Original Research

Correlation between thigh skinfold thickness and physical fitness factors in Korean adults and older individuals

Dong Wook Lee[1],[†], San Sung Hwang[1],[†], Hee Seong Jeong[2],[3],*, Wi-Young So[4],*

[1]Department of Physical Education, Yonsei University, 03722 Seoul, Republic of Korea
[2]Department of Sports and Health Management, Mokwon University, 35349 Daejeon, Republic of Korea
[3]International Olympic Committee Research Centre Korea, 03722 Seoul, Republic of Korea
[4]Sports Medicine Major, College of Humanities and Arts, Korea National University of Transportation, 27469 Chungju, Republic of Korea
*Correspondence: jhs@mokwon.ac.kr (Hee Seong Jeong); wowso@ut.ac.kr (Wi-Young So)
[†]These authors contributed equally.

Abstract

Background: This cross-sectional epidemiological study aimed to compare the differences in physical fitness variables according to the skinfold thickness in the thigh area in adults and Korean older individuals. **Methods**: We analyzed data from the 2015 National Fitness Survey. A total of 4034 healthy adults (2442 men, 1592 women) with an average age of 38.19 ± 12.41 years and 880 healthy older subjects (369 men, 511 women) with an average age of 72.32 ± 5.49 years participated in this study. The skinfold thickness of the thigh was measured using a skinfold caliper (Dynatron, Dynatronics, USA). The participants underwent physical fitness tests, including the hand squeeze strength test, abdominal curl ups, standing double-leg long jump, 50 m shuttle run, sit and reach, and 20 m shuttle run for adult men and women. Older men and women performed the following tests: hand squeeze strength, abdominal curl ups, sit to stand test, single leg balance (open eyes), sit and reach, Apley scratch test for shoulder mobility, and 6-minute walk test. Independent t-tests and Pearson correlation analyses were used for the analysis. **Results**: Among the older men, significant differences were found in thigh skinfold thickness ($t = -21.122$, $p < 0.001$), abdominal curl ups ($t = 2.165$, $p = 0.031$), and sit and reach in men ($t = 2.609$, $p = 0.009$), and thigh skinfold ($t = -29.611$, $p < 0.001$), and Apley scratch test for shoulder mobility in women ($t = -2.120$, $p = 0.034$). There was a significant correlation between thigh skinfold thickness and physical activity (thigh skinfold thickness) in adult men ($t = -54.202$, $p < 0.001$), nondominant hand squeeze strength ($t = 2.632$, $p = 0.009$), abdominal curl ups ($t = 4.292$, $p < 0.001$), sit and reach ($t = 3.063$, $p = 0.002$), twenty meters shuttle run ($t = 4.657$, $p < 0.001$). However, no significant differences were found in dominant hand squeeze strength, standing double leg long jump, or 50 m shuttle run in men ($p > 0.05$). In adult women, there was a significant correlation between thigh skinfold thickness and physical activity (thigh skinfold thickness ($t = -49.405$, $p < 0.001$), dominant hand squeeze strength ($t = 7.789$, $p < 0.001$), nondominant hand squeeze strength ($t = 6.944$, $p < 0.001$), abdominal curl ups ($t = 5.347$, $p < 0.001$), standing double leg long jump ($t = 5.890$, $p < 0.001$), sit and reach ($t = 5.384$, $p < 0.001$), twenty meter shuttle run ($t = 5.223$, $p < 0.001$). However, no significant differences were found in fifty meter shuttle run in women ($p > 0.05$). Among older men, only single leg balance and sit and reach were correlated with thigh skinfold (single leg balance $r = 0.169$, $p = 0.01$; sit and reach $r = -0.201$, $p = 0.001$). In women, only abdominal curl ups, sit and reach, and Apley scratch test correlated with thigh skinfold (abdominal curl ups $r = -0.088$, $p = 0.002$; sit and reach $r = -0.137$, $p = 0.002$; Apley scratch test $r = 0.090$, $p = 0.041$). **Conclusions**: The effect of thigh skinfold thickness on the level of physical activity was more pronounced in adults than in older subjects. Our findings show that muscle strength and body fat in the lower extremities can affect overall muscle strength, endurance, and balance.

Keywords: Body composition; Korea; Physical fitness; Thigh skinfold thickness

1. Introduction

Overweight and obesity are on the increase worldwide, and the incidence of various obesity-related diseases is on the rise [1,2]. Obesity can be attributed to various factors. such as overeating, lack of exercise, and dietary patterns [3]. It is estimated that approximately 40 million people in the United States are overweight [4]. Similar to the global trend, the dietary preferences in Korea have changed with the introduction of westernized eating habits and the development of modern technology and science. Consequently, excessive energy consumption and reduced physical activity has led to an imbalance [5] with a sharp incrase

in overweight and obesity rates [6]. Currently, social problems related to overweight and obesity continue to occur at an alarmingly high rate [7].

