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Original Article

Relationship Between Muscle Mass and Usual Walking Speed Mediated by Muscle Strength, Respiration and Depression in Elderly Female

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Key Words
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Background: The elderly population is increasing rapidly worldwide. Muscle mass, usual walking speed (UWS), knee extension strength (KES), hand grip strength (HGS), peak expiratory flow (PEF), and depression is used for sarcopenia diagnosis. All four of these factors (KES, HGS, PEF, and depression) correlated with UWS and also to muscle mass. But, many studies have suggested that no correlation exists between muscle mass and UWS.

Objects: This study aimed: 1) to investigate whether muscle mass reduction affected UWS, as mediated by KES, HGS, PEF and depression, and 2) to explored whether significant changes in these mediators varied by the body segment in which muscle mass evaluated in elderly female aged 65–80 years.

Methods: A total of 100 female aged 65–80 years were surveyed. Muscle mass was measured by body segment (upper and lower segment), and KES, HGS, PEF, depression, and UWS were also assessed. Median analyses were progressed in IBM SPSS software (ver. 23.0, IBM Co.) using a downloaded INDIRECT macro.

Results: The direct effect of the KES and PEF were significant, and the indirect effect of KES and PEF were not significant. Thus, KES and PEF served as full mediators of the effect of muscle mass on UWS. Regardless of bodily region, KES and PEF combined with muscle mass were significant mediators of UWS, with similar indirect effect sizes.

Conclusion: KES and PEF are the only mediators regardless of body part. Therefore, mediating the KES and PEF may prevent sarcopenia progression in elderly female. Also, sarcopenia can be readily assessed by evaluating either the upper or lower body; it is not necessary to measure total muscle mass.

INTRODUCTION

The elderly population is increasing rapidly worldwide. As the elderly population exceeded 14%, Korea became an aged society in 2017, and in 2022, the elderly population is 17% (Available from: http://kosis.kr/eng/statisticsList/statisticsListIndex.do?menuId=M_01_01&vwcd=MT_ETITLE&parmTabId=M_01_01). The elderly has various chronic diseases, which increases social and economic costs. Therefore, government policies and national research are being developed to reduce these costs and maintain a healthy life for the elderly while managing chronic diseases.

Sarcopenia is defined as the progressive skeletal muscular disorder including decrease of muscle mass, strength and function with the aging process [1,2]. Sarcopenia is an important cause of frailty [3]. And elderly suffer from reduced quality of life and increase of morbidity and mortality because of the sarcopenia [4-6]. Therefore, the worldwide interested in sarcopenia and assigned an individual International Statistical Classification of Diseases and Related Health Problems code (M62.84) in 2016 [7].

Asian Working Group for Sarcopenia (AWGS) suggested the algorithm about the sarcopenia identifying and diagnosing in 2019 [7]. According to AWGS, Sarcopenia is defined as a state of low Bioelectrical Impedance Analysis (BIA) with low muscle strength or low physical performance. Severe sarcopenia is defined as a state of low BIA with low muscle strength and low physical performance [7]. According to the sarcopenia diagnostic criteria, it cannot be diagnosed as sarcopenia if the muscle strength and physical performance is maintained even if the muscle mass is reduced. In other words, if the elderly do not want to be diagnosed with sarcopenia or not to be severe sarcopenia, the physical function or strength must be increased or maintained.

Muscle mass, which is a basic condition for diagnosing sarcopenia, is decreases at different rate for each gender and body part. As for the changes in muscle mass in the elderly, the thickness of the upper extremity muscle did not decrease, but the thickness of the lower extremity muscle decreased, indicating that the muscle mass decreased at a different rate for each region. Also, in the case of females, a remarkable decrease in leg muscle mass became evident at 40–50 years of age, but the decrease in arm muscle mass was much less [8].

The usual walking speed (UWS) test is used to anticipate functional decline in the elderly [9] and to identify those at increased risk of mortality [10]. Therefore, the UWS is considered a very significant functional vital sign in the elderly [11-13] and is used to elderly's physical function evaluation tool to screening sarcopenia. The UWS is a complex activity influenced by various factors such as psychological and physical factors [13]. Among the physical factors, the factors related to body strength include knee extension strength (KES) [14-16], hand grip strength (HGS) [17,18], and peak expiratory flow (PEF) [19,20]. Also, the psychological factor depression, sarcopenia case finding tool, is correlated with the UWS [21]. Although all four of these factors (KES, HGS, PEF, and depression) correlated with UWS and also to muscle mass [22]. But, many studies have suggested that no correlation exists between muscle mass and UWS [23,24].

