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Proposed Turkish body mass index cut-off points compared with the World Health Organization and Asia-Pacific indices

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Abstract

It is important to determine specific Body Mass Index (BMI) cut-off points on country and sex bases since there are anthropometric differences. Therefore, a study was proposed to find out specific body mass index [BMI-TR (kg/m^2)] cut-off points for Turkish young adults. BMI-TR was compared with the classifications of the World Health Organization's Index (BMI-WHO) and Asia-Pacific Index (BMI-AP). In this research a study enclosing the weight and height measurements of 196 cases (97 Male, 99 Female, age average 22.5 years) were examined. The recorded total data were calculated according to BMI-WHO and BMI-AP, subsequently the same data were computed according to Empirical Rule to find out the cut-off points of the BMI-TR and also specific BMI-TR cut-off points for males and females. The data were compared for both BMI-WHO and BMI-AP categorizations and showed inconsistent results. Therefore, BMI-TR was calculated and classified according to sex. In this study, Turkish specific BMI results for BMI-TR Males and BMI-TR Females revealed that the percentage of females showing normal BMI was higher (78.8%), than males (70.1%), and being underweight (14.4 % for males, 10.1 % for females) was more serious than being obese (5.2% for males, 4.0 % for females) in the "young adult" age group. BMI calculations should include age groups, sex and adjustment of height decrease for elderly on country basis.

Key words: Turkish-BMI, body mass index height adjusted, BMI-WHO, BMI Asia-Pacific, anthropometry

Dünya Sağlık Örgütü ve Asya-Pasifik endeksleri ile karşılaştırılan Türkiye beden kitle endisi kesim noktaları için öneri

Öz

Beden Kitle Endisi (BKE) hesaplamalarında, toplumlararası antropometrik farklılıklar nedeniyle ülke ve cinsiyet bazında belirli kesim noktalarının belirlenmesi önemlidir. Bu sebeple bu araştırmada, Türk genç yetişkinleri için spesifik beden kitle endisi [TR-BKE (kg/m^2)] kesim noktalarını saptamak için bir çalışma yürütülmüştür. TR-BKE, Dünya Sağlık Örgütü endisi (DSÖ-BKE) ve Asya-Pasifik endisi (AP-BKE) sınıflandırmaları ile karşılaştırılmıştır. Bu araştırmada 196 olgunun (97 Erkek, 99 Kadın, yaş ortalaması 22,5 yıl) ağırlık ve boy ölçümlerini içeren verileri incelenmiştir. DSÖ-BKE ve AP-BKE'ye göre hesaplanan BKE sınıflandırılmıştır. Bu verilere istatistiksel Ampirik Kural uygulanarak TR-BKE ve ayrıca erkekler ve kadınlar için TR-BKE erkek ve TR-BKE kadın endisi kesim noktaları bulunmuştur. Veriler hem DSÖ-BKE hem de AP-BKE'ye göre sınıflandırıldığında sonuçlar tutarsızlık göstermiştir. Bu nedenle TR-BKE hesaplanarak cinsiyete göre belirlenmiştir. Bu çalışmada, Türkiye'ye özgü BKE kesim noktaları ve aynı zamanda erkekler ve kadınlar için ayrı BKE kesim noktaları bulunmuştur. Buna göre "genç erişkin" yaş grubunda erkeklerin %70,1'i kadınlarda ise %78,8'i normal sınıflamaya, erkeklerin %14,4'ü, kadınların ise %10,1'i zayıf gruba girerken, erkeklerin %5,2'i ve kadınların %4,0'ı obez gruba girmektedir. Bu sonuç Türk genç erişkinler için obez olma durumuna kıyasla, zayıf olma durumunun daha ciddi olduğunu ortaya çıkartmıştır. BKE hesaplamalarında araştırılan ülkeye özgün olarak; yaş gruplarının, cinsiyetin ve bu hesaplamalarda yaşlanmaya bağlı boy kısalma miktarının göz önüne alınması önerilmiştir.

