnov (K-S) goodness-of-fit test* with *K-S Z-test statistic values*and

corresponding statistically nonsignificant *p-values* given in Table 5, at $\alpha = 0.05$ significance level.

The data for these multiple dependent variables have homogeneous variances as a result of *Levene's homogeneity of variance test* with *Levene's F-test statistic values* and corresponding statistically non significant *p-values* given in Table 5, at $\alpha = 0.05$ significance level.

Table 5: Kolmogorov-Smirnov and Levene tests results for checking *normality* and *homogeneity of variances* assumptions belonging to the multiple dependent variables

		life exp.	life exp. at 60	healthy life exp.
Kolmogorov-Smirnov goodness-of-fit test	*K-SZ*-test statistic values	1.148	1.093	0.717
	Sig. values	0.144	0.183	0.683
Levene's homogeneity of variance test	Levene's *F*-test statistic values	0.733	0.978	2.110
	Sig. values	0.726	0.585	0.246

As a result of *Box's M test*, for the aim of checking *homogeneity of covariance matrices of the dependent variables life exp., life exp. at 60*, and *healthy life exp.*, it is decided that the observed covariance matrices of these multiple dependent variables are equal across groups by using *Box's M-test statistic value* 27.466 and corresponding statistically non significant *p-value* 0.155 at $\alpha = 0.05$ significance level.

By using *Bartlett's test of sphericity*, it is decided that the residual covariance matrix is not proportional to an identity matrix by using *Bartlett's approximate* χ^2 *test statistic value*12.609, and corresponding statistically significant *p-value* 0.029. Providing *sphericity* assumption also shows that these three dependent variables measures are correlated.

As seen from *residuals sum-of-squares and cross-products (SSCP) matrix* given in Table 6, *life exp.* and *life exp. at 60* are highly correlated with the Pearson correlation coefficient*r-value* 0.839; *life exp.* and *healthy life exp.*, and also *life exp. at 60* and *healthy life exp.* are moderately correlated with *r-values* 0.662 and 0.661, respectively.

Table 6: Residuals sum-of-squares and cross-products (*SSCP*) matrix belonging to the multiple dependent variables

		life exp.	life exp. at 60	healthy life exp.
Sum-of-squares and cross-products	life exp.	4.636	4.007	5.071
	life exp. at 60	4.007	4.921	5.214
	healthy life exp.	5.071	5.214	12.643
Covariance	life exp.	.662	.572	.724
	life exp. at 60	.572	.703	.745
	healthy life exp.	.724	.745	1.806
Correlation	life exp.	1.000	.839	.662
	life exp. at 60	.839	1.000	.661
	healthy life exp.	.662	.661	1.000

In the step of an overall multivariate tests of significance for the *between-subjects factors*, thought to be effective on these multiple dependent variables given in Table 2, by using *Pillai's trace*, *Wilks' lambda*, *Hotelling's trace*, and *Roy's largest root*multivariate test statistics;
Statistically significant risk factors are determined as *gender*, *prevalence of raised fasting blood glucose*, *raised blood pressure*, and *obesity*, *mortality rates from cardiovascular* and *cancer diseases* and also *alcohol consumption* with thecorresponding statistically significant *p-values* given in Table 7, at $\alpha = 0.05$ significance level.

Table 7: *MANOVA* results belonging to the multiple dependent variables

	Significance values of the statistically significant risk factors belonging to the multivariate test statistics used in *MANOVA*			
Statistically significant risk factors	Pillai's trace	Wilks' lambda	Hotelling's trace	Roy's largest root
Gender/Cardiovascular dis.death	0.003	0.003	0.003	0.003
Bloodglucose/Obesity/Alcohol/Cancer dis.death	0.000	0.000	0.000	0.000
Bloodpressure	0.015	0.009	0.006	0.001

After the multivariate test statistics have shown statistical significance for the risk factors given in Table 7 by using the *MANOVA* technique, univariate tests of significance for the same risk factors are investigated by using the *univariate ANOVA* technique as given in Table 8. It can be said that the same risk factors are found statistically significant for each dependent variable with thecorresponding significance values given in Table 8, at $\alpha = 0.05$ significance level.

