Estimated anthropometric measurements of Turkish adults and effects of age and geographical regions

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\textbf{A B S T R A C T}

The purpose of this paper is to estimate the anthropometric characteristics of the Turkish population by geographical region, age and gender. A survey of 4205 samples consisting of 2263 male and 1942 female civilian subjects was done in the year of 2007. It contains data from all seven geographical regions of Turkey and from all age groups. In the study, height and weight of the subjects were measured by age. Then, these data were used for estimating anthropometric measurements of the Turkish population. The main result of this study is the anthropometric measurements table for Turkey which shows 37 measurements that are commonly used in industry. The anthropometric measurements that are used to make the designs fit human shape and the human/machine or human/environment interface should be updated through time due to changing body types over time (secular trends) due to numerous factors. In this study, we not only update these variables, which are 30 years old, but also investigate the age and region effects on stature and weight of Turkish population.

Relevance to industry: During the design phase of a product, incorporating anthropometric information would yield more efficient designs, which are more user friendly, safer and enable higher performance and productivity. So the anthropometric measurements table that is extracted from this study can be used by industry to produce better human oriented products for Turkish population.

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1. Introduction

Anthropometry is the branch of the human sciences that deals with body measurements. Humans are variable. This variability is mostly related with ethnicity, gender and age (Jurgens et al., 1990). Anthropometric data are one of the essential factors in designing machines and tools (Norris and Wilson, 1997). During the design phase, incorporating the information from anthropometry would yield more efficient designs, ones that are more user friendly, safer and enable higher performance and productivity. The lack of properly designed machines and equipment may reduce the work performance and increase the frequency of work-related injuries (Botha and Bridger, 1998).

The anthropometric data available for different populations vary greatly. The collection of anthropometric data is extremely time-consuming and expensive. Despite these, there are many sources of anthropometric data for national populations, which can be found in papers in scientific journals, such as Gite and Chatterjee (1999) and Dewangan et al. (2005) for Indian agricultural workers, Xiao et al. (2005) for Chinese, Klamklay et al. (2008) for Thai, Barroso et al. (2005) for Portuguese, Mokdad (2002) for Algerians, Adult data (Peebles and Norris, 1998) and its companion volumes Child data (Norris and Wilson, 1995) and Older Adult data (Smith et al., 2000) and the anthropometric database People size (Open Ergonomics Ltd., 2000).

In Turkey, there are very few studies on anthropometry. The most extensive study in Turkey is the Anthropometric Survey of Turkey (Government Statistics Department, 1937). This survey was conducted in 10 regions of Turkey under the executive orders of Atatürk, the founder of the Republic of Turkey. In this survey, weight, height, span and sitting height were measured. Another study on anthropometrics was done by Çiner (1960). In this study, anthropometric characteristics of 2501 females between the ages of 18 and 40 were measured from different regions of Turkey. The sample was divided into two subgroups, one between the ages of 18–20 and the other for those above age of 21. These two groups were compared according to their anthropometric characteristics. The study by Özok (1981) was the first study from the engineering perspective of anthropometrics. This study took 1000 worker samples from 50 different industrial facilities. Kayış and Özok
(1989) conducted a comprehensive survey on Turkish army man. In this study, 51 different anthropometric measurements are taken from 5109 soldiers. Gönen and Kalınkara (1991) also conducted a small survey on female population of Turkey. In this survey, samples from different age groups were taken and statistical analyses were done if aging affects anthropometric characteristics. But, the sample size was small with only 195 participants.

The studies in this area are far from sufficient. Most of them are dated; some used very small sample sizes or used male military recruits as subjects. Others were taken from specific geographic locations, but not nationally from across Turkey. This study will assist in closing the gaps in this area since it is current and covers all age groups between 20 and 85 and all seven geographical regions. It has a sample size of 4205 consisting of 2263 males and 1942 female civilian subjects.