Anahtar sözcükler: *Türkiye-BKE, yaşa bağlı BKE boy uyarlaması, DSÖ-BKE, Asya-Pasifik BKE, antropometri*

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Introduction

Macroscopically, the perception of the physical appearance of a person is definable in a glance in terms of fatness or thinness, yet it may not always reflect the reality of that person's health status. The deviation of a human body from normal weight range can be scientifically determined by the calculation of the Body Mass Index (BMI), the ratio of body weight to height squared (kg/m^2) found by Dr. Lambert Adolphe Jacques Quetelet 1796-1874, who was a Belgian (Flemish) statistician, astronomer and sociologist, this index was named after him (Quetelet Index-QI) (Nuttal, 2015). When the body mass indices were compared for determination of body fat, QI was found more precise than the other indices, namely Weight-height ratio, Rohrer's Index, Ponderal Index, Sheldon Index, Nicholson and Zilvas Leanness Index (Watson *et al.*, 1979). However, this BMI index essentially cannot distinguish between increased body adiposity and muscle mass, moreover it is not valid for groups like athletes and people who has high body weight and very short stature (Bogin and Varela Silva, 2012). This index is most commonly used for anthropometric research which provides an approximate measure of thinness and fatness (Knai *et al.*, 2007). World Health Organization (WHO) has conventionally classified the body mass as underweight ≤18.5, normal weight 18.50 < BMI < 25, overweight ≥ 25 and obese ≥ 30 categories. However, worldwide trends led WHO to introduce new sub-divisions for underweight (severely, moderate and mild), obese (Class I, II, III) classifications. They renamed the "overweight" category as "preobese" (WHO Consultation on Obesity and WHO, 1999/2000). Furthermore, the issue of whether the cut-off points of this index is appropriate for all populations has been studied and the necessity of establishing population specific index cut-off points considering body fat ratio and health risks has been found and consecutively the Asian Pacific BMI (BMI-AP) has been created. Accordingly, it was suggested that each country must take their own measures on risks related to overweight and obesity (WHO Expert Consultation, 2004; Lim et al., 2017).

The anthropometric data of societies differ widely. Therefore, it is clear that population-specific cut-off points should be applied according to various factors. The objective of this research was to find out the BMI cut-off points for Turkish (BMI-TR) young adults and to compare this classification with BMI-WHO and BMI-AP cut-off points including age, sex and regional (coastal and inland areas of Turkey) factors.

Materials and methods

The Ethics Approval date and number is 17/05/2019-E.3889 and its Bar Code is *BD6932777823*. This study was conducted in accordance with the Principles of the Declaration of Helsinki.

The anthropometric data of this research covers the weight and height measurements of 196 subjects (97 Male, 99 Female) measured by the authors for BMI calculations. These subjects were within the age range of 20-25 years (average 22.5 years) defined as "young adults" because the median age in Turkey is 32.7 years (Türkiye İstatistik Kurumu, 2021). There were no cases among the subjects that had any disease or physical disability. To achieve standardization, all the measurements were recorded in the morning, at the same hour. Measurement of height was obtained by a wall-mounted length measuring apparatus (MST-B01, Istanbul, Turkey), with a capacity of 200 cm and 1 mm spacing. The body weights of subjects were measured by a digital glass body analysis scale with a capacity of 150 Kg. and LCD display (Precision Measurement Technology with 100 gr. precision) (Fakir Hausgeräte, Hercules, Istanbul, Turkey). In order to remove the effect of clothing, height measurements were taken without shoes, only with socks, in an upright position where heels were in contact. And during weight measurement each individual wore a t-shirt and a jean. During the measurements, the subjects' inhabited cities were recorded as coastal or inland because, Turkey is a peninsula which is surrounded by Black Sea, Aegean Sea and Mediterranean Sea. In order to assess intra-observer error, 82 individuals (of the total 196) were randomly selected for remeasuring by the same author under the same conditions, at a different time and the data was processed by Student's *t*- Test.

Then the BMI of Turkish young adult subjects were calculated by using the ratio of body weight to height squared. The statistical calculations were done with IBM SPSS Statistics 20 program. To assess the reliability and strength of internal consistency between a set of scale variables Chronbach's Alpha coefficient (α) was calculated. Data were summarized by descriptive statistics and contingency tables which were analysed according to Kolmogorov-Smirnov and Shapiro-Wilk tests. According to the distribution of data, Turkish BMI (BMI-TR) was constructed by Empirical rule for both total data and separately for both sexes. BMI-TR was categorized as follows: the mean ± 1 SD was equal to 68% of the total data which show the normal weight range, the values under the mean -1 SD was equal to 16% of the total data which show the underweight range, the overweight range was between the mean +1 SD and mean +2 SD which was equal to 13.5% of the total data, and values over mean +2 SD was equal to 2.5% of the total data which shows the obese range. This method was applied for both sexes according to the Empirical Rule (Figures 1 and 2).

