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RESEARCH ARTICLE

The Relationship Between Fall Risk, Balance, Posture, Strength, and Functional Parameters In Healthy Adults

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Abstract
The aim of this study is to examine the relationship between posture, fall risk, balance, strength, and functional parameters in healthy adults with exercise habits. In our study, 45 individuals over 55 years of age who came to Denizli province 1200 Asmalı Evler Healthy Aging Center were included. The quadriceps, hamstring, and hand grip strengths of the participants were measured with a dynamometer. Their balance was assessed with the functional reach test, their posture with the New York Posture Rating Chart, their fear of falling with the fall effectiveness scale (FES-1), their functionality with the 30-second sit-stand test, and their flexibility with the sit and reach test. According to the correlation analysis, moderate and high levels of significant positive correlation between hamstring strength and hand grip strength; A weak to moderate positive correlation was found between quadriceps strength and hand grip strength and functional reach test. A moderately significant negative correlation was found between quadriceps strength (right), functional reaching test and fall activity scale and sit and reach test, between quadriceps strength (left) and functional reaching test, waist/hip ratio, and New York Posture Rating Chart ($p<0.05$). There was no significant relationship between other parameters ($p>0.05$). These results support that hand grip strength is a valid method for estimating lower extremity strength among healthy adults at the group level. However, there is a weak relationship between balance and hand grip strength.

Keywords
Athlete injury, anxiety, sports surface

INTRODUCTION

Balance capability refers to the capability to conserve the center of gravity, fixed body alignment, and posture on the support base (Horak, 1987). Balance control capability can be branched into dynamic and static balance control capability in accord with movement. Dynamic balance control capability controls the balance of the body during movements similar to walking, while static balance control capability controls the balance of the body while standing still (Bressel et al., 2007; Winter et al., 1990). Elements affecting balance capability have been explored numerous times (Bok et al., 2013; Gatev et al., 1999; Han et al., 2014; Lord, 1991; Shumway- Cook, 2001). A specific grade of muscle strength is needed to maintain an upright posture, and the lower extremity muscles near the ankle and knee joint must work agreeably to maintain stance stability

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and prohibit falls (Gatev et al., 1999; Lord, 1991; Shumway-Cook, 2001). Lord et al. reported that decreased sensation and muscle weakness in the legs and increased reaction time are important factors associated with postural instability (Lord, 1991). Eika et al. showed that hand grip strength and lower extremity strength decreased with increasing age in both genders (Eika et al., 2019). Alonso et al. discovered that hand grip strength was significantly related to the strength of the lower extremities in elder adult women, suggesting that hand grip strength could be used as an index of overall strength capability for clinical screening among elder women. Additionally, they associated lower hand grip strength with worse dynamic balance and mobility performance (Alonso et al., 2018). Neri et al. set up that weak hand grip strength was affiliated with a significantly higher threat of falling(Neri et al., 2021). In the study of Muehlbauer et al., they found almost no significant relationship (except for one) between lower extremity muscle strength, power, and balance variables in healthy and physically active elderly people. They stated that there are studies that both support and do not support this result they found, and therefore, they mentioned that more studies are needed to elucidate whether the strength, power, and balance performances of healthy older adults are independent or dependent on each other (Muehlbauer et al., 2012). For these reasons, our study aims to examine the relationship between posture, fall risk, balance, strength, and functional parameters in healthy adults.

MATERIALS AND METHODS

Ethical approval of the study was obtained from Pamukkale University Non-Interventional Clinical Research Ethics Committee at the board meeting dated 08.02.2022 and numbered 03 (Protocol No: 60116787-020-168745). After detailed written and verbal information was given to all participants, written informed consent was obtained from each participant.

Participants

Healthy individuals over 55 years of age, who regularly come to Denizli 1200 Evler Mahallesi Active Aging Center to exercise for at least 3 months, participated in our study. Individuals who scored below 23 points on the mini-mental test, had any neurological problems, had vestibular and cognitive impairments, had a medical condition that would limit exercise participation, and used walking aids were excluded from the study. All participants were given the necessary information and the factors affecting the balance were evaluated.

