Relationships between intramuscular fat, muscle strength and gait independence in older women: A cross-sectional study

Akazawa, Naoki
Okawa, Naomi
Tamura, Kimiyuki
Moriyama, Hideki

(Citation)
Geriatrics & Gerontology International,17(10):1683-1688

(Issue Date)
2017-10

(Resource Type)
journal article

(Version)
Accepted Manuscript

Title page

Title

Relationships between intramuscular fat and muscle strength or degree of gait independence in dependent elderly women: a cross-sectional study

Running title

Intramuscular fat in dependent elderly

Author's names

Naoki Akazawa, PT, PhD, Naomi Okawa, PT, MS, Kimiyuki Tamura, MD, and Hideki Moriyama, PT, PhD

Naoki Akazawa, PT, Ph.D.

Department of Physical Therapy Faculty of Health and Welfare, Tokushima Bunri University

Boji 180, Yamashiro-cho, Tokushima-city, Tokushima 770-8514, Japan

Naomi Okawa, PT, MS

Department of Rehabilitation, Kasei Tamura Hospital

Shimabashihigashinocyo 1-11, Wakayama-city, Wakayama 640-8413, Japan

Kimiyuki Tamura, MD

Department of Rehabilitation, Kasei Tamura Hospital

Shimabashihigashinocyo 1-11, Wakayama-city, Wakayama 640-8413, Japan

Hideki Moriyama, PT, Ph.D.

Department of Rehabilitation Science, Graduate School of Health Sciences, Kobe University

Tomogaoka 7-10-2, Suma-ku, Kobe 654-0142, Japan

Tel & Fax +81 78 796 4574, E-mail morihide@harbor.kobe-u.ac.jp

Corresponding author

Hideki Moriyama, Ph.D.

Professor

Department of Rehabilitation Science, Graduate School of Health Sciences, Kobe University

Tomogaoka 7-10-2, Suma-ku, Kobe 654-0142, Japan

Tel & Fax +81 78 796 4574

E-mail morihide@harbor.kobe-u.ac.jp

Main Text

Title

Relationships between intramuscular fat and muscle strength or degree of gait independence in dependent elderly women: a cross-sectional study

Abstract

Aim: The objective of this study was to examine relationships between intramuscular fat and muscle strength or degree of gait independence and to clarify characteristics of intramuscular fat in dependent elderly women.

Methods: Twenty-five dependent elderly women (dependent group), twenty-two frail elderly women (frail group), and twenty-two healthy elderly women (healthy group) were participated in this study. The dependent elderly could not walk with or without assistance. The frail elderly could walk independently and had the presence of three or more of the following five components: slowness, weakness, weight loss, exhaustion, and low physical activity. Outcome measures were quadriceps intramuscular fat (echo intensity) measured with ultrasonography and quadriceps muscle strength of the dependent, frail, and healthy groups and degree of gait independence (gait score of functional independence measure) in the dependent and frail groups.

Results: The echo intensity in the dependent group was significantly negatively correlated with the muscle strength and gait score of functional independence measure (correlation coefficients = - 0.635 and - 0.344, respectively). Furthermore, the echo intensity in the dependent group was significantly higher than that in the healthy group. There was no significant difference between the echo intensity in the dependent and frail groups.

Conclusions: Our results suggest that there are negative relationships between intramuscular fat and muscle strength or degree of gait independence in dependent elderly women. In addition, intramuscular fat of these persons are greater increase than that of healthy elderly.

Keywords

degree of gait independence, dependent elderly, echo intensity, intramuscular fat, muscle strength.

TEXT

Introduction

Decrease of muscle mass, muscle strength, and physical performance with aging have known as sarcopenia.[1] In addition, recent studies have reported that increase of intramuscular fat occurs with aging,[2, 3, 4] and these phenomena are associated with decreasing muscle strength, gait speed, and gait endurance.[2, 5-8] The results of major longitudinal study suggested that decrease of quadriceps muscle strength with aging is attributed to increasing intramuscular fat.[9] Furthermore, Lang et al[10] reported that intramuscular fat is greater contributed independently to the risk of hip fracture than other factors including muscle mass, muscle strength, and physical function. Considering these knowledge, decreasing intramuscular fat is needed for improving muscle strength, balance, and gait ability in elderly.

