

## **The Influence of Short-term Strength Training on Health-related Quality of Life and Executive Cognitive Function**

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**Abstract** Strength training has been reported as a potentially useful exercise to improve psychological aspects in the elderly, but its effects remain controversial. This study investigated the effectiveness of strength training conducted twice a week for 12 weeks for improving health-related quality of life (HRQOL) and executive cognitive function. The study was a single-blind randomized controlled trial with assessments before and after intervention. HRQOL and executive function were assessed using the SF-36 Health Status Survey and a computerized neuro-cognitive assessment using task-switch reaction time trials, respectively. Subjects comprised 119 participants  $\geq 65$  years old, randomized to either strength training ( $n=65$ ) or health education classes (controls,  $n=54$ ). The strength training program was designed to strengthen the large muscle groups most important for functional activities and to improve balance. The effects of the intervention on the eight dimensions of the SF-36 in the control and training groups were analyzed. Only the mental health scale of the SF-36 was significantly improved for the training group compared with controls after 12 weeks. Task-switch reaction time and correct response rate remained unchanged. Short-term strength training might have modest positive effects on HRQOL, although this training period may not be sufficient to affect executive function in relatively healthy older people. *J Physiol Anthropol* 29(3): 95–101, 2010 <http://www.jstage.jst.go.jp/browse/jpa2>  
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### **Introduction**

Moderate physical activity and training in elderly people is well known to increase the capacity for physical function, thus improving health-related quality of life (HRQOL). Such activity also has positive effects on impairment of mental health, such as mood and anxiety (Blumenthal et al., 1989; Emery and Gatz, 1990; Revnic et al., 2007; Schechtman and Ory, 2001; Yasunaga et al., 2006). Moreover, neuropsychological assessments have suggested that habitual physical exercise attenuates cognitive declines accompanying aging (Colcombe et al., 2004; Kramer et al., 2003; Prakash et al., 2007). However, most research on the effects of physical exercise on HRQOL and cognitive functions has primarily focused on aerobic exercise, not on anaerobic exercise such as strength training. This is because cardiovascular improvement has been considered necessary to achieve favorable influences on psychological aspects. Aerobic exercise is more effective in improving cardiovascular fitness than anaerobic exercise.

However, in recent years, strength training has been reported as a potentially useful exercise to facilitate independency in daily life and prevention of falls in weak elderly individuals (Arai et al., 2007; Atlantis et al., 2004; Liu-Ambrose et al., 2004; Olney et al., 2006). Accordingly, several studies have shown interesting findings in which strength training might also have psychological aspects (Cassilhas et al., 2007; de Vreede et al., 2007; Özkaya et al., 2005; Perrig-Chiello et al., 1998; Tsutsumi et al., 1997). In the most recent study, Cassilhas et al. (2007) found positive effects on mental health, quality of life, and cognitive functions in elderly individuals after 24 weeks of resistance training. Conversely, Tsutsumi et al. (1997) demonstrated that while participation in 12 weeks of strength training can improve mood and physical self-efficacy

in older adults, cognitive functioning remains constant. These results seem somewhat inconsistent, and remain controversial. Furthermore, the number of studies on this issue is too small to allow any conclusions to be reached regarding the effects of strength training on psychological aspects.

When considering exercise intervention as a preventive strategy, it is important to remember the large numbers of older people in most communities. Health services are thus unable to provide sufficient attention to all subjects for long periods of time, because limitations exist to the services that can be provided in a community, such as the use of specialized staff, and also to the social security payments that can cover the cost of such staff. Systems must therefore be developed to achieve the maximum positive effects from resistance training in the minimum period. We have already found that short-term, low-frequency exercise (2 days/week for 12 weeks) may be beneficial for physical function in a subset of older people (Arai et al., 2007). Therefore, using the same training program, the present study examined whether short periods of resistance training affect HRQOL and cognitive function. HRQOL was evaluated using the Medical Outcomes Survey Short Form 36 (SF-36), which is a reliable and valid measure for community-dwelling elderly (Stewart et al., 1988) and for the general Japanese population (Fukuhara et al., 1998).