The evaluated factors are as follows:

Standardized Mini Mental Test (SMMT)

A standardized mini-mental test, which consists of eleven items gathered under five main headings as orientation, recording memory, attention and calculation, recall, and language, and evaluated out of a total score of 30, was administered to all participants. People who scored 23 points or less from the test were excluded from the study (Güngen et al., 2002).

Fall Activity Scale (FES-1)

Participants provided information about the level of anxiety about falls during activities of daily living; It was assessed on the FES-1 scale, which consists of 16 items of four points (1=not at all concerned, 4=very concerned), providing a total score ranging from 16 points (no concern about falling) to 64 points (severe concern about falling) (Ulus et al., 2012).

Quadriceps Muscle Strength Measurement

Quadriceps strength was evaluated while the participants were positioned to sit in a chair with their knees flexed at 90 degrees and arms crossed over the trunk, with their feet not touching the ground. The measurement was performed with the PowerTrack 2 Commander device and according to the device's instructions for use. Two measurements on the right and left extremities were made with an interval of one minute and the averages were taken (Kendall et al.).

Hamstring Muscle Strength Measurement

After the participants were positioned to take the most comfortable prone position on the stretcher, the hamstring strength was evaluated by bringing the knee to 60-70 degrees of flexion. The measurement was performed with the PowerTrack 2 Commander device and according to the device's instructions for use. Two measurements on the right and left extremities were made with an interval of one minute and the averages were taken (Kendall et al.).

Hand Grip Force Measurement

Participants were seated in a chair with back support and fixed arms. Participants were instructed to sit upright and rest their forearms on the arm of the chair with their wrists just at the end of the chair. Two measurements of the right and

left hands were evaluated with a Jamar brand of the results was recorded (Vermeulen et al., 2015).

Waist and Hip Circumference Measurement

Hip and waist circumference measurements of all participants were taken twice and the average of the measurement results were recorded (Hughes et al., 2004).

Waist/hip Ratio

The waist/hip ratio was calculated by dividing the waist circumference by the hip circumference.

30 Second Sit To Stand Test

All participants were asked to get up from the chair in a full and upright position with the arms crossed on the chest in a standard size chair without arms, and the hips should fully contact the chair while sitting, and the number of sitting and standing up in 30 seconds was counted with the start instruction. Measurements were made twice with an interval of 30 seconds and the average was taken (Jones et al., 1999).

Sit and Reach Test

The participants were asked to lie on the bench as much as possible without bending the knees, with the arms extended forward and the hands placed one above the other, in the section where the sit and reach table is located. Measurements were made twice with an interval of 15 seconds and the average was taken (Sweet et al., 2004).

Functional Reach Test

All participants were asked to reach forward as far as they could without raising their heels and losing their balance, by making fists with their desired extremities with a tape measure fixed on the wall, with their hands in 90 degrees flexion and referencing the 3rd metacarpal, and the difference between the starting point was recorded. The measurements were measured twice with a 15-second interval and averaged (Duncan et al., 1990).

Posture Analysis

Posture Analysis was calculated and recorded by an experienced physiotherapist in a special room with New York Posture Analysis (McRoberts et al., 2013).

Statistical Analysis

The G*Power 3.1.9.7 program was used to determine the sample size of the study. Our study was calculated as at least 45 people to achieve dynamometer at one minute intervals. The average 80% power with r:0.395 α=0.05 type I error β=0.10 type II error (Kim & Kim, 2018).

Data were analyzed with SPSS 25.0 (IBM SPSS 25 Software, IBM Corp, Armonk, NY, USA) package program. Continuous variables were expressed as mean ± standard deviation and categorical variables as numbers and percentages. The conformity of the data to the normal distribution was examined with the Shapiro-Wilk test. After examining the normal distributions of the data, the relationships between continuous variables were made using Spearman or Pearson correlation analysis.