2. Methods

2.1. Materials

This study is based on the study done with 4205 individuals consisting of 2263 males and 1942 females from seven regions of Turkey. Individuals were selected from households of primary school children. A random cluster sampling frame was applied to select the study subjects. In every school that was associated with the study, three classes were selected randomly. Field workers who were guidance counselors in these schools received an appointment approximately one week before visiting the household of the students who were in the selected classes. Regular measurement tools are used such as digital scales for weight and tape measure for stature. It was the authors’ intent to use stadiometers but it was difficult to bring the families to a specific location. The response rate was, respectively, high with a mean of 77%. Field workers measured the height and weight of the household members who are greater than 20 and recorded their ages.

This study was taken by the field workers from 18 different cities: Denizli and Kütahya from Aegean region; Zonguldak from Black Sea region; Aksaray, Ankara, Kayseri and Konya from Central Anatolia region; Bitlis from Eastern Anatolia region; Adapazarı, Balıkesir, Bursa, İstanbul and Kocaeli from Marmara region; Antalya and Mersin from Mediterranean region; Diyarbakır, Gaziantep and Şanlıurfa from Southeast Anatolia region. While composing our sample set, the real regional distribution of Turkish population was considered and the 18 cities were selected accordingly. Table 1 shows the real regional distribution in Turkey and in the study. A chi-square goodness of fit test was also done; and according to the test (p value is 0.265), the distribution of samples among regions is similar to the real regional distribution in Turkey. This is an expected result since we make our sampling plan according to the real regional distribution.

Age is an important factor in anthropometry. Taking only younger people would take us to overestimation of the measurements. In the survey, every age group is included between 20 and 85 considering the real age distribution. By taking every individual in the household of primary school children, the authors thought that it would be possible to simulate the real age distribution. However, many individuals who were the households of primary school children were middle-aged. This caused a small bias in age groups towards age of 40–44. This can be seen in Table 1 which shows the real distribution of individuals according to age compared with the sample age distribution. p value for the age distribution in chi-square goodness of fit test is very small meaning that there is not a very good fit between real age distribution in Turkey and in the study. But this is not a very big deal since we have taken enough observations in every age group for statistical inference.

2.2. Methods for creating anthropometric measurements table

There are almost 300 measurements in anthropometry; however ergonomists generally use 37 of them. These 37 anthropometric measurements are estimated for Turkish population using the survey data and ratio scaling method (Pheasant, 1982).

To estimate the anthropometric measurements from the survey data, the ‘ratio scaling’ technique was used, discussed in more detail by Pheasant and Haslegrave (2006). Pheasant (1982) conducted a validation study of this technique and found that its errors are acceptable for most purposes. Moreover, no consistent pattern was found in the errors. This method suggests that; if the parameters of variables x and y are known in a reference population A (or more precisely in a sample drawn from it) but only the parameters of x are known in population B (which is called the “target population”), then

\[
\frac{m_y}{m_x} \text{(in reference population A)} = \frac{n_y}{n_x} \text{(in target population B)}
\]

and

\[
\frac{s_y}{s_x} \text{(in reference population A)} = \frac{s_y}{s_x} \text{(in target population B)}
\]

provided that populations A and B are similar in terms of age range, gender and ethnicity.

Here target population stands for the sample from the study whose parameters will be estimated using the known parameters of the reference population. Dimension x, which is known in both populations, is called as the “scaling dimension”. Stature is most commonly used for this purpose since it is commonly available for populations in which other data are not available. Here also, stature is used as the scaling dimension and other measurements are scaled with respect to stature and reference populations which are discussed below.

The simplest method for ratio scaling is to collect, from a variety of reference populations, the coefficients E₁ and E₂ and simply multiply the average of each of these by the relevant parameter for stature in the target population to obtain the estimates of the mean.
Table 2

