Effects of Physical Exercise on Fall Risk Factors in Elderly at Home in Intervention Trial

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Abstract

Objective: In this study, we used an intervention approach to examine the effects of physical exercise on elderly people living at home in a rural area.

Methods: Two regions in a village were randomly assigned as the control and intervention regions. The subjects were 60 years of age or older and were able to carry out their activities of daily living independently. The numbers of subjects were 56 and 81 for the control and intervention regions, respectively. In the control region, lectures on health were provided twice. In the intervention region, instructions on ten types of physical exercise were provided six times during this three-month study. In addition, the subjects in the intervention region were instructed to do exercises by themselves at home three days per week. The effects were compared by evaluating motor functions in maximum step length, 10-m full-power walking parameters, right knee extension torque, right hip flexion torque, and stepping time on a 40-cm staircase; data were obtained before and after the intervention.

Results: Analysis of covariance (ANCOVA) showed significant improvements in right maximum step length, the mean of the right and left maximum step lengths, and right hip flexion torque in the intervention region.

Conclusion: The three-month physical exercise program improves the motor functions of the elderly.

Key words: control region, intervention region, fall prevention, muscle strength, balance exercises

Introduction

Falls and resultant fractures in the elderly are the third greatest cause of conditions requiring care; thus, fall preventive measures are of critical importance (1). The factors contributing to falls in the elderly include muscle weakness, balancing disorders and gait disorders (2). Interventions to improve these factors, such as balance training, physical exercise and strength training, are reported to reduce the incidence of falls (3), and

various community-based exercise instruction programs have been offered in Japan to prevent falls. However, as Kanashiro et al. (4) and Ohtaka et al. (5, 6) point out, few studies have verified the efficacy of these Japanese fall prevention programs through a comparison with a control group; Haga et al. (7) compared a training group with a control group, and Suzuki et al. (8) performed a randomized controlled study.

There are various types of physical exercise including exercises with or without the use of equipment and exercises for individuals or for groups. Exercise programs provided in the form of group instruction without the use of equipment have significant advantages over other programs because they efficiently instruct elderly people on exercises which can be readily carried out anytime and anywhere. To disseminate fall prevention techniques among the elderly, it is essential to clarify the effects of group instruction on exercises that are

Received Mar. 1, 2006/Accepted Jun. 15, 2006

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easily carried out. Therefore, it is necessary to establish fall prevention programs and verify their effects.

The purpose of this study is to assess the effects of physical exercise on improving muscle strength and balancing ability in the elderly at home in a rural area using an intervention approach.

Methods

Study design and subjects (Fig. 1)

This study was an intervention trial in which a village was randomly divided into control and intervention regions and the residents in the latter region received instructions on physical exercise.

To recruit subjects, the president of a senior club including 15 branch areas agreed to seek volunteers aged 60 or older in all the branch areas, excluding people needing long-term care. The exclusion criteria were high blood pressure (Diastolic blood pressure >110 mmHg, Systolic blood pressure >180 mmHg), high pulse rate (>100 beat/min), high body temperature (>37.5°C), clear arrhythmia, lumbago or joint pain, respiratory insufficiency, or dizziness.

From a total of 2,189 people aged 60 or older, 233 who needed long-term care were excluded (at home, n=200; in long-term care facilities, n=33); 1,000 and 956 people in the control and intervention regions were considered eligible, and 71 and 101 people expressed their willingness to participate in the study, respectively. Fifteen out of 71 (21.1%) and 20 out of 101 (19.8%) participants in the control and intervention regions ultimately withdrew from the study, leaving 56 and 81

individuals, regarded as the subjects of this study, who underwent the remeasurement test that was carried out three months later, respectively.

Intervention methods

The study period was three months from September 2003 through December 2003. In the control region, lectures about health but not related to falls were provided once per month, two in total. In the intervention region, exercise instructions were provided initially following the measurement of baseline motor functions, and then twice per month giving a total of six times. Measurements before and after the intervention and exercise instruction sessions were carried out at the social welfare center in the village, where sufficient space could be secured.

