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Original Research

Adductor Pollicis Muscle Thickness and Its Relationship with Other Anthropometric Measurements: A Sample of Healthy Turkish Population

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Abstract

Objective: The aim of the authors of this study was to determine the reference values for the Adductor Pollicis Muscle Thickness (APMT) in individuals belonging to a healthy population and to compare these values with other anthropometric measurements.
Materials and Methods: In this cross-sectional study, the APMT in the dominant and non-dominant hands of 385 healthy individuals categorized according to age and gender variables were measured with a caliper. Individuals in the “A” category according to the Subjective Global Assessment (SGA) test were included in the study, and anthropometric measurements.
Results: In the study, 193 women and 192 men were included, and various anthropometric measurements were taken. The mean APMT values of the dominant and non-dominant hands were 20.87 ± 3.23 mm and 19.28 ± 2.93 mm in men and 16.78 ± 3.10 mm and 15.43 ± 2.92 mm in women, respectively, which indicates that there were significant differences between the members of the two genders and between the members of the same gender ($p<0.001$). There was a high level of positive correlation between the mean APMT values of the dominant hand and the mid-upper arm circumference ($p<0.001$).
Conclusion: In this study, a high-level and positive correlation was found between APMT values and mid-upper arm circumference (MUAC), mid-upper arm muscle circumference (MUAMC) and mid-upper arm muscle area (AMA) values. APMT measurement emerges as a useful and new anthropometric measurement method in the assessment of the nutritional status of a person.

Keywords: *Anthropometric measurements, adductor pollicis muscle, nutritional status*

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Introduction

Adequate and balanced nutrition is necessary for the body to carry out various physiological functions healthily (Nix, 2013). Nutritional status is an indicator of how adequately the physiological, nutritional needs of an individual are met. Therefore, whether people have a sufficient and balanced diet is revealed by assessing their nutritional status (Leslie & Hankey, 2015).

Biochemical, physical, or functional methods can be used to assess nutritional status. Among these methods, physical methods are generally used to determine body composition and they generally provide information about muscle and fat mass in the body. Therefore, several physical methods are used to determine various body compositions such as lean body mass. There are various methods for determining body composition, such as dual-energy x-ray absorptiometry (DEXA), air displacement plethysmography (ADP), neutron activation analysis, underwater weighing (hydro densitometry), measurements of total body potassium (K^{40}), total body water (TBW) and total body electrical conductivity (TOBEC), magnetic resonance imaging (MRI) and ultrasonography (US), which give results with higher reliability and accuracy. However, it is not always possible to use these methods in the clinical setting, not only because their cost is high but also because there is a need for specialized staff to use them. On the other hand, some simpler anthropometric measurements such as body weight, height, waist/hip circumference, and skinfold thickness are used to determine body composition (Duren et al., 2008).

Anthropometric measurements are subject to some disagreements among clinicians because they have morphological and functional limitations in reflecting protein and fat reserves in various parts of the body. The leading disadvantage is that the results vary depending on the person who performs the measurement. However, these measurements come to the forefront due to some of their advantages: they are easy to perform, have non-invasive techniques, are repeatable, practical, and affordable, and do not require intensive labor in studies with large sample sizes such as epidemiological studies (Mony et al., 2016).

Anthropometric measurements, which are frequently used in the clinical applications and included in the literature, are generally based on the measurement of the circumference of various parts of the body (mid-upper arm circumference, waist circumference, hip circumference, etc.) or skinfold thickness (biceps, triceps, etc.). These measurements are usually performed by using equipment such as a non-stretching measuring tape or caliper (Hammond, 2012). The values obtained through anthropometric measurements are used as components of various formulas, and thus calculations of the muscle area or muscle circumference can be made. For example, anthropometric measurements are used in the calculation of lean body mass, an important parameter in the assessment of nutritional status. By using some predictive formulas including measurements such as arm circumference and triceps skinfold thickness (TSF), arm muscle circumference and corrected arm muscle area are calculated, and then lean body mass can be determined based on this. However, due to the aforementioned concerns about anthropometric measurements, it may be difficult to interpret the results regarding lean body mass. Due to all these factors, there is a need for new anthropometric measurement techniques enabling clinicians to practically measure lean body mass in the clinic (Barreio et al., 2018; Melo et al., 2014). Recently, the Adductor Pollicis Muscle Thickness (APMT) has drawn attention as a new anthropometric measurement method to determine lean body mass and thus assess the nutritional status of the person (Pereira et al., 2018).