According to the World Health Organization (WHO), a body mass index (BMI) of 25 or more indicates overweight, and a BMI of 30 or more indicates obesity. According to the global disease burden report, obesity and overweight had reached epidemic levels in 2017, killing more than 4 million people annually [8]. It has been reported that obesity can shorten life expectancy because it accelerates aging at the cellular and clinical levels [9].

Overweight and obesity are major risk factors of various cardiovascular diseases, such as hypertension, arte-

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riosclerosis, and diabetes, and a considerable amount of the national budget is allocated to programs for the management of these diseases [10,11]. If the rate of overweight and obesity continues to increase in the future, more funds will have to be allocated to fight all these various diseases, leading to substantial losses at the national level. The national policy of Korea currently emphasizes the importance of exercise to improve health and fitness and to prevent overweight and obesity [12,13]. It is widely accepted that diet is important not only for nutrition, but also for exercise, in the management of overweight and obesity [14]. Many studies have shown that a higher muscle mass promotes basal metabolism and immunity [15]. Previous research has indicated an inverse association between the strength level of the lower extremities and the incidence of various diseases [16]. Another study examined the correlation between thigh fat and disease [17]. It has also been shown that subjects with a larger thigh circumference have a lower risk of diabetes [18]. These studies have demonstrated that the amount of muscle and fat in the thighs can have a huge impact on health. There are various methods for measuring body fat, including the body composition analyzer and the measurement of double layers of skin using a caliper [19]. In this line, the skinfold measurement method using calipers is widely employed worldwide in the field to analyze and evaluate body composition simply and reliably [20]. Although body fat is also important, Bouchard *et al.* [21] found that leg strength and body fat mass are good predictors of body function in older individuals. However, they also reported that the relative importance of these factors varied with age and sex. Thigh fat and muscle were also found to be associated with cardiometabolic diseases [17]. In addition, it is known that changes in the distribution of body fat can be a risk factor for chronic diseases [22], and found that a healthy amount of subcutaneous fat of the thigh and thigh muscles can prevent diabetes; similarly, the muscle mass of the thighs has been reported to prevent coronary heart disease [17].

There are studies on the association between fat and disease, but little is known about the association between fat in the lower extremities and physical fitness level, and no studies have been conducted in this regard on the Korean population. Therefore, the purpose of this study is to investigate the association between the two factors by comparing the difference in physical fitness variables according to the thigh skinfolds thickness in the sample of adults and older subjects. The secondary purpose is to compare the difference in physical ability according to the thickness of the thigh skinfold. We hypothesized that the thickness of thigh skinfold would be related to physical fitness level; specifically, we hypothesized that a higher thickness value of the thigh skinfold would be associated with lower physical fitness level.

2. Methods

2.1 Study design and population

Since the precision of measurement data is greatly affected by the consistency and accuracy of the measurement method, the measurements were performed by staff members of the Korea Institute of Sports Science who were previously trained on the procedures at the same institute. Additional training was conducted to ensure unification of the measurement method. The training consisted of theory and practice with a special focus on the accuracy of the measurements. Each investigator underwent a 10-h training course. The measurements were carried out from October to November 2015. The process for the removal of invalid data consisted of four steps. First, the data was searched and inspected. Second, dubious records were removed. In a third step, dubious coding data were removed, and in the fourth and last step, the input data was removed from the computer program. Finally, a total of 4034 healthy adults with an average age of 38.19 ± 12.41 years (2442 males, 1592 females) and 880 healthy older subjects with an average age of 72.32 ± 5.49 years (369 males, 511 females) voluntarily participated in this study. The study was conducted in 2015 by the National Fitness Survey, and the subjects were adult males and females over the age of 19 years. In this study, based on "The Survey of National Physical Fitness 2015" report [23], patients were classified into low thigh skinfold and high thigh skinfold groups on the basis of the average value of the data set according to age and sex.

2.2 Data collection

The subjects of measurement for the 2015 National Physical Fitness Survey were adult men and women over the age of 19, and the variables considered for sampling were sex, age, and region, as in the previous survey. The subjects were divided into the following age groups: 19–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–80, and over 80 years. The subjects were recruited from various regions, including Seoul, Gyeonggi/Incheon, Gangwon, Chungbuk, Chungnam/Daejeon, Jeonbuk, Jeonnam/Gwangju, Gyeongbuk/Daegu, and Gyeongnam/Busan/Ulsan. Since the precision of the measurement data is greatly affected by the consistency and accuracy of the measurement method, the personnel who performed the measurements underwent training.

