Associations between Physical Strength, Cerebral Function and Mental Health in Independent-Living Elderly Japanese Women

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Abstract

Objectives: To evaluate the physical strength, cerebral function, and mental health conditions in elderly persons, and to examine the correlation between these functions.

Methods: The subjects were 151 independent-living elderly Japanese women, mean age 70 $\pm$ 5 years ($\pm$ SD; range, 60 to 80 years), with normal abilities in daily life. The health check-up was conducted from April to May 1997. Physical strength was estimated by measuring seven activities. Cerebral functions were assessed by six sub-tests of the General Aptitude Test Battery (GATB). Their mental health status was measured by four sub-scales of the General Health Questionnaire (GHQ)-28.

Results: The physical strength and almost all of the cerebral functions decreased with age. Social dysfunction and severe depression on the GHQ sub-scales also worsened with age. Physical strength was strongly correlated with cerebral functions after adjusting for the confounding effect of aging. There were also interrelations between physical strength and mental health.

Conclusions: This study provided important information on the correlation between physical and mental status in elderly women. Future longitudinal studies with the intervention of physical training are required to determine whether a causal relationship exists between these factors.

Key words: physical strength, cerebral function, mental health, GATB (General Aptitude Test Battery), GHQ (General Health Questionnaire)

Introduction

With the rapid increase in the elderly population, the number of bedridden elderly individuals and those with senile dementia has become a major public health problem in Japan (1, 2). According to epidemiological research in Japan, the prevalence of dementia is 7.2% in people aged 60 years and older and 8.5% in people ages 65 years and older (3, 4). In this situation, an extension of life span per se is no longer the goal of the elderly, an improvement in functional independence and the achievement of a better quality of life (QOL) being more important. (5). It is necessary to improve

not only physical function but also cerebral function and mental health condition to achieve a better QOL.

Several epidemiological studies in the United States of America (USA) have reported that the physical, mental, and social well-being of elderly individuals are very closely interrelated (6–9). In Japan, Ohta et al. reported that mental health is strongly correlated with bio-psycho-social factors in aged people (10). To the best of our knowledge, no previous studies have been conducted on the mutual relationship between cerebral function, physical function, and mental health status. In this study, we report the correlation between these functions in independent-living elderly Japanese women.

Material and Methods

Subjects

The subjects were 151 independent-living elderly women

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Table 1 Characteristics of subjects

	n	Mean	SD	Min	Max
Age (years)	151	70	5	60	80
Height (cm)	151	148.1	5.2	129.8	159.1
Weight (kg)	151	49.6	7.6	32.8	78.9
Body mass index (kg/m ²)	151	22.6	3.1	15.1	31.7
Systolic blood pressure (mmHg)	151	144	24	91	222
Diastolic blood pressure (mmHg)	151	78	12	48	110
Physical strengths					
Grip strength (kg)	151	19.9	3.9	10.5	29.0
Vertical jump height (cm)	146	9.9	3.6	1.9	18.4
Jumping reaction time (sec)	146	0.6	0.2	0.3	1.5
Time to stand up and sit down (sec)	151	2.6	1.2	1.1	8.9
Sit and reach distance (cm)	151	9.6	8.0	-28.4	26.0
Time of balancing on one leg with eyes closed (sec)	150	6.7	11.6	0.0	90.0
Tapping score (beat/sec)	151	144	19	87	183
Cerebral functions					
Motor coordination	151	67	18	22	132
Form perception	150	11	3	4	19
Verbal aptitude	150	12	5	0	28
Spatial perception	150	8	3	1	18
Manual dexterity	151	42	5	28	50
Finger dexterity	147	25	5	15	38
GHQ sub-scales					
Somatic symptoms	151	1.7	1.8	0	7
Anxiety/insomnia	151	1.7	1.6	0	6
Social dysfunction	151	0.5	0.8	0	3
Severe depression	151	0.5	1.1	0	7

GHQ: General Health Questionnaire.

with normal abilities in daily life (ADL). The characteristics of the subjects are shown in Table 1. Of the 151 subjects, 102 women were new members of a physical exercise class for the elderly under the supervision of Nagoya City, and the other 49 women were members of the elderly people's club in the vicinity of Nagoya City University Medical School.

After an explanation of the aims and the methods of the study, all subjects signed an informed consent form. The subjects were then requested to complete a questionnaire to check their health status and to bring it with the informed consent form on the day of the study. The study was conducted at Nagoya City University Medical School from April to May 1997.