First, Lameu et al. (2004a) demonstrated that the nutritional status of an individual could be assessed by measuring APMT, the area between the thumb and index finger. In this study, they determined the anatomical features of the area to be measured by using various imaging techniques. The Adductor Pollicis Muscle (APM) is located between two bones and is relatively flat due to its structure. Therefore, the true value of this muscle can be determined through direct measurement. In addition, the APM is the only muscle in the body that can be measured directly, and the subcutaneous fat tissue on it is at the minimum level. In this way, to determine the true value of body muscle mass, no formulas or equations used to make other anthropometric measurements such as measurements of arm muscle circumference and arm muscle area are needed (Pereira et al., 2018).

In the present study, it was aimed to determine the values for APMT for the first time in a sample of healthy individuals in the Turkish population, and to compare the obtained values with the reference measurements obtained in studies conducted with participants from various races and nationalities.

Materials and Methods

In this cross-sectional study, 385 healthy individuals over the age of 18 years were included. The measurements of the 18- to 65-year-old participants were carried out at Sivas Cumhuriyet University. The participants comprised the academic and administrative staff and students of the same university. The measurements of the participants aged >65 were carried out in Kayseri Metropolitan Municipality Mustafa Kumlu Ulu Çınarlar Elderly Life and Care Center. Before the study was conducted, the ethics committee approval of the study was

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obtained from the Sivas Cumhuriyet University Non-Interventional Clinical Research Ethics Committee (numbered: 2019-08/09). After the participants were informed about the method and purpose of the study, the informed consent forms indicating that they volunteered to participate in the study were obtained from them. Assessment of the nutritional status of the volunteer participants was carried out using the Subjective Global Assessment (SGA) test (Detsky et al., 1987). The SGA was administered by the expert dietitians included in the study team. The inclusion and exclusion criteria of the study are as follows:

Inclusion criteria

- Being over the age of 18 years
- Not having a disease (chronic, etc.) preventing the person from performing physical activities indoors and outdoors
- Being in the “well-nourished (A)” category after the SGA test
- Not having lost more than 5% of their body weight in the last month before the measurements are taken.

Exclusion criteria

- Being in the "moderately malnourished (B)" or "severely malnourished (C)" category after the SGA test
- Having any mental, degenerative, or severe metabolic disorder, peripheral neuropathy, or sequelae due to upper extremity trauma.

Based on several previous studies, the sample size of the study was calculated as 385 ($\alpha = 0.05$ and $1-\beta = 0.1$) (Lameu et al., 2004a; Ghorabi et al., 2014). Of the people in the sample, 193 were women, and 192 were men. The study was completed with these 385 individuals. The researchers completed the study in 12 months between December 2020 and December 2021. Within the scope of the study, the participants’ demographic characteristics such as age and gender were recorded, and all anthropometric measurements were taken by the same expert dietitian in order to minimize the differences between the measurements. The participants were categorized into four different age groups: 18-24 years, 25-44 years, 45-64 years, and ≥65 years. In the study, the APMT measurements of the dominant and non-dominant hands of the participants were taken separately, which prevented the dominant or non-dominant hand-related bias.

A digital scale with a ± 0.1 kg precision was used to measure the participants’ weights (ADE GmbH & Co., Germany). During the weight measurements, the participants wore light clothes. The height measurements were made using a 205 cm portable height meter (ADE

GmbH & Co., Germany) with a ±1 cm precision that can be calibrated. The measurement was made while the person was standing upright, and facing straight ahead. The person's head was level with the Frankfurt plane (an imaginary line in which eye and auricle are aligned). Weight and height measurements were repeated 3 times and the average of the three measurements was used as the body weight and height. Body mass index (BMI) was calculated by dividing weight (in kilograms) by the square of height (in meters) (Weisell, 2002).

Body frame size measurements were calculated by dividing the person's height by his or her wrist circumference. In the calculation, the values of the two components were taken in centimeters. A non-stretching measuring tape was used to measure the wrist circumference. The measurements were repeated three times and the average of the three measurements was used as the body frame size. Women with a body size <10.1 and men with a body size <9.6 were considered to have a large body type. Women with a body size between 10.1 and 11.0 and men between 9.6 and 10.4 were considered to have a normal body type. Women with a body size >11.0 and men with a body size >10.4 were considered to have a small body type (Frisancho, 1984; Ghorabi et al., 2014).