In this study, the body skinfold thickness of the thigh was measured using a skinfold caliper (Dynatron, Dynatronics, USA). Subcutaneous fat thickness was measured with a resolution of 0.1 mm. To ensure the accuracy of the data, participants were asked (1) not to drink alcohol 24-h before the session; (2) not to exercise 12 h before the measurement; (3) and to avoid drinking water or eating for 6 h. Additionally, we excluded women during the menstruation period from the fat measurements. Height and weight

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data were collected along with body fat thickness. BMI was calculated by dividing body weight by the square of the participant's height (m^2). A BMI of 25 kg/m^2 or higher was considered overweight, and a BMI of 30 or higher was considered obese [24].

2.3 Physical fitness examination in adult and older individuals

The physical fitness tests included the hand squeeze strength test, abdominal curl ups, standing double-leg long jump, 50 m shuttle run, sit and reach, and 20 m shuttle run for adult men and women. Using these tests, we measured muscular strength, local muscular endurance, power, speed, flexibility, and cardiopulmonary endurance. In the case of older men and women, the tests used were the hand squeeze strength, abdominal curl ups, sit to stand test, single leg balance (open eyes), sit and reach, Apley scratch test for shoulder mobility, and 6-minute walk test.

2.3.1 Hand squeeze strength

The subjects were asked to hold the grip of the dynamometer by wrapping it around the second finger and to adjust it with the adjusting screw for a better fit. The subjects were instructed to keep the torso and arms at an angle of 15° and to pull the dynamometer with the arms straight. The task was carried out twice alternating sides, and each peak was measured with a resolution of 0.1 kg.

2.3.2 Abdominal curl ups

The subjects were asked to keep their legs approximately 30 cm apart, with the knees bent at a right angle, and both hands lying on a mat with the hands behind their heads. An assistant held the ankles of the subject with both hands, and the subject then raised the upper body upon hearing the starting signal, and then returned to the supine position after touching their knees with the elbows. The number of times that both elbows touched both knees was recorded, and this task was conducted only once.

2.3.3 Standing double-leg long jump

The participant stood in a comfortable position with the feet approximately 10–20 cm apart on a starting point. The participant was asked to stand on the starting point and to jump as far as possible. The distance from the starting point to the landing point of the nearest heel was measured. The task was performed twice, and the highest record was considered for analysis. The distances were measured in cm.

2.3.4 Fifty-meter shuttle-run test

The starting signal source indicated that the subject had to move towards the finish line, which was located approximately 3–5 m ahead of the starting line. The subject was instructed to prepare to run upon receiving the ready signal. After the "set" command, there was an interval of about 2 s before the starting signal was given. With the starting signal, the 50 meter shuttle run started, and the time taken to reach the finish line was measured. The time resolution was 0.1 seconds.

2.3.5 Sit and reach

After removing the shoes, the subject sat upright with his knees straight so that the soles of the feet touched the vertical surface of the measuring instrument. The distance between both feet with the legs straight did not exceed 5 cm. The subject was in a ready position, with both hands stretched out on the ruler. The exercise was performed without bouncing and measured in 0.1 cm increments.

2.3.6 Twenty meter shuttle-run test

A line was drawn at each end of a straight 20 m course. The start signal was given 5 s after the ready signal. The subject had to arrive at the other end of the course before the next signal was given, and then to go back to the initial point. The task was ended when the finish line was not reached before the signal for two consecutive times. The number of round trips achieved was recorded.

2.3.7 Sit to stand

The subjects were asked to sit cross-legged in the middle of the chair with their arms on their chest, their back straight, and their feet completely attached to the floor. When the "start" signal was given, the subject had to stand up completely, and then perform the sitting motion. The total number of times that the subject was able to correctly perform the sit-stand movement in an interval of 30 s was measured.

2.3.8 Single leg balance (open eyes)

When the starting signal was given, the subject had to lift one leg and keep both arms parallel to the ground. The test ended when the subject lowered his or her leg. The exercise was performed twice and the best result (longest time in seconds) was recorded.

2.3.9 Apley scratch test for shoulder mobility

Subjects were asked to stand and bring their hands together in the back, with one hand coming from the shoulder and the other from the lower back. The movement is performed with the palms down and the fingers trying to reach as far as possible. One elbow faces upward, and other hand with the palm up at the back of the waist. The subject is asked to try to overlap the middle fingers of both hands and to keep their hands steady and their middle finger properly positioned. The task was repeated twice and the highest result was considered for analysis. The measurements were performed with a resolution of 0.1 cm.

2.3.10 Six-minute walk test

The subject was given a starting signal in a standing start position on the starting line. The task consisted of walking as far as possible within 6 min. To adjust the pace, the subject was informed of the remaining time. After 6 min, the task was ended, and the subject was asked to move to the nearest 5 m mark and to walk slowly for a few minutes. The distance was measured with a resolution of 0.1 m.

The safety of the adults and older subjects was ensured in all fitness tests by following the guidelines stated in the book of "Advanced Fitness Assessment and Exercise Prescription", "The Senior Fitness Test Manual", the "Essentials of Strength Training and Conditioning", and the "ACSM's guidelines for expense testing and prescription" [25–28].

