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Original Article

One-repetition maximum can be estimated with a handheld dynamometer and circumference in community-dwelling older adults

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Abstract. [Purpose] One-repetition maximum is an essential statistic for physical therapists and coaches in rehabilitation and athletic settings. In a previous study, we showed that one-repetition maximum of the knee extensor could be predicted more accurately with the combination of maximal voluntary isometric contraction strength, as measured by a handheld dynamometer, muscle thickness, and thigh circumference, in young adults. However, there has been no study in older adults investigating the relationship between one-repetition maximum and maximal voluntary isometric contraction strength, or muscle thickness, and thigh circumference. Therefore, the aim of this study was to investigate the relationship between one-repetition maximum and maximal voluntary isometric contraction strength, or muscle thickness, and thigh circumference in older adults. [Participants and Methods] Twenty-eight older community-dwelling adults (18 males and 10 females) participated in this study. Muscle strength of the knee extensor was measured using one-repetition maximum and maximal voluntary isometric contraction strength. In addition, muscle thicknesses of the refutes femoris and the vastus intermedius, and thigh circumference were measured using ultrasonography and measuring tape, respectively. [Results] Stepwise regression analysis revealed that body mass, gender, thigh circumference at 15 cm above the patella, and maximal voluntary isometric contraction strength were significant and independent determinants (R^2=0.868). [Conclusion] One-repetition maximum could be predicted more accurately using a combination of maximal voluntary isometric contraction strength, as measured with a handheld dynamometer, and thigh circumference in older adults.

Key words: Maximal isometric strength, Muscle thickness, Knee extensor

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INTRODUCTION

In the various situation, resistance training is prescribed for muscle atrophy, and previous studies have reported a significant increase in the muscle strength and mass after resistance training in healthy adults[1, 2)], elderly participants[3, 4)], and clinical populations[5, 6)]. The guidelines of the American College of Sports Medicine recommend that high-intensity resistance training with at least 60–80% one-repetition maximum (1RM) for 8–12 repetition has been prescribed to prevent atrophy and/or increase muscle mass for health novice and older population[7, 8)]. Therefore, the exact 1RM measurement is necessary for determining the training intensity to prescribe resistance training. However, measuring 1RM could have risks of occurring musculoskeletal injury and elevate in blood pressure among the elderly and clinical population. In addition, measuring 1RM is needed to use the torque machine or dynamometer, which is very huge and expensive machine. Therefore, it is often unavailable to use in rehabilitation settings, such as hospital, and nursing homes, etc. Therefore, a more accessible and

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affordable method has been established to predict 1RM.

Previous studies have focused on maximum voluntary isometric contraction measured using a handheld dynamometer (HDD) that is highly reliable, for 1RM estimation. In particular, Tan et al. reported that 1RM of knee extensors and elbow flexors was estimated using MVIC as measured using HDD[9]. In addition, Kanada et al. reported that 1RM could be estimated more accurately using MVIC in addition to body composition measurement[10]. Furthermore, Nakamura et al. focused on ultrasonography and circumference measurements, which is noninvisible and required minimal effort or cooperation from the participants, and reported that 1RM could be estimated more accurately by MVIC and ultrasound measurement[11]. However, the participants in these previous studies were young healthy participants, and it is unclear whether there was a similar relationship between 1RM and MVIC, muscle thickness, and circumference in older population who have many opportunities to be prescribed resistance training. Therefore, this study aimed to measure the 1RM, MVIC, muscle thickness, circumference of knee extensor for older community-dwelling participants, and investigate whether 1RM could be estimated with these measurements. The hypothesis of this study was that it is possible to estimate 1RM by measuring MVIC, muscle thickness, and circumference, which is similar with the studies for young population.

PARTICIPANTS AND METHODS

Twenty-eight older community-dwelling adults aged >60 years participated in this study. The inclusion criteria were age >60 years, residing in the community, and the ability to walk independently (or with a cane). The exclusion criteria were cognitive impairment, severe cardiac or musculoskeletal disorders, previous diagnosis of pulmonary disease, and hearing impairment. All the participants were fully informed of the purpose and procedures of the study, and all provided written informed consent. This study was approved by the Ethics Committee of our university (Niigata University of health and Welfare) (18104) and conducted in accordance with the Declaration of Helsinki. In order to evaluate the increase in blood pressure, 1RM and MVIC measurements were performed while measuring blood pressure as appropriate.

Data on age, gender, height, and weight were collected directly from the participants. Body mass index (BMI) was then calculated by dividing the participants' weight by the square of their height.