Muscle strength training increases muscle mass and decreases intramuscular fat of healthy elderly.[11] Recently, frailty has been defined as a clinical syndrome which three or more of the following five components are presented: slowness, weakness, weight loss, exhaustion, and low physical activity and leads to increasing adverse outcomes such as falling, hospitalization, and mortality.[12] Cadore et al[13] examined muscle strength training effects in frail elderly who could walk independently and was defined based on Fried's criteria.[12] Consequently, similar to healthy elderly, they confirmed that muscle strength training is effective method for improving intramuscular fat and muscle mass in frail elderly.[13] Conversely, in a clinical setting, physical therapist often intervene to dependent elderly result from deterioration of frailty.[14] Ikezoe et al[14] reported that quadriceps muscle mass of dependent elderly who were not able to walk independently was less than that of elderly who able to walk independently. However, they have not measured the intramuscular fat of dependent elderly. Taken together, whether there are relationships between intramuscular fat and muscle strength or degree of gait independence in dependent elderly remains unclear. Furthermore, characteristics of intramuscular fat in dependent elderly compared with healthy and frail elderly have not yet been revealed. We speculate that intramuscular fat in dependent elderly is greater increase than that of frail and healthy elderly and increase of intramuscular fat in dependent elderly is correlate with decrease of muscle strength and gait independence.

Previous studies reported that prevalence of malnutrition is 49-67 % in elderly patients requiring rehabilitation,[15] and that preventing weight loss (i.e. maintenance of nutrition) is play an important role for improving activities of daily living.[16] Recent report[8] revealed that body mass index (BMI) is negatively associated with intramuscular fat in healthy elderly women. Therefore, identifying the relationship between intramuscular fat and BMI in dependent elderly is highly important.

The objective of this study was to examine relationships between intramuscular fat and muscle strength, degree of gait independence, and BMI and to clarify characteristics of intramuscular fat in dependent elderly women.

Methods

Participants

Twenty-five dependent elderly women (dependent group), twenty-two frail elderly women (frail group), and twenty-two healthy elderly women (healthy group) participated in this study. All participants were community-dwelling and were recruited using advertisements. The dependent elderly who was not able to walk independently (defined as Functional independence measure [FIM] gait score 5 and under). The frail elderly who could walk independently (defined as FIM gait score 6 or 7) and was defined based on Fried's criteria.[12] Potential participants who had dementia and neurological disorders were excluded. Each participant provided their written informed consent. The study protocol was approved by the Ethics Committee of X University.

Study design

Cross-sectional study was used in this study.

Outcome measure

Outcome measures were quadriceps intramuscular fat and muscle mass measured with ultrasonography and quadriceps muscle strength of the dependent, frail, and healthy groups, and degree of gait independence in the dependent and frail groups.

Intramuscular fat and muscle mass measurement

Transverse ultrasound images (Figure 1) were acquired with a B-mode ultrasound imaging devise (Nanomaxx, SonoSite japan, Tokyo, Japan) and liner-array probe (L25n / 13 - 6 MHz) (Nanomaxx, SonoSite japan, Tokyo, Japan). Water soluble transmission gel was applied to the skin surface and the probe was pressed lightly against the skin to avoid deformation of the muscle. The ultrasound images were filmed by the same investigator. The intramuscular fat and muscle mass of the quadriceps were assessed from echo intensity and muscle thickness. Regions of interest which including as much muscle as possible but avoiding bone and surrounding fascia were selected for measuring the echo intensity. The echo intensities were determined by computer-assisted 8-bit gray-scale analysis. The mean echo intensity of the regions was expressed as a value between 0 (black) and 255 (white). High echo intensity represents the increase of intramuscular fat.[17] The quadriceps echo intensity was calculated as the mean echo intensity of the four individual quadriceps muscles.[7, 8] The muscle thickness was determined as the distance between adipose tissue-muscle interface for vastus lateralis, rectus femoris, and vastus medialis and as bone-muscle interface for vastus intermedius. The quadriceps muscle thickness was obtained as the sun of the four individual quadriceps portions.[7, 8] The echo intensities and muscle thicknesses were determined using Image J 1.49 software (National Institute of Health, USA).[7, 8] The participants were placed in a supine position with the lower limbs relaxed. The images from vastus lateralis, rectus femoris, vastus intermedius, and vastus medialis were obtained at 30 % of the distance between the anterior superior iliac spine and the proximal end of the patella. The ultrasound images acquired from the right leg.[18] We have confirmed that there were no significant differences in the echo intensity and muscle thickness between right and left quadriceps in the twenty healthy elderly women (age 75.8 ± 7.9 years). Intraclass correlation coefficient of the echo intensity and muscle thickness measurement in the eight dependent elderly women (age 86.3 ± 6.3 years), using measurements taken 2 weeks apart, were 0.907 and 0.934, respectively.

Muscle strength measurement

The maximal isometric strength of quadriceps on the right leg was measured with a handheld dynamometer (micro FET2) (Hoggan Health Industries, Salt Lake, USA). This muscle strength measurement was done in a sitting position with a knee flexion at 90 degree and handheld dynamometer was placed distal to the knee joint. The muscle strength (N) was measured 2 times. A maximal value was obtained and torque was calculated by multiplying strength (N) by lever arm (m).