Holtain Tanner/Whitehouse (Holtain Ltd., United Kingdom) type caliper, which can measure the subcutaneous fat layer with a ± 0.2 mm precision, was used for the measurements of APMT and TSF thickness. Triceps Skinfold thickness measurement was made by measuring the distance between the tip of the acromion of the scapula and the olecranon of the ulna while the elbow was flexed at 90 degrees. The measurement was taken 1 cm below the marked point while the individual was standing upright and his or her arm was hanging freely. Skinfold thickness was measured while the individuals were standing upright with their shoulders and arms in a relaxed position. All measurements were taken from the right side of the body. The area where the skinfold thickness would be measured was marked, and then the skin fold was lifted using the thumb and index finger to ensure that it was completely separated from the underlying muscle layer. The subcutaneous tissue was fixed to the jaws of the caliper 1 cm below the fold. The grasped skinfold was held constant during measurement, and skinfold thickness was read directly within 2-4 seconds. Measurements were repeated three times after the tissue was allowed to recover. The average of these three values was accepted as the skinfold thickness value (Heymsfield et al., 1982).

While determining the location of the measurements to be made to assess the APMT, it is accepted that the metacarpal bones of the thumb and index fingers form the two sides of a triangle, and the line to be drawn between the metacarpophalangeal joints at the end of these bones forms the base of the triangle. The bisectors of this imaginary triangle are drawn with a

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compass and their intersection points are marked. The measurement was made with a caliper at the intersection point where the wrist standing at the tip of the kneecap was 90 degrees to the homolateral lower extremity while the individual was in a sitting position. This measurement was repeated three times, and the average of the three measurements was taken into account (Lameu et al., 2004b).

Mid-upper arm circumference (MUAC) measurement was performed with a non-stretching measuring tape while the participant was standing upright by marking the midpoint of the distance between the tip of the acromion process of the scapula and the olecranon process of the ulna. This measurement was repeated 3 times, and the average was taken into account. Mid-upper arm muscle circumference (MUAMC) measurement was calculated using the following formula: MUAMC = (MUAC) - (π x TSF). The following formula was used to calculate the mid-upper arm area (AA): AA = $(MUAC))^2/4\pi$. The mid-upper arm muscle area (AMA) was calculated using the following formula: of AMA = $(MUAMC)^2/4\pi$. Adductor Pollicis Muscle Thickness Index (APMi) was calculated by dividing the APMT value measured in millimeters (mm) by the height in square meters (m^2) (Ghorabi et al., 2014).

Statistical analysis

The data obtained from the study were analyzed by using the SPSS 23.0 program. Whether the data were normally distributed was checked with the Kolmogorov-Smirnov test. Normally distributed data were given as mean ± SD, and non-normally distributed data were given as median. The student's t test was used to compare two independent groups with normal distribution. The Mann-Whitney U test was used to compare two independent groups without normal distribution. The ANOVA was used for the comparison of more than two groups. To determine which group was different from the others, Tukey test used for those meeting the homogeneity assumption, and Tamhane's T2 test was used for those not meeting the homogeneity assumption. The state, direction and degree of the relationship between continuous variables were analyzed using the Pearson correlation coefficient. In this study, the statistical power was calculated as %90 ($1-\beta = 0.1$) and p values less than 0.05 were considered statistically significant.

Results

A total of 385 individuals, 193 women and 192 men, between the ages of 18-90 were included in the study. The anthropometric and demographic characteristics of all the participants and the categorization of these data by gender are shown in Table 1. APMT and APMi measurements were made for both the dominant and non-dominant hands of the participants. The mean APMT values of the dominant hand in women and men were 16.78 ± 3.10 mm and 20.87 ± 3.23 mm, respectively, and there was a significant difference between these mean values (Table 2; p<0.001). The mean APMT values of the non-dominant hand was 15.43 ± 2.92 mm in women and 19.28 ± 2.93 mm in men, and the difference between these two mean values was significant (Table 2; p<0.001).

Table 1: Categorization of the anthropometric and demographic characteristics of the participants by gender.

Variables	All (n=385) mean ± SD	Female (n=193) mean ± SD	Male (n=192) mean ± SD
Age (Year)	45.37± 19.60	45.45 ± 19.91	45.30 ± 19.34
Body weight (kg)	73.12 ± 13.80	66.95 ± 14.05	79.32 ± 10.35
Height (m)	1.65 ± 0.10	1.57 ± 0.07	1.73 ± 0.07
BMI[1] (kg/m^2)	26.75 ± 5.17	27.01 ± 6.41	26.49 ± 3.50
TSF[2] (mm)	21.07 ± 6.77	21.94 ± 6.59	20.19 ± 6.85
APMT[3] (mm)	18.82 ± 3.77	16.78 ± 3.10	20.87 ± 3.23
APMi[4] (mm/m^2)	6.89 ± 1.38	6.77 ± 1.46	7.01±1.29
MUAC[5] (cm)	29.44 ± 4.06	27.89 ± 4.23	31.01 ± 3.20
MUAMC [6] (cm)	22.67 ± 3.79	21.00 ± 2.87	24.35 ± 3.87
AA[7] (cm^2)	69.97 ± 19.56	63.38 ± 19.41	76.59 ± 17.40
AMA[8] (cm^2)	42.08 ± 11.68	35.79 ± 9.94	48.40 ± 9.72