RESULTS

47 individuals, 21 males and 26 females, who regularly do sports in the healthy aging center with an average age of 68.62±0.90 years and an average weight of 89.58±1.95 kg, participated in our study. Participants reported that they exercise 1.18±0.08 hours a day, 4.33±0.33 days a week. Only 11% of the participants reported a history of falls in the past 12 months. The descriptive values of our evaluation results are given below (Table 1).

Hamstring strength (right) versus hand grip strength (right) (r=0.593, p=0.001), hamstring strength (right) versus hand grip strength (left) (r=0.657, p=0.001), hamstring strength (left) hand grip strength (right) (r=0.584, p=0.001), hamstring strength (left) and hand grip strength (left) (r=0.647, p=0.001) significant positive moderate and high correlation; Quadriceps strength (right) versus hand grip strength (right) (r=0.332, p=0.026), quadriceps strength (right) versus hand grip strength (left) (r=0.541, p=0.001), quadriceps strength (left) hand grip strength (right) (r=0.416, p=0.004), quadriceps strength (left) and hand grip strength (left) (r=0.544, p=0.001), hand grip strength (left) and functional reach (r= 0.339, p=0.023, a significant positive, weak and moderate correlation was found. Quadriceps strength (right) sit and reach test (r=-0.339, p=0.023), quadriceps strength (left) sit and reach test (r=-0.331, p=0.026), functional reach test and sit and reach test (r= -0.364, p=0.014), fall activity scale and sit and reach test (r=-0.364, p=0.014), waist/hip ratio and newyork posture analysis were found to be significantly negative and weakly correlated (Table 2).

Table 1. Evaluation results of participants

	Mean±standard deviation	Median (Min-Max)
Hamstring Strength (Right)	89.58±5.01	86.35 (40.70-157)
Hamstring Strength (Left)	88.99±5.01	84.15 (40.70-167)
Quadriceps Strength (Right)	154.10±5.78	155.50 (80.30-245)
Quadriceps Strength (Left)	124.97±5.33	122 (48.40-225)
Hand Grip Force (Right)	25.92±0.91	24.88 (13.05-57.25)
Hand Grip Force (Left)	25.11±0.88	24.70 (13.75-57.50)
Sit and Reach Test (cm)	24.50±0.87	24.88 (10-34.50)
Fall Activity Scale (score)	23.45±1.22	22 (16-54)
Mini Mental Test (points)	25.11±0.58	26 (12-30)
New York Posture Analysis (points)	40.84±1.62	39 (17-59)
Thirty Second Sit to Stand Test (pcs)	11.75±0.03	12 (7.50-17)
Functional Reach Test (cm)	29.08±1.01	28.50 (16-51.50)
Waist/hip Ratio	0.90±0.01	0.90 (0.74-1.07)

Between hamstring strength and thirty-second sit and stand test, functional reach test, sit and reach test, fall activity scale, new york posture analysis; between quadriceps strength and thirty-second sit and stand test, functional reach test, fall efficiency scale, New York posture analysis; between hand grip strength (right) and thirty-second sit and stand test, functional reach test, sit and reach test, fall activity scale, and New York posture analysis; between hand grip strength (left) and the thirty-second sit and stand test, sit and lie down test, fall activity scale, new york posture analysis; between the thirty-second sit and stand test and the functional reach test, sit and lie down test, fall efficiency scale, and New York posture analysis; between sit and lie test and new york posture analysis; There was no significant relationship between the fall activity scale and the New York posture analysis ($p>0.05$) (Table 2).

DISCUSSION

The main finding of this study is that hand grip strength is positively related to lower extremity muscle strength in healthy adults and there is a weak positive correlation between the functional reach test, which is an indicator of dynamic balance and functionality, and hand grip strength. These findings are important because hand grip strength can be used clinically as a measure of muscle strength ability in healthy individuals. It has also been shown that hand grip strength can provide information about the dynamic balance and functionality of individuals.