Measurements

Physical strength was estimated by seven tests. Grip strength was determined with a digital grip dynamometer (Takei Kiki Co., Tokyo, Japan) in the standing position, and the higher score of the two hands was used for the analysis (11). Vertical jump height was calculated from the vertical jump duration which was measured as the time between jumping off the ground and landing. Jumping reaction time was the time between seeing a flash of light and jumping off the ground. The vertical jump and jumping reaction time were measured with a jump-meter (VINE Co., Tokyo, Japan). The time required to get up from a recumbent position to sitting down on a chair was measured. Sit and reach distance was the distance from the tip of the feet to the tip of the fingers with flexion of the trunk. The time of balancing on one leg with eyes closed was measured for standing on one leg and keeping the

position. The tapping score was estimated by a tapping counter (Takei Kiki Co., Tokyo, Japan) for 30 sec. The higher score of the two hands was used for analysis.

Cerebral functions were estimated by the General Aptitude Test Battery (GATB). The GATB was developed in 1947 by the USA Employment Service to measure occupational aptitude (12). The GATB evaluates nine factors: intelligence, verbal aptitude, numerical aptitude, spatial perception, form perception, clerical aptitude, motor coordination, finger dexterity, and manual dexterity. In this study, we used sub-tests of the GATB adapted by Japanese Ministry of Labor to evaluate the following six factors of cerebral functions. Motor coordination is the ability to work rapidly and accurately by coordinating eyesight and hands or fingers which was evaluated by counting the number of dots made in a small circle in a given time. Form perception is the ability to recognize an actual object or illustration accurately in detail. This was evaluated by the ability to search out the same figure that was described in the question. Verbal aptitude is the ability to understand the meaning of words and to make effective use of them. This was evaluated by the ability to complete sentences. Spatial perception is the ability to understand the solid or to imagine the solid from the plane which was evaluated by the ability to search out the solid construction of the unfolded drawing in the question. Manual dexterity is the ability to move the hands skillfully at will which was evaluated by the ability to insert pegs into holes on a board. Finger dexterity is the ability to manipulate small objects with rapid and precise movement of the fingers which was evaluated by the ability to insert a bolt through a washer and into a hole on a

board (13).

The mental health status was measured by the General Health Questionnaire (GHQ). The GHQ is a self-administered screening questionnaire of 60 items and was designed to detect persons with psychiatric disorders (14, 15). The GHQ has been used for studies on the mental health of elderly couples (16, 17). In this study, we used the Japanese version of the GHQ-28 that was translated by Maruyama (18). The GHQ-28 consists of four sub-scales that measure somatic symptoms, anxiety and insomnia, social dysfunction, and severe depression. Each of these sub-scales includes seven items. Items were scored by using 2-point scores of 0-0-1-1. The sum of the scores is used to indicate the severity of the psychological distress (18).

Statistical analyses

Linear regression analyses were performed to calculate the correlation coefficients between age and physical strength, cerebral functions, and GHQ scores. Partial correlations, adjusted for age, were analyzed between physical strength, cerebral functions, and GHQ scores. Calculations were performed using SPSS, Version 8.0 (SPSS Inc., Chicago, IL, USA). Statistical significance for all analyses was set at 0.05.

Results

Spearman's rank correlation coefficients between age and physical strength, cerebral functions, and GHQ scores are shown in Table 2. The correlation coefficients between age and grip strengths, vertical jump heights, sit and reach distances, time of balancing on one-leg with eyes closed, and tapping scores were negative with statistical significance. On the other hand, the jumping reaction times and time to stand up and sit down were positively correlated with age. For cerebral functions, five functions, excluding spatial perception, were negatively associated with age. The motor coordination, manual dexterity, and finger dexterity scores were especially highly correlated with age. On the GHQ sub-scales, severe depression and social dysfunction were positively correlated with age. The other two sub-scales,

Table 2 Spearman's rank correlation coefficients between age and physical strengths, cerebral functions, and GHQ scores

	n	r
Physical strengths		
Grip strength (kg)	151	-0.240**
Vertical jump height (cm)	146	-0.301***
Jumping reaction time (sec)	146	0.216**
Time to stand up and sit down (sec)	151	0.204*
Sit and reach distance (cm)	151	-0.197*
Time of balancing on one leg with eyes closed (sec)	150	-0.343***
Tapping score (beat/sec)	151	-0.251**
Cerebral functions		
Motor coordination	151	-0.411***
Form perception	150	-0.190*
Verbal aptitude	150	-0.213**
Spatial perception	150	-0.147
Manual dexterity	151	-0.369***
Finger dexterity	147	-0.425***
GHQ sub-scales		
Somatic symptoms	151	-0.021
Anxiety/insomnia	151	-0.051
Social dysfunction	151	0.162*
Severe depression	151	0.224**

GHQ: General Health Questionnaire.