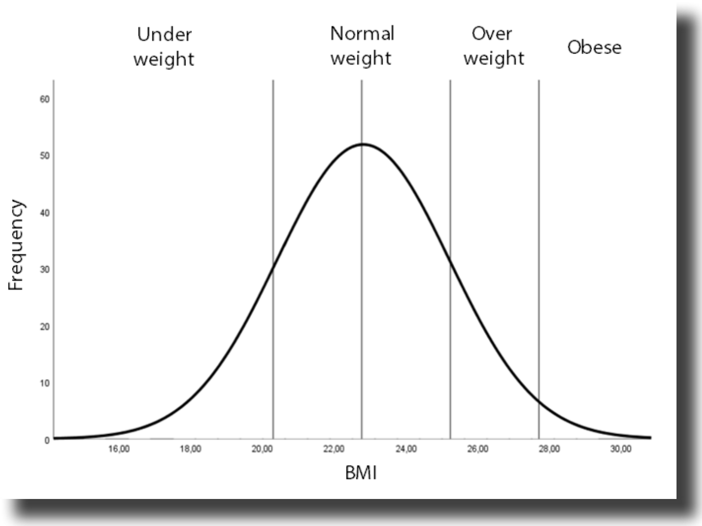

Figure 1. *Classifications of Body Mass Index (BMI) for Turkish young males according to Empirical Rule*

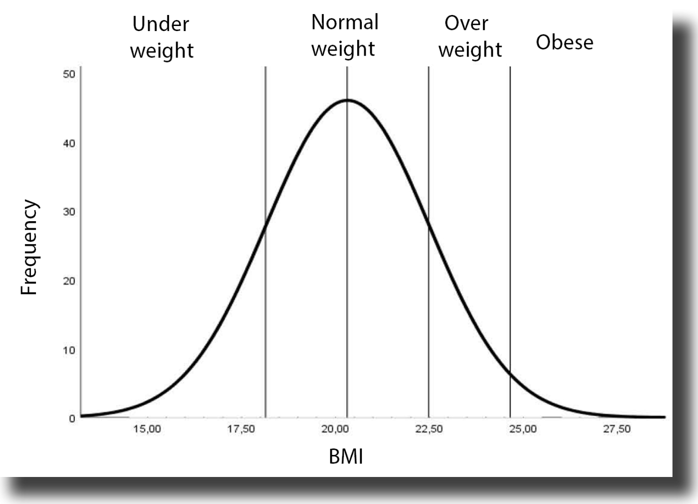

Figure 2. *Classifications of Body Mass Index (BMI) for Turkish young females according to Empirical Rule.*

The data of this research was computed to find the influence of sex, on BMI-TR and effect of their interaction. In order to establish this relation, two-factor experimental design model with interaction effect is as follows:

$$BMI = \mu + SEX + BMI\text{-}TR + SEX*BMI\text{-}TR + \epsilon$$

where μ = total mean of BMI and ϵ = error term.
Sex and BMI –TR was scaled as given below:
SEX: 1= Male, 2= Female.

$$\text{BMI-TR} = \begin{cases} 1, BMI \leq 18.82 \\ 2, 18.82 < BMI \leq 24.18 \\ 3, 24.18 < BMI \leq 26.86 \\ 4, 26.86 < BMI \end{cases} \quad (1)$$

According to the result of two-factor experimental design model, all pairwise comparisons of BMI-TR levels were determined by Tukey and Scheffe's methods. In addition, BMI values for individuals living in coastal and inland areas were compared by hypothesis testing applying t-test statistics.

Results

The result of reliability test showed that coefficient α was 0.952 (α ≥ 0.9 indicates excellence). This result shows 95.2% high internal consistency among the variables. Due to the increase of correlations between the items alpha increases proportionally (Vaske *et al.*, 2017). The *t*-test statistics evaluating intra-observer errors between the repetitive measurements in weight and height did not display any statistically significant difference between the two measurements (p value < 0.001).

All data were processed to obtain the descriptive statistics (number of subjects, minimum, maximum, median, mean, standard deviation) for age, weight, height and BMI of subjects according to sex where minimum BMI in the sample was 16.33 and the maximum BMI was 29.71 (Table 1). The same data set was used in BMI classification for BMI-WHO and BMI-AP classifications (Table 2). When the cut-off points of both BMI-WHO and BMI-AP classifications were applied to the Turkish data, incompatible results were obtained. Therefore, BMI-TR was established according to the Empirical rule based on the mean and standard deviation of the Turkish data (Table 2).