The abilities of adequate planning and executing goals are important for cognitive function in a society. Cognitive and neuro-psychologists call such cognitive function the executive function (Alvarez and Emory, 2006). Impairment of executive function results in difficulties with activities of daily living, such as making a meal that might involve sequentially and flexibly washing, cutting, and boiling food (Carlson et al., 1999). Executive function is known to decrease with age (Cepeda et al., 2001; Verhaeghen and Cerella, 2002), and most dementia patients (Dishman et al., 2006; Sarter and Turchi, 2002) show impaired executive function. In recent years, physical exercise has been considered to contribute to the prevention of decrease in executive function in the elderly (Colcombe and Kramer, 2003; Kramer et al., 2003; Kramer et al., 1999; McAuley et al., 2004). A task-switch reaction time test has been used as a suitable examination to evaluate executive function (Cepeda et al., 2001; Davidson et al., 2006; Friedman et al., 2008; Kramer et al., 1999). In this test, the subject is asked to sequentially execute two tasks in a block for which several sequential presentations of one task (repeat condition) are suddenly interrupted by another task (switch condition). Generally, mean reaction time (RT) is longer in the switch condition than in the repeat condition. The prolonged effect of switch-RT is known to increase with age (Cepeda et al., 2001). The present study therefore examined whether short-term strength training has any positive impact on cognitive aging using the task-switch reaction time test.

## Methods

This study was a single-blind randomized controlled trial

using assessments before and after the intervention. The study was conducted in three institutions in Japan: the Tokyo Metropolitan Institute of Gerontology, located in Itabashi City, in the Tokyo Metropolitan Area; the University of Kitasato, located in Sagami-hara City, in Kanagawa Prefecture; and Kanagawa University of Human Services, located in Yokosuka City, in Kanagawa Prefecture. This study was approved by the ethics committees of the Tokyo Metropolitan Institute of Gerontology. Exercise intervention and health education classes were conducted in the gymnastic rooms or halls of these institutions.

### *Participants*

Of the 190 participants in the first investigation, 171 participants met the eligibility criteria. Participants were randomly assigned into the exercise intervention group ( $n=86$ ) or the health education group ( $n=85$ ), which formed the control group. Participants were residents of the three cities in Japan mentioned above. Subjects were recruited via advertisements in publications in these communities and through clubs for the elderly in these areas. The details of this study were explained before the study began, and written informed consent was obtained from all participants.

Inclusion criteria were as follows: community-dwelling; age  $\geq 65$  years; ambulatory with or without assisting devices; and meeting none of the exclusion criteria. Exclusion criteria for the study were: 1) cerebrovascular or cardiovascular accidents reported within the past 6 months; 2) acute liver problems or active phase of chronic hepatitis; 3) diabetes mellitus with a history of hypoglycemic attack, or with fasting levels of plasma glucose  $\geq 200$  mg/dl, or with complications such as retinopathy or nephropathy; 4) systolic blood pressure  $>180$  mmHg or diastolic blood pressure  $>110$  mmHg at rest; 5) diagnosis of severe heart disease or an acute orthopedic problem; 6) diagnosis of dementia or depression by a medical doctor, inability to understand and follow the instructions of the research staff, or a Mini-Mental State Examination (MMSE) score  $\leq 23$  in individuals with dementia; and 7) restriction of physical activities by a medical doctor.

### *Exercise intervention protocol*

This exercise program was constructed according to the American College of Sports Medicine guidelines (American College of Sports Medicine Position Stand. Exercise and physical activity for older adults, 1998) and other research (Evans, 1999). The intervention protocol for this study has been described in detail previously (Arai et al., 2007). Briefly, the program comprised a 3-month facility-based program using progressive resistance training (PRT) and balance training. This program was designed to strengthen the large muscle groups most important for functional activities and to improve balance capacity. Included in the activities were leg press, knee extension, hip abduction, and rowing. Participants were asked to train twice weekly for 1.5 h each session for a total of 24 training sessions, with each class consisting of 8–10

individuals under the direct supervision of a physical therapist, a trained exercise instructor, and a nurse.

