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The Effects of Manual Resistance Training on Improving Muscle Strength of the Lower Extremities of the Community Dwelling Elderly —A Clinical Intervention Study with A Control Group—

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Abstract. [Purpose] This study focused on the effects of Manual Resistance Training (MRT) performed by elderly people for their lower extremities. [Subjects and Methods] The subjects were 53 elderly persons. The isometric strength of the right knee-extensor of the subjects in the intervention group was assessed after MRT once a week for 12 weeks followed by MRT, twice a week for 12 more weeks. Subjects in the control group only received the muscle strength measurement and did not perform MRT. [Results] From the baseline, the muscle strength of the intervention group significantly increased by 13.2% after 12 weeks, and 29% after 24 weeks. A significant difference was observed between the muscle strength of the intervention group and that of the control group. Those with greater muscle strength experienced relatively low muscle strength augmentation, compared with those with less muscle strength. [Conclusion]MRT resulted in improvements in muscle strength, similar to the results reported for a prior intervention with a resistance training method. The intensity of the MRT was inferred to be more than 70% of 1-repetition maximum. MRT may have less impact if it is performed by people with relatively high muscle strength.

Key words: Manual resistance training, Muscle strength, Elderly

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INTRODUCTION

The Cabinet Office of the Government of Japan published its annual report on the aging of society in 2008 and stated that the proportion of elderly people (aged more than 65 years old) will represent over 25% of the total population in 2013 due to the progressive aging of society[1)]. Elderly people need to maintain their muscle strength to sustain an independent life. However, the loss of muscle strength with aging is inevitable and elderly people are disproportionately affected, especially in their lower extremities, even if they have lived a healthy life without disease[2–4)]. This decrease in muscle mass and strength is called sarcopenia[5)].

It has been suggested that Resistance Training (RT) can delay the progress of sarcopenia and improve the condition of elderly people by strengthening muscle and augmenting muscle mass[6,7)]. RT for elderly people uses a wide range of equipment and methods, such as body weight, free weights, elastic bands, training machines and manual resistance. In addition, Taaffe[8)] introduced resistance provided by a partner (so-called manual resistance). RT with body weight and free weights is rarely employed to strengthen muscles yet is mainly prescribed at low intensity as a self-training option for maintaining general health condition. Thus, it is a physical activity which can be performed safely by elderly people who have never previously performed resistance training[9)]. RT with an elastic band is safe, convenient and a widely-practiced method with an intensity ranging from low to moderate. The findings on the effects of RT with an elastic band have been reported[10,11)]. The effects of RT with training machines are also well reported. RT with training machines is a recognized standard method which is safe and accurately adjusts the resistance intensity from moderate to high; as a result, it is nowadays used for elderly people[12,13)].

Manual Resistance Training (MRT) is a method which is also practiced in subject's home, at the bedside in facilities such as hospitals, and in the rehabilitation room without training machines. However, we could find no study in the literature which solely observed the effects of MRT among elderly people. We found only a few studies, such as a case study of patients with muscle dystrophy and an intervention study with young adults as subjects[14–16]. This meant that components of MRT, i.e. intensity and appropriate training volume which can be adjusted by physical therapists using their body weight and muscle strength, are neither well documented nor studied, despite the fact that these basic components need to be interpreted carefully when RT is applied in clinical settings.

Consequently, this study had two objectives. The first was to examine the increase in muscle strength according to a certain training volume. Occasionally, the training volume is limited on account of the physical therapist or the patient not always being available. Hence we chose 1 set, once a week frequency as we considered it to be the minimum exercise protocol. The other objective was to observe the gain in muscle strength achieved by MRT with a twice a week frequency. This scheme was chosen because it is the most appropriate and recommended RT for elderly people[17,18]. In addition, we deduced the intensity of MRT in this study by comparing the findings with those of other studies.

SUBJECTS AND METHODS

Subjects

Forty people (more than 65 years old) participated in this study from April 2006 to May 2007. They were in the MRT group and performed MRT with a physical therapist for 24 weeks. The participants had been living independently, and had been able to go out using public transportation services. They had not performed any regular resistance training for the lower extremities for at least 6 months nor had they been involved in any exercise program in any facility, hospital or institution. People with mental conditions, progressive diseases, neurological conditions, cardiac and/or respiratory conditions, and severe musculoskeletal conditions were excluded from the study. Nineteen elderly people were chosen to be compared with the MRT group; they were assigned to the control group. Their performance was recorded but they performed no resistance training. All participants agreed to continue the lifestyle that they had been following during the research period. This agreement also excluded taking part in any other new training program. The participant provided their informed consent verbally and then provided written consent forms prior to the start of the study. This research was therefore conducted in compliance with the ethical principles of the Declaration of Helsinki.