In the statistical analysis, according to the ANOVA results, there were a significant difference between the levels of sex, BMI-TR classifications and interaction effect in terms of BMI values. As a result of this test, pairwise comparisons of BMI-TR levels were found to be statistically different by Tukey and Scheffe's methods (p value <0.05 for all levels). BMI-TR index was significant according to sex which demonstrated the need to classify BMI by sex. Relying on this result, BMI-TR index was established according to sex namely as BMI-TR Male and BMI-TR-Female (Table 3).

Then the data were processed based on BMI-TR and divided into two subgroups as inland and coastal regions. The 35.7% of the sample group were from the coastal and 64.3% were from the inland areas of Turkey. Amongst the male subjects, normal weight percentage was 70.1% of which, inland and coastal distribution was 57.4% and 42.6% respectively and for female subjects, normal weight percentage was 78.8% of which, inland and coastal distribution was 64.1% and 35.9% respectively. For the rest; underweight group was 14.4%, overweight 10.3%, obese 5.2% for males, and for females; underweight group was 10.1%, overweight 7.1%, obese 4.0%.

Table 1. *Descriptive statistics for age, height, weight and Body Mass Index (BMI) of subjects according to sex*

Sex	Statistics	Age (years)	Weight (kg)	Height (m)	BMI (kg/m²)
Male	N	97	97	97	97
	Minimum	20	48	160	16.72
	Maximum	25	96	190	29.35
	Median	22.00	71.00	177.00	22.53
	Mean	22.56	71.19	176.80	22.76
	SD	1.338	8.744	5.522	2.47
Female	N	99	99	99	99
	Minimum	20	44	151	16.33
	Maximum	25	82	182	29.71
	Median	22.00	53.00	164.00	19.95
	Mean	22.43	54.67	164.12	20.28
	SD	1.089	7.241	5.983	2.28
Total	N	196	196	196	196
	Minimum	20	44	151	16.33
	Maximum	25	96	190	29.71
	Median	22.00	63.00	170.00	21.16
	Mean	22.49	62.84	170.40	21.50
	SD	1.217	11.513	8.569	2.68

Table 2. *BMI data classification according to World Health Organization Index (BMI-WHO), BMI-Asia-Pacific Index (BMI-AP) and BMI-Turkish (BMI-TR) for both sexes.*

	Classification	Range	Male%	Female%	Total%
BMI-WHO	Underweight	BMI ≤ 18.5	3.1	18.2	10.7
	Normal	18.5 < BMI ≤ 25.0	81.4	77.8	79.6
	Overweight	25.0 < BMI ≤ 30.0	15.5	4.0	9.7
	Obese	30.0 < BMI	0.0	0.0	0.0
	TOTAL		100	100	100
BMI-AP	Underweight	BMI ≤ 18.5	3.1	18.2	10.7
	Normal	18.5 < BMI ≤ 22.9	55.7	73.7	64.8
	Overweight	22.9 < BMI ≤ 24.9	25.8	4.0	14.8
	Obese	24.9 < BMI	15.5	4.0	9.7
	TOTAL		100	100	100
BMI-TR	Underweight	BMI ≤ 18.82	3.1	25.3	14.3
	Normal	18.82 < BMI ≤ 24.18	72.2	69.7	70.9
	Overweight	24.18 < BMI ≤ 26.86	18.5	2.0	10.2
	Obese	26.86 < BMI	6.2	3.0	4.6
	TOTAL		100	100	100

Table 3. *BMI data classification according to specific BMI-Turkish (BMI-TR) cut-off points for males (BMI-TR Males) and females (BMI-TR Females).*

	Classification	Range	%
BMI-TR MALE	Underweight	BMI ≤ 20.29	14.4
	Normal	20.29< BMI ≤ 25.23	70.1
	Overweight	25.23 < BMI ≤ 27.7	10.3
	Obese	27.7< BMI	5.2
BMI-TR FEMALE	Underweight	BMI ≤ 18.0	10.1
	Normal	18.0 < BMI ≤ 22.58	78.8
	Overweight	22.58< BMI ≤ 24.84	7.1
	Obese	24.84 < BMI	4.0