Table 8: Tests of between-subjects factors effects for each dependent variable by using the univariate *ANOVA* technique

	Significance values of the statistically significant risk factors belonging to each dependent variable by *ANOVA*		
Statistically significant risk factors	life exp.	life exp. at 60	healthy life exp.
Gender/Cardiovascular dis.death/Cancer dis.death	0.000	0.000	0.000
Prevalence of raised fastingblood glucose	0.001	0.001	0.020
Prevalence of raised blood pressure	0.001	0.001	0.001
Prevalence of obesity	0.000	0.019	0.000
Alcohol consumption	0.000	0.001	0.001

After determining the statistically significant risk factors by univariate *ANOVA* technique given in Table 8, *Tukey's HSD*, *Scheffe*, and *Fisher's LSD* post-hoc tests are performed to evaluate pairwise comparisons for the factors' levels means belonging to these multiple dependent variables measures. Also *independent samples t-test* is performed for testing the

differences between means of the factors' two levels. Homogeneous subsets among the group means are determined by using *SNK*, *Tukey's HSD*, *Duncan*, and *Scheffe*post-hoc tests after performing pairwise comparisons among all levels of the specified risk factors.

By using *independent samples t-test*, statistically significant pairdifferences are found between *gender*, *mortality rate from cardiovascular disease*, and *alcohol consumption* factors' levels given in Table 2 with *t*-test statistic and the corresponding significance values given in Table 9, at $\alpha = 0.05$ significance level.

Table 9: Independent samples *t*-test results for the statistically significant risk factors having two levels belonging to the multiple dependent variables

Statistically significant risk factors		Multiple dependent variables		
		life exp.	life exp. at 60	healthy life exp.
Gender	*t*-test statistic values	-6.810	-7.798	-3.925
	sig. values	0.000	0.000	0.001
Cardiovascular disease death	*t*-test statistic values	7.409	9.549	5.088
	sig. values	0.000	0.000	0.000
Alcohol consumption	*t*-test statistic values	4.785	3.605	3.654
	sig. values	0.000	0.001	0.001

By using *Tukey's HSD*, *Scheffe*, and *Fisher's LSD*post-hoc tests, statistically significant differences are determined between pairs of the risk factors' levels given in Table 2 with the corresponding significance values given in Table 10, at $\alpha = 0.05$ significance level, belonging to the *life exp* .dependent variable measure. By using these post-hoc tests, statistically significant differences are determined between each pair of the risk factors' levels given in Table 10 except between second and third levels of *prevalence of raised fasting blood pressure*, and *prevalence of obesity* factors.

Also no statistically significant difference is found between the second and the third levels of *prevalence of raised fasting blood glucose* factor by using *Scheffe*post-hoc test.

Table 10: Multiple comparisons among levels of the statistically significant risk factors belonging to the*life exp.* dependent variable

		Significance values for post-hoc tests		
Statistically significant risk factors	Factor levels	Tukey's *HSD*	Scheffe	Fisher's *LSD*
Prevalence of raised fasting blood glucose	1-2	0.002*	0.002*	0.001*
	1-3	0.000*	0.000*	0.000*
	2-3	0.044*	0.055	0.017*
Prevalence of raised blood pressure	1-2	0.017*	0.022*	0.006*
	1-3	0.002*	0.002*	0.001*
	2-3	0.235	0.265	0.106
Prevalence of obesity	1-2	0.000*	0.000*	0.000*
	1-3	0.014*	0.019*	0.005*
	2-3	0.517	0.547	0.279
Cancer disease death	1-2	0.000*	0.000*	0.000*
	1-3	0.000*	0.000*	0.000*
	2-3	0.003*	0.005*	0.001*

*indicates statistically significant difference between pair of factor level means

By using *SNK*, *Tukey's HSD*, *Duncan*, and *Scheffe*post-hoc tests,homogeneous subsets in terms of the observed age means are displayed for the statistically significant risk factors belonging to the*life exp.* dependent variable in Table 11, at $\alpha = 0.05$ significance level.