Therefore, we investigated whether muscle mass reduction, an basic symptom of sarcopenia, affected UWS, as mediated by KES, HGS, PEF, and depression. Also, we explored whether significant changes in these mediators varied by the body segment in which muscle mass evaluated; the timing of muscle mass loss differs between the upper and lower limbs [8].

We hypothesized that the effect of muscle mass on UWS may be mediated by KES, HGS, PEF, and depression, and that the mediators would differ by body segment.

MATERIALS AND METHODS

1. Subjects

Volunteers were recruited by advertisement. The inclusion criteria were: 1) elderly female (aged 65–80 years); 2) not hospitalized (living independently at home); 3) the ability to answer questions; and 4) no history of hip fracture or surgery. The exclusion criteria were: 1) pulmonary disease (pneumonia, chronic obstructive pulmonary disease, asthma, or tuberculosis); 2) severe osteoporosis; 3) a history of heart surgery or pacemaker implantation; and 4) a history of stroke. The height, weight, age, smoking status, hypertension and diabetes status, and back pain severity were recorded. In total, 110 female aged 65–80 years were recruited; 10 were subsequently excluded from the study (2 subjects had a history of stroke, 3 subjects couldn't answer the questions, and 5 subjects had a severe osteoporosis). Their general characteristics are shown in Table 1. Prior to the experiment, all subjects were informed about the aims of the study and provided written informed consent. The study was approved by the Institutional Review Board at Yonsei University Wonju campus (IRB no. 1041849-201706-BM-058-01).

2. Outcome Measures

1) Muscle mass

Muscle mass was measured using an Inbody 370 instrument (BioSpace) after the subject was weighed. We entered age, height, and sex information into the device and followed the manual. To measure muscle mass, both soles are placed on a total of four electrodes. Both arms are positioned so as to not touch the torso, and handles containing four electrodes are grasped with both palms. When all eight electrodes are in contact, muscle mass measurements are taken. Each partici-

Table 1. Subject characteristics

Variable	Participant (N = 100)
Age (y)	72.4 ± 4.9
Height (cm)	152.2 ± 5.6
Weight (kg)	58.4 ± 8.6
Body mass index (kg/m^2)	25.2 ± 3.3
Hypertension	50
Diabetes	17
Smoking	2
Back pain	37
Knee pain	23
Depression	7

Values are presented as mean ± standard deviation or number only.

pant maintains the measurement posture for 1 minute. Muscle mass is determined by impedance analyses at three frequencies (5, 50, and 250 kHz). The eight electrodes in contact with the hands and soles reveal the levels of muscle and fat in each body segment (right and left arms, right and left legs, and the trunk) and the results are printed.

2) Knee extension strength

The KES was measured using a hand-held dynamometer (HHD) (MT-100, SAKAImed). Each participant was seated with the hips and knees at 90° of flexion and both arms crossed in front of the chest. One side of the HHD strap was fixed to the chair leg and the other to an ankle. The strap length was adjusted to ensure the knee was not extended during knee extension. Then, the subject was instructed to extend one leg with the maximum possible force [25]. Knee extensions were performed three times for 5 seconds each time. Measurements were made on either side and the peak force recorded. The average bilateral peak force was used in the analysis [26]. The HHD shows the tension (1–1,000 kgf) when both straps are tied and has an accuracy of 2%. Measurements are displayed at 0.1 kgf intervals and in units of N or kgf.

3) Hand grip strength

We used a dynamometer to measure HGS. The measurement was made in a standing position, with the elbow fully extended and the shoulder at 30° of flexion and with the wrist and palm perpendicular to the arm. Participants were instructed to squeeze the handle as hard as possible. Both arms were tested. Subjects squeezed three times for 3 seconds each time and the maximal grip strength was used in the analysis, in addition to the mean bilateral maximal grip strength [27]. The HGS was measured using a dynamometer (JAMAR; Sammons Preston, Inc.), which is considered to be the most accurate device available [28]. The dynamometer indicates maximal grip strength when the handle is firmly held. The range of measurement is 0–90 kg and the instrument presents results at 1-kg intervals.

4) Peak expiratory flow rate

Respiratory muscle strength was assessed by spirometrically measuring the PEF rate (Avad 9; Bionet Co., Ltd.) [29]. The spirometer measures forced vital capacity, forced expiratory volume in 1 second, and the PEF. A maximal expiratory velocity of 14 L/s can be measured. According to the manual, the volume measurement error is 5% and the flow measurement error is 10%. Subject age, height, weight, and race are entered into the instrument. To measure the PEF, the subject was instructed to exhale as quickly as possible through the mouthpiece after maximal inspiration. Maximal inspiration and expiration speed were measured three times [30]. The speed was expressed in L/s. The mean values of the three measurements were used in the analysis.