[1]Body Mass Index; [2]Triceps Skinfold Thickness; [3]Adductor Pollicis Muscle Thickness; [4]Adductor Pollicis Muscle Thickness Index; [5]Mid-upper Arm Circumference; [6]Mid-upper Arm Muscle Circumference; [7]Mid-upper Arm Area; [8]Mid-upper Arm Muscle Area.

The analysis of the intra-gender mean APMT values of the dominant and non-dominant hands demonstrated a statistically significant difference in both men and women. These APMT values of the dominant and non-dominant hands were 16.78 ± 3.10 mm and 15.43 ± 2.92 mm respectively in the female participants, and 20.87 ± 3.23 mm and 19.28 ± 2.93 mm respectively in the male participants (Table 2; p<0.001). There was a significant difference between the mean APMi values for the dominant and non-dominant hands of the women. These APMi values for the dominant and non-dominant hands were 13.57 ± 3.70 mm/m^2 and 13.25±3.96 mm/m^2, respectively (Table 3; p<0.001). Similarly, there was a significant difference between the mean APMi values for the dominant and non-dominant hands of the men (Table 3; p<0.001).

Table 2: Descriptive analysis of the Adductor Pollicis Muscle Thickness values of the participants' dominant and non-dominant hands between the same and different gender.

Variables **Gender**	**Dominant Hand Apmt[1] (mm) mean ± SD**	**Non-Dominant Hand Apmt[1] (mm) mean ± SD**	***p* Value**
Female	16.78 ± 3.10	15.43 ± 2.92	[3]p<0.001
Male	20.87 ± 3.23	19.28 ± 2.93	[3]p<0.001
***p* value**	[2]p<0.001	[2]p<0.001	

[1]Adductor Pollicis Muscle Thickness; [2]*p*: Independent samples t-test; [3]*p*: One sample t-test.

Table 3: Descriptive analysis of the Adductor Pollicis Muscle Thickness Index (APMi) values of the participants' dominant and non-dominant hands between the same and different gender.

Variables **Gender**	**Dominant Hand Apmi[1] (mm/m^2) mean ± SD**	**Non-Dominant Hand Apmi[1] (mm/m^2) mean ± SD**	***p* Value**
Female	6.77 ± 1.46	6.23 ± 1.36	[3]p<0.001
Male	7.01 ± 1.29	6.27 ± 1.55	[3]p<0.001
***p* value**	[2]p>0.05	[2]p>0.05	

[1]Adductor Pollicis Muscle Thickness Index; [2]*p*: Independent samples t-test; [3]*p*: One sample t-test.

Table 4: Descriptive analysis of the Adductor Pollicis Muscle Thickness and Index (APMi) values according to body frame sizes of female participants.

Variables	**APMT[4] (mm)**			**APMi[5] (mm/m^2)**		
Body Frame Sizes	**mean ± SD**	***p* value**	**Significant difference[6]**	**mean ± SD**	***p* value**	**Significant difference[7]**
SFS[1] (n=47)	15.10±2.59			5.80±1.11		
MFS[2] (n=51)	16.59±2.59	<0.001	1#2, 1#3	6.61±1.11	<0.001	1#2, 1#3, 2#3
LFS[3] (n=95)	17.71±3.24			7.34±1.50		

[1]Small Frame Size; [2]Medium Frame Size; [3]Large Frame Size; [4]Adductor Pollicis Muscle Thickness; [5]Adductor Pollicis Muscle Thickness Index; [6]Tukey's test; [7]Tamhane's T2 test.