Degree of gait independence measurement

The degree of gait independence in the dependent and frail groups were assessed with the FIM gait score. Good validity and reliability of FIM gait score have been warranted by the previous studies.[19, 20]

Statistical analysis

Statistical analyses were done using SPSS statistics version 23 (IBM SPSS Japan, Tokyo, Japan). Normally distributed variables were checked with Shapiro-Wilk test. Pearson product-moment correlation test was used to determine correlation between the echo intensity or muscle thickness and the muscle strength or BMI in the dependent group. Regarding correlation between the echo intensity or muscle thickness and the FIM gait score in the dependent group, we examined using Kendall correlation test. Stepwise regression analysis was used to determine the relative contribution of the echo intensity and muscle thickness of the dependent group in the muscle strength and FIM gait score. To compare the echo intensity, muscle thickness, muscle strength, and characteristics (age, height, weight, and BMI) in the dependent, frail, and healthy groups, one-way analysis of variance were done. If main effect was observed, we did Tukey test so as to investigate whether there were significant differences between the dependent, frail, and healthy group. When significant differences were present in the Tukey test, 95 % confidence intervals (CI) were calculated. With respect to comparing the FIM gait score between the dependent and frail groups, we did Mann-Whitney U test. Statistics significance was set at $p < 0.05$.

Results

The echo intensity in the dependent group was significantly negatively correlated with the muscle strength (correlation coefficients = - 0.635, $p = 0.001$) (Figure 2), FIM gait score (correlation coefficients = - 0.344, $p = 0.03$) (Figure 2), and BMI (correlation coefficients = - 0.608, $p = 0.001$). Also, the muscle thickness in the dependent group was significantly positively associated with the muscle strength (correlation coefficients = 0.613, $p = 0.001$), FIM gait score (correlation coefficients = 0.524, $p = 0.001$), and BMI (correlation coefficients = 0.669, $p < 0.001$). In the results of the stepwise regression analyses, the echo intensity was significantly associated with the muscle strength (standard partial regression coefficient = - 0.635, $p = 0.001$), when compared with the muscle thickness (standard partial regression coefficient = 0.293, $p = 0.283$) ($R^2 = 0.403$). Conversely, the muscle thickness was significantly associated with the FIM gait score (standard partial regression coefficient = 0.634, $p = 0.001$), when compared with the echo intensity (standard partial regression coefficient = - 0.047, $p = 0.865$) ($R^2 = 0.402$).

Table 1 and 2 shows the characteristics, echo intensity, muscle thickness, and muscle strength of the dependent, frail, and healthy groups. There were no significant main effects for all characteristics values (Table 1). In the echo intensity, muscle thickness, and muscle strength, significant main effects were observed (Table 2). The results of the Tukey test, the echo intensity of the dependent and frail groups was significantly higher than that of the healthy group (difference between the dependent and healthy group = 95% CI 2.8 to 24.0, difference between the frail and healthy group = 95% CI 0.1 to 21.9). There was no significant difference between the echo intensity in the dependent and frail groups. In the muscle thickness and muscle strength, these valuables of the dependent group were significantly lower than those of the healthy group (difference in the muscle thickness = 95% CI - 0.4 to - 1.6 cm, difference in the muscle strength = 95% CI - 11.4to - 30.0 Nm). No significant differences were observed between the muscle thickness and muscle strength of the dependent and frail groups. There was no significant difference between the muscle thickness in the frail and healthy groups. The muscle strength of the frail group was significantly lower than that of the healthy group (difference in the muscle strength = 95% CI - 2.8 to - 22.1 cm). The FIM gait score of the dependent group was significantly lower than that of the frail group (4.0 ± 1.4 versus 6.5 ± 0.5 score).

Discussion

There was negative relationship between the intramuscular fat and muscle strength, and the intramuscular fat was more contribute to the muscle strength compared with the muscle mass in the dependent elderly. Then, negative relationship between the intramuscular fat and degree of gait independence was observed in the dependent elderly. However, this relationship was smaller than that of between the muscle mass and degree of gait independence. The intramuscular fat of the dependent elderly was greater increase than that of the healthy elderly. Considering these results, decreasing intramuscular fat of the dependent elderly may improve the muscle strength and degree of gait independence. Moreover, the intramuscular fat of the dependent elderly was negatively correlated with the BMI. Preventing weight loss (i.e. maintenance of nutrition) may be important approach for maintaining intramuscular fat in dependent elderly.

Consistent with the result of the longitudinal study[9] which examined in healthy elderly, in this study, the intramuscular fat of the dependent elderly was stronger correlates with the muscle strength than the muscle mass. In contrast, the intramuscular fat contributing to the degree of gait independence was less than the muscle mass. Lang et al[10] reported that intramuscular fat is associated to risk of hip fracture compared with muscle strength and muscle mass. Based on these results, intramuscular fat may correlate with fall closely, and then assist of gait may compensate the decrease of balance ability correlating fall.