Studies showing the relationship between hand grip strength and quadriceps and hamstring are available in the literature (Kilgour et al., 2013; Norman et al., 2010; Stel et al., 2003). In parallel with our study, there is a study in the literature showing that hand grip strength is positively and moderately related to hamstring and quadriceps muscle strength (Alonso et al., 2018). Pijnappels et al. on the other hand, they found a significant relationship between hand grip strength and knee extension strength (Pijnappels et al., 2008). In some studies in the literature, a weak relationship was found between hand grip strength and quadriceps-hamstring strength (Fragala et al., 2016; Yeung et al., 2018). In our study, there is a moderately positive relationship between hand grip strength and quadriceps and hamstring muscle strength, in line with these studies.

In the literature; Alonso et al. while they found a significant correlation between hand grip strength and lower extremity strength, they reported that with a decrease in hand grip strength, your dynamic balance and mobility performance decreased, and the relationship between hand grip strength and fall risk and balance (Alonso et al., 2018).

Table 2. The Relationship between participants' fall risk, balance, posture, strength and functional parameters

	r	p
Hamstring Strength (right)-Hand Grip Strength (right)	0.593	**0.001***
Hamstring Strength (right)-Hand Grip Strength (left)	0.657	**0.001***
Hamstring Strength (left)-Hand Grip Strength (right)	0.584	**0.001***
Hamstring Strength (left)-Hand Grip Strength (left)	0.647	**0.001***
Quadriceps Strength (right)-Hand Grip Strength (right)	0.332	**0.026***
Quadriceps Strength (right)-Hand Grip Strength (left)	0.541	**0.001***
Quadriceps Strength (left)-Hand Grip Strength (right)	0.416	**0.004***
Quadriceps Strength (left)-Hand Grip Strength (left)	0.544	**0.001***
Hand Grip Strength (right)-Functional Reach Test	0.217	0.152
Hand Grip Strength (left)-Functional Reach Test	0.339	**0.023***
Hamstring Strength (right)-Functional Reach Test	0.181	0.235
Hamstring Strength (left)-Functional Reach Test	0.219	0.148
Quadriceps Strength (right)-Functional Reach Test	0.217	0.153
Quadriceps Strength (left)-Functional Reach Test	0.258	0.087
Hand Grip Strength (right)-Fall Activity Scale	-0.076	0.616
Hand Grip Strength (left)-Fall Activity Scale	0.036	0.810
Hamstring Strength (right)-Fall Activity Scale	-0.230	0.125
Hamstring Strength (left)-Fall Activity Scale	-0.262	0.079
Quadriceps Strength (right)-Fall Activity Scale	-0.039	0.796
Quadriceps Strength (left)-Fall Activity Scale	0.012	0.937
Waist/hip Ratio - New York Posture Analysis	-0.321	**0.034****
Functional Reach Test – Sit and Reach Test	-0.364	**0.014***
Hamstring Strength (right)-Sit and Reach Test	-0.241	0.111
Hamstring Strength (left)-Sit and Reach Test	-0.203	0.182
Quadriceps Strength (right)-Sit and Reach Test	-0.339	**0.023****
Quadriceps Strength (left)- Sit and Reach Test	-0.331	**0.026****
Sit and Reach Test - Fall Activity Scale	-0.364	**0.014***
Hand Grip Strength (right)-Sit and Reach Test	-0.147	0.330
Hand Grip Strength (left)-Sit and Reach Test	-0.273	0.066
Hamstring Strength (right)-Thirty Second Sit and Stand Test	0.139	0.362
Hamstring Strength (left)-Thirty Second Sit and Stand Test	0.204	0.178
Quadriceps Strength (right)-Thirty Second Sit and Stand Test	0.257	0.088
Quadriceps Strength (left)-Thirty Second Sit and Stand Test	0.177	0.244
Hand Grip Strength (right)-Thirty Second Sit and Stand Test	0.031	0.840
Hand Grip Strength (left)-Thirty Second Sit and Stand Test	0.017	0.910
Hamstring Strength (right)-New York Posture Analysis	-0.139	0.374
Hamstring Strength (left)-New York Posture Analysis	-0.135	0.388
Quadriceps Strength (right)-New York Posture Analysis	-0.192	0.217
Quadriceps Strength (left)-New York Posture Analysis	0.055	0.725
Hand Grip Strength (right)-New York Posture Analysis	-0.029	0.852
Hand Grip Strength (left)-New York Posture Analysis	-0.098	0.525
Thirty Second Sit and Stand Test - Functional Reach Test	0.102	0.506
Thirty Second Sit and Stand Test - Sit and Reach Test	0.083	0.581
Thirty Second Sit and Stand Test - Fall Activity Scale	0.117	0.437
Thirty Second Sit and Stand Test - New York Posture Analysis	-0.048	0.758
Functional Reach Test - Fall Activity Scale	0.148	0.326
Functional Reach Test - New York Posture Analysis	-0.002	0.991
Sit and Reach Test - New York Posture Analysis	0.228	0.136
Fall Activity Scale- New York Posture Analysis	-0.010	0.948