In the present study, the participants were categorized in terms of their body frame size. Intergender differences for the APMT and APMi values of the participants were also assessed in terms of their body frame sizes. The mean of APMT and APMi values of both female and male participants increased in direct proportion to their body frame sizes, classified as small, medium and large. The analysis of the mean APMT values of the women demonstrated that there was a significant difference between the small frame size and medium frame size, and between the small frame size and large frame size (Table 4; 15.10 ± 2.59 mm vs. 16.59 ± 2.59 mm, p<0.001, and 15.10 ± 2.59 mm vs. 17.71 ± 3.24 mm, p<0.001 respectively). There was a similar relationship between the small frame size and medium frame size, between the small frame size and large frame size, and between the medium frame size and large frame size in terms of the mean APMi values of the women (Table 4; 10.35 ± 2.06 mm/m^2 vs. 11.92 ± 2.26 mm/m^2, p<0.001; 10.35 ± 2.06 mm/m^2 vs. 16.05 ± 3.23 mm/m^2, p<0.001; and 11.92 ± 2.26 mm/m^2 vs. 16.05 ± 3.23 mm/m^2, p<0.001 respectively). As for the mean APMT values of the

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male participants, there was a significant difference between the small frame size and large frame size, and between the medium frame size and large frame size (Table 5; 17.38± 2.04 mm vs. 21.51 ± 3.20 mm, $p<0.001$; and 19.72 ± 2.77 mm vs. 21.51 ± 3.20 mm, $p<0.001$ respectively). As for the mean APMi values of the male participants, there was a significant difference between the small frame size and large frame size, and between the medium frame size and large frame size (Table 5; 13.14 ± 4.36 mm/m^2 vs. 19.35 ± 3.60 mm/m^2, $p<0.001$; 14.96 ± 4.61 mm/m^2 vs. 19.35 ± 3.60 mm/m^2, $p<0.001$ respectively).

Mean APMT and APMi values for dominant and non-dominant hands were compared separately for both men and women according to age group categorization (18-24, 25-44, 45-64 and ≥65 years). It was determined that the mean APMT values of the dominant hand in women aged 18-24 (15.82 ± 2.04 mm) were lower than the mean values of the group aged 45-64 (17.71 ± 3.08 mm) ($p = 0.018$). In addition, it was observed that the mean APMT values of the dominant hand in men aged 18-24 were lower than the mean values of both the 45-64 and the ≥65 age group. It was found that the mean APMT values of the dominant hand of men aged 18-24 (19.27 ± 2.87 mm) were lower than the mean APMT values of both men aged 45-64 (21.84 ± 3.30 mm) and aged ≥65 (21.76 ± 2.88 mm) years ($p<0.001$). It was detected that the mean APMT values of the non-dominant hand in women did not differ significantly between age groups ($p>0.05$). The average of the APMT values of the non-dominant hand in men aged 18-24 (18.15 ± 2.59 mm) were found to be lower than men in both the 45-64 (20.31 ± 3.16 mm) and the ≥65 (19.66 ± 2.61 mm) age group ($p = 0.002$).

In women, the mean of dominant hand APMi values between the ages of 18-24 (6.19 ± 0.96 mm/m^2) are lower than both 45-64 (7.22 ± 1.40 mm/m^2) and ≥65 (7.31 ± 1.61 mm/m^2) age groups ($p<0.001$). Meanwhile, the mean of dominant hand APMi values of women aged 25-44 (6.39 ± 1.47 mm/m^2) is significantly lower than the mean of both 45-64 and ≥65 age groups ($p<0.001$). The mean APMi values of the non-dominant hands of women aged 18-24 (5.74 ± 0.89 mm/m^2) are lower than both 45-64 (6.58 ± 1.29 mm/m^2) and ≥65 (6.76 ± 1.53 mm/m^2) age groups ($p<0.001$). Besides, it was stated that the average APMi values of the non-dominant hands of the women aged 25-44 (5.84 ± 1.39 mm/m^2) were lower than the averages of the 45-64 and ≥65 age groups ($p<0.001$).

In men, the mean of dominant hand APMi values in the 18-24 (6.20 ± 1.00 mm/m^2) age group is lower than the mean of the 45-64 (7.29 ± 1.29 mm/m^2) and ≥65 (7.75 ± 1.13 mm/m^2) age group ($p<0.001$). On the other hand, it was found that the mean of dominant hand APMi of men aged ≥65 years was higher than the mean of APMi between the ages of 25-44 (6.79 ± 1.20 mm/m^2) ($p<0.001$).

Table 5: Descriptive analysis of the Adductor Pollicis Muscle Thickness and Index (APMi) values according to body frame sizes of male participants.