Physical exercises

In 2002, we developed seven types of exercise to aid in preventing falls, including stretching exercises, muscle strength improvement exercises without the use of equipment, but utilizing body weight, and balance improvement exercises (9). In this study, we used a total of ten types of exercise by including some additional strength improvement exercises. The exercises included the following: for stretching i) side trunk flexion in a standing position, ii) trunk rotation in a standing position, and iii) trunk back extension in a standing position; for muscle strength improvement iv) hip joint extension in a prone position, v) trunk back extension in a prone position supported with both elbows, vi) hip joint abduction in a side lying position, vii) half squats in a standing position, and viii)

Fig. 1 Trial profile.

flexion of one hip joint to 90° in a standing position and the repetition of slow steps; and for balance improvement ix) raising one upper limb and the lower limb of the other side in a crawling position (hands-and-knees or hands-and-feet) and x) holding an airplane pose while standing on one foot with both arms stretched out and tilting the body forward or, if this exercise was too difficult, balancing on one foot or maintaining balance with one hand on the wall.

The subjects in the intervention region were instructed to carry out these ten exercises as well as for walking 30 minutes at least three days per week (10, 11). They received a poster that illustrated and explained the physical exercises and were asked to record their exercise implementation status on an “exercise practice calendar”.

Measurement and methods

On the basis of an initial interview with a physician and the measurements of blood pressure and pulse rate, the physician determined whether each individual was or was not able to carry out the exercises. The measurement items relating to physical characteristics and motor functions included body height, body weight, body mass index, maximum step length (m), walking speed (m/min), step length (m), cadence (steps/min) in 10-m full-power walking, right knee extension torque (Nm), right hip flexion torque (Nm), and stepping time on a 40-cm staircase (sec). Each measurement session was preceded by an explanation and demonstration by the examiners as well as a rehearsal for the participants. After the rehearsal, the participants performed the exercises one time each for measurement. Maximum step length was measured with a tape measure. For the 10-m full-power walking, the subjects walked along a 14-m walkway while time was measured with a stopwatch and the number of steps required to traverse the inner 10 m was recorded. For right knee extension torque and right hip flexion torque, isometric contraction strength was measured using μ Tas F-01 (Anima Corporation, Tokyo, Japan) while the subject was in a sitting position with both lower legs raised from the floor and with both the hip and knee joints flexed to 90°. Stepping time on the 40-cm staircase was measured with a stopwatch as the time required to climb up and down the staircase, crossing from one side to the other side. We also collected information about the subjects' typical habits of daily exercise using a questionnaire.

To achieve the standardization of “To standardize” the measurement and exercise methods, our staff were taught the methods of measuring physical characteristics and motor functions, as well as the physical exercises before the initiation of the study. Physical characteristics and motor functions were measured before and after the intervention. Duties were shared among the staff: public health nurses asked subjects about their physical condition and measured blood pressure and pulse rate; physicians determined whether individual subjects were sufficiently fit to carry out the physical exercises; and physical therapists taught the participants how to carry out each exercise.

Statistical analyses

The baseline values of all the subjects' demographic characteristics and motor functions were compared using the

chi-square test and an unpaired *t*-test, respectively. Data of right hip flexion torque with non-normal distribution were analyzed by the *t*-test after log transformation. We conducted analysis of covariance (ANCOVA) with an initial value as the covariate to compare values between the two groups at the baseline and before and after the intervention. Statistical significance was set at 5%. SPSS Ver. 12 (SPSS Japan Incorporated) was used as the statistical software.

Ethical approval

Written informed consent was obtained from all the subjects after they were provided with an explanation of the background, purposes and methods of the study, the feedback of individual results, and the method of publication of the study results. Ethical approval was obtained from the Ethical Committee of the Niigata University of Health and Welfare.

Results

Comparison of characteristics of dropouts and subjects

A total of 35 subjects (20.3%) dropped out of both regions (15 and 20 from the control and intervention regions, respectively), 16 subjects (9.3%) dropped out of the physical exercises (seven and nine from the control and intervention regions, respectively), and 19 (11.0%) dropout of the remeasurement test (eight and eleven from the control and intervention regions, respectively). Differences in gender, age and motor function were compared between the dropouts and the participants in the control and intervention regions. Only one significant difference was found between the dropouts and the participants in the control region, namely, the 10-m full-power walking stride (0.77 ± 0.14 m vs 0.86 ± 0.13 m; $p=0.02$).