Methods

Before the intervention, the MRT group underwent a medical examination by a physician to ensure they were fit to take part in RT. Eight physical therapists (males: n=6; females: n=2; mean age=31.3 years old from 22 to 48; mean body weight=61.7 kg, from 48 to 80 kg) conducted MRT for the major muscles of the MRT group participants' lower limbs. All physical therapists had attended a lecture on manual resistance training before starting the trial. The training comprised 6 components which were all single-joint movements: quadriceps-setting by spine position, abduction of hip joints in the side-lying position, extension of hip joints and flexion of knee joints in the prone position, flexion of the hip joints and extension of the knee joints in the sitting position. The intensity of manual resistance was insufficient for multiple-joint movement, and eccentric contraction wood have been difficult to perform because the participants were elderly people. Therefore, for each movement, concentric contraction of selected muscles was conducted with a full-range of motion for 7 seconds. This duration of 7 seconds was employed for a single motion because many prior studies employed a method which included concentric, hold, eccentric for 6 to 8 seconds[19–22]. In addition, one set comprising 10 times of resistance was performed. Before and after the resistance training, 5 minutes' stretching of muscles was practiced for both warm-up and cooling down.

The training frequency was once a week during the first 12 weeks in order to identify the effects of the training. During the next 12 weeks, training was held twice a week on non-consecutive days, as this is the RT frequency recommended for elderly people. The intensity of the training was adjusted by physical therapists themselves using their body weight and muscle strength. They delivered submaximal resistance and the intensity of this resistance was adjusted from 13 (somewhat hard) to 15 (hard), according to the Rating of Perceived Exertion (RPE)[23]. The participants indicated right after the training the resistance they thought to be most appropriate for the training intensity on a card on which a scale of the RPE was printed. A training session consisted of warm-up, MRT and cooling down and lasted approximately 30 minutes in total. The participants were asked about their physical condition and had their blood pressure measured before the training. At the end of each session, the participants drank water, if they wanted to, and they could leave the training room, if their physical condition had not been worsened by the training.

The muscle strength of both the Manual Resistance Training group and the control group was assessed at baseline (BL), at week 12 (T1), and at week 24 (T2). Maximal voluntary isometric strength of the right knee extensor was measured using a hand-held dynamometer (μTas-F1; ANIMA Corp, Tokyo, Japan) with an attached band. According to some researchers[24,25], better accuracy is observed (intra-class correlation coefficient of inter-rater, intra-session and inter-session reliability for the knee extension measurement, 0.98, 0.96 and 0.91 respectively) if examiners use the band-attached sensor of a hand-held dynamometer.

The participants sat on a platform (height=45 cm), with their hips and knees at 90 degrees of flexion. The right-side extremity of the participants was fixed to the base of the platform using the sensor band of the hand-held

Table 1. Subject characteristics for the manual resistance training (MRT) and control (C) groups at base line

Group	n	Age (yr)	Height (cm)	Body mass (kg)	BMI (kg/m^2)
MRT	34	75.7 ± 5.6	152.8 ± 7.4	56.6 ± 8.1	24.3 ± 3.1
C	19	76.0 ± 4.6	150.6 ± 8.6	54.2 ± 8.2	23.9 ± 3.1

Values are mean ± SD. BMI = body mass index.

Table 2. Changes in knee extension strength in the two groups during resistance training

Variable	Baseline (BL)	12weeks (T1)	% change from baseline	24weeks (T2)	% change from baseline
Muscle strength of knee extensor (kgf)					
MRT (n=34)	23.8 ± 5.7	26.7 ± 6.2$^{*\#\#}$	13.2	30.2 ± 6.8$^{**\#\#\dagger\dagger}$	29
C (n=19)	21.6 ± 8.3	21.9 ± 8.3	0.5	20.3 ± 8.4	–6.3
Muscle-weight ratio (%, kgf/kg)					
MRT (n=34)	42.5 ± 10.0	48.4 ± 11.1$^{\#\#}$	14.9	54.7 ± 12.0$^{**\#\#\dagger\dagger}$	31.1
C (n=19)	40.3 ± 13.7	41.2 ± 14.1	1.6	38.0 ± 14.5	–6