A “conditioning phase,” a “strengthening phase,” and a “functional training phase” were incorporated into the program for each month. The first phase was designed to condition physical functions through low-intensity exercise with high repetition. In this phase, participants learned proper forms, speed control, and a breathing technique. The second phase began at 60% of 1 repetition maximum (1 RM), defined as the maximum weight that could be lifted through a full range of motion with proper form. Evaluation of 1 RM was performed on the first day of the second phase. Weight was adjusted accordingly to ensure that the intensity was moderate to high. Resistance was increased if the participant was able to effortlessly complete 3 sets of 10 repetitions. A rest of approximately 2 min, sometimes more, was provided between sets of machine training. The third phase involved balance training such as stepping and walking on an unstable mat in addition to PRT. Tasks of balance and functional training progressively increased in difficulty on the basis of individual ability. Each training session consisted of 2–3 sets of 10 repetitions, and each session was preceded by warm-up and cool-down periods of 15 min that consisted of stretching the muscle groups involved in the strength training.

#### *Health education program*

Subjects in the health education group, which functioned as a control group, received 1.5 h of lectures on health promotion for older people twice a month for 3 months. Contents of the lectures were intended to help older people successfully cope with aging. Titles of lectures in the health education program included “Conditions for Successful Aging,” “Aging and Cognitive Function,” “Fall Prevention for Seniors,” “Health of Vessels,” “Gait Pattern of Seniors,” and “Knowledge of Resistance Training.” Each of the three institutions performed a full course of these lectures.

#### *HRQOL assessment*

HRQOL was measured using the SF-36. Results were analyzed using the following eight dimensions: Physical Functioning; Role Physical; Bodily Pain; General Health; Vitality; Social Functioning; Role Emotional; and Mental Health. Scores ranged from 0 to 100, with higher score reflecting better QOL. This is a reliable and valid measure in community-dwelling elderly (Stewart et al., 1988) and in the general Japanese population (Fukuhara et al., 1998a; Fukuhara et al., 1998b). Each dimension score was weighted in a three-step process to produce a standardized t-score (where the population mean score was 50, SD=10). In this study, score <50 meant that the score representing the specific health concept was below that of the Japanese national norm after adjusting for age and sex.

#### *Measurement of executive cognitive function using the task-switching test*

For the computerized portion (task-switching paradigm) of this experiment, Intel 486-based computers with 15-inch (38-cm) monitors were used. Subjects responded to stimuli presented on a computer screen, using the numeric keypad. Stimuli for the task-switching paradigm were presented at the center of the screen. Each of the four possible stimuli comprised either a single digit (1 or 3) or three digits (1 1 1 or 3 3 3). In other words, either one or three numerical ones or threes were presented. Preceding each target stimulus, either the phrase “What number?” or the words “How many?” appeared, depending on which task was being performed on that trial. The phrase “What number?” required subject to identify the number present on the screen (either the number 1 or the number 3), while the phrase “How many?” required identification of how many digits were present (either one digit or three digits) using the “1” and “3” keys on the numeric keypad.

During each trial, the instruction phrase (“What number?” or “How many?”) appeared for 250 ms at a fixed point on the screen, then a response stimulus (digits), appeared for 1750 ms transposed on the instruction phrase. The next trial followed after a 500-ms pause. The instruction phrase would switch randomly every second or third trial in a block. When the same instruction was repeated, subjects performed the same strategy to resolve the task (non-switch trials), but when the instruction changed, subjects would have to change the previous strategy to another (switch trials). The main dependent variables were mean reaction time (RT) and correct response rate required to perform switch and non-switch trials, respectively.

