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Variations in arm span and total arm length in the elderly and using these measurements as alternative to body height[1]

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Abstract

During the aging process, total body height decreases due to bone tissue loss caused by anatomical changes, osteoporosis, and osteopenia, as well as a decrease in the distance between the joints. Decreasing of body height in the aged people brings along the problem that the body mass index (BMI) cannot be calculated correctly. Alternative measurements are being developed to precisely calculate BMI in elderly peoples. In this study, the arm span will be looked at in order to replace body height. The change in arm span and its variation in the elderly will be assessed in this research primarily. Standard anthropometric measurements of body height, arm span, half-arm span and total arm length were taken from a total of 325 individuals, 154 women and 171 men, aged between 65 through 90 years. The biggest change in body height was observed throughout the age period studied (r = 0.227; AdjR2 = 0.048), as shown by the correlation and regression analysis results. The age groups' differences in arm span (r = 0.158; AdjR2 = 0.022) indicate that this metric cannot be used as an alternative variable to total body height, or stature. Total arm length appears to be the most logical measurement when stature is not available in the old population, as evidenced by the little amount of change in this variable over the aging period.

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Introduction

As a result of narrowing of intervertebral and interarticular spaces, loss of bone tissue (osteoporosis and osteopenia), and other anatomical changes, body height, or stature, decreases during aging. Although this decreasing varies between individuals, the general trend is that the decreasing in stature becomes more apparent from the age of 60-65 years (Cline et al., 1989). While some researchers estimated that a person's height would change by 1-3 cm over a decade (Chumlea et al., 1985), other researchers reported that the change would be between 1.5 and 2.5 cm (Miall et al., 1967).

Body mass index (BMI), which is considered as a reference variable, especially by the World Health Organization (WHO), is an important indicator for assessing malnutrition and overall health condition in the elderly (Hall and Cole, 2006). Decreasing of stature in the elderly brings with it the problem that the BMI, which is frequently used for body structure and nutritional status, cannot be calculated correctly (Can, 2021). Additionally, even though body weight fluctuates less than body height, it still causes issues with BMI computation. Alternative studies have been carried out to get around this bias, which causes data on public and individual health to be incorrectly assessed. In light of relevant studies, an accurate body height value is needed for more precise BMI calculation, and therefore, measures that will be an option to stature in old age are needed. In this framework, the measurements taken from main long bones or extremities, which are considered to show relatively less fluctuate during the aging process and which are taken as reference by researchers (e.g. Pelin and Duyar, 2003), were preferred.

When the researches are evaluated, it becomes clear that the equations developed to determine body height make the usage of knee height stand out. This orientation of the researchers is based on the idea that knee height is more correlated with stature (Fogal et al., 2015; Knous ve Arisawa, 2002; Chumlea et al., 1985; Shahar ve Pooy, 2003; Myers et al., 1994; Palloni and Guend, 2005; Donini et al., 2000; Zhang et al., 1998; Cockram and Baumgartner, 1990). Although some researchers claim that knee height is the best reference variable, others think that this variable is in doubt because of the way the ankle and the sole of the foot change as we age (Roubenoff and Wilson, 1993). For example, Pini et al. (2001) calculated that the decreasing is 10 mm due to the deformation and narrowing in this part of the body.

Arm span is a linear dimension that has been suggested as an alternative to body height since it is less impacted by aging than the body parts that make up the upper limb (Allen, 1989; Mohanty et al., 2001; Popovic, 2018; Quanjer et al., 2014). It is thought that its use has some? benefits, especially when degenerative alterations or spinal deformations are present (Allen, 1989). However, there are studies with contradictory results about the usage of arm span in addition to these accurate assessments. For example, Mitchell and Lipschitz (1982) hypothesized that weak and constrained joint movements make it challenging to fully extend the elbows, making it impossible to acquire the proper anatomic posture for measuring the arm span and obtaining valid data. On the other side, arm span is recommended over body height for the elderly who are unable to stand or who are bedridden (Kwok and Whitelaw, 1991; Nygaard, 2008).