Variables	APMT[4] (mm)			APMi[5] (mm/m^2)		
Body Frame Sizes	Mean ± SD	*p* value	Significant difference[6]	Mean ± SD	*p* value	Significant difference[7]
SFS[1] (n=9)	17.38±2.04			5.62±0.65		
MFS[2] (n=48)	19.72±2.77	<0.001	1#3, 2#3	6.37±0.97	<0.001	1#2, 1#3, 2#3
LFS[3] (n=135)	21.51±3.20			7.33±1.28		

[1]Small Frame Size; [2]Medium Frame Size; [3]Large Frame Size; [4]Adductor Pollicis Muscle Thickness; [5]Adductor Pollicis Muscle Thickness Index; [6]Tukey's test; [7]Tamhane's T2 test.

In the present study, the correlation between the mean APMT values of the dominant and non-dominant hands of all the participants and some of their anthropometric measurements was presented in Table 6. There was a weak positive correlation between the mean APMT values of the dominant hand and anthropometric measurements such as height, BMI and TSF whereas there was a high level of positive correlation between the mean APMT values of the dominant hand and the anthropometric measurements such as MUAMC and AMA. There was a high level of positive correlation between the mean APMT value of the dominant hand and the MUAC. There were similar correlations between the mean APMT values of the non-dominant hand and the aforementioned anthropometric measurements.

Table 6: Correlation of participants Adductor Pollicis Muscle Thickness (APMT) and values of anthropometric variables.

	DAPMT[1]	NDAPMT[2]	[9]*p* value
Body weight (kg)	0.582	0.570	<0.001
Height (m)	0.317	0.319	<0.001
BMI[3] (kg/m^2)	0.359	0.348	<0.001
TSF[4] (mm)	0.329	0.314	<0.001
MUAC[5] (cm)	0.619	0.611	<0.001
MUAMC[6] (cm)	0.470	0.470	<0.001
AA[7] (cm^2)	0.593	0.586	<0.001
AMA[8] (cm^2)	0.556	0.556	<0.001

[1]Dominant Hand Adductor Pollicis Muscle Thickness; [2]Non-dominant Hand Adductor Pollicis Muscle Thickness; [3]Body Mass Index; [4]Triceps Skinfold Thickness; [5]Mid-upper Arm Circumference; [6]Mid-upper Arm Muscle Circumference; [7] Mid-upper Arm Area; [8]Mid-upper Arm Muscle Area; [9]*p*: Pearson correlation test.

Finally, in Table 7, the correlation between the BMI values of the male and female participants categorized in 4 different age groups and the mean APMT values of their dominant and non-dominant hands were given. There was a positive and weak correlation between these variables in the whole sample in terms of their dominant and non-dominant hands (r: 0.359; $p<0.001$ and r: 0.348; $p<0.001$ respectively). There was a positive but weak correlation between

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the BMI values of the female and male participants in the 18-24 age group and their mean APMT values of the dominant and non-dominant hands (Table 7). The correlation between these variables of both hands was moderate and positive in the 45-64 age group and ≥65 age group but high and positive in the 25-44 age group (Table 7).

Table 7: Correlation between BMI and APMT values according to age categorization and gender of the participants.

Subgroups	DAPMT[2]			NDAPMT[3]		
All sample (n = 385)	BMI[1]	r [4]*p*	0.359 <0.001	BMI[1]	r [4]*p*	0.348 <0.001
Female 18-24 years (n = 49)	BMI[1]	r [4]*p*	0.395 0.005	BMI[1]	r [4]*p*	0.346 0.015
Female 25-44 years (n = 48)	BMI[1]	r [4]*p*	0.547 <0.001	BMI[1]	r [4]*p*	0.569 <0.001
Female 45-64 years (n = 48)	BMI[1]	r [4]*p*	0.485 <0.001	BMI[1]	r [4]*p*	0.511 <0.001
Female ≥ 65 years (n = 48)	BMI[1]	r [4]*p*	0.371 0.009	BMI[1]	r [4]*p*	0.355 0.013
Male 18-24 years (n = 48)	BMI[1]	r [4]*p*	0.499 <0.001	BMI[1]	r [4]*p*	0.466 0.001
Male 25-44 years (n = 48)	BMI[1]	r [4]*p*	0.624 <0.001	BMI[1]	r [4]*p*	0.613 <0.001
Male 45-64 years (n = 48)	BMI[1]	r [4]*p*	0.351 0.014	BMI[1]	r [4]*p*	0.416 0.003
Male ≥ 65 years (n = 48)	BMI[1]	r [4]*p*	0.482 0.001	BMI[1]	r [4]*p*	0.534 <0.001

[1]Body Mass Index; [2]Dominant Hand Adductor Pollicis Muscle Thickness; [3]Non-dominant Hand Adductor Pollicis Muscle Thickness; [4]*p:* Pearson correlation test.