Values are mean ± SD. MRT = manual resistance training. C = control. *($p \le 0.05$), **($p \le 0.01$) = Significant difference between MRT and Control . $^{\#\#}$($p \le 0.01$) = Significant difference from baseline. ††($p \le 0.01$) = Significant difference from 12weeks.

dynamometer. The band was tightly placed above the medial condyle of the tibia. To avoid pain, a towel was inserted between the popliteal fossa and the edge of the platform. The participants put their left foot on the floor to stabilize their sitting position. A wooden step was provided if the subjects could not reach the floor. In this position, the participants extended their right knee joint at maximum effort for 5 seconds. The participants were ordered to keep their trunk straight. The observers held the band gently with their hand in order to keep the correct position of sensor. Assessments were conducted twice; the second measurement was made 60 seconds after the first and the greater of the two values was recorded.

A statistical analyses were performed using SPSS for Windows, version 15.0 J; SPSS, Inc., Tokyo. Descriptive statistics (mean and standard deviation) were computed for age, height, body weight, body mass index (BMI), muscle strength and percent-increase rate of muscle strength. Analysis of Variance (ANOVA) and Student's t-test were used to evaluate both groups at the same times (at BL, T1 and T2). The change in muscle strength was monitored at different times among each group with repeated measurements ANOVA. The Bonferroni-adjusted t-test was used, when necessary, to identify the cause of a change. Spearman's rank correlation coefficient was used for determining the association of the percentage of gain in muscle strength between BL, T1 and T2. The MRT group was categorized into two sub-groups following the median value of muscle strength at BL. In order to compare the difference of percent-increase rate, Student's t-test was used between sub-groups. Significance in this study was set at≤0.05.

RESULTS

In the MRT group, 34 participants completed the 24-week resistance training; in the control group, 19 participants completed a three-time assessment. The age and physical characteristics of both groups (27 females and 7 males in the MRT group, 14 females and 5 males in the control group) at baseline are indicated in Table 1. There was no substantial variation regarding any aspect between the two groups. Six participants (3 females and 3 males) in the MRT group quit the training: two of them were injured due to falls, three suffered from diseases of the internal organs, and one of them changed the hospital. There was no notable disparity of age or physical characteristics among the dropouts, the MRT group, and the control group.

Table 2 shows the changes of the muscle-weight ratio (muscle strength of right-knee extensor divided by body weight) of both groups at each assessment from BL to T2, and the percentage increases from BL. A significant difference in both muscle strength and muscle-weight ratio was not found between the MRT group and the control group at BL. At T1, both muscle strength and muscle-weight ratio had increased considerably ($p \le 0.01$) in the MRT group; and a significant change was observed in muscle strength ($p \le 0.05$) between the MRT group and the control group. At T2, muscle strength and muscle-weight ratio had risen appreciably compared to BL and T1 findings ($p \le 0.01$) in the MRT group. A significant difference was also noted between the MRT group and the control group ($p \le 0.01$). In the MRT group, the percentage increases in muscle strength at T1 and T2 from BL were 13.2% and 29% respectively; the muscle-weight ratio increases at T1 and T2 from BL were 14.9% and 31.1% respectively. On the other hand, no remarkable progress was seen in the control group.

There were significant associations ($p \le 0.01$) between

Table 3. A rate of change in knee extension strength in the two groups during resistance training

Group	n	12 weeks (T1)	24 weeks (T2)	
		% change from base line	% change from 12 weeks	% change from base line
Low	18	15.1 ± 17.3	17.8 ± 14.0*	35.7 ± 27.4*
High	16	9.4 ± 8.6	8.9 ± 8.1*	19.0 ± 15.2*

Values are mean ± SD. *(p≤0.05) = Significant difference between groups.

muscle strength and the two increase rates of muscle strength (from T1 to T2, and from BL to T2); the association coefficients were respectively –0.44 and –0.48. This result shows a moderately negative association. The MRT group was divided into two subgroups at the median value, 24.1 kgf. Table 3 shows the percentage increase of muscle strength from BL to T1 and T2, as well as from T1 to T2, for both subgroups. Over the whole period, a lower increase rate was observed in the subgroup with higher muscle strength (24.3–42.2 kgf), compared with the subgroup with lower muscle strength (11.8–24.1 kgf). Moreover, between the subgroups, significant differences were found for the period from BL to T2 and T1 to T2.

We note that the average attendance rate of the MRT program was over 95% which is considerably high. We also note that no severe injuries occurred during the resistance training.