Comparisons of baseline values between control and intervention regions

No significant difference was found in the male-female ratio between the two regions ($p=0.312$). The average age in the control region was higher by 1.5 years than that in the intervention region ($p=0.04$). The maximum right step length ($p=0.046$), maximum left step length ($p=0.029$) and average of the right and left maximum step lengths ($p=0.032$) in the control region were larger than those in the intervention region. No statistically significant differences were found in the other measurements.

Comparisons of differences in pre- and post-intervention values between control and intervention regions (Table 1)

We compared baseline data between the two regions by ANCOVA with age as the covariate because the average ages were significantly different between the two groups. Next, we compared differences in the data before and after the intervention between the two groups using a *t*-test when $p \geq 0.1$ in the analysis of the baseline data and using ANCOVA with the preintervention data as the covariate when $p < 0.1$. As a result, maximum right step length, the average of the right and left maximum step lengths, and right hip flexion torque showed significant differences. Additionally, the improvement in the step length of 10-m full-power walking was not statistically

Table 1 Comparison of changes in pre- and post-intervention data between the control and intervention regions

	Control region		Intervention region		p value [#]	p value ^{&}
	Pre Mean±SD	Post Mean±SD	Pre Mean±SD	Post Mean±SD		
Number of subjects	56		81			
Sex (male : female)	27 : 29 (48.2% : 51.8%)		32 : 49 (39.5% : 60.5%)		0.312 ^s	
Age (years)	72.1±4.0		70.6±4.3		0.042	
Height (cm)	154.5±8.1		152.9±7.5		0.358	0.231
Weight (kg)	56.6±9.1	57.3±9.0	54.5±7.5	55.2±7.6	0.083	0.706
Body fat rate (%)	31.5±5.0	31.1±6.7	30.8±5.6	31.6±5.9	0.211	0.457
Maximum width of step (m)						
Right leg	113.8±11.9	113.8±12.0	109.4±12.9	113.6±12.6	0.023	0.023
Left leg	114.1±12.4	114.3±12.8	109.1±13.3	111.9±12.2	0.012	0.256
Mean of right and left legs (m)	113.9±11.9	114.1±12.1	109.3±12.7	112.8±12.2	0.014	0.047
10-m full-power walking						
Walking speed (m/min)	142.8±25.2	140.5±20.8	136.3±22.5	139.9±21.3	0.058	0.203
Step length (m)	0.86±0.13	0.86±0.12	0.82±0.11	0.84±0.11	0.032	0.051
Cadence (step/min)	166.9±27.2	163.9±20.1	165.9±17.1	167.7±17.8	0.599	0.794
Right knee extension torque (Nm)	72.6±23.5	82.8±23.4	67.8±21.2	80.6±24.8	0.152	0.218
Right hip flexion torque (Nm)	79.1±24.1	79.0±18.9	71.6±23.8	79.5±23.6	0.085	0.022
40-cm staircase stepping time (sec)	2.7±0.6	2.9±0.6	2.8±0.6	2.8±0.7	0.367	0.68

[#] p values for ANCOVA with age as covariate in compared with the pre- and post-intervention data between the control and intervention regions.

[&] p values for ANCOVA with pre-intervention data as covariate compared with difference in the pre- and post-intervention data between the control and intervention regions when the corresponding p[#] was less than 0.1; p values for t-test when the corresponding p[#] was 0.1 and over what or parallelism could not be assumed between the two groups.

^s p value for χ^2 test.

significant (p=0.051). No differences were found in the other measured items.

Exercise habits before intervention and exercise situation during intervention

In the control region, the percentage of those who had habits of regular exercise was 64%, whereas those who did not exercise regularly comprised 36%; in the intervention region, these percentages were 55% and 45%, respectively. These percentages were not significantly different between the two regions (p=0.371).

There were no accidents due to the exercises performed during this study.

In the intervention region, the average attendance rate at each exercise instruction session was 68.9±23.1%. To assess how many exercise items were performed routinely by the participants in the intervention group, we analyzed 66 participants (81.5%) who recorded their exercise activities for 80 days or more during the three-month period of the study. We found that the percentages of those who did all of the exercises, those who did half of the exercises, and those who did almost none of the exercises were 48.9%, 17.4% and 33.7%, respectively.