In this study, firstly the change patterns and variation of arm span in the elderly will be examined. In addition, we aim to test whether this anthropometric variable can be used instead of body height alternatively, especially in advanced age groups, and whether it has advantages in eliminating the bias in classical calculation of BMI.

Materials and method

Anthropometric measurements were gathered from total 325 individuals, 154 women, and 171 males, aged between 65 to 90 years, as part of a study to identify potential dimensions for stature (Table 1). All of the participants were born and live in Hatay province in Southern Turkey. In order to ensure statistical significance, the minimum number of participants for each group in the study was set at 30 for both sexes.

Table 1. Distribution of the elderly by age and sex

Age groups (years)	Females	Males	Total
65-69	34	47	81
70-74	30	31	61
75-79	30	33	63
80-84	30	30	60
85+	30	30	60
Total	154	171	325

The study was carried out on four linear anthropometric dimensions: (1) body height, (2) arm span, (3) half-arm span, and (4) total arm length. These measurements were taken following the standard procedures recommended by the International Biological Programme (IBP) (Tanner et al., 1978; Duyar, 2000). The anthropometric dimensions and the measurement techniques followed are as follows:

1. Body height: It was measured with a stadiometer with a precision of 0.1 cm. The participant stood on the stadiometer with bare feet, heels together, head in the Frankfurt plane, and shoulders relaxed and back straight.

2. Arm span: The measurement was performed with a steel tape measure. During the measurement, the participant was made to open both arms at a 90-degree angle and the distance between the dactylion points, the ends of the middle fingers of both hands was measured.

3. Half-arm span: The measurement was taken with a steel tape measure. It was performed by opening the left arm at a 90-degree angle and measuring the distance between the dactylion point and the jugular notch on the sternum.

4. Total arm length: The participant's arm and hand were extended slightly forward and to the side, allowing the arm to gain its full length. One end of the segmentometer was placed lightly the left acromiale and the other end was placed lightly the extreme point of the middle finger (dactylion) of the outstretched hand of the participant.

In order to evaluate the dimensional changes in stature and other anthropometric variables in the elderly in a practical way, five age groups were defined at 5-year intervals. The distribution of the age groups is as follows; Group 1 = 65-69 years, Group 2 = 70-74 years, Group 3 = 75-79 years, Group 4 = 80-84 years and finally Group 5 is 85 years and above.

The socioeconomic characteristics of the participants in the study show that they are in the lower socioeconomic status of the society (see for details Can, 2021). Although there are older adults among the participants in the upper and middle socioeconomic groups, their percentage and quantity are significantly fewer than in the lower socioeconomic group. Alongside these findings, it was discovered that 57.2% of the participants had never attended school. The average number of children, which one of the socioeconomic indicators, in the sample is 5 which suggests that its socioeconomic status is rather low, and also closely proportional to all the other indicators (Can, 2021).

After the design phase of the research, permission was obtained from the Hatay Mustafa Kemal University Ethics Committee on 14.02.2019 (Decision No. 10). This work was supported by the Scientific Research Projects Coordination Unit of Istanbul University with Project Number 33806.

Results

The results obtained in the study according to sex and age groups and basic statistical data are presented in Table 2. When body height is taken into account, it is shown that the aging process invariably results in decreased average heights for both men and women in older ages (Table 2). In our sample, the mean height varies between Age Groups 1 and 5 by about 50 mm on average. The most notable decline in both sexes was observed in the transition between Age Groups 3-4, according to our analysis of the age groups individually. The pattern of decreasing in stature is similar among the sex groups (Table 2).