2.4 Statistical analysis

According to the central limit theorem, if the number of subjects is over 30, the sample has a normal distribution and is reliable [29]. This study included 4034 adults and 880 older subjects. More specifically, the study included 2442 adult males, 1592 adult females, 369 older male subjects, and 511 older female subjects. Therefore, a normal distribution was ensured. For this reason, the cutoff point for thigh skinfold thickness was based on the normal distribution.

First, male adults from the lowest (1) to the middle (1224) rank were defined as "low thigh skinfold subjects". Those from the middle (1225) to the last (2442) rank were defined as "subjects with high thigh skin folds". Female adults from the lowest (1) to the middle (796) rank were defined as "low thigh skinfold subjects", while those from the middle (797) to the last (1592) rank were defined as "subjects with high thigh skin folds".

Second, older male subjects from the lowest (1) to the middle (186) rank were defined as "low thigh skinfold subjects", while those from the middle (187) to the last (369) rank were defined as "subjects with high thigh skin folds". Similarly, older female subjects from the lowest (1) to the middle (256) rank were defined as "low thigh skinfold subjects", and those from the middle (257) to the last (511) rank as "subjects with high thigh skin folds".

The data of the study were analyzed using the Statistical Package for Social Sciences (SPSS) version 25.0 (IBM Corp., Armonk, NY, USA). An independent t-test was used to determine the average difference between thigh skinfold thickness and physical fitness level according to sex in adults and the older. The association between thigh skinfold thickness and body fitness level was determined using Pearson correlation analysis. The alpha level for all analyses was set to 0.05. The magnitude of the correlation was rated as trivial (<0.10), small (0.10–0.29), moderate (0.30–0.49), large (0.50–0.69), very large (0.70–0.89), or nearly perfect (0.90–0.99) [30].

3. Results

3.1 Participant characteristics

Table 1 shows the number of subjects and the general characteristics of the subjects, including age, height, weight, and BMI. In adults, there were significant differences in age ($t = 3.304$, $p = 0.001$), height ($t = -3.205$, $p = 0.001$), weight ($t = -14.044$, $p < 0.001$), and BMI ($t = -13.598$, $p < 0.001$) between the groups of men with high and low thigh skinfold. Further, there were significant differences in age ($t = 3.728$, $p < 0.001$), height ($t = -2.048$, $p = 0.041$), weight ($t = -7.147$, $p < 0.001$), and BMI ($t = -6.133$, $p < 0.001$) between the groups of women with high and low thigh skinfold. Excluding age ($t = -0.208$, $p = 0.836$), there were significant differences in the other variables, namely height ($t = -4.021$, $p < 0.001$), weight ($t = -7.708$, $p < 0.001$), and BMI ($t = -6.269$, $p < 0.001$), between the high and low thigh skinfold groups of older men. Further, there were significant differences in age ($t = 2.457$, $p = 0.014$), height ($t = -2.528$, $p = 0.012$), weight ($t = -3.730$, $p < 0.001$), and BMI ($t = -2.460$, $p = 0.014$) between the groups of older women with high and low thigh skinfold thickness.

3.2 Differences in each group of adults

Table 2 shows the test results of the low- and high-thigh skinfold thickness groups of adults. In the adult male group, there were significant differences in all variables (thigh skinfold $t = -54.202$, $p < 0.001$, non-dominant hand squeeze strength $t = 2.631$, $p = 0.009$, abdominal curl ups $t = 4.292$, $p < 0.001$, sit and reach $t = 3.063$, $p = 0.002$, and twenty meter shuttle run $t = 4.657$, $p < 0.001$). The dominant hand squeeze strength, standing double-leg long jump, and 50 m shuttle run were not significant ($p > 0.05$). In the adult female group, there were significant differences in all variables (thigh skinfold $t = -49.405$, $p < 0.001$, dominant hand squeeze strength $t = 7.789$, $p < 0.001$, non-dominant hand squeeze strength $t = 6.944$, $p < 0.0001$, abdominal curl ups $t = 5.347$, $p < 0.001$, standing double leg long jump $t = 5.890$, $p < 0.001$, sit and reach $t = 5.384$, $p < 0.001$, and twenty meters shuttle run $t = 5.223$, $p < 0.001$). The 50 m shuttle run were not significant ($p > 0.05$).

3.3 Differences in older individuals

Table 3 shows the test results between the low-thigh skinfold and the high-thigh skinfold in older individuals. In the older male group, there were significant differences in thigh skinfold ($t = -21.122$, $p < 0.001$), abdominal curl ups ($t = 2.165$, $p = 0.031$), and sit and reach ($t = 2.609$, $p = 0.009$), while in the older female group, there were significant differences in thigh skinfold ($t = -29.611$, $p < 0.001$) and Apley scratch test for shoulder mobility ($t = -2.120$, $p = 0.034$).