<table>
<thead>
<tr>
<th>Turkish</th>
<th>E\textsubscript{1} (Mean)</th>
<th>E\textsubscript{2} (SD)</th>
<th>E\textsubscript{1} (Mean)</th>
<th>E\textsubscript{2} (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td>Men</td>
<td>Women</td>
</tr>
<tr>
<td>1. Stature</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>2. Eye height</td>
<td>0.940</td>
<td>0.988</td>
<td>0.934</td>
<td>0.961</td>
</tr>
<tr>
<td>3. Shoulder height</td>
<td>0.829</td>
<td>0.926</td>
<td>0.818</td>
<td>0.934</td>
</tr>
<tr>
<td>4. Elbow height</td>
<td>0.630</td>
<td>0.741</td>
<td>0.628</td>
<td>0.724</td>
</tr>
<tr>
<td>5. Hip height</td>
<td>0.527</td>
<td>0.716</td>
<td>0.510</td>
<td>0.684</td>
</tr>
<tr>
<td>6. Knuckle height</td>
<td>0.437</td>
<td>0.556</td>
<td>0.453</td>
<td>0.592</td>
</tr>
<tr>
<td>7. Finger tip height</td>
<td>0.376</td>
<td>0.617</td>
<td>0.393</td>
<td>0.618</td>
</tr>
<tr>
<td>8. Sitting height</td>
<td>0.522</td>
<td>0.568</td>
<td>0.531</td>
<td>0.539</td>
</tr>
<tr>
<td>9. Sitting eye height</td>
<td>0.460</td>
<td>0.605</td>
<td>0.461</td>
<td>0.513</td>
</tr>
<tr>
<td>10. Sitting shoulder height</td>
<td>0.355</td>
<td>0.531</td>
<td>0.349</td>
<td>0.474</td>
</tr>
<tr>
<td>11. Sitting elbow height</td>
<td>0.137</td>
<td>0.469</td>
<td>0.145</td>
<td>0.447</td>
</tr>
<tr>
<td>12. Thigh thickness</td>
<td>0.084</td>
<td>0.296</td>
<td>0.096</td>
<td>0.276</td>
</tr>
<tr>
<td>13. Buttock–knee length</td>
<td>0.333</td>
<td>0.469</td>
<td>0.356</td>
<td>0.474</td>
</tr>
<tr>
<td>14. Buttock–popliteal length</td>
<td>0.259</td>
<td>0.531</td>
<td>0.297</td>
<td>0.474</td>
</tr>
<tr>
<td>15. Knee height</td>
<td>0.353</td>
<td>0.481</td>
<td>0.309</td>
<td>0.434</td>
</tr>
<tr>
<td>16. Popliteal height</td>
<td>0.244</td>
<td>0.383</td>
<td>0.247</td>
<td>0.408</td>
</tr>
<tr>
<td>17. Shoulder breadth (bideltoïd)</td>
<td>0.278</td>
<td>0.790</td>
<td>0.229</td>
<td>0.316</td>
</tr>
<tr>
<td>18. Shoulder breadth (biacromial)</td>
<td>0.229</td>
<td>0.296</td>
<td>0.221</td>
<td>0.303</td>
</tr>
<tr>
<td>19. Hip breadth</td>
<td>0.195</td>
<td>0.333</td>
<td>0.193</td>
<td>0.500</td>
</tr>
<tr>
<td>20. Chest (bust) depth</td>
<td>0.131</td>
<td>0.333</td>
<td>0.162</td>
<td>0.335</td>
</tr>
<tr>
<td>21. Abdominal depth</td>
<td>0.161</td>
<td>0.481</td>
<td>0.164</td>
<td>0.513</td>
</tr>
<tr>
<td>22. Shoulder–elbow length</td>
<td>0.209</td>
<td>0.296</td>
<td>0.171</td>
<td>0.421</td>
</tr>
<tr>
<td>23. Elbow–fingertip length</td>
<td>0.273</td>
<td>0.309</td>
<td>0.267</td>
<td>0.316</td>
</tr>
<tr>
<td>24. Upper limb length</td>
<td>0.435</td>
<td>0.580</td>
<td>0.439</td>
<td>0.539</td>
</tr>
<tr>
<td>25. Shoulder-grip length</td>
<td>0.382</td>
<td>0.469</td>
<td>0.373</td>
<td>0.474</td>
</tr>
<tr>
<td>26. Head length</td>
<td>0.110</td>
<td>0.173</td>
<td>0.111</td>
<td>0.105</td>
</tr>
<tr>
<td>27. Head breadth</td>
<td>0.089</td>
<td>0.272</td>
<td>0.096</td>
<td>0.105</td>
</tr>
<tr>
<td>28. Hand length</td>
<td>0.111</td>
<td>0.173</td>
<td>0.105</td>
<td>0.132</td>
</tr>
<tr>
<td>29. Hand breadth</td>
<td>0.051</td>
<td>0.086</td>
<td>0.047</td>
<td>0.079</td>
</tr>
<tr>
<td>30. Foot length</td>
<td>0.153</td>
<td>0.235</td>
<td>0.145</td>
<td>0.394</td>
</tr>
<tr>
<td>31. Foot breadth</td>
<td>0.061</td>
<td>0.136</td>
<td>0.055</td>
<td>0.092</td>
</tr>
<tr>
<td>32. Span</td>
<td>1.011</td>
<td>1.210</td>
<td>0.997</td>
<td>1.145</td>
</tr>
<tr>
<td>33. Elbow span</td>
<td>0.543</td>
<td>0.679</td>
<td>0.527</td>
<td>0.697</td>
</tr>
<tr>
<td>34. Vertical grip reach (standing)</td>
<td>1.273</td>
<td>1.444</td>
<td>1.177</td>
<td>1.158</td>
</tr>
<tr>
<td>35. Vertical grip reach (sitting)</td>
<td>0.714</td>
<td>0.852</td>
<td>0.714</td>
<td>0.853</td>
</tr>
<tr>
<td>36. Forward grip reach</td>
<td>0.440</td>
<td>0.519</td>
<td>0.435</td>
<td>0.523</td>
</tr>
</tbody>
</table>