Table 2. Change in stature according to age groups in male and female elderly (mm)

Age group (years)	Females			Males		
	n	Mean	SS	n	Mean	SS
Group 1 (65-69)	34	1525.2	58.2	47	1663.2	55.9
Group 2 (70-74)	30	1510.6	66.4	31	1672.1	63.8
Group 3 (75-79)	30	1508.3	57.5	33	1647.9	84.7
Group 4 (80-84)	30	1480.4	50.1	30	1609.3	74.7
Group 5 (85+)	30	1474.7	53.4	30	1611.6	65.3

Table 3. Change in arm span according to age groups in female and male elderly (mm)

Age group (years)	Females			Males		
	n	Mean	SS	n	Mean	SS
Group 1 (65-69)	34	1552.0	78.8	47	1705.4	82.3
Group 2 (70-74)	30	1513.5	103.7	30	1713.0	83.0
Group 3 (75-79)	30	1537.2	106.9	33	1702.0	94.6
Group 4 (80-84)	30	1503.4	80.9	30	1665.0	79.9
Group 5 (85+)	30	1494.4	102.6	30	1666.1	96.7

Table 4. Change in half-arm span according to age groups in female and male elderly (mm)

Age group (years)	Females			Males		
	n	Mean	SS	n	Mean	SS
Group 1 (65-69)	34	789.0	34.6	47	855.6	41.4
Group 2 (70-74)	30	772.2	43.9	31	860.4	36.6
Group 3 (75-79)	30	767.4	55.1	33	850.6	49.6
Group 4 (80-84)	30	767.2	40.1	30	828.9	42.4
Group 5 (85+)	30	765.2	41.2	30	834.8	44.5

According to Table 3, the age period between 80 and 85+ is the least amount of a decrease in arm span in both genders. Compared to older women, the change in arm span in older men is less noticeable. In contrast to men, women see a more dramatic and sharper changing between age groups.

According to Table 4, women's half-arm span exhibited a declining trend across all age groups. Male individuals did not exhibit change in a trend direction as did female participants, and there was no consistent pattern across age groups. In comparison to males, females showed the most obvious change between Groups 2-3, whereas males showed the greatest decrease between Groups 3-4

Table 5. Change in arm length according to age groups in male and female elderly (mm)

Age group (years)	Females			Males		
	n	Mean	SS	n	Mean	SS
Group 1 (65-69)	34	707.1	28.2	47	727.8	44.5
Group 2 (70-74)	29	701.7	40.3	31	748.0	37.5
Group 3 (75-79)	30	706.6	34.0	33	743.5	46.8
Group 4 (80-84)	30	691.2	39.5	30	728.8	36.8
Group 5 (85+)	30	695.5	38.8	30	734.3	41.3

It is seen in Table 5 that the total arm length, which is our last variable, also changes in both men and women during the aging process, but this change is less than those of other variables. For instance, the difference in arm length across the same age groups was found to be 10 mm on average, although the change in arm span and stature had values of roughly 50 mm and above between the mean values of Group 1 and Group 5.

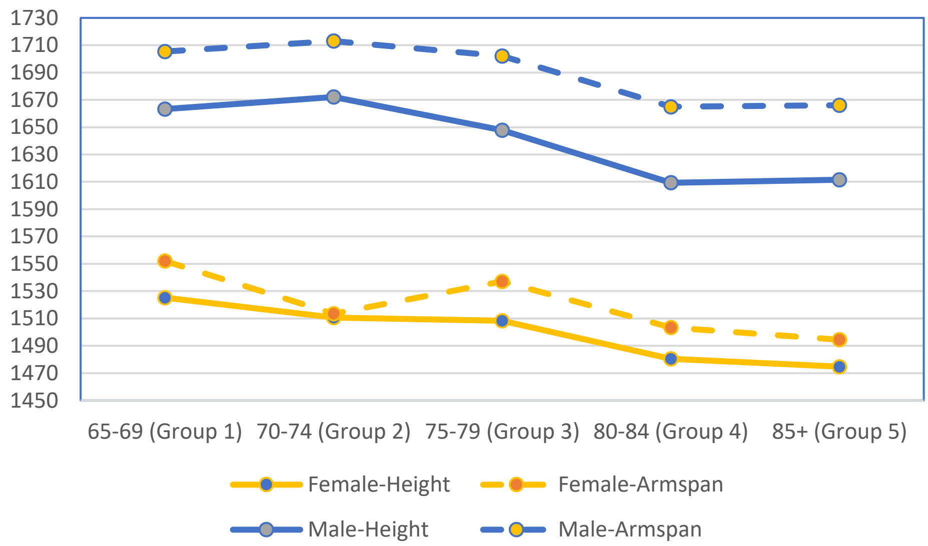

Figure 1. Changes of body height and arm span in females and males according to age groups