Table 1. Characteristics of all participants based on groups.

Variables		Men (n = 2811)		t	p	Women (n = 2103)		t	p
		Low thigh skinfold (mm)	High thigh skinfold (mm)			Low thigh skinfold (mm)	High thigh skinfold (mm)		
	Number	1224	1218			796	796		
	Age (years)	39.01 ± 12.92	37.36 ± 11.83	3.304	0.001**	40.61 ± 12.65	38.22 ± 12.88	3.728	<0.001***
Adults (n = 4034)	Height (cm)	172.43 ± 6.53	173.26 ± 6.20	−3.205	0.001**	159.49 ± 5.76	160.08 ± 5.74	−2.048	0.041*
	Weight (kg)	70.11 ± 8.69	75.22 ± 9.27	−14.044	<0.001***	55.62 ± 6.64	58.26 ± 8.02	−7.147	<0.001***
	Body mass index (kg/m^2)	23.57 ± 2.53	25.06 ± 2.88	−13.598	<0.001***	21.88 ± 2.57	22.76 ± 3.09	−6.133	<0.001***
	Number	186	183			256	255		
	Age (years)	72.26 ± 5.41	72.38 ± 5.59	−0.208	0.836	74.45 ± 6.06	73.12 ± 6.14	2.457	0.014*
Older (n = 880)	Height (cm)	163.79 ± 5.20	166.12 ± 5.93	−4.021	<0.001***	152.34 ± 5.89	153.61 ± 5.47	−2.528	0.012*
	Weight (kg)	62.00 ± 6.99	67.98 ± 7.88	−7.708	<0.001***	55.72 ± 7.96	58.16 ± 6.77	−3.730	<0.001***
	Body mass index (kg/m^2)	23.09 ± 2.17	24.63 ± 2.53	−6.269	<0.001***	24.01 ± 3.23	24.65 ± 2.61	−2.460	0.014*

Values are expressed as mean ± standard deviation. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; tested by independent t-test.

Table 2. Results from the independent t-test for sex differences in adults (aged 19–64 years).

Variables	Men (n = 2442)		Effect size	t	p	Women (n = 1592)		Effect size	t	p
	Low thigh skinfold (n = 1224)	High thigh skinfold (n = 1218)				Low thigh skinfold (n = 796)	High thigh skinfold (n = 796)			
Thigh skinfold (mm)	10.50 ± 2.32	20.54 ± 6.03	−2.735	−54.202	<0.001***	15.06 ± 3.12	25.78 ± 5.26	−2.746	−49.405	<0.001***
Dominant hand squeeze strength (kg)	42.87 ± 8.70	42.25 ± 8.28	0.073	1.803	0.071	26.33 ± 5.96	24.16 ± 5.11	0.395	7.789	<0.001***
Non-dominant hand squeeze strength (kg)	40.76 ± 8.46	39.89 ± 7.91	0.106	2.631	0.009**	24.93 ± 5.66	23.11 ± 4.74	0.353	6.944	<0.001***
Abdominal curl ups (reps/min)	37.59 ± 13.21	35.40 ± 11.93	0.174	4.292	<0.001***	24.35 ± 13.22	20.88 ± 12.68	0.268	5.347	<0.001***
Standing double leg long jump (cm)	202.20 ± 35.49	199.93 ± 30.66	0.069	1.692	0.091	146.88 ± 28.64	138.70 ± 26.68	0.296	5.890	<0.001***
Fifty meters shuttle run (sec)	9.04 ± 1.77	9.05 ± 1.60	−0.004	−0.109	0.913	11.31 ± 1.94	11.37 ± 2.00	−0.030	−0.612	0.540
Sit and reach (cm)	10.18 ± 8.25	9.1 ± 8.25	0.124	3.063	0.002**	16.41 ± 7.7	14.25 ± 8.26	0.270	5.384	<0.001***
Twenty meters shuttle run (reps)	38.03 ± 20.55	34.38 ± 18.05	0.190	4.657	<0.001***	22.02 ± 11.51	19.19 ± 10.00	0.264	5.223	<0.001***

Values are expressed as mean ± standard deviation. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; tested by independent t-test.

3.4 Correlation between thigh skinfold and physical fitness in adults

Table 4 shows the correlation between thigh skinfold thickness and levels of physical activity in adults. Except for the 50 m shuttle run test ($p > 0.05$), there was a significant negative correlation between thigh skinfold thickness and physical fitness level in men (dominant hand squeeze strength $r = –0.044$, $p = 0.030$, non-dominant hand squeeze strength $r = –0.051$, $p = 0.011$, abdominal curl ups $r = –0.100$, $p < 0.001$, standing double leg long jump $r = –0.054$, $p = 0.007$, sit and reach $r = –0.079$, $p < 0.001$, and twenty meter shuttle run $r = –0.110$, $p < 0.001$) and women (dominant hand squeeze strength $r = –0.175$, $p < 0.001$, non-dominant hand squeeze strength $r = –0.156$, $p < 0.001$, abdominal curl ups $r = –0.123$, $p < 0.001$, standing double leg long jump $r = –0.139$, $p < 0.001$, sit and reach $r = –0.127$, $p < 0.001$, and twenty meter shuttle run $r = –0.116$, $p < 0.001$).