All subjects participated in a practice phase. If the subject completely understood the task, they moved into the test phase; otherwise, they repeated the practice phase. The test phase consisted of 60 trials (3 blocks of 20 trials) with 24 switch trials and 36 non-switch trials. Less than 15 min was required for the task-switching test for one person. The task-switching test was conducted at approximately the same time on the same date and place for both the exercise and control groups.

#### *Statistical analysis*

After randomization, we evaluated differences in each measurement between groups using the unpaired t-test. Sex distributions between groups were confirmed by a  $\chi^2$  test. For SF-36 data, the effect of strength training compared with the control group was evaluated using two-way ANOVA with a repeated-measures design. When ANOVA revealed interactions between groups and time courses, within-group analyses were performed using a paired-samples t-test. Conversely, reaction times and correct response rates of task-switch trials for estimating executive function were analyzed using 3-way ANOVA with a repeated-measures design. The 3-way ANOVA was conducted to reveal whether the prolonged effect of switch trials after intervention differed between groups by testing interactions between group, time, and task.

Statistical significance was set at the  $p < .05$  level. Effect sizes were calculated and expressed by  $\eta^2$ . Data were analyzed using SPSS 14.0J for Windows software (SPSS, Chicago, IL).

## Results

### *Attrition and continuance*

Of the 171 participants who started, 137 completed the intervention program. Fourteen subjects dropped out from the exercise intervention group, and 20 dropped out from the control group. Reasons for not completing interventions included loss of interest or accidents that did not originate directly from these programs, including hospitalization and health conditions such as colds. Among those who dropped out due to illness, the illness had no apparent relationship to the training intervention in all cases. Of the 137 participants who completed the intervention program, 119 attended all assessments, both pre- and post-intervention. The training and control groups thus comprised 65 and 54 participants, respectively. The present study dealt with data from 119 participants in the following analysis.

Table 1 shows the results of statistical analysis of comparisons between baseline characteristics of the control and training groups. No significant differences were seen for any variables in the pre-intervention period. This confirmed that the two groups displayed similar characteristics at the beginning of the study.

### *SF-36 outcomes*

Effects of the intervention on the eight dimensions of the SF-36 for control and training groups are shown in Table 2. Two-way ANOVA (Group vs. Time) analysis revealed significant main effects of time for Physical Functioning ( $p < .01$ ,  $\eta^2 = .066$ ), General Health ( $p < .01$ ,  $\eta^2 = .091$ ), and Vitality ( $p < .01$ ,  $\eta^2 = .061$ ). However, no significant interactions were seen between Group and Time for these variables. Conversely, analysis found a significant interaction ( $p < .05$ ,  $\eta^2 = .036$ ) between Group and Time on Mental Health, and revealed significant improvements ( $p < .05$ ,  $\eta^2 = .065$ ) in

Mental Health for the training group, but not for the control group.

### *Reaction times and correct response rates in the task-switch test*

Table 3 shows results of mean reaction times and correct response rates obtained from task-switch and repeat trials. Overall effects of time (pre-intervention vs. post-intervention) were found in mean reaction times of the task-switch test, with post-intervention reaction times identified as significantly shorter than pre-intervention reaction times under both switch and repeat trials. Correct response rates on post-intervention were also significantly increased compared to pre-intervention under both switch and repeat trials. No significant interactions were identified.