5) Depression

Depression status was screened using the widely used Korean version of Geriatric Depression Scale (GDS-KR). The scale contains 30 simple yes/no items. Scores < 13 reflect borderline, 14–18 mild, 19–21 moderate, and > 22 severe depression [31]. The GDS-KR exhibits high internal consistency (Cronbach's alpha coefficient 0.90) and the total item correlation is also significant (Pearson correlation test, $p < 0.01$). The test-retest reliability is 0.91 and the concurrent validity is good [32].

6) Usual walking speed

We used a 10-minute walk test to measure the UWS, as in previous studies. We marked a 10-minute line and measured the time taken to traverse the middle 6 m (moving start and moving end). We instructed all subjects to walk at their normal pace (i.e., not fast and not slow) [33]. Two measurements were taken and the average was obtained and analyzed.

3. Statistical Analysis

1) Mediation analysis

Mediation analysis was performed using IBM SPSS software (ver. 23.0, IBM Co.) running the INDIRECT macro (www.processmacro.org) [25]. Bootstrapping was employed; this increases the power of studies with small sample sizes. We resampled 5,000 times and calculated bias-corrected (BC) 95% confidence intervals (CIs). When the BC 95% CI is not zero, the effect is significant.

INDIRECT macro can estimate the path coefficients in a multiple mediator model (an "a" path coefficient: independent variable on mediators; a "b" path coefficient: mediators on dependent variable). We used a causal step approach to interpret the effects. When both a direct and an indirect effect (yielding an "a × b" path coefficient) were significant, we considered this to indicate partial mediation. When the direct effect was not significant but the indirect effect (the "a × b" path coefficient) was significant, full mediation was in play. If either path "a" or path "b" was not significant, that path was excluded from the mediator. To prevent multicollinearity between variables, Pearson correlation analysis was performed prior to mediation analysis [34].

2) Statistical model building

We constructed a parallel multi-parametric model. The mediators were KES, PEF, HGS, and PEF, and the dependent variable was UWS. The independent variable was muscle mass. As mentioned above, as the muscle mass is divided into upper and lower extremity muscle mass (ULMM), upper extremity muscle mass (UMM), and lower extremity muscle mass (LMM), and the muscle mass of each body part served as an independent variable, we performed a total of three analyses.

Table 2. Results of Pearson correlation coefficients between independent variables

Variable	KES	HGS	PEF	Depression	Mean ± SD
KES	1				21.09 ± 6.07
HGS	0.623**	1			22.88 ± 5.03
PEF	0.023*	0.319**	1		5.01 ± 1.32
Depression	−0.023*	−0.215*	−0.311**	1	11.71 ± 5.29

KES, knee extension strength; HGS, hand grip strength; PEF, peak expiratory flow; Mean ± SD, mean ± standard deviation. *p < 0.05, **p < 0.01.

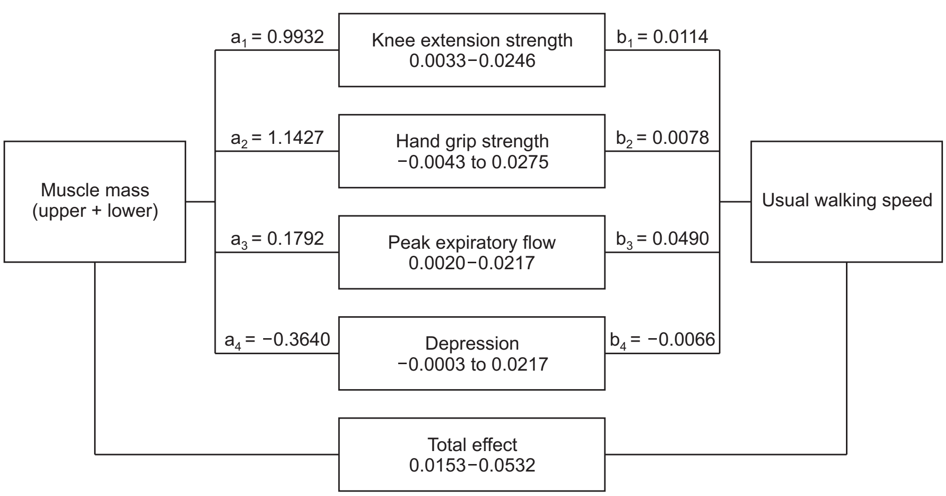

Figure 1. Effect of upper and lower muscle mass on usual walking speed.