An example. (Estimating eye height of Turkish males)

- Mean eye height of Turkish males:
  \[ E_1 = \text{Mean eye height} \times \text{mean stature in the study} \]
  \[ = 0.939 \times 1708 = 1605 \text{ mm} \]
- SD of eye height of Turkish males:
  \[ E_2 = \text{SD of eye height} \times \text{standard deviation of stature in the study} \]
  \[ = 0.983 \times 81 = 80 \]
- 5th percentile of eye height:
  \[ E_3 = (z_{\text{value}} \times \text{SD of eye height}) + \text{Mean of eye height} \]
  \[ = (-1.64 \times 79.6) + 1605 = 1473 \text{ mm} \]
- 95th percentile of eye height:
  \[ E_4 = (1.64 \times 80) + 1605 = 1736 \text{ mm} \]

2.3. Methods for evaluating age and geographical effects on anthropometry

To determine effects of region and age on stature and weight of Turkish population, Analyses of Variance (ANOVA) was applied to the sample data. To do the analyses, Minitab statistical software was used and “General linear model” was applied. Age, region and gender are put into the model as factors. Region and gender are fixed factors whereas age is a random factor. Two separate analyses were done on two separate responses (stature and weight).

3. Results

3.1. Anthropometric measurements table

After calculations are done, the anthropometric data table for Turkish population which is shown in Table 3 is formed.

The Turkish population has relatively small arms when compared with Western Europe countries, but has similar arm/stature ratios to countries, in the Far East. When we examine the abdominal depth; Turkish population has similar ratios with the British and US populations, who have a high abdominal depth/stature ratio, but unlike Far Eastern countries such as China or Japan whose ratio is much smaller than westerners. For the other ratios, the Turkish population is often similar to countries in Central Europe. These comparisons are made by comparing the ratios in Table 2 with the data compiled from various studies (Lewin, 1969; Ingemark and Lewin, 1968; Rebille et al., 1983; Batogowska and Slowikowski, 1974; Abraham, 1979; Abeysekera and Shanavaz, 1987) by Pheasant and Haslegrave (2006).

3.2. ANOVA results for the effects of age and geographical regions

According to the ANOVA results which are shown in Table 4, gender, age and region affect stature (p value < 0.000 for gender and age; < 0.025 for region) and weight (p value < 0.000 for all factors) significantly in the stated significance order. Sex is the most important factor in both stature and weight analysis. Also age is a significant factor for both responses. But region is the least effective factor.