DISCUSSION

To the base of our knowledge, this is the first study to have focused on the effect of MRT on the lower extremities of elderly people. Participants were community-dwelling elderly people who had no experience of RT, and the major muscles of their lower extremities were the targets of the resistance training. First, MRT of 1 set of 10 repetitions with submaximal resistance was provided once a week for 12 weeks. Muscle strength and the muscle-weight ratio significantly increased (by 13.2% and 14.9%, respectively) from BL, and a significant difference was observed in muscle strength between the MRT and the control group. Prior studies using 1 set of RT, once a week for the lower extremities, reported that from BL, leg press or leg extension strength was dramatically increased between 14.2% and 38% by RT with 8-or 9-week interventions[26–28]. By comparison, the rates of increase in isometric strength in this study were smaller, although the duration of training was longer. Factors influencing these differences in results are the methods of training and assessment previously employed by the other researchers differ from those used in this study: leg press versus leg extension, different training weights for strength testing and one repetition maximum (1RM). According to the American College of Sports Medicine, "In general, strength increases after resistance training in older adults seem to be greater with measures of 1-RM or 3-RM performance compared with isometric or isokinetic measures"[29]. Moreover, it has been acknowledged that a dramatic gain in dynamic strength, e.g. 1RM, can be associated with neural adaptation[30,31]. Neural adaptation not only occurs in elderly people but also in the rest of the population. Studies following the same subject and assessing the extensor strength of both knee joints before and after RT on lower extremities of adults and elderly people show a considerable improvement in dynamic strength, e.g. 1RM, rising from 41% to 134% over the course of 10 to 14 weeks. In contrast, isometric muscle strength increase is relatively low: 14% to 37%[19,20,32,33]. Therefore, regarding the results of the present study, we can safely assert that a relatively small variation in isometric strength depends on the testing/training's specificity.

Prior studies targeting muscle strength of lumbar or cervical extension, showed significant increases of muscle strength after RT of 1 set, once a week[34,35]. In contrast, DeMicheli et al.[36] reported that isometric torso rotation strength remained at 4.9% after RT of 1 set, once a week. They also found no significant difference between the findings of the control group and the RT group. While the training intensity in the study of DeMicheli et al. was 60% of 1RM, it was more than 70% of 1RM in the above-mentioned studies which reported improvement after RT of 1 set, once a week. Therefore, we suggest that moderate intensity, 60% of 1RM, is insufficient for achieving significant increases in muscle strength with the minimum volume of RT, 1 set, once a week. In addition, we can infer that the MRT intensity in the present study was at least 60 % of 1RM because the muscle strength was increased by MRT of 1 set, once a week. This finding will hopefully encourage trainers and elderly people who are experiencing difficulties to undergo numerous sessions of training.

In our study, from T1 to T2, MRT of 1 set of 10 repetitions at submaximal resistance, twice a week, was conducted for 12 weeks. Muscle strength and muscle-weight ratio increased by 29% to 31.1% in the 24 weeks from BL. In comparison to the control group, significant differences in muscle strength and muscle-weight ratio were observed. Some researchers measured the isometric strength of the knee or leg extension after twice a week RT, which included knee extensor measurements of adults or elderly people without prior RT experience. For example, Braith et al.[19] found an increase in isometric strength of 21% (1 set, 18 weeks, 36 sets in total); Häkkinen et al.[37] found an increase of 37% (3 to 6 sets, 21 weeks, 154 to 200 sets in total) and an increase of 27% [38] (3 to 5 sets, 24 weeks, 160 to 240 sets in total; this includes approximately 25% explosive strength training). In the present study, the number of MRT sets 36, calculated on the basis of once a week MRT conducted during the initial 12 weeks followed by twice a week MRT for a further 12 weeks. The results of the present study show a slightly greater increase in muscle strength than that reported by Braith et al.[19] who used a training period of shorter duration. In comparison with the study of Häkkinen et al.[37,38], the results of the present study show slightly less or similar increases in muscle strength, even though Häkkinen et al. employed a much greater number of sets of RT.

Regarding the similar increases seen in muscle strength despite the performance diverse number of sets, Wolfe et al. concluded that a single-set program, as opposed to a multiple-set program, provides a similar increase in muscle strength in an initial short-term training (from 6 to 16 weeks) for people without former RT experience[39]. Moreover, Carpinelli et al. found no significant change in the enhancement of muscle strength between single-set programs and multiple-set programs from 4 weeks to 25 weeks of RT[40].