Table 11: Homogeneous subsetsfor the statistically significant risk factors belonging to the*life exp.* dependent variable

Post-hoc tests	Factor levels	Subsets		
	Prevalence of raised fasting blood glucose	1	2	3
SNK, Tukey's *HSD* Duncan, Scheffe	1=per.of.pop.rais.glucose<6%			84.70
	2=6%<per.of.pop.rais.glucose<10%		81.06	
	3=per.of.pop.rais.glucose>10%	77.33		
	Prevalence of raised blood pressure	1	2	
SNK, Tukey's *HSD* Duncan	1=per.of.pop.rais.pressure<15%		84.27	
	2=15%<per.of.pop.rais.pressure<25%	81.67		
	3=per.of.pop.rais.pressure>25%	79.80		
Scheffe	1=per.of.pop.rais.pressure<15%		84.27	
	2=15%<per.of.pop.rais.pressure<25%	81.67	81.67	
	3=per.of.pop.rais.pressure>25%	79.80		
	Prevalence of obesity	1	2	3
SNK, Tukey's *HSD* Duncan, Scheffe	1=per.of.pop.BMI≥30<15%		82.70	
	2=15%<per.of.pop.BMI≥30<25%	81.38		
	3=per.of.pop.BMI≥30>25%	81.71		
	Cancer disease death	1	2	3
SNK, Tukey's *HSD* Duncan, Scheffe	1=mor.rate from ca.d.d<100			85.10
	2=100<mor.rate from ca.d.d <150		81.67	
	3= mor.rate from ca.d.d >150	79.17		

From Table 11, *prevalence of raised fasting blood glucose* factor's first, second and third levels are obtained in three different homogeneous subsets with the observed age means 84.70; 81.06; and 77.33 years and *p*-values 1.000 for the three homogeneous subsets, respectively, by *SNK*, *Tukey's HSD*, *Duncan*, and *Scheffe*post-hoc tests.

Prevalence of raised blood pressure factor's first level is in the second homogeneous subset;second and third levels are in the first homogeneous subset with the observed age means 84.27; 81.67 and 79.8 years and *p*-values 1.000; 0.086, 0.195 and 0.086 for the first and the second homogeneous subsets, respectively, by*SNK*, *Tukey's HSD*, and *Duncan*post-hoc tests. On the other hand, *Scheffe*test

cannot distinguish this factor's second level is whether in the first subset or in the second subset with the observed age mean 81.67 years and *p*-values 0.223 and 0.063 for the first and the second homogeneous subsets, respectively.

Prevalence of obesity factor's first level is in the second homogeneous subset;second and third levels are in the first homogeneous subset with the observed age means 82.70; 81.38 and 81.71 years and *p*-values 0.272, 0.507, 0.272 and 0.538; 1.000 for the first and the second homogeneous subsets, respectively, by *SNK*, *Tukey's HSD*, *Duncan*, and *Scheffe*post-hoc tests.

Mortality rate from cancer disease factor's first, second and third levels are obtained in three different homogeneous subsets with the observed age means 85.1; 81.67; and 79.17 years and *p*-values 1.000, respectively, by *SNK*, *Tukey's HSD*, *Duncan*, and *Scheffe*post-hoc tests.

By using *Tukey's HSD*, *Scheffe*, and *Fisher's LSD*post-hoc tests, statistically significant differences are determined between pairs of the risk factors' levels given in Table 2 with the corresponding significance values given in Table 12, at $\alpha = 0.05$ significance level, belonging to the *life exp. at 60* dependent variable measure. By using these post-hoc tests, statistically significant differences are determined between each pair of the risk factors' levels given in Table 12except between second and third levels of *prevalence of raised blood pressure;* between first and third, and also second and third levels of *prevalence of obesity* factors.

Also no statistically significant difference is found between the second and the third levels of *prevalence of raised fasting blood glucose* factor by using *Tukey's HSD*, and *Scheffe*post-hoc tests.