The first point that draws attention at this stage is that while body height and arm span have approximately the same values among women, the length of the arm span has obviously larger values than the body height among men (Fig. 1). Arm span similarly shows decreased mean values in older men and women, parallel to the decline in body height. In women, this dimension shrinks on average by 5.8 cm, whereas in men it shrinks by roughly 4.0 cm. Thus, it can be said that the decreasing of the arm span is less apparent in men than in women. While the decreasing or changing in stature display at similar rates in both sexes, there is no similar change in arm span. The change in arm span in women is greater than in men.

When the findings on half-arm span are analysed, both sexes experience a decline over time. Another remarkable point is that in the older group of women, the half-arm span tends to stabilize after the age of 70 years.

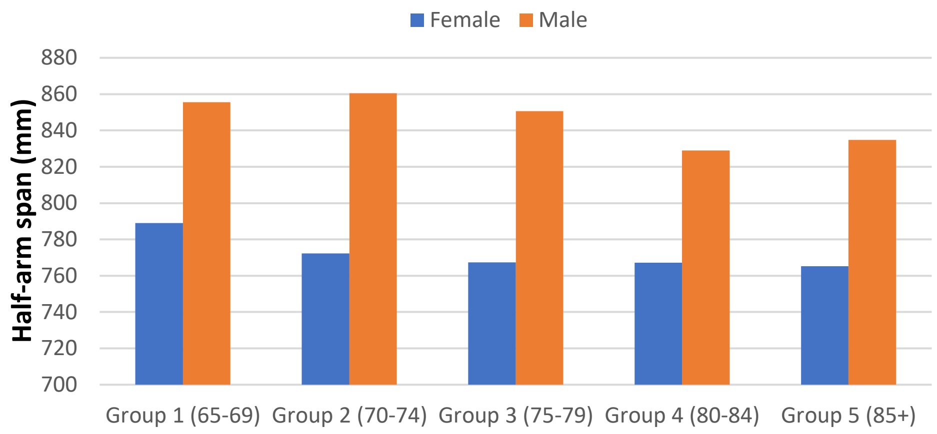

Figure 2. Change and variation of half-arm span by age and sex

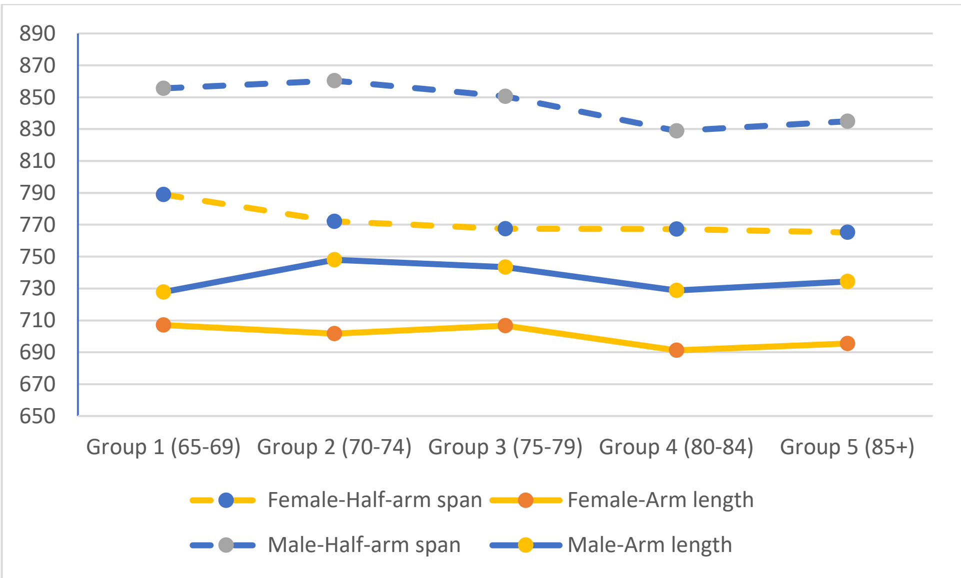

Figure 3. Changes of half-arm span and arm length in females and males according to age groups

It is important to identify the variable that changes the least with age when analysing the data using statistical methods. Total arm length (r = -0.059) was found to be the variable that showed the least change with age, that is, the least change was noticed despite the increase in age (Table 6). On the other hand, the variable that changes the more with age is body height (r = -0.227), followed by half-arm span (r = -0.170) and arm span (r = -0.158). According to the results of the correlation analysis, body height was the variable that changed the most with age while arm length experienced the least.

Table 6. Correlation matrix of anthropometric variables (females and males, *n* = 325)

	Age	Stature	Arm span	Half-arm span	Arm length
Age	1	-0.227**	-0.158**	-0.170**	**-0.059**
Stature		1	0.846**	0.852**	0.717**
Arm span			1	0.942**	0.721**