In the present study, although a single-set program was employed, the increase in muscle strength after MRT was similar to that of multiple-set programs because RT lasted 24 weeks and the participants were elderly people without prior RT experience. Braith et al. and Häkkinen et al.[19,37,38] reported augmentations of muscle strength similar to that of our findings with a RT intensity of more than 70% of 1RM. We infer from this that the RT intensity of the present study was also in the region of 70% of 1RM. Also, RT intensity of 70% of 1RM in a prior study achieved an increase in muscle strength with a regimen of 1 set, once a week. Nevertheless, the present study employed the RPE to adjust RT intensity, which ranged from 13 (somewhat hard) to 15 (hard). Fiatarone[9] states that RPE intensity of 15 (hard) to 17 (very hard) corresponds to 80% of 1RM. Thus, we can safely say that the MRT intensity in this study was more than 70 % of 1RM.

The intensity of MRT may have been relatively insufficient for participants with strong muscle strength. The present study showed a moderately negative association between percent-increase rates of muscle strength in the two periods (T1 to T2, BL to T2) and muscle strength at BL. Moreover, the percent-increase rate of the group with high muscle strength was lower than that of the group with low muscle strength. Although the number of prior studies which have focused only on the effects of MRT is limited, the effects of MRT on increase in muscle strength were reported[14–16]. Vetter et al.[15] and Dorgo et al.[16] employed university students who obviously have higher muscle strength than elderly people in their study. They conducted their training effectively. For example, if the trainers were physically smaller than participants who had high muscle strength they applied techniques (effective training position) and tools which would give appropriate resistance. On the other hand, such special treatment was not employed in the present study since the participants were elderly people who generally have low muscle strength (only the antigravity position was appropriately applied). Physical therapists in the present study included women, who have relatively low muscle strength. These physical therapists may not have delivered sufficient resistance to the participants who had strong muscle strength. This would be explain the low percent-increase rate of the group that had high muscle strength, compared with the group with low muscle strength.

Another reason is may be because of the characteristics of increase in muscle strength. Hunter et al.[41] reported that negative associations (e.g. leg press, $r=-0.62$, $p=0.05$) between an increase in 1RM (by training type) and 1RM at BL, using 6 types of training for 15 elderly women. At the beginning, the participants were divided into two groups, with high muscle strength and low muscle strength. The increase in muscle strength of the participants who had relatively high muscle strength was lower than that of the other participants. Similarly, Lexell et al.[42] found a negative association ($r = -0.42$, $p<0.05$) between the percent-increase rate and dynamic strength at BL in knee extension, after conducting RT with 35 elderly people. Consequently, they concluded that those with stronger knee extensors showed smaller increase in muscle strength. Thus, it would appear that people with strong muscle strength show a lower increase in muscle strength than people with low muscle strength, after performing RT to increase muscle strength.

To sum up, “a lack of intensity of manual resistance” and “characteristics of the resistance training” may lead less increase of muscle strength in participants with strong muscle strength. However, it is difficult to identify the cause from the result of the present study. Therefore, it is important to consider the appropriate method when conducting MRT for people with strong muscle strength.

It is implicit that elderly people who are in nursing care homes have lower muscle strength than others. Therefore, elderly people who live in nursing care homes are likely frail elderly. In our study, although there were different levels of muscle strength among subjects at baseline, all of them were living at home independently. There are interesting studies which have examined the effect of RT on frail elderly who were living in a nursing care home. Fiatarone et al.[43] conducted high-intensity RT (80% of 1 RM) 3 times a week for 8 weeks with elderly volunteers (aged 90 ± 1 years) who were institutionalized in a nursing care home. A large increase in 1RM of knee extension (175%) was observed. Interestingly, Ikezoe et al.[44] also reported a 22% improvement of isometric muscle strength in knee extension among 13 elderly people in a nursing care home after conducting low intensity 4–6 times a week for 12 months (weight of one’s lower extremity and/or ankle cuff weight from 0.5 kg to 3.0 kg). Namely, for frail elderly, a large increase in muscle strength is observed after high-intensity RT, and even after low-intensity RT, an improvement is recognized. Thus, high-intensity RT can be employed, and for frail elderly, MRT may be highly useful.

In order to interpret the findings of this present research, it necessary to consider the following points. This study did not employ the double blind treatment between examiners and subject; also participants were not randomly categorized into the MRT group and the control group. In addition, this study did not examine the difference of the effect of muscle strengthening due to the combination of physical therapists and subjects. Further research into the effect of RT on physical functions, such as gait, ascending and descending of steps, and the Timed Up-and-Go Test, are necessary because the present study focused only the effect of muscle strength by MRT.

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