There were no significant differences in the intramuscular fat, muscle mass, and muscle strength between the dependent and frail elderly. However, the degree of gait independence in the dependent elderly was significantly lower than that of the frail elderly. The previous study[21] has indicated that muscle strength training improves muscle strength of lower limbs in frail elderly but not timed up and go test and gait speed. Moreover, Cadore et al[13] reported that muscle strength, balance, and gait training interventions improves muscle strength of lower limbs and timed up and go test in frail elderly. Considering these results, balance training is needed for improving gait ability in frail elderly.[13] In fact, the previous study[22] has suggested that balance training improves not only berg balance scale but also dynamic gait index in frail elderly. In other word, balance ability is closely associated with gait ability in frail elderly. Then, the decreasing the degree of gait independence in the dependent elderly compared with the frail elderly may be attributed to the decrease of the balance ability. On the other hand, the condition of the intramuscular fat, muscle mass, and muscle strength in the dependent elderly were worse than these of the healthy elderly. These results suggest that improving the intramuscular fat, muscle mass, and muscle strength are needed for improving the degree of gait independence in the dependent elderly.

Results comparing the intramuscular fat and muscle mass between the frail and healthy elderly, the intramuscular fat of the frail elderly was greater increase than that of the healthy elderly, although there was no difference in the muscle mass. These results were concordance with the previous study which examined the differences of the intramuscular fat and muscle mass between the hip osteoarthritis patients and healthy persons.[23]Therefore, the intramuscular fat may be early affected of the motor dysfunction compared with the muscle mass. In other words, early intervention for improving intramuscular fat may be more important than intervention for muscle mass in frail elderly.

Muscle strength training using machine with moderate load (40-60% of 1 repetition maximum) is useful in decrease intramuscular fat in frail elderly,[13] however doing machine training is difficult for dependent elderly. Fukumoto et al[24] examined the effects of high-velocity (concentric phase of each repetition as rapidly as possible and returned to the initial position eccentrically in 3 s) and low-velocity (both the concentric and eccentric phases in 3 s) muscle strength training with an elastic band on intramuscular fat and muscle mass in hip osteoarthritis patients. As a result, the intramuscular fat of gluteus maximus in the high-velocity muscle strength training group was larger decrease than that in the low-velocity muscle strength training group, but muscle mass did not change in the both groups. These results suggest that high-velocity muscle strength training with low load efficiently decreases intramuscular fat and intramuscular fat of dependent elderly who cannot use training machine.

This study has four limitations. First, we used an ultrasonography for assessing the intramuscular fat and muscle mass. Although measurement accuracy of intramuscular fat and muscle mass in magnetic resonance imaging (MRI) and computed tomography are better than these of ultrasonography, ultrasonography has advantage points in noninvasive, easily accessible, and cost. Also, measurement validity of intramuscular fat and muscle mass of ultrasonography has proven by previous studies using muscle biopsy[17, 25] and MRI.[26, 27] Secondly, all participants were women in this study. Previous study has confirmed that increase rate of intramuscular fat in man is larger than that in woman.[9] Furthermore, effect of muscle strength training on muscle mass in frail elderly man was larger than that in frail elderly woman.[28] Based on these knowledges, whether results of this study which obtained from woman adapts to man remains unclear. Thirdly, we cannot mention causal relationship between decreasing intramuscular fat and improving muscle strength and degree of gait independence, because this study was cross-sectional design. From now on, further studies will be needed for revealing this causal. Finally, echo intensity is fluctuated by scanning conditions,[29, 30] and therefore we are not able to show the cut-off point of the echo intensity.

Considering there were relationships between intramuscular fat and muscle strength or degree of gait independence in the dependent elderly women, increase and decrease of intramuscular fat may become the index for low or high muscle strength and degree of gait independence in these populations. In addition, intramuscular fat of dependent elderly women is higher than that of healthy elderly women, and this result may indicate that decreasing intramuscular fat is important for improving muscle strength and degree of gait independence in dependent elderly women.

Acknowledgments

We greatly appreciate the cooperation of the participants and staff members of this study.

Disclosure statement

The authors have no conflict of interest to declare.

References

1. Cruz-Jentoft AJ, Baeyens JP, Bauer JM *et al*. European Working Group on Sarcopenia in Older People. Sarcopenia: European consensus on definition and diagnosis in older people. *Age Ageing* 2010; 39: 412-423.
2. Sipilä S, Suomonen H. Knee extension strength and walking speed in relation to quadriceps muscle composition and training in elderly women. *Clin Physiol* 1994;

14: 433-442.