**Table 1** Baseline characteristics on first investigation

	Control (N=54) Mean±SD	Training (N=65) Mean±SD	<i>p</i>
Age, years	75.2±6.3	73.6±4.7	0.129
Female sex, N (%)	30 (56)	40 (62)	0.509
BMI	24.5±3.0	23.8±3.7	0.307
MMSE	27.9±2.1	27.8±1.8	0.954
SF-36			
Physical functioning	51.1±5.1	50.5±6.7	0.563
Role Physical	51.5±9.0	49.5±10.2	0.284
Bodily Pain	50.0±9.7	49.7±9.0	0.834
General Health	47.6±8.1	47.5±7.9	0.897
Vitality	57.1±8.4	57.3±7.6	0.901
Social Functioning	53.6±6.3	52.5±9.0	0.457
Role Emotional	50.8±10.1	51.3±9.4	0.777
Mental Health	53.2±9.9	53.5±8.5	0.866
Task-switching test			
Reaction time, msec			
Switch trial	988.9±337.7	948.2±296.6	0.485
Repeat trial	928.8±321.2	888.9±246.6	0.446
Correct response, %			
Switch trial	84.3±12.8	87.4±11.2	0.156
Repeat trial	90.7±10.5	91.5±9.0	0.651

**Table 2** Effects of the intervention on eight dimensions of the SF-36 in control and training groups

	Control (N=54)				Training (N=65)				ANOVA					
	Pre		Post		Pre		Post		Group		Time		Interaction	
	Mean	DS	Mean	DS	Mean	DS	Mean	DS	<i>F</i>	<i>p</i>	<i>F</i>	<i>p</i>	<i>F</i>	<i>p</i>
Physical functioning	51.1	5.1	52.3	4.2	50.5	6.7	51.6	5.5	0.466	0.496	8.272	0.005	0.000	0.992
Role Physical	51.5	9.0	50.6	10.0	49.5	10.2	50.6	9.2	0.426	0.515	0.013	0.910	1.080	0.301
Bodily Pain	50.0	9.7	50.3	8.6	49.7	9.0	51.4	9.4	0.059	0.809	1.283	0.260	0.656	0.419
General Health	47.6	8.1	49.4	8.8	47.5	7.9	50.3	9.6	0.070	0.791	11.749	0.001	0.748	0.389
Vitality	57.1	8.4	58.5	8.8	57.3	7.6	60.3	8.8	0.578	0.449	7.557	0.007	1.060	0.305
Social Functioning	53.6	6.3	53.1	6.7	52.5	9.0	52.7	8.1	0.401	0.528	0.047	0.829	0.186	0.667
Role Emotional	50.8	10.1	50.4	10.7	51.3	9.4	51.8	9.0	0.368	0.546	0.002	0.961	0.198	0.657
Mental Health	53.2	9.9	51.8	10.5	53.5	8.5	56.2	8.8*	2.791	0.097	0.423	0.517	4.402	0.038

\*  $p < 0.05$  compared with pre-intervention within training group

**Table 3** Mean reaction times and correct response rates obtained from task-switch and repeat trials

Group		Control (N=54)				Training (N=65)				ANOVA					
		Pre		Post		Pre		Post		Trial type		Time		Interaction (Trial×Time ×Group)	
Trial type		Repeat	Switch	Repeat	Switch	Repeat	Switch	Repeat	Switch	<i>F</i>	<i>p</i>	<i>F</i>	<i>p</i>	<i>F</i>	<i>p</i>
Reaction time (msec)	Mean	928.8	988.9	867.8	930.7	888.9	948.2	857.6	900.9	32.39	<0.01	6.99	0.01	0.25	0.62
	SD	321.2	337.7	239.9	263.0	246.6	296.6	272.7	285.8						
Correct response rate (%)	Mean	90.7	84.3	92.0	88.3	91.5	87.4	93.9	89.7	17.49	<0.01	51.86	<0.01	1.60	0.21
	SD	10.5	12.8	8.7	12.1	9.0	11.2	7.1	11.0						

## Discussion

The present study investigated effects of short-term strength training interventions on HRQOL and cognitive function, as so-called executive function, in elderly individuals. SF-36 was measured to evaluate HRQOL, showing a training effect on mental health as one of the eight dimensions for the SF-36. Task-switch trials to estimate executive function did not reveal any marked effects of strength training.