3.5 Correlation between thigh skinfold and physical fitness in older individuals

Table 5 shows the correlation between thigh skinfold thickness and levels of physical activity in older individuals. In older males, there was a positive correlation between thigh skinfold thickness and single leg balance with open eyes ($r = 0.169$, $p = 0.001$) and a negative correlation between thigh skinfold and sit and reach ($r = –0201$, $p < 0.001$). In older females, thigh skinfold thickness was negatively correlated with abdominal curl ups ($r = –0.088$, $p = 0.046$) and sit and reach ($r = –0.137$, $p = 0.002$) and positively correlated with the result of the Apley scratch test ($r = –0.090$, $p = 0.041$).

4. Discussion

In this large epidemiological study, we aimed to record and analyze the correlation between thigh skinfold thickness and physical fitness factors in Korean adults and older individuals. Overall, the group with low thigh skinfold thickness showed better results than the group with high skinfold thickness for physical fitness factors in both adults and older Korean subjects. According to the results, there were partial significant differences in major physical fitness factors between the groups with low and high thigh skinfold thickness for both sexes and for the age groups assessed. However, the correlation between physical activity and thigh skinfold was higher in the adult group than in the older group.

There was a significant difference between the male groups with low and high thigh skinfold thickness in physical fitness factors, including strength (non-dominant hand squeeze), local endurance (abdominal curl-ups), trunk and lower extremity flexibility (sit and reach), and the cardiorespiratory task (20 m shuttle run). In addition, in Korean female adults, power (standing double-leg long jump) and speed (50 m shuttle run) were significantly different

between the groups of thigh skinfold thickness. Although these results require further verification, a decrease in physical activity was observed with increased thigh skinfold thickness. The results of this study are similar to those of a previous study that found lower levels of physical activity and weak cardiorespiratory capacity and strength in a group of obese subjects compared with healthy control subjects [31]. Furthermore, Doymaz, and Cavlk [32] found that low thigh skinfold thickness in both male and female adults was associated with improved trunk muscular endurance. Therefore, our results suggest that adults with low body fat and thigh skinfold thickness have higher levels of physical activity, improved flexibility, and increased muscular and cardiopulmonary endurance. There was a significant negative correlation in all physical fitness factors between thigh skinfold thickness and physical fitness factors in adult males and females, except for speed (50 m shuttle run). Thus, low thigh skinfold thickness appears to be associated with better physical performance and fitness factors.

Among Korean older men, the low thigh skinfold thickness group and the high skinfold thickness group showed significant differences in physical fitness factors, including local endurance (abdominal curl-ups), and trunk and lower extremity flexibility (sit and reach). In addition, in older Korean women, the results of the upper extremity flexibility (Apley scratch test) were significantly improved. Similar to the results of this study, Park and Ramachandran [33] confirmed that flexibility was reduced in obese older individuals. However, according to a study by De Stefano and Zambon [34] comparing obese and normal-weight older people, the leg strength of overweight and class I obese older individuals is higher than that of normal-weight older people, but flexibility is decreased in class II and class III obesity.

In older men, there was a significant negative correlation between flexibility and thigh skinfold thickness. However, there was a significant positive correlation between balance ability and thigh skinfold thickness. It can be interpreted that a lower thigh skinfold thickness is associated with better flexibility, and that higher values of thigh thickness are associated with a better sense of balance. In the case of single leg balance, only men showed a significant difference among the older subjects. It has been shown that balance problems increase the risk of falls [35] and that not only falls but also the fear of falls may negatively affect the quality of life of older individuals [36]. In addition, in a recent study, static balance was associated with the risk and fear of falling, and a better static balance resulted in lower risk and levels of fear [37]. Therefore, it can be inferred that the level of balance ability in older subjects is an important physical ability, and maintaining a good level increases the quality of life. However, considering the weak correlation with single leg balance ($r = 0.169$, $p = 0.001$) and sit and reach ($r = –0.201$, $p < 0.001$), it is thought that further detailed studies considering more factors are needed to test

Table 3. Results of independent *t*-test for sex differences in the older (aged over 65 years).