3. Goodpaster BH, Carlson CL, Visser M *et al*. The attenuation of skeletal muscle and strength in the elderly: The ABC study. *J Appl Physiol* 2001; 90: 2157-2165.
4. Arts IM, Pillen S, Schelhaas HJ, Overeem S, Zwarts MJ. Normal values for quantitative muscle ultrasonography in adults. *Muscle Nerve* 2010; 41: 32-41.
5. Goodpaster BH, Park SW, Harris TB *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: 1059-1064.
6. Visser M, Goodpaster BH, Kritchevsky SB *et al*. Muscle mass, muscle strength, and muscle fat infiltration as predictors of incident mobility limitations in well-functioning older persons. *J Gerontol A Biol Sci Med Sci* 2005; 60: 324-333.
7. Wilhelm EN, Rech A, Minozzo F, Radaelli R, Botton CE, Pinto RS. Relationship between quadriceps femoris echo intensity, muscle power, and functional capacity of older men. *Age* 2014; 36: 1113-1122.
8. Rech A, Radaelli R, Goltz FR, da Rosa LH, Schneider CD, Pinto RS. Echo intensity is negatively associated with functional capacity in older women. *Age* 2014; doi: 10.1007/s11357-014-9708-2.
9. Delmonico MJ, Harris TB, Visser M *et al.* Longitudinal study of muscle strength,

quality, and adipose tissue infiltration. *Am J Clin Nutr* 2009; 90: 1579-1585.

10. Lang T, Cauley JA, Tylavsky F, Bauer D, Cummings S, Harris TB. Computed tomographic measurements of thigh muscle cross-sectional area and attenuation coefficient predict hip fracture: The health, aging, and body composition study. *J Bone Miner Res* 2010; 25: 513-519.
11. Radaelli R, Botton CE, Wilhelm EN *et al*. Low-and high-volume strength training induces similar neuromuscular improvements in muscle quality in elderly women. *Exp Gerontol* 2013; 48: 710-716.
12. Fried LP, Tangen CM, Walston J *et al*. Frailty in older adults: Evidence for a phenotype. *J Gerontol A Biol Sci Med Sci* 2001; 56: 146-155.
13. Cadore EL, Casas-Herrero A, Zambom-Ferraresi F *et al*. Multicomponent exercises including muscle power training enhance muscle mass, power output, and functional outcomes in institutionalized frail nonagenarians. *Age* 2014; 36: 773-785.
14. Ikezoe T, Mori N, Nakamura M, Ichihashi N. Atrophy of the lower limbs in elderly women: is it related to walking ability?. *Eur J Appl Physiol* 2011; 111: 989-995.
15. Strakowski MM, Strakowski JA, Mitchell MC. Malnutrition in rehabilitation. *Am J Phys Med Rehabil* 2002; 81: 77-78.

16. Nishioka S, Wakabayashi H, Nishioka E, Yoshida T, Mori N, Watanabe R. Nutritional improvement correlates with recovery of activities of daily living among malnourished elderly stroke patients in the convalescent stage: A cross-sectional study. *J Acad Nutr Diet* 2016; 116: 837-843.

17. Pillen S, Tak RO, Zwarts MJ *et al*. Skeletal muscle ultrasound: correlation between fibrous tissue and echo intensity. *Ultrasound med Biol* 2009; 35: 443-446.

18. Taniguchi M, Fukumoto Y, Kobayashi M *et al*. Quantity and Quality of the Extremity Muscle in Women with Knee Osteoarthritis. *Ultrasound Med Biol* 2015; 41: 2567-2574.

19. Dodds TA, Martin DP, Stolov WC, Deyo RA. A validation of the functional independence measurement and its performance among rehabilitation inpatients. *Arch Phys Med Rehabil* 1993; 74: 531-536.

20. Hamilton BB, Laughlin JA, Fiedler RC, Granger CV. Interrater reliability of the 7-level functional independence measure (FIM). *Scand J Rehabil Med* 1994; 26: 115-119.

21. Serra-Rexach JA, Bustamante-Ara N, Hierro Villarán M *et al*. Short-term, light- to moderate-intensity exercise training improves leg muscle strength in the oldest old: a randomized controlled trial. *J Am Geriatr Soc* 2011; 59: 594-602.

22. Wolf B, BFeys H, De Weerdt *et al*. Effect of a physical therapeutic intervention for balance problems in the elderly: a single-blind, randomized, controlled multicentre trial. *Clin Rehabil* 2001; 15: 624-636.

23. Fukumoto Y, Ikezoe T, Takeuchi H et al. Muscle mass and composition of the hip, thigh and abdominal muscles in women with and without hip osteoarthritis. *Ultrasound Med Biol* 2012; 38: 1540-1545.

24. Fukumoto Y, Tateuchi H, Ikezoe T *et al*. Effects of high-velocity resistance training on muscle function, muscle properties, and physical performance in individuals with hip osteoarthritis: a randomized controlled trial. *Clin Rehabil* 2014; 28: 48-58.

25. Reimers K, Reimers CD, Wagner S, Paetzke I, Pongratz DE. Skeletal muscle sonography: a correlative study of echogenicity and morphology. *J Ultrasound Med* 1993; 12: 73-77.

26. Dupont AC, Sauerbrei EE, Fenton PV, Shragge PC, Loeb GE, Richmond FJ. Real-time sonography to estimate muscle thickness: comparison with MRI and CT. *J Clin Ultrasound* 2001; 29: 230-236.