Discussion

In the assessment of nutritional status, anthropometric measurements of various parts of the body are used. The results obtained through various formulas, which include the values of these measurements, give indirect information about the function level and integrity of the muscles (based on muscle circumferences or areas). Catabolic states resulting from various metabolic processes or inactivity can lead to the atrophy of the muscles in the body. Like other peripheral muscles, the APM is adversely affected by catabolism, inactivity, or malnutrition (de Melo & da Silva, 2014).

APMT is the only muscle structure that can be measured directly in the body because it has almost a flat shape and the adipose tissue it contains can be neglected. All these features brought APMT to the forefront as a new anthropometric measurement method that can be used in determining a person's nutritional status. Edwards et al. (1977) anatomically measured APMT using a method that included electromyography and electrical stimulation of the ulnar

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nerves. On the other hand, the idea of anthropometric measurement of this muscle with a caliper was first put applied by Lameu et al. (2004a). However, this method, in which the ulnar nerves are stimulated, is very difficult to implement, expensive, and requires expertise. On the other hand, the anthropometric method put out by Lameu et al. (2004b) is based on measuring APMT with a caliper. The method is simple, non-invasive, easy-to-apply, inexpensive, and repeatable. Owing to its anatomical location, APMT is less affected by the changes in the hydration status in the body compared to other anthropometric measurements. Due to all these features, APMT measurement has recently come to the fore as a new alternative method for the assessment of nutritional status (da Costa et al., 2018).

In the existing literature, the relationship between APMT and various diseases has been investigated in a wide spectrum of patients including cirrhosis patients, individuals undergoing major surgery, critically ill patients, individuals with HIV, and kidney transplant patients (Augusti et al., 2016; Bielemann et al., 2016; Caporossi et al., 2012; Cortez et al., 2017; Dos Reis et al., 2018). However, studies conducted with healthy individuals to establish reference values for APMT values are very few (Ghorabi et al., 2014; Lameu et al., 2004b; Gonzalez et al., 2010).

A comprehensive literature review revealed that the majority of the studies conducted to determine the reference values for APMT, and the relationship between various disorders and APMT were carried out in Brazil. It is well known that Brazilian society consists of black, mulatto, and white people (Lameu et al., 2004a). In several studies, it has been determined that in various parts of their body, muscle, and bone mineral density are higher in blacks and Hispanics than they are in Caucasians (Araujo et al., 2010; Wagner & Heyward, 2000). In the present study, APMT and various anthropometric measurements were made in a healthy Turkish population. Individuals belonging to Turkish society are Caucasians and differ from Brazilians in this respect. Therefore, before conducting a study on APMT values in the Turkish population by using the reference values of the aforementioned and previous studies, it became necessary to determine such reference values in a sample from this population, and thus this study was carried out (Lameu et al., 2004b; Gonzalez et al., 2010).

In our study, the mean APMT values were higher in the male participants than were those in the female participants. This difference was consistent with the differences determined in other studies in which APMT values in healthy individuals were assessed (Ghorabi et al., 2014; Lameu et al., 2004b; Gonzalez et al., 2010). In addition, the mean APMi values were significantly higher in the male participants than were those in the female participants. In a study conducted with healthy individuals, the mean APMi values were higher in the male participants than were those in the female participants, consistent with the results of our study (Ghorabi et al., 2014). However, in another study conducted with healthy individuals, the difference between the genders in terms of their APMT and APMi values was not significant (Lameu et al., 2004b). Men's having higher APMi values compared to women, as in our study, is an expected result because men have greater muscle mass than women.

In the current study, descriptive analysis of the mean APMT and APMi values was performed based on the body frame sizes. After the analysis, it was found that in both genders, the body frame sizes, classified as small, medium, and large, increased as the mean APMT and APMi values increased. Ghorabi and colleagues (2014) also stated that the body frame sizes increased in parallel to the increase in the mean APMT and APMi values in both men and women. Lameu et al.(2004b) investigated the relationship between the mean APMT and APMi values, and body frame sizes in all the participants, not based on gender. Although Lameu et al. (2004b) did not take the gender factor into account, they determined that the mean APMT and APMi values increased as the size of the body frame sizes increased, as in our study.