Table 3. Mediation of UWS by ULMM via KES, HGS, PEF, and depression

Variable	a path	b path	Indirect effect (a × b)	BC 95% CI	
				Lower	Upper
Indirect effect					
KES	0.9932	0.0114	0.0113	0.0033	0.0246*
HGS	1.1427	0.0078	0.0089	−0.0043	0.0275
PEF	0.1792	0.0490	0.0088	0.0020	0.0217*
Depression	−0.3640	−0.0066	0.0024	−0.0003	0.0102
Total			0.0314	0.0153	0.0532
Comparison					
KES vs HGS			0.0025	−0.0199	0.0230
KES vs PEF			0.0026	−0.0099	0.0155
KES vs Depression			0.0090	−0.0010	0.0226
HGS vs PEF			0.0001	−0.0183	0.0193
HGS vs KES			0.0065	−0.0072	0.0242
PEF vs Depression			0.0064	−0.0027	0.0201

BC, bias-corrected; CI, confidence interval; KES, knee extension strength; HGS, hand grip strength; PEF, peak expiratory flow. *Significant mediator.

RESULTS

1. Results of Pearson Correlations Between Independent Variables

To prevent multicollinearity, Pearson correlation coefficients were calculated to explore correlations between the mediators. The correlation coefficients were low. Therefore, KES, HGS, PEF, and depression are possible mediators that do not exhibit multicollinearity (Table 2).

2. Relationship Between ULMM and UWS

We investigated the effect of the sum of ULMM on the UWS (Figure 1). ULMM was the independent variable. The total effect of ULMM on UWS was 0.0308 (p = 0.005), and the direct effect was –0.0006 (p = 0.9555). The BC 95% CI showed that the total indirect effect of ULMM on UWS was significant (0.0095–0.0521) because the range did not include 0. Of the mediators, only KES (BC 95% CI: 0.0033–0.0246) and PEF (BC 95% CI: 0.0020–0.0217) exerted indirect effects. The HGS and depression did not serve as a mediator. The indirect effect of KES was 0.113 and that of PEF indirect effect was 0.0088. These indirect effects did not differ significantly. Thus, KES and PEF served as full mediators when the ULMM effect on UWS was examined (Table 3).

3. Relationship Between UMM and UWS

The UMM served as the independent variable when we investigated the effect on the UWS of the four mediators (Figure 2). The total effect of UMM on UWS was 0.0386 (p = 0.330) and the direct effect was –0.0470 (p = 0.1948). Neither the total nor direct effect of UMM on UWS was significant. Detailed analysis indicated that both KES (BC 95% CI: 0.0026–0.0681) and

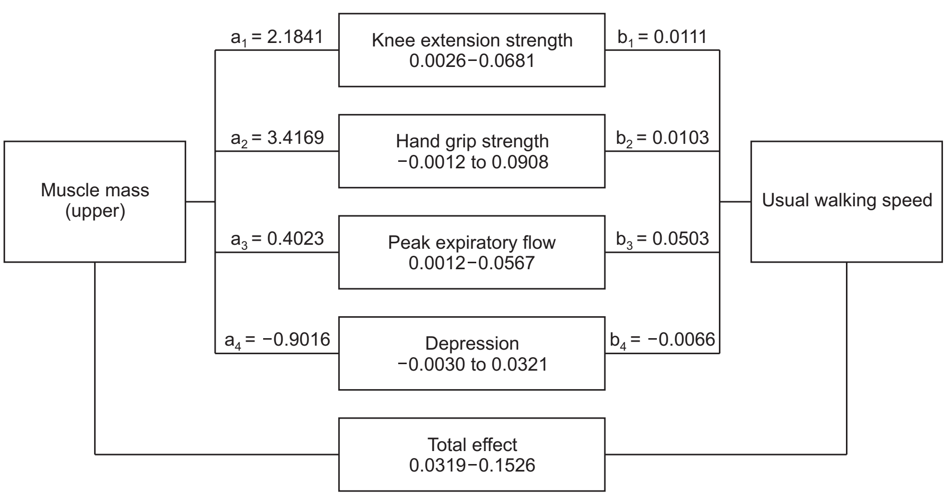

Figure 2. The effect of upper muscle mass on usual walking speed.