27. Miyatani M, Kanehisa H, Ito M, Kawakami Y, Fukunaga T. The accuracy of volume estimates using ultrasound muscle thickness measurements in different muscle groups. *Eur J Appl Physiol* 2004; 91: 264-272.

28. de Jong N, Chin A Paw MJ, de Groot LC, Hiddink GJ, van Staveren WA. Dietary supplements and physical exercise affecting bone and body composition in frail elderly persons. *Am J Public Health* 2000; 90: 947-954.

29. Watanabe Y, Yamada Y, Ishihara T *et al*. Echo intensity obtained from ultrasonography images reflecting muscle strength in elderly men. Clin Interv Aging 2013; 8: 993-998.

30. Nishihara K, Kawai H, Hayashi H *et al*. Frequency analysis of ultrasonic echo intensities of the skeletal muscle in elderly and young. Clin Interv Aging 2014; 9: 1471-1478.

Figure legends

Figure 1. Representative ultrasound image.

Figure 2. Relationships between the echo intensity and muscle strength or functional independence measure (FIM) gait score in the dependent group.

Table1. Characteristics of participants of the dependent, frail, and healthy groups.

	Dependent group (n = 25)	Frail group (n = 22)	Healthy group (n = 22)	Main effect p value
Age (year)	83.4 ± 7.8	81.4 ± 5.0	81.9 ± 2.2	0.427
Height (cm)	142.4 ± 23.4	148.1 ± 7.1	148.9 ± 4.0	0.260
Weight (kg)	48.3 ± 9.0	52.6 ± 15.9	49.7 ± 7.1	0.422
BMI[†] (kg/m^2)	22.7 ± 4.8	23.8 ± 6.1	22.4 ± 2.6	0.567

[†]Body mass index

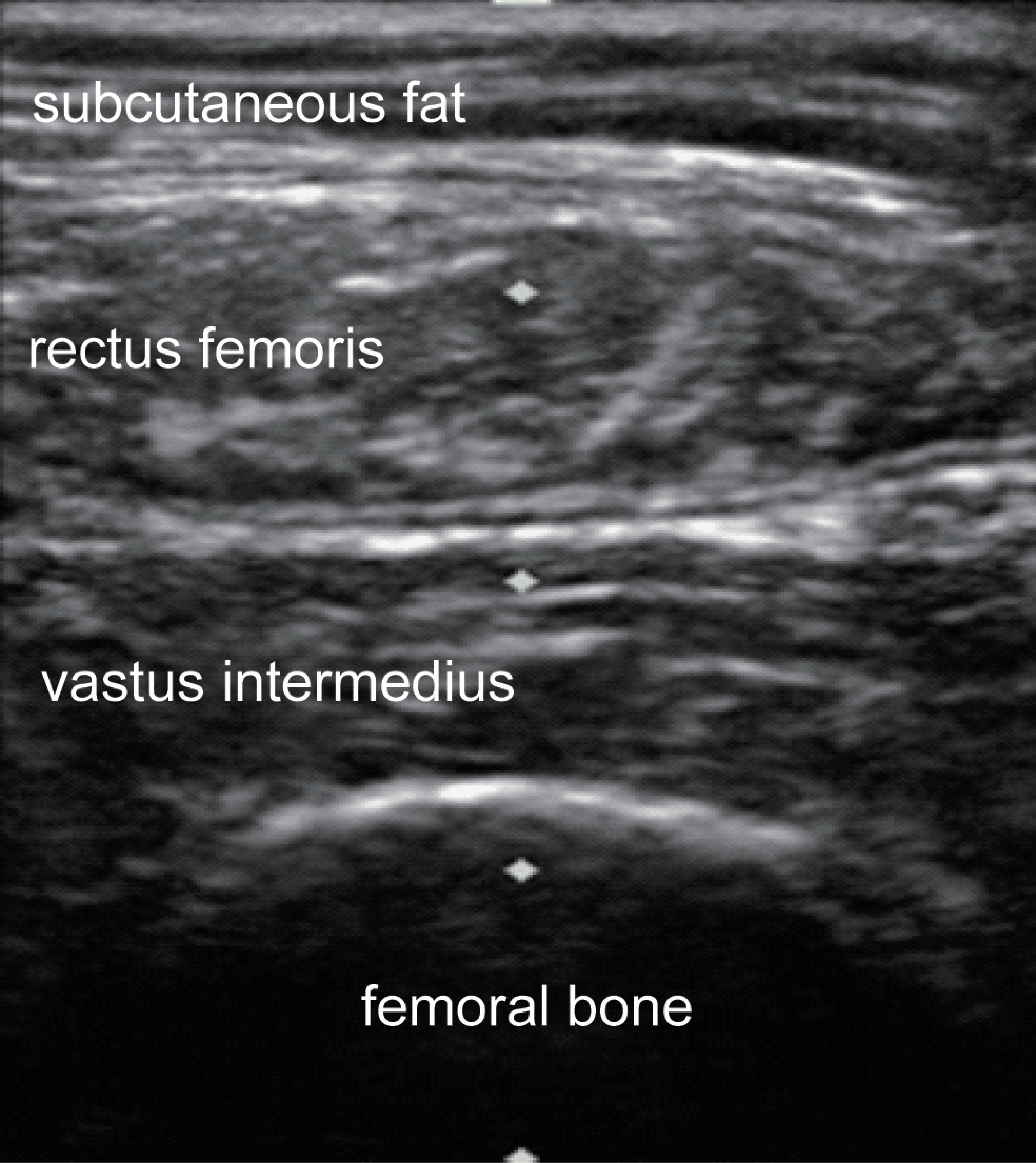
Data are shown as mean ± standard deviation.