In another study, there was a meaningful relationship between dynamic balance and hand grip strength (Wiśniowska-Szurlej et al., 2019), while in the study of Fujita et al., weaker hand grip strength and higher dynamic balance disorder were reported (Fujita et al., 2019). In our study, a weak positive correlation was found between the left hand grip strength and the functional reach test, which is one of the tests of dynamic balance. There are many factors affecting dynamic balance, we think that hand grip strength can be used as a parameter in evaluating dynamic balance, but more studies are needed in the literature on this subject.

Laughton et al. reported that the decrease in lower extremity muscle strength negatively affects postural sway and Kligytė et al. found a significant relationship between the decrease in lower extremity muscle strength and the ability to control balance (Kligyte et al. 2003; Laughton et al. 2003). Shumway-Cook et al. reported that lower extremity muscle strength should be at a certain threshold value in order to maintain balance and that coordination between the muscles in the lower extremity maintains static balance and prohibit falls (Shumway-Cook & Woollacott, 1995). In our study, however, no correlation or significance was found between quadriceps and hamstring muscle strength and functional reach test, which is one of the indicators of dynamic balance. Similar to our study in the literature, Muehlbauer et al.'s study evaluated the relationship between muscle strength and balance in healthy elderly individuals with different methods as reactive balance and proactive balance and reported that there was no relationship between lower extremity muscle strength and dynamic balance (Muehlbauer et al., 2012). In a study conducted on adult women in 2011, it was concluded that knee flexor muscle groups did not show any significance with the functional reach, while knee extensor muscle groups were weakly correlated with functional reach test (Yıldırım et al., 2011). Conflicting results in the literature on this subject show that more studies are needed.

When we look at the studies in the literature examining the relationship between fear of falling and muscle strength, Yardimci et al. They found that there was a negative correlation between hand grip strength and fear of falling, and they found that upper extremity muscle strength affected the fear of falling (Yardimci et al., 2021). In the literature, there are negative correlations between lower extremity muscle strength and fear of falling (Binda et al., 2003; Delbaere et al., 2004; Trombetti et al., 2016). However, in our study, no significant relationship was found between strength and the FES-1 fall efficiency scale. We think that this is because our sample group is active individuals.

In our study, we found that the waist/hip ratio was positively correlated with the New York posture analysis. There is no study in the literature that directly examines this relationship and gives results. Therefore, this result could not be discussed. Although more studies are needed, we think that the waist/hip ratio shows that it can be a practical method to evaluate the posture analysis status.

In our study, we found a weak negative correlation between the sit and reach test and the functional reach test, which measures dynamic balance and functional reaching ability. In the literature review, only Overmoyer et al. we found a study in which they examined the relationship between flexibility and dynamic balance in healthy active young adults (age = 21.9 ± 2.6 years), where they reported a significant relationship between flexibility and balance (Overmoyer & Reiser, 2015). Our study shows parallelism with this study in the literature, but more literature studies are needed to discuss this issue.