In the present study, the mean APMT values of the dominant hands of the male and female participants increased until the age of 65 but decreased after the age of 65. In our study, this increase in the mean APMT values determined by age and gender was consistent with the increases in other studies (Ghorabi et al., 2014; Lameu et al., 2004b; Gonzalez et al., 2010). The analysis of the mean APMi values of both dominant and non-dominant hands demonstrated that there was a constant increase in these values in parallel with the increase in age in both genders until the age of 65. On the other hand, a decrease was observed in the mean APMi values of the non-dominant hands of the male participants over the age of 65. In studies conducted to establish reference APMT and APMi values in healthy individuals, it was observed that the APMi value decreased in the participants aged 65 and over, in our study, but this value, except for the non-dominant hands of the male participants, continued to increase (Lameu et al., 2004a; Ghorabi et al., 2014; Lameu et al., 2004b; Gonzalez et al., 2010). This difference may have resulted from the fact that the types of calipers used to determine APMT values were different and that the races of the participants whose measurements were made differed from one study to another. While the participants in Ghorabi et al. (2014) 's study belonged to the Iranian community, the participants in Lameu et al. (2004a) 's and Gonzalez et al. (2010) 's studies belonged to the Brazilian community. As for the present study, APMT and other anthropometric measurements were made on individuals belonging to the Turkish community.

In addition, in their studies, Gonzalez et al. (2010) and Lameu et al. (2004a) used Lange (Beta Tech. Inc., United States) brand caliper while Ghorabi et al. (2014) used Vogel (Marc

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Vogel GmbH., Germany) brand caliper. The brand of the caliper used in our study was Holtain Tanner/Whitehouse (Holtain Ltd., United Kingdom). Although the calipers used in all the aforementioned studies exert a pressure of 10 g/mm^2 per unit surface, the reason why the mean APMi values of the participants aged 65 and over in our study were higher than those in other studies was probably due to differences between the types of the calipers used to determine APMT values. What is more, compared to other studies, the mean APMT values for both dominant and non-dominant hands were higher in both genders in our study. This difference is thought to stem from the fact that the origin of the participants and the type of the caliper used for measurements were different.

In our study, there was a correlation between the participants' mean APMT values and the anthropometric values of the other variables. While the correlation between the mean APMT values for the dominant and non-dominant hands and the values for the variables such as height, BMI, and TSF was positive but weak, the correlation between the mean APMT values for the dominant and non-dominant hands and the values for the variables such as body weight, MUAMC, AA, and AMA was positive and moderate. On the other hand, there was a positive and high-level correlation only between the mean MUAC and APMT values. Gonzalez et al. (2010) found a positive very weak correlation between APMT measurements of the dominant hand and body weight and a positive weak correlation between APMT measurements of the dominant hand and BMI. Contrary to our study, Gonzalez et al. (2010) determined a negative weak correlation between height and APMT measurements. Lameu et al. (2004a) found a positive and weak correlation between APMT values and BMI, consistent with the results of our study. Ghorabi et al. (2014), as in our study, found a positive and moderate correlation between APMT measurements and MUAMC, AA, and AMA. However, in the same study, while the correlation between APMT measurement and MUAC was positive and moderate, in our study, although the correlation was positive, its level was high.

Finally, the participants in our study were categorized according to age and gender variables, and the correlation between the mean APMT value and BMI was investigated for both dominant and non-dominant hands. The most striking result belonged to the male participants aged 25-44. In men in this age group, the correlation between BMI and the mean APMT was positive and at a high level. In the other age groups, the correlation between BMI and the mean APMT value was positive but weak or moderate. Lameu et al. (2004a) categorized the participants according to age ranges and gender, as we did, and investigated the correlation between BMI and the mean APMT value. In terms of the results regarding all the participants,

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the comparison of our study and Lameu et al.'s (2004a) study demonstrated that the direction and level of the correlations were consistent.

APMT values which clearly reflect the measured body region anatomically come to the fore in the assessment of nutritional status because the measurements can be made easily, can be repeated, and are low cost. In the present study, unlike studies in the literature, for the first time, measurements were taken from healthy individuals belonging to another race (Turkish population). The present study was conducted based on the fact that the muscle mass ratios of individuals vary from one race to another. In conclusion, the present study is of importance because its participants were healthy individuals belonging to the Turkish population and because it generated the first data for future studies on APMT values in healthy individuals.

Limitations of the study

In the current study, APMT values were measured with a Holtain Tanner/Whitehouse type caliper. As a result of the literature review, it was determined that Lange type caliper was generally used in studies with APMT measurements. In our study, different types of calipers were not used while APMT measurements were taken, so the effect of caliper difference on APMT could not be compared. This situation emerged as a limitation of the study.

Declaration of conflicting interests

The authors confirm that there is no conflict of interest.

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