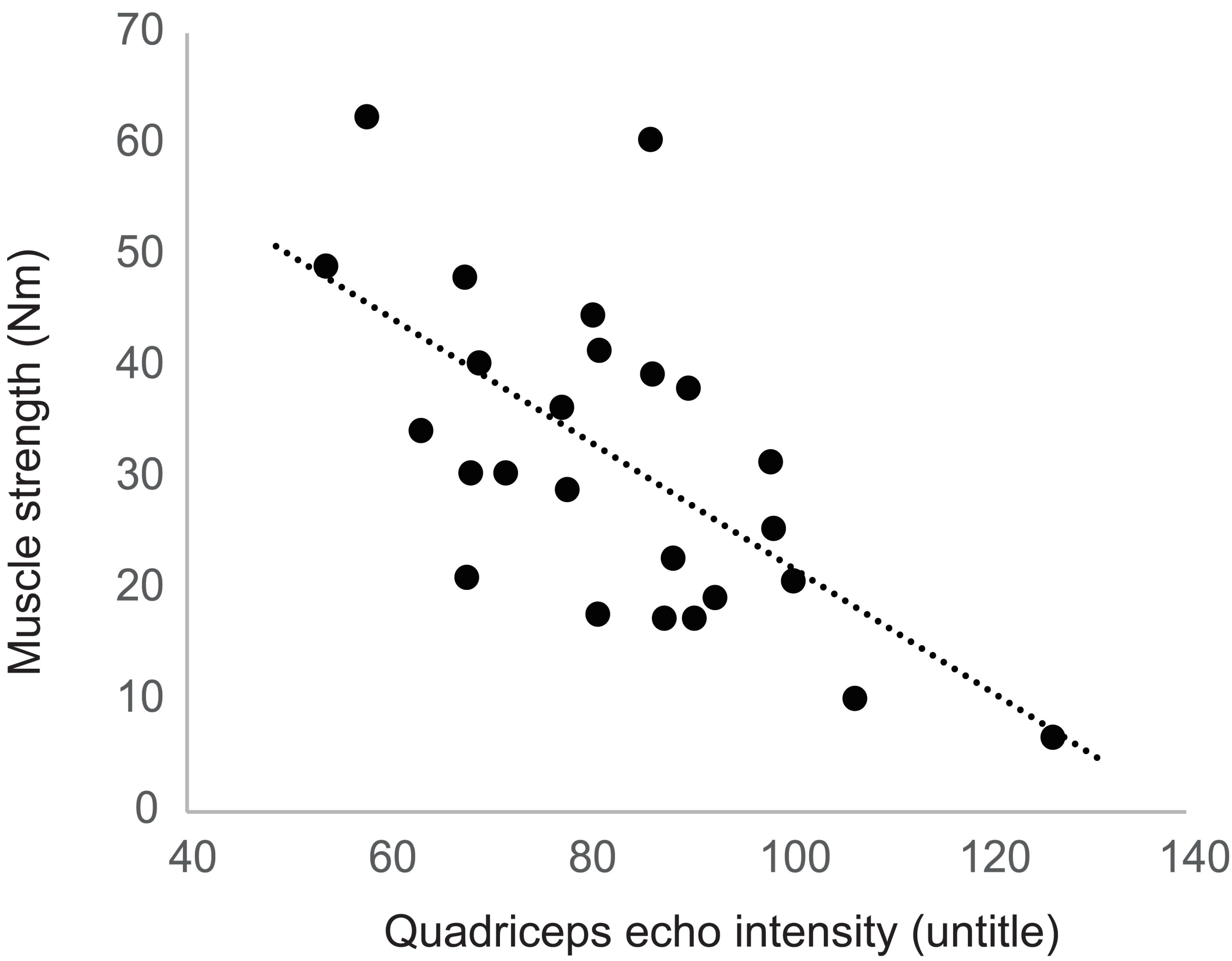
Table2. Quadriceps echo intensity, muscle thichness, and muscle strength of the dependent, frail, and healthy groups.