Half-arm span				1	0.754**
Arm length					1

*******P*<0.05 was considered as significant**

Regression analysis was also carried out to show how the variables were related to the age. Arm length, with an AdjR2 value of 0.000, exhibited a very little change compared to the other variables in this research, which established the model with the weakest association with age (Table 7). The variable with the greatest change is body height (AdjR2=0.048), which is consistent with the findings of the correlation study. The other variables are half-arm span (AdjR2=0.026) and arm span (AdjR2=0.022), respectively

Table 7: Regression equations between age and other anthropometric measurements (males + females)

Equations	AdjR^2	F	Sig.
Age= -0.018 * Body height + 103.1	0.048	17.5	0.000
Age= -0.010 * Arm span + 90.8	0.022	8.3	0.004
Age= -0.022 * Half-arm span + 93.6	0.026	9.6	0.002
Age= -0.010 * Arm length + 82.9	0.000	1.1	0.000

Discussion

When the present study's data were evaluated, it was found that there was a difference in mean body height for both sexes between Group 1 (65-69 years) and Group 5 (85+ years) of about 50 mm. Similar values (43–50 mm) are typically attained when our findings are compared to those of studies published in the literature (Table 8). According to the literature, the body height decline in old age is approximately 45–50 mm, and the findings of our study are within this range. Despite being a typical aspect of human biology, this "dramatic" decreasing of body height causes biases and inaccuracies when estimating nutritional status (particularly when using BMI and related classifications). In order to make such conclusions, it would be helpful to find measurements that are more stable over time, especially with increasing age.

Table 8: The amount of decrease in body height at older ages in different studies

Reference	Mean decrease in stature (mm)
Weinbrenner et al. (2006)	43
Atamtürk (2010)	44
Dey et al. (1999)	45
Santos et al. (2004)	48
Coqueiro et al. (2009)	50
Chumlea et al. (1998)	50