Variables	Men (n = 369)		Effect size	t	p	Women (n = 511)		Effect size	t	p
	Low thigh skinfold (n = 186)	High thigh skinfold (n = 183)				Low thigh skinfold (n = 256)	High thigh skinfold (n = 255)			
Thigh skinfold (mm)	8.57 ± 2.13	19.66 ± 6.78	−2.865	−21.122	<0.001***	12.02 ± 2.93	22.73 ± 4.97	−2.920	−29.611	<0.001***
Dominant hand squeeze strength (kg)	31.04 ± 6.83	31.71 ± 7.84	−0.091	−0.873	0.383	20.80 ± 5.76	19.95 ± 5.13	0.156	1.751	0.081
Non-dominant hand squeeze strength (kg)	29.57 ± 6.57	29.85 ± 7.43	−0.040	−0.388	0.698	19.46 ± 5.47	18.86 ± 4.70	0.117	1.331	0.184
Abdominal curl ups (reps/min)	13.73 ± 9.78	11.60 ± 9.09	0.226	2.165	0.031*	5.82 ± 8.61	4.73 ± 6.06	0.154	1.649	0.100
Sit to standing (reps/30 sec)	17.63 ± 6.84	18.45 ± 7.95	−0.011	−1.061	0.289	16.24 ± 6.78	15.66 ± 5.84	0.091	1.034	0.302
Single leg balance (open eyes) (s)	24.07 ± 30.72	30.03 ± 31.99	−0.019	−1.823	0.069	19.76 ± 24.05	20.06 ± 23.79	−0.012	−0.139	0.889
Sit and reach (cm)	6.18 ± 8.30	3.88 ± 8.64	0.272	2.609	0.009**	11.11 ± 8.76	9.85 ± 8.83	0.143	1.619	0.106
Apley scratch test (cm)	−9.50 ± 11.31	−10.08 ± 12.69	0.049	0.468	0.640	−6.58 ± 12.25	−4.40 ± 11.00	0.188	−2.120	0.034*
Six minute walk test (m)	508.22 ± 155.14	517.02 ± 145.40	−0.058	−0.562	0.575	456.78 ± 150.58	460.75 ± 135.03	−0.027	−0.314	0.754

Values are expressed as mean ± standard deviation. * $p < 0.05$, **$p < 0.01$, ***$p < 0.001$; tested by independent *t*-test.

Table 4. Correlationships between thigh skinfold and physical fitness in adults (aged 19–64 years).

Variables	Thigh skinfold of men (n = 2442)		Thigh skinfold of women (n = 1592)	
	r	p	r	p
Dominant hand squeeze strength (kg)	−0.044	0.030*	−0.175	<0.001***
Non-dominant hand squeeze strength (kg)	−0.051	0.011*	−0.156	<0.001***
Abdominal curl ups (reps/min)	−0.100	<0.001***	−0.123	<0.001***
Standing double leg long jump (cm)	−0.054	0.007**	−0.139	<0.001***
Fifty-meter shuttle run (s)	−0.018	0.378	0.027	0.280
Sit and reach (cm)	−0.079	<0.001***	−0.127	<0.001***
Twenty-meter shuttle run (reps)	−0.110	<0.001***	−0.116	<0.001***

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; tested by Pearson's correlationship analysis.

Table 5. Correlationships between thigh skinfold and physical fitness in the older (aged over 65 years).

Variables	Thigh skinfold of older men (n = 369)		Thigh skinfold of older women (n = 511)	
	r	p	r	p
Dominant hand squeeze strength (kg)	0.067	0.202	−0.066	0.135
Non-dominant hand squeeze strength (kg)	0.083	0.110	−0.035	0.430
Abdominal curl ups (reps/min)	−0.071	0.173	−0.088	0.046*
Sit to stand test (reps/30 sec)	0.090	0.084	−0.052	0.242
Single leg balance (open eyes) (s)	0.169	0.001**	0.011	0.810
Sit and reach (cm)	−0.201	<0.001***	−0.137	0.002**
Apley scratch test (cm)	−0.003	0.949	0.090	0.041*
Six minutes walk test (m)	0.008	0.882	0.033	0.450

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; tested by Pearson's correlationship analysis.

this possibility. In a previous study, muscle strength was found to improve balance, and male participants showed a decrease of 12% in lower extremity muscle strength and a decrease of 8% in upper extremity muscle strength at ages 60–69 and 70–80 years [38]. Many women lose 4% more strength in the lower body (14%) than in the upper limbs (10%) [39]. The loss of muscle strength is more common in women than in men, but different factors may influence this phenomenon.