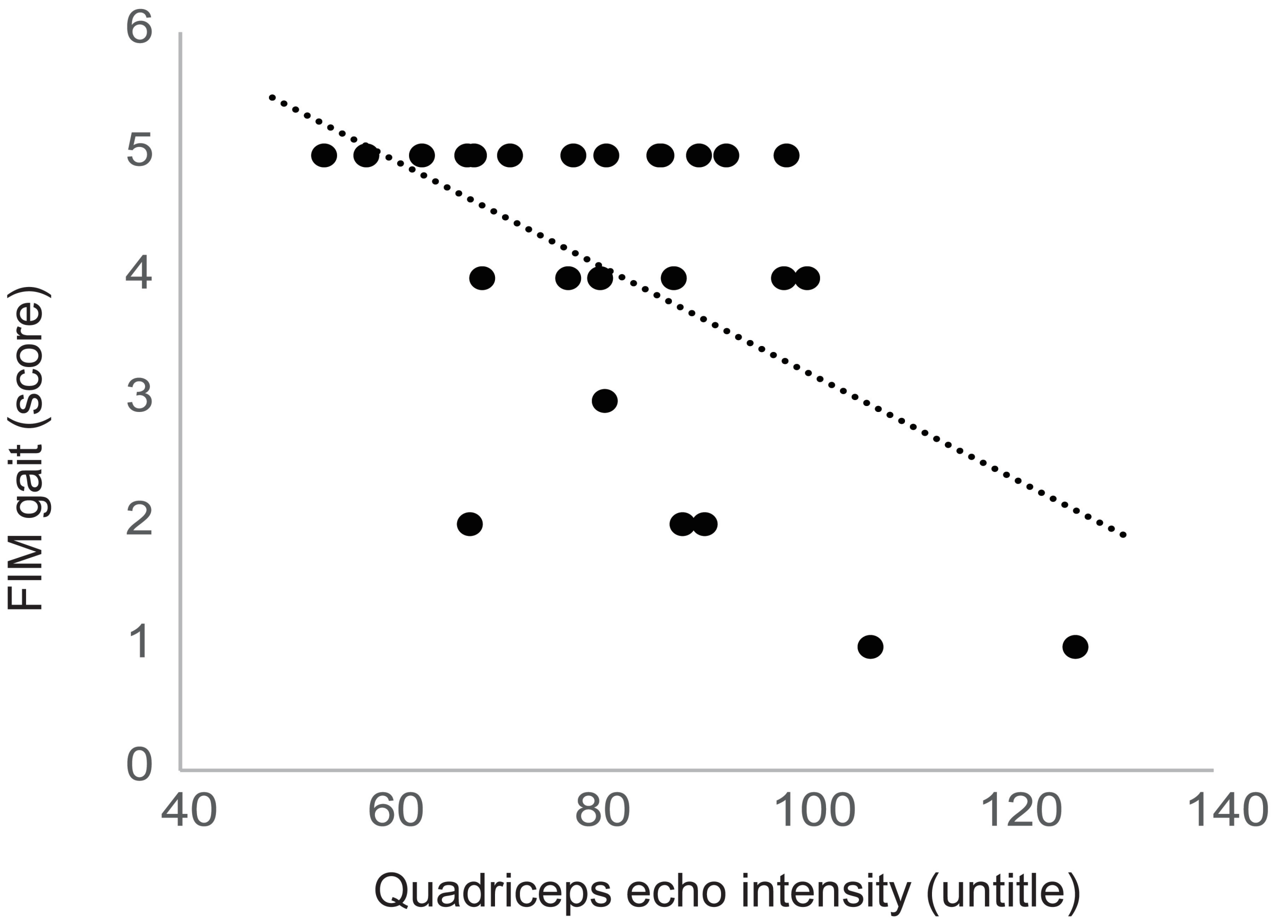
	Dependent group (n = 25)	Frail group (n = 22)	Healthy group (n = 22)	Main effect p value
Echo intensity (untitle)	82.9 ± 16.4**	80.6 ± 12.2*	69.5 ± 16.1	$p < 0.01$
Muscle thickness (cm)	3.0 ± 0.9**	3.5 ± 0.8	4.0 ± 0.9	$p < 0.01$
Muscle strength (Nm)	31.8 ± 14.5**	40.1 ± 13.5**	52.5 ± 11.8	$p < 0.01$

*$p < 0.05$, **$p < 0.01$ (Significant differences compared with the Healthy group; based on Tukey test)

Data are shown as mean ± standard deviation.


subcutaneous fat
rectus femoris
vastus intermedius
femoral bone


70
60
50
40
30
20
10
0
40
60
80
100
120
140
Muscle strength (Nm)
Quadriceps echo intensity (untitle)


6
5
4
3
2
1
0
40
60
80
100
120
140
FIM gait (score)
Quadriceps echo intensity (untitle)