Table 4. Mediation by UMM of UWS via KES, HGS, PEF, and depression

Variable	a path	b path	Indirect effect (a × b)	BC 95% CI	
				Lower	Upper
Indirect					
KES	2.1841	0.0111	0.0242	0.0026	0.0681*
HGS	3.4169	0.0103	0.0352	−0.0012	0.0908
PEF	0.4023	0.0503	0.0202	0.0012	0.0567*
Depression	−0.9016	−0.0066	0.0060	−0.0030	0.0321
Total			0.0856	0.0319	0.1526
Contrast					
KES vs HGS			−0.0111	−0.0743	0.0470
KES vs PEF			0.0039	−0.0346	0.0442
KES vs Depression			0.0182	−0.0100	0.0616
HGS vs PEF			0.0150	−0.0356	0.0736
HGS vs KES			0.0293	−0.0090	0.0815
PEF vs Depression			0.0143	−0.0125	0.0523

BC, bias-corrected; CI, confidence interval; KES, knee extension strength; HGS, hand grip strength; PEF, peak expiratory flow. *Significant mediator.

PEF (BC 95% CI: 0.0012–0.0567) were significant mediators, but HGS and depression were not. KES (a_1 = 2.1841) was more related to the UMM than was the PEF (a_3 = 0.4023). The effect of PEF (b_3 = 0.0503) on UWS was greater than that of KES (b_1 = 0.0111); the indirect effects of KES and PEF were 0.0242 and 0.0202, respectively. These values did not differ significantly. Thus, KES and PEF were full mediators of the UMM effect on UWS (Table 4).

4. Relationship Between LMM and UWS

The LMM served as the independent variable when we investigated the effect of the four mediators on the UWS (Figure 3). The total and direct effects of LMM on UWS were 0.0207 (p = 0.0008) and 0.6578 (p = 0.6578), respectively. The total effect of LMM on UWS was significant but the direct effect was not. Detailed analysis indicated that both KES (BC 95% CI: 0.0052–0.0340) and PEF (BC 95% CI: 0.0029–0.0291) were significant mediators, but HGS and depression were not. The KES (a_1 = 1.4303) was more associated with LMM than was the PEF (a_3 = 0.2569). The effect of PEF (b_3 = 0.0473) on UWS was greater than that of KES (b_1 = 0.0112). The indirect effect of KES was 0.0160 and that of PEF 0.0122. These figures did not differ significantly. Thus, KES and PEF served as full mediators of the effect of LMM on UWS (Table 5).

DISCUSSION

We investigated the effect of various categories of muscle mass on UWS mediated via KES, HGS, PEF, and depression, all of which were associated with muscle mass and UWS in previous studies. We hypothesized that these physical and psychological factors might be mediators. If so, factor adjustment

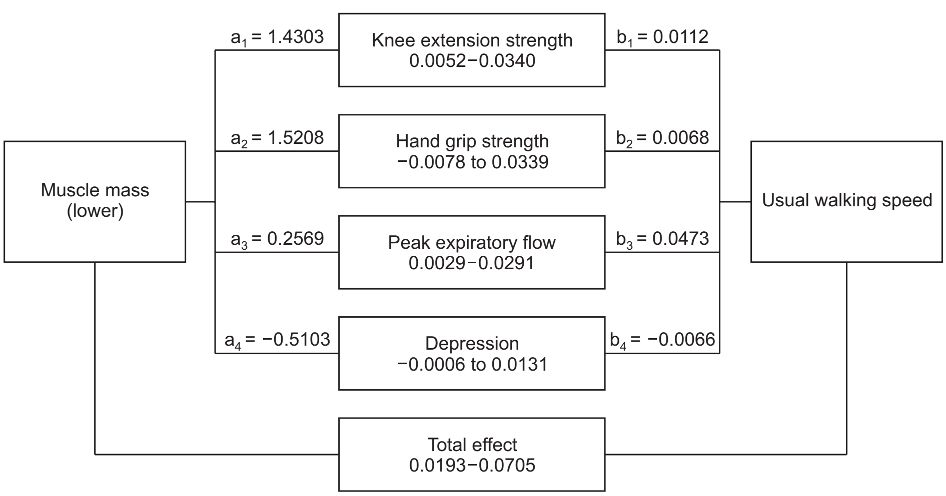

Figure 3. The effect of lower muscle mass on usual walking speed.

Table 5. The effect of LMM on UWS via KES, HGS, PEF, and depression

Variable	a path	b path	Indirect effect (a × b)	BC 95% CI	
				Lower	Upper
Indirect					
KES	1.4303	0.0112	0.0160	0.0052	0.0340*
HGS	1.5208	0.0068	0.0104	−0.0078	0.0339
PEF	0.2569	0.0473	0.0122	0.0029	0.0291*
Depression	−0.5103	0.0042	0.0034	−0.0006	0.0131
Total			0.0419	0.0193	0.0705
Comparison					
KES vs HGS			0.0057	−0.0241	0.0337
KES vs PEF			0.0038	−0.0241	0.0337
KES vs Depression			0.0126	−0.0010	0.0313
HGS vs PEF			−0.0018	−0.0266	0.0241
HGS vs KES			0.0070	−0.0116	0.0301
PEF vs Depression			0.0088	−0.0037	0.0257

BC, bias-corrected; CI, confidence interval; KES, knee extension strength; HGS, hand grip strength; PEF, peak expiratory flow. *Significant mediator.

should slow sarcopenia progression.