1RM of knee extensor in dominant leg was measured using with a torque machine bilaterally (Multi safety gym set, wild fit, Japan). The participants were instructed to sit on a chair with 70° hip flexion angle, and were instructed to grasp the sitting board. As warm-up protocol, each participant performed five repetitions at 50% of the participant's predicted 1RM. After warm-up protocol, 1RM measurements were performed, and the initial load was selected by participant's predicted 1RM. The load was increased until the participants could not lift the weight through from knee flexion from 90° to full extension, with proper form. 1RM measurements were repeated with sufficient rest between trials to avoid fatigue. In this study, 1RM would be determined within 3–5 attempts.

After performing 1RM measurements, MVIC strength of knee extensor was measured using HHD (μ-tas F1, ANIMA Co., Tokyo, Japan) in a sitting position with hip and knee flexion of 90°. The MVIC measurements for 3 s were repeated three times with sufficient rest period. The maximal value of three measurement was adopted in future study, and we calculated the knee extension torque (Nm) base on the previous study[11].

According to the previous study[11], we measured the muscle thickness of quadriceps muscle (refutes femoris and vastus intermedius) used by ultrasonography (LOGIQ e V2; GE Healthcare Japan, Tokyo, Japan). We measured muscle thickness of quadriceps muscle at 5, 10, and 15 cm above the patella and the midpoint between the anterior superior iliac spine and the proximal end of the patella[11, 12]. We defined the muscle thickness of quadriceps muscle as the distance between the inner edges of the fascia and the femoral bone. In addition, we measured the thigh circumference used by a cloth tape to the nearest 0.1 cm in the same site to muscle thickness measurements.

SPSS (version 24.0; IBM Corp., Armonk, NY, USA) was used for statistical analysis. The normality of all variables was evaluated using Shapiro-Wilk tests. First, the correlation between 1RM and other variables was determined using Pearson correlation coefficient. Second, stepwise regression analysis was employed to investigate the associations between 1RM and independent variables, such as age, BMI, gender (male, 0; female, 1), muscle thickness, thigh circumference, and MVIC. The variance inflation factor (VIF) was examined to monitor the multicollinearity effect. The differences were considered statistically significant at an alpha level of 0.05. Finally, paired t-tests were used to compare the differences between measured and predicted 1RM. Descriptive data are shown as mean ± SD values.

RESULTS

The demographic data of all the participants and all variables are shown in Table 1. In addition, Table 2 showed the Pearson correlation coefficients between 1RM and other variables. MVIC was measured using HDD and was most strongly correlated with 1RM ($R=0.733$, $p<0.01$); muscle thickness and thigh circumference were significantly correlated with 1RM ($R=0.500$–0.678, $p<0.01$).

Table 3 showed the result of stepwise regression analysis for investigating 1RM estimation. The result revealed that MVIC, age, gender, and thigh circumference at 15 cm above the patella were significant and independent determinants, and the following estimation formula was created: 1RM (kg)=0.05 × MVIC − 0.70 × age − 5.83 × gender (male=0, female=1)

Table 1. All variables for measurements

	Mean ± SD	Range
Age (years)	70.4 ± 4.2	64 to 81
BMI (kg/m^2)	22.7 ± 2.4	18.0 to 26.6
1RM (kg)	24.0 ± 7.5	10.0 to 37.5
MVIC (Nm)	119.1 ± 39.2	53.6 to 208.8
Male: female	18: 10	
Muscle thickness (cm)		
5 cm above patella	1.54 ± 0.42	0.98 to 2.90
10 cm above patella	2.07 ± 0.55	1.13 to 3.62
15 cm above patella	2.77 ± 0.65	1.59 to 3.62
Midpoint	3.57 ± 0.7	2.35 to 5.15
Thigh circumference (cm)		
5 cm above patella	37.5 ± 2.9	32.3 to 44.6
10 cm above patella	41.8 ± 3.2	36.3 to 48.9
15 cm above patella	41.8 ± 3.2	36.3 to 48.9
Midpoint	48.4 ± 3.5	41.2 to 55.4

RM: repetition maximum; MVIC: maximum voluntary isometric contraction; BMI: body mass index.

Table 2. The relationship between 1RM and other variables

		Thigh circumference (cm)				Muscle thickness (cm)			
	MVIC (Nm)	5 cm above patella	10 cm above patella	15 cm above patella	midpoint	5 cm above patella	10 cm above patella	15 cm above patella	Midpoint
Correlation coefficient	0.733	0.678	0.642	0.637	0.626	0.670	0.608	0.538	0.500
p value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

RM: repetition maximum; MVIC: maximum voluntary isometric contraction.