The arm span, which is thought to be highly correlated with stature, is considered to be an effective variable in total body height estimation. Studies suggesting the idea that arm span is highly correlated with stature are based on the long bones do not change with age (Quanjer et al., 2014; Mohanty et al., 2001; Popovic, 2018). For example, using this strategy, Dequeker et al. (1969) claim that in adulthood, the ratio of these two variables is approximately 1.0. However, since both body height and arm span decrease in old age, it is not possible to say that the ratio between these two dimensions is the same as in adulthood. When the difference between body height and arm span was analysed, it was found approximately -50 mm in the age Group 1 (65-69 age group) and approximately -40 mm in the age Group 5 (85+ age group). Furthermore, body height and arm span were found to differ by -60 mm by Kwok and Whitelaw (1991), -73 mm by Omran and Morley (2000) and -77 mm by Friedlaender et al. (1977). As a result, based on the findings of our study and other studies in this field that stature and arm span decrease with age. Thus, it does not seem possible to use the arm span and its sub-variable half-arm span as an option to body height. Determining real body height might be challenging in physically weak people who are hospitalized, confined to wheelchairs, or bedridden. The arm span has been shown to be employed as an alternative to the estimation of body height in elderly and bedridden patients when the literature research is evaluated (Kwok and Whitelaw, 1991; Nygaard, 2008; Uzun ve et al., 2018).

As mentioned above half-arm span, which is a sub-variable of arm span, decreases old age. When we look at the change pattern of this variable, it was determined that there was a decrease of 23.8 mm in women and 20.8 mm in men in old age groups. As in the arm span, the amount of decreasing in women is higher than in men in half-arm span. Similarly, Shahar and Pooy (2003) noted that as people age, their half-arm spans shrink by 22 mm. Therefore, it can be claimed that the half-arm span cannot be used as a substitute for body height if we examine the correlation analysis effect between body height and half-arm span. As a matter of fact, the correlation coefficient (*r*) value was found to be 0.852 in the present study. This correlation value means that half-arm span shortens at approximately the same rate as body height, so it cannot be an alternative variable to stature.

For the purpose of the study, it is important to identify variables that can be an option to the decreasing of body height because of aging. Total arm length, among the measurements taken, was the parameter that shown the least variation with aging ($r = -0.059$). The total arm length, which has been determined to decrease by about 10 mm in the aging period, in line with research in the literature (Mitchell and Lipschitz, 1982; Sethi et al., 1995). Moreover, Sethi et al. (1995) found the amount of change to be 6 mm. As a result, the total arm does not undergo a remarkable change during the aging process. Thus, the use of total arm length in body height calculations may provide more reliable body height estimations.

Generally speaking, there is small change in the morphology of long bones during the aging period (e.g., Kwok and Whitelaw, 1991). However, it is clearly seen that the arm span and half-arm span, which were measured as alternative variables to body height in this study. Because of to the participants' inability to fully open their arms during the study and their failure to settle into the necessary anatomical position, these two variables decreased as they aged. Another reason is the anatomical posture that occurs because of not being upright due to spinal deformation. The research pointed out that the measurements of arm span and half-arm span result in deviations from the initial length due to morphological modifications (Golshan et al., 2003; Hickson and Frost, 2003; Mitchell and Lipschitz, 1982; Chhabra, 2008).

Correlation and regression analyses were performed to determine the variables that showed the least change in linear dimensions with old age. Body height shows the greatest change among the variables examined when correlation and regression analyses' findings are evaluated (r = -0.227; AdjR2=0.048). The pattern of change in arm span (r = -0.158; AdjR2=0.022) reveals that this variable cannot be an alternative variable to body height. The use of this variable will not produce an appropriate conclusion because the half-arm span, a sub-variable of the arm span, also changes with age (r = -0.170; AdjR2=0.026).

In literature, it is seen that knee height and tibia length are frequently used as an option to body height. When we first examined the knee height, Baumgartner et al. (1995) suggested that this variable decreases by 5 mm in old age, while Pini et al. (2001) reported that the change was 10 mm. On the other hand, studies in which tibia length was used yielded results close to the results obtained at knee height. Similarly, Trotter and Gleser (1959) showed that the tibia length is decreased by 9 mm in old age.

In conclusion, total arm length, which can be used as an alternative to stature among the variables, is clearly identified from the data and analysis as the variable that aging the least (r = -0.059; AdjR2=0.000). However, total arm length measurement is more practical for both the patients and the people taking the anthropometric measurements. Therefore, when body height is not accessible in older people, total arm length appears to be the most appealing variable.

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