We found that KES and PEF were the only significant mediators. The direct effect of muscle mass (ULMM, UMM, and LMM) on UWS was not significant. Thus, KES and PEF are significant indirect mediators only.

According to a previous study, a remarkable decrease in LMM occurs between 40–50 years of age in females, but the UMM does not decrease significantly 40–70 years of age. Thus, muscle mass decreases differently by body region. Females aged 60–80 years exhibit marked LMM loss although the UMM is almost unchanged [8]. Our work suggests that, regardless of bodily region, KES and PEF combined with muscle mass (ULMM, UMM, and LMM) were significant mediators of UWS, with similar indirect effect sizes. As we combined muscle mass with KES and PEF when evaluating sarcopenia, we did not need to assess the total body muscle mass. Measuring either the UMM or LMM may be an alternative to measuring the total muscle mass.

During low-intensity exercise, type I fibers are activated, but highly intensive exercise activates both type I and II fibers. The principal symptom of sarcopenia in the elderly is a reduction in type II fibers [35]. KES and PEF are highly intensive exercises. Therefore, higher KES and PEF values may indicate reduced loss of type II fibers caused by sarcopenia. We found that both KES and PEF were significant mediators of UWS. High-level muscle exercise may prevent future muscle strength loss, postponing physical performance limitations [14]. Therefore, we suggest that KES and PEF are not only good measures of sarcopenia, but also that strengthening and maintaining the KES and PEF may slow sarcopenia progression.

HGS is the simplest measure of muscle strength and function [36]. HGS is generally used instead of total muscle strength [37] or walking speed [38]. HGS is used to screen for sarcopenia in the elderly. However, we found that HGS was not a significant mediator of the effect of muscle mass on UWS. Although HGS indicates overall muscle strength, HGS reflects only upper extremity function [30]. Furthermore, in females, the decrease in UMM is less than in males [8], and the rate of muscle strength reduction is also lower in females than males [39]. Thus, because of the unique characteristics of female aging, HGS was not a significant mediator of UWS.

The “a” path coefficient of depression was significant but the “b” path coefficient was not. Therefore, depression was not a significant mediator of UWS. In previous studies, depressive symptoms correlated with muscle mass [22], and the duration of symptoms predicted physical functioning [21]. However, the correlation between sarcopenia and depressive symptoms varied by gender in another study; male but not female sarcopenia correlated with depressive symptoms [40]. All of our subjects were females, and we evaluated only the severity, and not the duration, of depression. Also, the mean depression score was 11.71 ± 5.29, reflecting either normality or only mild depression. Therefore, depression was not a significant mediator.

Our study had certain limitations. First, it is difficult to generalize our data to elderly males and older elderly females as we studied only females aged 65–80 years. As aging progresses, the changes differ between males and females; further studies should investigate elderly males. Second, we cannot identify causal relationships because our study was cross-sectional in design. Finally, we measured only four factors (KES, HGS, PEF, and depression); other factors may also mediate the effects of muscle mass on UWS.

CONCLUSIONS

We sought indirect mediators of the effects of UMM and LMM on UWS. KES and PEF were the only mediators found, regardless of body part. Thus, KES and PEF can be used to screen for sarcopenia, and maintaining KES and PEF may prevent sarcopenia progression in younger elderly females. Also, sarcopenia can be readily assessed by evaluating either the upper or lower body; it is not necessary to measure total muscle mass.

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CONFLICTS OF INTEREST

No potential conflict of interest relevant to this study was reported.

AUTHOR CONTRIBUTIONS

Conceptualization: YB. Data curation: YB. Formal analysis:

YB. Investigation: YB. Methodology: YB. Project administration: CY. Supervision: YB, CY, OK, SC. Validation: YB. Visualization: YB. Writing - original drafting: YB. Writing - review and editing: YB, CY, OK, SC.