Discussion

Most of the BMI studies, focus on extreme obesity and its direct influence on health risks (Ogden *et al.*, 2014; Erem, 2015; Lim *et al.*, 2017; Flegal *et al.*,2019). It is stated that the serious health risks among overweight people is evident in their early adulthood (Zajacova and Burgard, 2010). It is also mentioned that there is a need to take precautions for obesity related health problems and expenses, especially in heavily industrialized countries (Knai *et al.*, 2007). The worldwide pooled data analysis shows that there is an obesity trend. Although, it also underlines that there is a moderate and/or severe underweight problem; in central and east west Africa, and south and southeast Asia, the other parts of these two continents show high trends in obesity (NCD-RisC, 2016).

As far as economics is concerned, it has to be acknowledged that underweight population, albeit to a lesser extent, may also be a factor for increased expenditure on health policy budgets just as obese population. Because extreme underweight situations have the potential of many important health-risks as; hypotension, anaemia, leucopoenia, bradycardia, anorexia nervosa, edema, constipation, amenorrhea, reduced; cholesterol, sex hormones, T3 and bone density, loss of clear thinking and concentration (Kodama, 2010). Additionally, the state of underweight pregnant women may lead to foetal growth deficiencies such as reduced birth weight and head circumference of the foetus (Ronnenberg *et al.*, 2003). Furthermore, it is declared that inadequate maternal nutrition in early gestation may cause obesity of the new-born after birth due to the postnatal enhanced nutrition (Painter *et al.*, 2005). It is indicated that there is strong evidence in developmental factors which contribute to the future metabolic diseases including insulin resistance and obesity (Gluckman *et al.*, 2005).

This economic burden connected to underweight population may be a matter of malnutrition due to low income and / or inefficient chewing function in connection with number of missing teeth (Uysal *et al.*, 2009). Yet, the restoration of missing teeth also puts a heavy financial burden on individuals. The issue of underweight is related to social behaviour influenced by social preferences, media pressure (Kodama, 2010), fashion industry employing androgynous looking models (Martin, 2009). It is stated that, in fashion industry, severely underweight model employment is so vast that even deaths among models are encountered whose BMI ratio ranges are between 13.5-14.5 and the models starve themselves in order to fit into the clothing sizes on the runway to guarantee further employment contracts. Hence, the clothing industry production is mainly made according to the sizes of these severely thin models and in order to consume these goods, especially youngsters are in continuous effort to lose weight and stay thin as much as they can (Jestratijevic *et al.*, 2010). It is apparent that health risks and the burden of this situation on the economy may occur when the normal distribution deviates to both sides.

In this study, Turkish data were performed on "young adults" within the age group of 20-25 years (the mean BMI was 22.76 for males, and 20.28 for females). However, WHO has a wider and intersecting range for defining young people (adolescence 10-19 years and youth as 15-24 years) (WHO, 1989). The data of this research were classified in accordance with BMI-WHO and BMI- AP which showed inconsistency in the cut-off points of categories. The computed data of this research showed that although no subject fell into the obese category of the BMI-WHO (BMI >30.0), there were 9.7% individuals (15.5% male, 4.0% female) in the obese category of BMI-AP (BMI> 24.9) (Table 2). Therefore, BMI-TR was established according to the Empirical rule because Turkey has a unique feature as a country that extends like a bridge between Asia and Europe (Table 2). When these data were computed according to BMI-TR cut-off points; in the obese category of BMI-TR (BMI > 26.86) there were 4.6% individuals (6.2% male, 3.0% female) (Table 2). On the other hand, from the aspect of underweight category, the same results 10.7% (3.1% male, 18.2% female) were obtained for BMI-WHO and BMI AP, as their underweight cut-off points are equal (BMI ≤ 18.5). However, there were 14.3% individuals (3.1% male, 25.3% female) in the underweight category of BMI-TR (BMI ≤ 18.82). It was found that for young adults (20-25 years) being underweight is more serious than being obese (Table 2). The BMI–TR and the data were also separated by sex because of the differences in the morphology of female and male bodies. When specific cut-off points were established according to sex, it was found that the percentage of female showing normal BMI was higher (78.8%), than male (70.1%) (Table 3).