3.3. Aging effect on stature and weight

Age effect upon stature and weight in Turkish population is very similar to US and British populations. This is due to the abundance of food and increasing sedentary lifestyle. The effect of age on stature and weight in Turkish population can be seen in Figs. 1 and 2. These figures are extracted from the sample.

From Fig. 1, it can be easily seen that stature diminishes with increasing age. The shrinkage until age of 40 can be explained...
through the "secular trend". Secular trend in Turkish population has been very effective for the last 20–30 years. As in the case of developing countries, this can be explained as Turkey's rapid development rate with citizens' developing social and economic conditions. For the shrinkage after age of 40, aging is also effective. The shrinkage related with aging generally occurs in the intervertebral discs of the spine. Studies show that at around 40 years of age we begin to shrink in stature and that women shrink more than men. In our survey, shrinkage is very rapid between age 50 and 60.

Weight is a completely different story. From Fig. 2, it can be seen that weight is steadily increasing until a certain age which is 50 in men and 55 in women. After that age body weight begins to decrease. Health complaints and decreasing ability of the body to gain weight are among the main reasons. Also, another reason could be that the overweight has already died, and only the thin survive. Other studies also show an increase in weight until 55 years, followed by a decline.

3.4. Effects of geographical regions on stature and weight

Although Turkey has seven geographical regions (Aegean, Black Sea, Central Anatolia, Marmara, Mediterranean, and Southeast Anatolia), the residents of these seven geographical regions are not ethnically different from each other. But, there are substantial cultural differences between these regions. Although it's not as important as gender and age, there are some regional effects as can be seen in Figs. 1 and 2. Women in Aegean and Marmara regions – which are economically more developed regions – are lighter than women in the Black Sea, Central Anatolia and Southeast Anatolia. Whereas, men in Aegean, Eastern Anatolia and Mediterranean regions are lighter than men in Black Sea, Marmara and Southeast Anatolia. In regions where education level is higher women are lighter. However there is not such an effect for men. These results can be seen in Fig. 2.

4. Discussion

Today, anthropometry plays an important role in industrial design, clothing design, ergonomics, and architecture, where statistical data about the distribution of body dimensions in the
population are used to optimize products. However, one should note that it cannot be used to construct a manikin (a human model) since every measurement of a specific human body can be in a different percentile value. For example; a person’s stature can be at a value of the 95th percentile, but the arms can be rather small for instance a value of 75th percentile. But, this does not mean that we cannot use the anthropometric data. It is widely used for covering the most of the population in the designs like calculating the appropriate height of a working desk. For instance, this height is calculated taking 95th percentile value of the elbow height as reference for covering most of the population as suggested in Kroemer and Grandjean (2005). Many application areas of the anthropometric data are shown in human factors engineering books and related papers such as Mehta et al. (2008).

Changes in life styles, nutrition and ethnic composition of populations lead to changes in the distribution of body dimensions, and require regular updating of anthropometric data collections (Pheasant and Haslegrave, 2006). Here we updated these variables that are 30 years old for Turkey, and also investigate the age and regional effects on stature and weight of Turkish population.

In this study, an anthropometric survey consists of height, weight, age and region of 4205 individuals is done. This survey covers both the genders, seven geographical regions and all age groups. After the data from the study was gathered, firstly these data were used to estimate the other 35 anthropometric measurements of Turkish population.

Social and environmental influences such as the improved nutritional quality of diet and the reduction of infectious disease by improved hygiene, health care, urbanization and reduced family size have caused a ‘secular trend’ which means an increase in the overall stature of ethnic populations through time. Regarding the survey and past anthropometric studies (Çiner, 1960; Kayış and


Çiner, L.P., Chatterjee, D., 1999. All India anthropometric survey of agricultural workers: proposed action plan. All Indian Coordinated Research Project on Human Engineering and Safety in Agriculture. Central Institute of Agricultural Engineering, Bhopal, India.


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