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REFERENCES

1. **Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al.** Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing 2019;48(1):16-31. Erratum in: Age Ageing 2019;48(4):601.
2. **Chen LK, Liu LK, Woo J, Assantachai P, Auyeung TW, Bahyah KS, et al.** Sarcopenia in Asia: consensus report of the Asian Working Group for Sarcopenia. J Am Med Dir Assoc 2014;15(2):95-101.
3. **Wilson D, Jackson T, Sapey E, Lord JM.** Frailty and sarcopenia: the potential role of an aged immune system. Ageing Res Rev 2017;36:1-10.
4. **Kim JH, Lim S, Choi SH, Kim KM, Yoon JW, Kim KW, et al.** Sarcopenia: an independent predictor of mortality in community-dwelling older Korean men. J Gerontol A Biol Sci Med Sci 2014;69(10):1244-52.
5. **Delmonico MJ, Harris TB, Lee JS, Visser M, Nevitt M, Kritchevsky SB, et al.**; Health, Aging and Body Composition Study. Alternative definitions of sarcopenia, lower extremity performance, and functional impairment with aging in older men and women. J Am Geriatr Soc 2007;55(5):769-74.
6. **Goodpaster BH, Park SW, Harris TB, Kritchevsky SB, Nevitt M, Schwartz AV, et al.** The loss of skeletal muscle strength, mass, and quality in older adults: the health, aging and body composition study. J Gerontol A Biol Sci Med Sci 2006;61(10):1059-64.
7. **Chen LK, Woo J, Assantachai P, Auyeung TW, Chou MY, Iijima K, et al.** Asian Working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc 2020;21(3):300-7.e2.
8. **Kitamura I, Koda M, Otsuka R, Ando F, Shimokata H.** Six-year longitudinal changes in body composition of middle-aged and elderly Japanese: age and sex differences in appendicular skeletal muscle mass. Geriatr Gerontol Int 2014;14(2):354-61.
9. **Hardy SE, Perera S, Roumani YF, Chandler JM, Studenski SA.** Improvement in usual gait speed predicts better survival in older adults. J Am Geriatr Soc 2007;55(11):1727-34.
10. **Liu B, Hu X, Zhang Q, Fan Y, Li J, Zou R, et al.** Usual walking speed and all-cause mortality risk in older people: a systematic review and meta-analysis. Gait Posture 2016;44:172-7.
11. **Perry J, Garrett M, Gronley JK, Mulroy SJ.** Classification of walking handicap in the stroke population. Stroke 1995;26(6):982-9.
12. **Studenski S, Perera S, Wallace D, Chandler JM, Duncan PW, Rooney E, et al.** Physical performance measures in the clinical setting. J Am Geriatr Soc 2003;51(3):314-22.
13. **Fritz S, Lusardi M.** White paper: "walking speed: the sixth vital sign". J Geriatr Phys Ther 2009;32(2):46-9. Erratum in: J Geriatr Phys Ther 2009;32(3):110.
14. **Manini TM, Visser M, Won-Park S, Patel KV, Strotmeyer ES, Chen H, et al.** Knee extension strength cutpoints for maintaining mobility. J Am Geriatr Soc 2007;55(3):451-7.
15. **Bean JF, Kiely DK, Herman S, Leveille SG, Mizer K, Frontera WR, et al.** The relationship between leg power and physical performance in mobility-limited older people. J Am Geriatr Soc 2002;50(3):461-7.
16. **Fragala MS, Alley DE, Shardell MD, Harris TB, McLean RR, Kiel DP, et al.** Comparison of handgrip and leg extension strength in predicting slow gait speed in older adults. J Am Geriatr Soc 2016;64(1):144-50.
17. **Lee MC, Hsu CC, Tsai YF, Chen CY, Lin CC, Wang CY.** Criterion-referenced values of grip strength and usual gait speed using instrumental activities of daily living disability as the criterion. J Geriatr Phys Ther 2018;41(1):14-9.
18. **Auyeung TW, Lee SW, Leung J, Kwok T, Woo J.** Age-associated decline of muscle mass, grip strength and gait speed: a 4-year longitudinal study of 3018 community-dwelling older Chinese. Geriatr Gerontol Int 2014;14 Suppl 1:76-84.
19. **Kera T, Kawai H, Hirano H, Kojima M, Fujiwara Y, Ihara K, et al.** Relationships among peak expiratory flow rate, body composition, physical function, and sarcopenia in community-dwelling older adults. Aging Clin Exp Res 2018;30(4):331-40.
20. **Ridwan ES, Wiratama BS, Lin MY, Hou WH, Liu MF, Chen CM, et al.** Peak expiratory flow rate and sarcopenia risk in older Indonesian people: a nationwide survey. PLoS One

2021;16(2):e0246179.