Table 12: Multiple comparisons among levels of the statistically significant risk factors belonging to the*life exp. at 60* dependent variable

		Significance values for post-hoc tests		
Statistically significant risk factors	Factor levels	Tukey's HSD	Scheffe	Fisher's LSD
Prevalence of raised fasting blood glucose	1-2	0.001*	0.002*	0.000*
	1-3	0.000*	0.000*	0.000*
	2-3	0.088	0.106	0.036*
Prevalence of raised blood pressure	1-2	0.032*	0.041*	0.012*
	1-3	0.001*	0.002*	0.001*
	2-3	0.151	0.176	0.065
Prevalence of obesity	1-2	0.018*	0.023*	0.007*
	1-3	0.424	0.456	0.217
	2-3	0.353	0.385	0.174
Cancer disease death	1-2	0.000*	0.000*	0.000*
	1-3	0.000*	0.000*	0.000*
	2-3	0.020*	0.026*	0.008*

*indicates statistically significant difference between pair of factor level means

By using *SNK*, *Tukey's HSD*, *Duncan*, and *Scheffe*post-hoc tests, homogeneous subsets in terms of the observed age means are displayed for the statistically significant risk factors belonging to the *life exp. at 60* dependent variable in Table 13, at $\alpha = 0.05$ significance level.

Table 13: Homogeneous subsets for the statistically significant risk factors belonging to the *life exp. at 60* dependent variable

Post-hoc tests	Factor levels	Subsets		
	Prevalence of raised fasting blood glucose	1	2	3
SNK, Duncan	1=per.of.pop.rais.glucose<6%			26.70
	2=6%<per.of.pop.rais.glucose<10%		24.00	
	3=per.of.pop.rais.glucose>10%	21.67		
Tukey's *HSD*, Scheffe	1=per.of.pop.rais.glucose<6%		26.70	
	2=6%<per.of.pop.rais.glucose<10%	24.00		
	3=per.of.pop.rais.glucose>10%	21.67		
	Prevalence of raised blood pressure	1	2	
SNK, Duncan	1=per.of.pop.rais.pressure<15%		26.36	
	2=15%<per.of.pop.rais.pressure<25%	24.50		
	3=per.of.pop.rais.pressure>25%	22.80		
Tukey's *HSD*, Scheffe	1=per.of.pop.rais.pressure<15%		26.36	
	2=15%<per.of.pop.rais.pressure<25%	24.50	24.50	
	3=per.of.pop.rais.pressure>25%	22.80		
	Prevalence of obesity	1	2	
SNK, Tukey's *HSD* Duncan, Scheffe	1=per.of.pop.BMI≥30<15%		25.10	
	2=15%<per.of.pop.BMI≥30<25%	24.31		
	3=per.of.pop.BMI≥30>25%	24.71	24.71	
	Cancer disease death	1	2	3
SNK, Tukey's *HSD* Duncan, Scheffe	1=mor.rate from ca.d.d<100			27.20
	2=100<mor.rate from ca.d.d <150		24.17	
	3= mor.rate from ca.d.d >150	22.67		

From Table 13, *prevalence of raised fasting blood glucose* factor's first, second and third levels are obtained in three different homogeneous subsets with the observed age means 26.7; 24; and 21.67 years and *p*-values 1.000 for the three homogeneous subsets, respectively, by*SNK*, and *Duncan*post-hoc tests. On the other hand, this factor's first level is in the second homogeneous subset;second and third levels are in the first homogeneous subset with *p*-values 1.000; 0.057 and 0.071 for the first and the second homogeneous subsets, respectively, by*Tukey's HSD*, and *Scheffe*post-hoc tests.

Prevalence of raised blood pressure factor's first level is in the second homogeneous subset;second and third levels are

in the first homogeneous subset with the observed age means 26.36; 24.5 and 22.8 years,with *p*-values 0.05; 1.000 for the first and the second homogeneous subsets, respectively, by*SNK*, and*Duncan*post-hoc tests. On the other hand, *Tukey's HSD*, and *Scheffe*tests cannot distinguish this factor's second level is whether in the first subset or in the second subset with the observed age mean 24.5 years with *p*-values 0.119, 0.141; 0.081, 0.099 for the two homogeneous subsets, respectively.