Discussion

In this study, we examined the effects of physical exercise on the elderly living at home in a rural area using an intervention approach. Our analysis showed that the improvements in maximum right step length, the mean of the right and left maximum step lengths, and in right hip flexion torque in the intervention region were significant compared with those in the

control region.

Haga et al. (7) found a smaller decrease in physical strength in their intervention region than in their control region as the result of a one-year intervention with fall prevention exercises for the elderly (aged 75–84). Additionally, Suzuki et al. (8) performed a randomized controlled intervention study involving elderly women at home, and reported an improvement in physical functions in their intervention region after implementing a combination of resistance exercises, balance and gait training, and Tai Chi for the elderly twice monthly for a period of six months. Significant improvements were detected in the number of steps in tandem gait, the distance of functional reach, and muscle strength in knee extension. The results of this study support these previous data. Physical exercise for the elderly is, thus, considered to be effective in improving motor functions.

Our intervention consisted of three months of exercise, but an important feature of this study is that it adopted ten types of physical exercise that we developed in addition to walking (10, 11). There are many exercise methods for the elderly, including those that require the use of expensive equipment (12), those that require inexpensive equipment such as rubber tubes (13), and those that do not require any equipment. The physical exercises we developed involve no equipment, which makes them easy to carry out, and incorporate three factors of exercise: stretching, strength and balance. Furthermore, we focused on the continual practice of the exercises as self-exercises at home. What are required for fall prevention programs for the elderly at home are exercises that are easy to learn, safely implemented, easily continued and voluntarily implemented without restrictions on time or place. The group

instruction provided twice a month, offered guidance on the correct way to perform the exercises and a communication forum for the participants; these factors motivated the participants to continue the exercises. Our subjects were elderly people living in a rural village with a population of slightly more than 7,000, and who were able to carry out their daily life activities independently, but may require care in the future.

The adequacy of the physical exercises employed in this study was assessed on the basis of three conditions: the frequency of exercise, the duration of the study period and the load (intensity $\times$ duration) of the exercises. The frequency of the exercises employed in this study is considered to have been adequate because three times per week is regarded as sufficient for the improvement of motor functions in the elderly (14). The duration of the program was selected on the basis of previous studies that have shown that improvement in muscle strength is attained in three months (15, 16). Additionally, Fiatarone et al. (17) have reported significant increase in muscle strength and mass as a result of eight weeks of high-intensity strength training in nonagenarians. The load of the exercises in this study was set between “moderate” and “slightly hard” (18) in terms of exercise intensity, which was judged subjectively by each participant when his or her body weight was applied as the load for the exercise. In the control region, however, we did not know if they followed the instructions or not, although we instructed the participants to continue their daily lives as usual during the intervention period.

There were no problems with the measurement methods in this study because the reproducibility of the employed methods was previously confirmed (19) and because these methods were implemented in accordance with the standard (10).

An improvement of the motor functions of the elderly through physical exercise is expected to lead to the prevention of falls and bone fractures (2, 3, 20). Many studies conducted

in Europe and the US have examined the effects of physical exercise with respect to falls and bone fractures in the elderly. Rubenstein et al. (2) reviewed major studies involving nursing home residents and concluded that the relative risk of risk factors contributing to falls is high for such physical characteristics as muscle weakness, balance disorder and gait disorder. Province et al. (3) have indicated, on the basis of a meta-analysis of seven studies, that general exercise and balancing exercises are effective in preventing falls, but have no effect on injurious falls. Gillespie et al. (20) state, on the basis of a meta-analysis of 62 studies involving the elderly, that the most effective intervention is a multilateral approach including physical exercise to improve strength and balance, an evaluation of health and environmental risks, risk evaluation and renovation guide for housing, and responses to individual subjects by specialists.

Nevertheless, there have been to date an extremely limited number of studies in Japan that scientifically evaluate the associations between physical exercise and falls and fractures. Haga et al. (7) and Suzuki et al. (8) performed intervention studies with home-based exercises with Suzuki et al. reporting a significant decrease in the incidence of falls in the intervention region. In this study, we did not assess the incidence of falls as an endpoint because the observation period was short (only three months).

Future studies are needed to further examine the effects of exercise instruction not only on motor functions but also on fall prevention and on the prevention of fall-related injuries using long-term intervention approaches.

Acknowledgement

This research was supported in part by a grant from the Community General Health Promotion Program of 2003 established by the Japan Public Health Association.

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