In older women, flexibility and muscle endurance were negatively correlated with thigh skinfold thickness, and shoulder flexibility showed a positive correlation. This can be interpreted as a decrease in the flexibility of the shoulder as the thigh skinfold thickness increases. However, as mentioned above, there was a weak correlation with sit and reach ($r = -0.137$, $p = 0.002$) and Apley scratch test ($r = 0.090$, $p = 0.041$). No significant differences were found in the 6 minute walk test among older men or women. The reason might be that muscle mass and cardiopulmonary capacity are more important factors than body fat. In a previous study [40], women older than 60 years were 20–40% more flexible than men of the same age. In addition, even after the age of 60 years, regular physical activity and exercise can improve aerobic capacity, flexibility, and balance, and delay musculoskeletal loss in older individuals [41,42]. It has also been reported that muscle mass and strength decrease with age and that the rate of loss accelerates after the age of 60 years [43]. Moreover, it appears that older individuals have a higher body fat percentage (by 2–3%) compared with younger adults, which is explained by the fact that older individuals accumulate more fat around their visceral organs [44]. This explains why while body fat increases, the skinfold thickness of subcutaneous fat and musculoskeletal mass decreases [45].

The correlation between the measurements of thigh skinfold thickness and physical activity level was found to be higher in the group of adults than in the group of older subjects. This result appears to be influenced by a number of factors, such as decreased muscle strength, flexibility, and bone density due to aging [46]. We evaluated the correlation between thigh skinfold and physical activity and found that a higher thigh skinfold was associated with a decrease in the level of physical activity, which can lead to various diseases and injuries. Physical fitness ability is important for leading a healthy life, and in this study we found a weak but significant correlation between physical fitness level and thigh skinfold thickness. Although further research is needed to consider other factors such as lifestyle and muscle strength, our results suggest the possibility that managing body fat in the lower extremities can improve physical fitness ability.

Muscle factors should also be considered to confirm these findings. A previous study reported that the muscle area of the thigh is more involved in muscle strength and neuromuscular function than muscle density in adult males

and females [47]. Considering these aspects, it can be said that the thigh muscles play an important role in adult men and women. It should be noted that if the study had included the thickness of the thigh skin (thigh fat), the results might have been different. In adult men and women, it can be inferred that an individual with a small amount of thigh fat and high muscle mass has better physical ability than a person with high amounts of both fat and muscle.

In addition, assuming no differences in muscle mass, a person with less thigh fat can be inferred to have slightly better physical ability. The reason why the amount of physical activity in adults or older subjects is low may be because of insufficient thigh muscle mass, insufficient muscle strength, or excessive thigh fat.

As mentioned above, factors such as the amount of personal physical activity were not evaluated in this study. In addition, individual muscle mass was not considered. These two factors can affect the performance of various activities.

This study has some limitations. First, although it focused on a large population nationwide, no detailed information was collected. Second, the body fat skinfold thickness was obtained only from the thigh area. The reason for this was that the skin fold measurement sites for men and women are different, and hence we decided to use the thigh skinfold as a measurement site for both sexes. Third, although the measurements were performed by an experienced examiner, errors may occur due the different measurements performed in different regions. Fourth, it is difficult to infer a causal relationship because of the cross-sectional design of the study. Hence, further research is required to investigate this. Fifth, According to the central limit theorem, in a sample of more than 30 subjects, the data is normally distributed and the reliability is high [29]. However, since the number of adults and the number of older subjects were different, the results of the statistical significance levels may be inaccurate. In this study, thigh skinfold and physical activity levels were found to be correlated in adults, but this correlation was lower in the older subjects. Future studies should provide a more detailed analysis by measuring not only fat but also muscle strength in order to determine how body composition affects physical activity in older individuals.

5. Conclusions

Decreased thigh skinfold thickness in adult and older subjects may have a positive effect on physical fitness factors and physical activity, and this effect is stronger in adults than in older individuals. In Korean adults, muscle strength, muscular endurance, power, flexibility, and cardiopulmonary endurance were closely related to the thickness of the thigh skinfold, whereas balance and flexibility were found to be closely related to the thickness of the thigh skinfold in older subjects. Therefore, when considering health care programs for Korean adults and older subjects,

it is important to recognize the normal control of body fat and the musculoskeletal system of the lower extremities and to increase physical fitness while decreasing body fat in the lower extremities. Finally, in a modern society in which the prevalence of obesity is constantly increasing, health care programs are needed to prevent diseases and help people lead a healthy life.

Author contributions

Study design—DWL, SSH, HSJ, and WYS; study conduct—DWL, SSH, HSJ, and WYS; data collection—DWL, SSH, HSJ, and WYS; data analysis—DWL and SSH; data interpretation—HSJ and WYS; drafting manuscript—DWL and SSH; revising manuscript content—HSJ and WYS. All authors have read and approved the final manuscript.

Ethics approval and consent to participate

In this cross-sectional epidemiological study, we used a large sample representative of the Korean adult population from the 2015 National Fitness Survey, which was conducted by the Korea Institute of Sports Science, Ministry of Culture, Sports and Tourism of Korea, and informed consent was obtained from all participants. This study was conducted according to the principles of the Declaration of Helsinki. Since personal information such as participant name, phone number, home address, and social security number were not collected, ethical approval was waived.

Conflict of interest

The authors declare no conflict of interest.

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