Prevalence of obesity factor's first level is in the second homogeneous subset, andsecond level is in the first homogeneous subset with the observed age means 25.1, and 24.31 yearsand *p*-values 0.167, 0.343, 0.167 and 0.375; 0.189, 0.379, 0.189 and 0.412 for the first and the second homogeneous subsets,respectively, by *SNK*, *Tukey's HSD*, *Duncan*, and *Scheffe*post-hoc tests. On the other hand, these post-hoc tests cannot distinguish this factor's third level is whether in the first subset or in the second subset with the observed age mean 24.71 years.

Mortality rate from cancer disease factor's first, second and third levels are obtained in three different homogeneous subsets with the observed age means 27.2; 24.17; and 22.67 years, and *p*-values 1.000, for the three homogeneous subsets, respectively, by *SNK*, *Tukey's HSD*, *Duncan*, and *Scheffe*post-hoc tests.

By using *Tukey's HSD*, *Scheffe*, and *Fisher's LSD*post-hoc tests, statistically significant differences are determined between pairs of the risk factors' levels given in Table 2 with the corresponding significance values given in Table 14, at $\alpha = 0.05$ significance level, belonging to the *healthy life exp.* dependent variable measure. By using these post-hoc tests, statistically significant differences are determined between each pair of the risk factors' levels given in Table 14except between second and third levels of *prevalence of raised fasting blood glucose*, and *prevalence of obesity* factors. Also no statistically significant differences are found between the first and the second levels of *prevalence of raised fasting blood glucose*,and between the second and the third levels of *prevalence of raised blood pressure*, by using *Tukey's HSD*, and *Scheffe*post-hoc tests.

Table 14: Multiple comparisons among levels of the statistically significant risk factors belonging to the*healthy life exp.* dependent variable

		Significance values for post-hoc tests		
Statistically significant risk factors	Factor levels	Tukey's HSD	Scheffe	Fisher's LSD
Prevalence of raised fasting blood glucose	1-2	0.077	0.093	0.031*
	1-3	0.009*	0.012*	0.003*
	2-3	0.143	0.167	0.061
Prevalence of raised blood pressure	1-2	0.031*	0.040*	0.012*
	1-3	0.000*	0.001*	0.000*
	2-3	0.062	0.077	0.025*
Prevalence of obesity	1-2	0.001*	0.001*	0.000*
	1-3	0.006*	0.009*	0.002*
	2-3	0.938	0.944	0.737
Cancer disease death	1-2	0.000*	0.001*	0.000*
	1-3	0.000*	0.000*	0.000*
	2-3	0.020*	0.027*	0.008*

*indicates statistically significant difference between pair of factor level means

By using *SNK*, *Tukey's HSD*, *Duncan*, and *Scheffe*post-hoc tests, homogeneous subsets in terms of the observed age means are displayed for the statistically significant risk factors belonging to the *healthy life exp.* dependent variable in Table 15, at $\alpha = 0.05$ significance level.

Table 15: Homogeneous subsetsfor the statistically significant risk factors belonging to the *healthy life exp.* dependent variable