21. **Sanders JB, Bremmer MA, Comijs HC, Deeg DJ, Beekman AT.** Gait speed and the natural course of depressive symptoms in late life; an independent association with chronicity? J Am Med Dir Assoc 2016;17(4):331-5.
22. **Wu H, Yu B, Meng G, Liu F, Guo Q, Wang J, et al.** Both muscle mass and muscle strength are inversely associated with depressive symptoms in an elderly Chinese population. Int J Geriatr Psychiatry 2017;32(7):769-78.
23. **Liu LK, Lee WJ, Liu CL, Chen LY, Lin MH, Peng LN, et al.** Age-related skeletal muscle mass loss and physical performance in Taiwan: implications to diagnostic strategy of sarcopenia in Asia. Geriatr Gerontol Int 2013;13(4):964-71.
24. **Santos L, Ribeiro AS, Schoenfeld BJ, Nascimento MA, Tomeleri CM, Souza MF, et al.** The improvement in walking speed induced by resistance training is associated with increased muscular strength but not skeletal muscle mass in older women. Eur J Sport Sci 2017;17(4):488-94.
25. **Barbat-Artigas S, Pinheiro Carvalho L, Rolland Y, Vellas B, Aubertin-Leheudre M.** Muscle strength and body weight mediate the relationship between physical activity and usual gait speed. J Am Med Dir Assoc 2016;17(11):1031-6.
26. **Kim JH, Choi SH, Lim S, Kim KW, Lim JY, Cho NH, et al.** Assessment of appendicular skeletal muscle mass by bioimpedance in older community-dwelling Korean adults. Arch Gerontol Geriatr 2014;58(3):303-7.
27. **Aparicio VA, Ortega FB, Heredia JM, Carbonell-Baeza A, Sjöström M, Delgado-Fernandez M.** Handgrip strength test as a complementary tool in the assessment of fibromyalgia severity in women. Arch Phys Med Rehabil 2011;92(1):83-8.
28. **Kamath SU, Vivek N, Gowtham KR.** Motor function outcome assessment by grip and pinch strength following carpal tunnel release. Indian J Sci Technol 2016;9(4):56916.
29. **Cruz-Jentoft AJ, Baeyens JP, Bauer JM, Boirie Y, Cederholm T, Landi F, et al.**; European Working Group on Sarcopenia in Older People. Sarcopenia: European consensus on definition and diagnosis: report of the European Working Group on Sarcopenia in Older People. Age Ageing 2010;39(4):412-23.
30. **Ro HJ, Kim DK, Lee SY, Seo KM, Kang SH, Suh HC.** Relationship between respiratory muscle strength and conventional sarcopenic indices in young adults: a preliminary study. Ann Rehabil Med 2015;39(6):880-7.
31. **Jung IK, Kwak DI, Joe SH, Lee HS.** A study of standardization of Korean form of Geriatric Depression Scale (KGDS). J Korean Geriatr Psychiatry 1997;1(1):61-72.
32. **Kim JY, Park JH, Lee JJ, Huh Y, Lee SB, Han SK, et al.** Standardization of the Korean version of the geriatric depression scale: reliability, validity, and factor structure. Psychiatry Investig 2008;5(4):232-8.
33. **Pamoukdjian F, Paillaud E, Zelek L, Laurent M, Lévy V, Landre T, et al.** Measurement of gait speed in older adults to identify complications associated with frailty: a systematic review. J Geriatr Oncol 2015;6(6):484-96.
34. **Talaei-Khoei M, Fischerauer SF, Jha R, Ring D, Chen N, Vranceanu AM.** Bidirectional mediation of depression and pain intensity on their associations with upper extremity physical function. J Behav Med 2018;41(3):309-17.
35. **Evans WJ, Campbell WW.** Sarcopenia and age-related changes in body composition and functional capacity. J Nutr 1993;123(2 Suppl):465-8.
36. **Roberts HC, Denison HJ, Martin HJ, Patel HP, Syddall H, Cooper C, et al.** A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. Age Ageing 2011;40(4):423-9.
37. **Bohannon RW.** Are hand-grip and knee extension strength reflective of a common construct? Percept Mot Skills 2012;114(2):514-8.
38. **Alley DE, Shardell MD, Peters KW, McLean RR, Dam TT, Kenny AM, et al.** Grip strength cutpoints for the identification of clinically relevant weakness. J Gerontol A Biol Sci Med Sci 2014;69(5):559-66.
39. **Ishizaki T, Furuna T, Yoshida Y, Iwasa H, Shimada H, Yoshida H, et al.**; TMIG-LISA Research Group. Declines in physical performance by sex and age among nondisabled community-dwelling older Japanese during a 6-year period. J Epidemiol 2011;21(3):176-83.
40. **Kim NH, Kim HS, Eun CR, Seo JA, Cho HJ, Kim SG, et al.** Depression is associated with sarcopenia, not central obesity, in elderly Korean men. J Am Geriatr Soc 2011;59(11):2062-8.