A BMI study conducted in an Asian country Iran, which is neighbor to Turkey, there were 352 people within the age range of 18-29 years and it was found that 39 subjects (11.1%) were obese, and 20 subjects (5.7 %) were in underweight BMI categories (Shahvirdi *et al.*, 2019). Within the same aspect, BMI research involving Turkey, by using BMI-WHO cut-off points on 20.119 people, revealed that within the age group of 21-30 years; 8.9% of 1800 males and 15.9% of 836 females fell within the limits of obesity and attention was drawn to the burden of obesity on the country's economics related to the health expenses (Hatemi et al., 2003). However, in another research on Turkish people, 376 out of 2100 adults were within an age range of 18-29.9 years, showed 6.38% of males and 9.97% of females were in the obese category according to BMI-WHO. The mentioned research showed rising trends of obesity with ageing especially for females (Gültekin *et al.*, 2009). In a study of the same authors on the same context (age range from 18 to 65+) it was stated that anthropometric height measurements decrease proportionally with aging in both sexes again especially for females (Gültekin and Akın, 2005). This analytic finding enlightened us in explaining the BMI rise as ageing. It is a fact that BMI is a ratio and the square of height is the denominator (m^2), the BMI ratio increases as the height of the elderly decreases, this shows that the obesity in elderly may not always arise from the increase in weight (kg.) but from unavoidable decrease in height. Similarly, in *The Baltimore Longitudinal Study of Aging* (Sorkin *et al.*, 1999), height change with age for 1,068 men and 390 women were analyzed showing that the height decrease for both sex starts about 30 years of age and accelerates with age which was approximately 5 cm for men and 8 cm for women by age 80 years. For this reason, "true height" loss must be calculated according to age groups for different ethnic populations. As mentioned above, BMI studies shows that there is a worldwide trend in obesity but, if true height adjustments were inserted in the BMI calculations, the results would have been more precise and related health measures for the economy would be more efficient.

This pilot study was performed on subjects 20-25 years of age range where the decrease in height has not yet initiated. However, in longitudinal BMI studies, the anthropometric fact of height decrease with ageing must be taken into account while calculating BMI, otherwise it would be difficult to distinguish the rise in BMI, whether it has driven from weight increase or height decrease of the individual. Therefore, the Quatelet index should be modified for the elderly is as follows:

$$BMI_{HeightAdjusted}\ (kg/m^2) = \frac{Weight}{[Height+\Delta_{Height}]^2} \quad (2)$$

where;

Δ_{Height} = Mean height control of age group – Mean height of subject's group.

The former is the age range between 18-30 ages where the height decrease has not been started, and the latter ise the related age group that the subject belongs to.

In this study, it was assumed that there might have been a difference in BMI values of inland and coastal regions, as Turkey is a large country with a heterogenic population. Therefore, BMI values were computed according to inland and coastal areas however, the statistical analysis revealed that there was no significant difference between the mean BMI values of individuals for the inland and coastal areas (p value >0.05).

Conclusion

The results of this research revealed that;

1. There are anthropometric diversities present among male and female individuals of each country. Therefore, BMI index should be applied to each and every country according to both sex and their specific index cut-off points must be calculated. In this pilot study, male and female specific body mass index for Turkish "young adults" (BMI-TR) for age group 20-25 years is proposed.
2. Turkish specific BMI results for BMI-TR Males and BMI-TR Females showed that the percentage of females showing normal BMI was higher (78.8%), than males (70.1%), and being underweight (14.4 % for males, 10.1 % for females) was more serious than being obese (5.2% for males, 4.0 % for females) in the "young adult" age group.
3. The following equation is proposed for BMI calculation for elderly:

$$BMI_{Height\ Adjusted}\ (kg/m^2) = \frac{Weight}{[Height + \Delta_{Height}]^2} \quad (3)$$

For further research, BMI classifications should be applied; for every age range, according to sex for each country. It is suggested that for the elderly the height decrease must be taken into consideration by adjusting height, as given in the Equation 3.

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are delighted to find an intuitive recognition of body mass in the dialogue of William Shakespeare's play in "The Comedy of Errors":

> Antipholus of Syracuse: "Then she bears some breadth?"
>
> Dromio of Syracuse: "No longer from head to foot than from hip to hip. She is spherical, like a globe. I could find out countries in her".
>
> - William Shakespeare (1564-1616)
> The Complete Comedies[1]

[1] Shakespeare, W. (1936). The complete comedies. *The comedy of errors, Act 3 Scene II,* 184-188. Grolier Incorporated Text Copyright.

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