Post-hoc tests	Factor levels	Subsets		
	Prevalence of raised fasting blood glucose	1	2	
SNK, Duncan	1=per.of.pop.rais.glucose<6%		74.00	
	2=6%<per.of.pop.rais.glucose<10%		71.59	
	3=per.of.pop.rais.glucose>10%	68.33		
Tukey's *HSD*, Scheffe	1=per.of.pop.rais.glucose<6%		74.00	
	2=6%<per.of.pop.rais.glucose<10%	71.59	71.59	
	3=per.of.pop.rais.glucose>10%	68.33		
	Prevalence of raised blood pressure	1	2	3
SNK, Duncan	1=per.of.pop.rais.pressure<15%			74.27
	2=15%<per.of.pop.rais.pressure<25%		72.17	
	3=per.of.pop.rais.pressure>25%	69.80		
Tukey's *HSD*	1=per.of.pop.rais.pressure<15%		74.27	
	2=15%<per.of.pop.rais.pressure<25%		72.17	
	3=per.of.pop.rais.pressure>25%	69.80		
Scheffe	1=per.of.pop.rais.pressure<15%		74.27	
	2=15%<per.of.pop.rais.pressure<25%	72.17	72.17	
	3=per.of.pop.rais.pressure>25%	69.80		
	Prevalence of obesity	1	2	3
SNK, Tukey's *HSD* Duncan, Scheffe	1=per.of.pop.BMI≥30<15%		73.60	
	2=15%<per.of.pop.BMI≥30<25%	71.23		
	3=per.of.pop.BMI≥30>25%	71.43		
	Cancer disease death	1	2	3
SNK, Tukey's *HSD* Duncan, Scheffe	1=mor.rate from ca.d.d<100			74.90
	2=100<mor.rate from ca.d.d <150		72.00	
	3= mor.rate from ca.d.d >150	69.83		

Prevalence of raised fasting blood glucose factor's first and second levels are obtained in the second homogeneous subset; third level is in the first homogeneous subset with the observed healthy age means 74 and 71.59; 68.33 years and *p*-values 1.000; 0.125 for the first and the second homogeneous subsets, respectively, by*SNK*, and*Duncan*post-hoc tests. On the other hand, *Tukey's HSD*, and *Scheffe*tests cannot distinguish this factor's second level is whether in the first subset or in the second subset with the observed healthy age mean 71.59 year with *p*-values 0.101 and 0.121; 0.270 and 0.301 for the two homogeneous subsets, respectively.

Prevalence of raised blood pressure factor's first, second and third levels are obtained in three different homogeneous subsets with the observed healthy age means 74.27; 72.17; and 69.8 yearsand *p*-values 1.000 for the three homogeneous subsets, respectively, by*SNK*, and*Duncan*post-hoc tests. This factor's first and second levels are in the second homogeneous subset;third level is in the first homogeneous subset with *p*-values 1.000; 0.080 for the two homogeneous subsets, respectively, by*Tukey's HSD* post-hoc test. On the other hand, *Scheffe*test cannot distinguish this factor's second level is whether in the first subset or in the second subset with the observed healthy age mean 72.17 years with *p*-values 0.056; 0.097 for the two homogeneous subsets, respectively.

Prevalence of obesity factor's first level is in the second homogeneous subset;second and third levels are in the first homogeneous subset with the observed healthy age means 73.6; 71.23 and 71.43 yearsand *p*-values 0.733, 0.936, 0.733 and 0.942; 1.000 for the two homogeneous subsets,respectively, by *SNK*, *Tukey's HSD*, *Duncan*, and *Scheffe*post-hoc tests.

Mortality rate from cancer disease factor's first, second and third levels are obtained in three different homogeneous subsets with the observed healthy age means 74.9; 72; and 69.83 yearsand *p*-values 1.000 for the three homogeneous subsets, respectively, by *SNK*, *Tukey's HSD*, *Duncan*, and *Scheffe*post-hoc tests.

4. Conclusions

In this study, *multivariate GLM technique* is applied on*life expectancy*, *life expectancy at age 60*, and *healthy life expectancy* data of the countries having longest lifetimes according to [32] by *gender*, *prevalence of raised fasting blood glucose*, *prevalence ofraised blood pressure*, *prevalence of obesity*, *mortality rates from cardiovascular* and *cancer diseases* and also *alcohol consumption* statistically significant risk factors.

In the aspect of *gender; male life exp.*, *life exp. at 60*, and *healthy life exp.* for the countries taken into the study are found as 79.93, 23.07, and 70.79 years in average, respectively. *Female life exp.*, *life exp. at 60*, and *healthy life exp.* for these countries are found as 84.79, 26.79, and 74.36 years in average, respectively, as an indicator of *public health*.

Average longest lifetimes in years for *life exp.*, *life exp. at 60*, and *healthy life exp.* data of these countries given in Table 16 are determined in the first levels of the statistically significant risk factors in Table 2as the main findings from this study as a contribution to the *public health*.