In our study, we could not find a meaningful connection between hamstring muscle strength and the sit-and-reach test, but we found a weak negative connection between quadriceps muscle strength and the sit-and-reach test. In a study conducted in 2018 evaluating lower extremity and functional parameters in the elderly, a significant relationship was found between lower extremity muscles and trunk flexibility, but unlike our study, in this study, muscle strength was not measured specifically for muscles, but measurements were made according to range of motion (Torpi, 2018). In the study of Akınoğlu et al., in which they examined the relationship between trunk muscle strength and sit and reach test on athletes, a significant relationship was found between trunk muscle strength and sit and reach test (Akınoğlu et al., 2020). However, both the sample group and the muscles evaluated in this study differ from our study.

Another finding of this study is that there is a weak negative correlation between sit and reach test and fall efficiency scale. In the literature, we

did not find any research that directly examines the sit-and-reach test and the fall effectiveness scale. However, there are studies in the literature that indicate that flexibility exercises are effective in increasing dynamic balance (Barrett & Smerdely, 2002; Costa et al., 2009; Overmoyer & Reiser, 2015). Thus, the relationship between flexibility and balance, albeit indirectly, is in parallel with the relationship we found between the sit and reach test and the fall effectiveness scale.

Wisniowska-Szurlej et al. found that lower limb flexibility in women was a connection with hand grip strength, while there was a relationship between upper limb flexibility and hand grip strength in men (Wiśniowska-Szurlej et al., 2019). Silva et al. In their study, they found that there was no significant relationship between hand grip strength and flexibility (de Almeida Silva et al., 2013). In our study, no relationship was found between hand grip strength and flexibility. We think that many factors affecting flexibility cause this difference.

In this study, no correlation was observed between the 30-second sit-to-stand test, which is frequently used in the literature to measure lower extremity muscle strength, and dynamic balance, and quadriceps, hamstring strength. In the literature, according to Torpi et al. In a study they conducted in 2018, they reported a moderate positive correlation between lower extremity muscle strength and the 30-second sit-stand test. (Torpi, 2018).Cebolla et al., in their study in 2015, reported that an increase in lower extremity muscle strength increased the 30-second sit-to-stand test performance (Cebolla et al., 2015). In our study, there was no significant difference between hand grip strength and 30-second sit-to-stand test. In 2021, Yee et al. investigated the role of the 30-second sit-to-stand test in the diagnosis of sarcopenia in elderly people and found a weak positive correlation between the hand grip strength and the 30-second sit-to-stand test (Yee et al., 2021). We think that due to the fact that our sample group exercised regularly and was healthy, they did not have difficulty in the 30-second sit and stand test, and therefore no correlation was observed.

In this study, there was no significant relationship between quadriceps, hamstring and hand grip strengths and New York Posture Rating Chart. There was no correlation between the thirty-second sit-to-stand test, which is one of the other parameters, and the functional reach test, sit-and-reach test, fall efficiency scale and New York Posture Rating Chart. There was no correlation between the functional reach test and sit-and-reach test, fall efficiency scale and New York Posture Rating Chart. There was no significant relationship between the sit-and-reach test and the New York Posture Rating Chart, and between the fall efficiency scale and the New York Posture Rating Chart, which are among the other parameters examined. We have not come across a study in the literature that directly examines and investigates the relationship between these parameters. Therefore, these parameters could not be discussed. More work is needed.

Conclusion

As a result, the fact that hand grip strength is moderately related to lower extremity muscle strength shows that it can give information about lower extremity muscle strength, while the relationship between hand grip strength and functional reach shows that hand grip strength can give an idea about dynamic balance and functional reach of individuals. On the other hand, we think that waist/hip ratio may be a parameter that can give an idea about posture analysis and that more studies are needed on these issues.

Conflict of interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

Ethics Committee

Ethical approval of the study was obtained from Pamukkale University Non-Interventional Clinical Research Ethics Committee at the board meeting dated 08.02.2022 and numbered 03 (Protocol No: 60116787-020-168745).

Author Contributions

Study Design, ET, AE, BNO; Data Collection, BNO, SÖM; Statistical Analysis, OA, AYÖ; Data Interpretation, ET, FÜ; Manuscript Preparation, BNO, ET, SÖM; Literature Search, AE, BNO, SÖM, ET, FÜ. All authors have read and agreed to the published version of the manuscript.

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