To date, it has been suggested that strength training plays an important role in increasing QOL among older adults by improving physiological and psychological function (Cassilhas et al., 2007; de Vreede et al., 2007; Tsutsumi et al., 1997). For example, Cassilhas et al. (2007) reported higher mean scores in a training group than in controls for SF-36, particularly for general health and vitality, using an intervention 3 times/week over 24 weeks. However, the present results showed a modest influence in SF-36-observed positive effects only on mental health. Although very few studies have been reported, the training period required to obtain greater benefits from strength training in terms of HRQOL might be >12 weeks. Indeed, Stiggebout et al. (2004) reported that training once or twice a week for 10 weeks did not show any significant effects on the SF-36, and de Vreede et al. (2007) showed that interventions 3 times/week for 12 weeks improved physical function scores in the SF-36. Conclusive explanations have not been provided as to why strength training improves HRQOL. One possibility is that more positive findings in the strength training group may reflect social aspects of going out and the associated positive environment. For instance, Olney et al. (2006) reported that supervision or inclusion in a social group may play a supportive role. Another interpretation is that execution of a strength-training program may result in a sense of achievement and sufficiency that is otherwise lacking in daily life, thus improving HRQOL.

Neurocognitive assessments could not identify any effects of strength training on executive cognitive function. However, various reports have suggested that exercise training has a positive impact on executive function (Colcombe and Kramer, 2003; Kramer et al., 1999). Executive control processes encompass those cognitive functions concerned with the

selection, scheduling, and coordination of computational processes, mediated mainly by pre-frontal brain functions (Davidson et al., 2006; Norman and Shallice, 1986). Moreover, neurocognitive evidence from magnetic resonance imaging studies suggests that older adults with greater levels of physical fitness suffer significantly less loss of gray matter in the frontal, temporal, and parietal lobes and significantly less loss of tissue in the anterior and posterior white matter tracts (Colcombe et al., 2004). Physical exercise may thus prevent structural brain tissue loss, thereby attenuating declines in executive cognitive function by somewhat enhancing biological mechanisms. Insulin-like growth factor (IGF)-1 enhanced by exercise stimulus has been identified as a biological-hormonal factor preventing brain tissue loss, increasing the levels of key neurochemicals that improve plasticity and neuronal survival, such as brain-derived neurotrophin factor (BDNF) (Adlard et al., 2005; Cotman and Berchtold, 2002; Vaynman et al., 2006). Cassilhas et al. (2007) found a significant increase in IGF-1 serum concentrations and improved executive cognitive function in a group that performed resistance training for 24 weeks compared with controls. The program of strength training in the present study was similar to that used by Cassilhas et al. (2007). Thus, as one interpretation of our results showing no significant improvement in executive function, the training program may not have been performed for long enough to enhance peripheral systems such as increasing serum concentrations of IGF-1. However, limitations might exist to the understanding of the effects of strength training on executive function that can be attained using the task-switching RT test, as analysis could not control for potential variables such as arousal level and sleep status in each participant. The test also could not be conducted in an experimental situation without noise, like a shielded room.

This study has shown that strength training in a short-term intervention has positive but modest effects on mental health according to SF-36 outcomes, but not on cognitive function. This modest impact of strength training might be caused not only by the short-term nature of the training period, but also by the selection bias toward participants with relatively high HRQOL and fitness level (Arai et al., 2007) compared to the Japanese standard. The lack of effect on other dimensions of



SF-36 outcomes and cognitive function does not necessarily imply that short-term strength training is less beneficial to HRQOL and cognition, but may relate to ceiling effects in this relatively healthy group of seniors in the present study. Indeed, a clinical assessment of patients who might be at a lower level of fitness and health identified a positive impact of strength training on HRQOL, even with training periods <12 weeks (Olney et al., 2006). Further studies that include subjects with lower levels of HRQOL and fitness are thus warranted. The present study in healthy older people at least revealed that short-term strength training has modest effects on HRQOL, but not cognitive function. Our results are probably useful as a preliminary reference to support further studies examining the effects of strength training on long-term preventative care in the elderly.

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