Table 16: Average longest lifetimes for the*life exp.*, *life exp. at 60*, and *healthy life exp.* data of the countriestaken into the study

	Longest lifetimes in average (years)		
First levelsof statistically significant risk factors	life exp.	life exp. at 60	healthy life exp.
Per. of pop. with raised fasting blood glucose≥126 mg/dl < 6%	84.7	26.7	74
Per. of pop. with raised blood pressure (SBP≥140 or DBP ≥ 90)<15%	84.27	26.36	74.27
Per. of pop. with BMI≥30 kg/m^2<15%	82.7	25.1	73.6
Mor. rate from c.d.d<100 person per 100.000 pop.	84.85	26.92	74.76
Mor. rate from ca.d.d<100 person per 100.000 pop.	85.1	27.2	74.9
Alcohol consumption<10 litres	83.58	25.74	73.53

An important statistical conclusion of this study is related to the discrimination problem of the post-hoc tests in determininghomogeneous subsets for the levels of the statistically significant risk factorsas follows;

In order to construct the homogeneous subsets for the levels of the statistically significant risk factors belonging to the *life exp.* dependent variable; *Scheffe*test cannot distinguish *prevalence of raised blood pressure* factor's second level is whether in the first subset or in the second subsetat $\alpha = 0.05$ significance level.

In order to construct the homogeneous subsets for the levels of the statistically significant risk factors belonging to the *life exp. at 60* dependent variable; while *SNK*, and*Duncan*post-hoc tests separately determine *prevalence of raised fasting blood glucose* factor's first, second and third levels in three different homogeneous subsets, *Tukey's HSD*, and *Scheffe*post-hoc tests determined this factor's first level in the second homogeneous subset, second and third levels in the first homogeneous subsetat $\alpha = 0.05$ significance level. Additionally, *Tukey's HSD*, and *Scheffe*tests cannot distinguish *prevalence of raised blood pressure* factor's second level is whether in the first subset or in the second subsetat $\alpha = 0.05$ significance level.

In order to construct the homogeneous subsets for the levels of the statistically significant risk factors belonging to the *healthy life exp.* dependent variable; *Tukey's HSD*, and *Scheffe*tests cannot distinguish *prevalence of raised fasting blood glucose* factor'ssecond level is whether in the first subset or in the second subsetat $\alpha = 0.05$ significance level. While *SNK*, and*Duncan*post-hoc tests separately determine *prevalence of raised blood pressure* factor's first, second

and third levels in three different homogeneous subsets, *Tukey's HSD* test determined this factor's first and second levels in the second homogeneous subset, and third level in the first homogeneous subsetat $\alpha = 0.05$ significance level. Additionally, *Scheffe*test cannot distinguish this factor's second level is whether in the first subset or in the second subsetat $\alpha = 0.05$ significance level.

As a conclusion; among the post-hoc tests in order to evaluate the statistically significant pair mean differences of the factor levels, *SNK*, and*Duncan*post-hoc tests give the best results. Especially in *Scheffe*test, a problem of discrimination is obviously seen indetermining the homogeneous subsetsfor the statistically significant risk factors levels. *Tukey's HSD* test has also a discrimination problem in assigning the levels of the statistically significant risk factors into some homogeneous subsets for the *life expectancy* data evaluated in this study.

In the light of this study, it would be interesting to investigate *life expectancy* of six different regions in the world given by Figure 1, by evaluating*causes of death* from *communicable* and *noncommunicable diseases*, *injuries*, *child and adult mortality*, *burden of diseases*, *cause-specific mortality and morbidity* and etc. in a further study.

Figure 1: Regions of World Health Organization (WHO) member countries [33]

Additionally, it would be interesting to evaluate countries by income levels such as *low-income*, *lower-middle-income*, *upper-middle-income* and *high-income*, benefiting from the World Bankclassification, in the aspect of *global life expectancy* in the World as an indicator of*global public health*.

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6. Conflict of interest

The author declares that there is no conflict of interest.

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