Table 3. Result of stepwise regression analysis for investigating 1RM

						95% CI		
Dependent variables: 1RM (kg)	Independent variables	Partial regression coefficient (B)	Atandard partial regression coefficient (β)	t value	p value	lower	upper	VIF
	Gender (male: 0, female: 1)	−8.387	−0.55	−6.34	<0.01	−11.04	−5.73	1.16
	Muscle thickness at 15 cm above patella (cm)	0.861	0.37	4.27	<0.01	0.46	1.27	1.15
R^2=0.679	MVIC (Nm)	0.034	0.18	2.21	=0.032	0.00	0.07	1.05

RM: repetition maximum; MVIC: maximum voluntary isometric contraction; VIF: variance inflation factor; R^2: Coefficient of determination; CI: confidence interval.

+ 0.66 × thigh circumference at 15 cm above the patella (cm) + 39.38. The coefficient was R^2=0.868 ($p<0.01$). In addition, the predicted 1RM from this formula was 24.5 ± 7.0 (kg), and no significant difference was observed between measured and predicted 1RM (p=0.815).

DISCUSSION

In this study, we investigated whether 1RM, an important index to prescribe resistance training, could be easily estimated for community-dwelling older population. Our results showed that 1RM could be estimated accurately with MVIC measured using HDD and thigh circumference. The results suggested that thigh circumference and MVIC could be used as indicators when prescribing resistance training in hospitals and nursing homes where 1RM measurement is difficult.

Our results showed a significant relationship between 1RM and MVIC, muscle thickness and thigh circumference for community-dwelling older population, consistent with previous reports on young healthy adults[9–11]. Although MVIC measurement is a static muscle strength measurement by isometric contraction, 1RM is a dynamic muscle strength measurement with joint movement, and the MVIC and 1RM measurements are different contraction modes. However, because MVIC measurement using HDD could be performed easily and inexpensively, it is possible to estimate 1RM in various situations and use it for setting training intensity. In addition, previous studies showed a strong relationship between muscle thickness measured using ultrasonography and muscle cross-sectional area[13–15)], and cross-sectional area and MVIC or isokinetic muscle strength[16–18)]. Moreover, it is assumed that the thigh muscle mass could be estimated easily in the thigh circumference measurement; thus, it was considered that there was a high correlation with 1RM and thigh circumference as well as the muscle thickness measurement.

In addition, the results of stepwise regression analysis revealed that MVIC, age, gender, and thigh circumference at 15 cm above the patella were significant and independent determinants for 1RM estimation (R^2=0.868). These results expand on the findings of the previous studies for investigating the relationship of 1RM and MVIC for young healthy adults[9–11)]. The reason why the thigh circumference was extracted significantly without extracting muscle thickness was to measure only the muscle thickness of refutes femoris and vastus immedialis in the knee extensor muscle group. In contrast, it is possible to measure the thigh circumference for the whole knee extensor muscle groups, for example vastus lateralis and medialis. Furthermore, muscle thickness measurement is needed to use the ultrasonography equipment; however, thigh circumference could be measured using only a measuring tape; this is cheaper and easier than ultrasonography measurements. Therefore, our results showed that MVIC and thigh circumference measurements can be used to estimate 1RM in various situations and used for setting training intensity.

For older adults, the training intensity of 70–80% 1RM is recommended for increase in muscle mass[19)]. In addition, recently, it has been reported that increasing the number of sets[20)] and slow-movement, tonic force generation[21, 22)] with even low-intensity resistance training could increase the muscle strength and muscle mass. However, although it is important to measure 1RM accurately for prescribing these resistance training, 1RM measurement requires huge and expensive equipment, such as the torque machine and/or dynamometer. In addition, it is possible that 1RM measurement could lead musculoskeletal injury or increase blood pressure for older adults. Therefore, it is important to estimate 1RM easily, inexpensively, and safely in various situations, such as rehabilitation settings and nursing homes. Our results showed that MVIC measured using HDD and circumference that can be performed for a low cost could estimate 1RM easily. Therefore, in the future, many applications in various situations and populations can be expected.

There was a limitation of this study. Since this study is the cross-sectional study, the effect of resistance training on muscle strength and muscle mass using the training intensity calculated with the estimation formula clarified in this study is unknown. Therefore, there is a need to conduct a training intervention study with the training intensity calculated using the estimation formula.

In this study, we measured MVIC using HDD, muscle thickness, and thigh circumference for older community-dwelling participants, and investigated whether 1RM could be estimated accurately. Our results showed that 1RM could be estimated accurately with MVIC and thigh circumference. In the future, it is expected that resistance training intervention will be performed using training intensity using this estimation formula.

Funding and Conflict of interest

None.

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