*** p<0.001, ** p<0.01, * p<0.05.

somatic symptoms and anxiety/insomnia, were not associated with age.

The partial correlation coefficients between physical strength and cerebral function adjusted for age are shown in Table 3. Grip strengths and tapping scores were positively correlated with almost all cerebral functions. On the other hand, time to stand up and sit down was negatively associated with four cerebral functions, viz., motor coordination, verbal aptitude, manual dexterity, and finger dexterity. There were significant positive correlations between sit and reach distances and the three cerebral functions, viz., form perception, manual dexterity, and finger dexterity. There

Table 3 Partial correlation coefficients between physical strengths and cerebral functions adjusted for age

		Motor coordination	Form perception	Verbal aptitude	Spatial perception	Manual dexterity	Finger dexterity
Grip strength (kg)	n	148	147	147	147	148	144
	r	0.051	0.303***	0.234**	0.167*	0.206**	0.154*
Vertical jump height (cm)	n	143	142	142	142	143	139
	r	0.066	0.071	0.144	0.037	0.210	0.167*
Jumping reaction time (sec)	n	143	142	142	142	143	139
	r	-0.048	-0.135	-0.138	-0.165*	-0.200**	-0.254**
Time to stand up and sit down (sec)	n	148	147	147	147	148	144
	r	-0.189*	-0.124	-0.263***	-0.095	-0.393***	-0.287***
Sit and reach distance (cm)	n	148	147	147	147	148	144
	r	0.106	0.140*	0.095	0.062	0.149*	0.218**
Time of balancing on one leg with eyes closed (sec)	n	147	146	146	146	147	143
	r	0.030	-0.085	0.011	0.001	0.056	0.139
Tapping score (beat/sec)	n	148	147	147	147	148	144
	r	0.141*	0.277***	0.392***	0.183*	0.151*	0.199*

*** p<0.001, ** p<0.01, * p<0.05.

Table 4 Partial correlation coefficients between physical strengths and GHQ scores adjusted for age

		Somatic symptoms	Anxiety/ insomnia	Social dysfunction	Severe depression
Grip strength (kg)	n	148	148	148	148
	r	-0.117	-0.100	-0.130	-0.052
Vertical jump height (cm)	n	143	143	143	143
	r	0.000	-0.084	-0.064	-0.173*
Jumping reaction time (sec)	n	143	143	143	143
	r	-0.006	0.022	0.133	-0.009
Time to stand up and sit down (sec)	n	148	148	148	148
	r	0.111	0.026	0.260***	0.106
Sit and reach distance (cm)	n	148	148	148	148
	r	-0.154*	0.054	0.009	0.014
Time of balancing on one leg with eyes closed (sec)	n	147	147	147	147
	r	-0.173*	-0.205*	-0.053	-0.046
Tapping score (beat/sec)	n	148	148	148	148
	r	-0.084	-0.088	-0.147*	-0.107

*** p<0.001, ** p<0.01, * p<0.05.

were significant negative correlations between jumping reaction times and spatial perception, manual dexterity, and finger dexterity. Vertical jump height was positively correlated with only one cerebral function, viz., finger dexterity. There was no significant correlation between time of balancing on one leg with eyes closed and any cerebral function.

Partial correlation coefficients between physical strength and GHQ scores adjusted for age are shown in Table 4. A significant negative correlation was found between vertical jump heights and severe depression. Time to stand up and sit down was positively correlated with social dysfunction. Sit and reach distance was negatively associated with somatic symptoms. Time of balancing on one leg with eyes closed was negatively correlated with somatic symptoms and anxiety/insomnia. There was a negative correlation between tapping scores and social dysfunction.

Discussion

The daily life activities of subjects of this study are believed to be higher than that of the general population of independent-living elderly women as they were members of a physical exercise class for the elderly or members of an elderly people's club. The results therefore possibly do not represent independent-living elderly women because of selection bias.

Significant negative correlations between age and many measurements of physical strength have been reported (19, 20). These results were confirmed in our study. Rubin et al. have investigated the influence of age on clinical and psychometric assessments in healthy elderly subjects, in patients with very mild and mild dementia of the Alzheimer type (21). They reported that age and the scores on quantitative clinical measures were not correlated, and that the scores did not vary among the three groups. In contrast, there were significant correlations between age and performance in many psychometric measurements such as memory, intelligence, and language skills in groups of healthy elderly individuals and those with very mild dementia.

Our results showed significant correlations between age and cerebral function as estimated by the GATB. Dexterity refers to the ability to use one's hands or the ability to manipulate objects with the hands (22). Poirier offered the most complete definition

of dexterity as a manual skill requiring rapid coordination of fine and gross movements based on a certain number of capacities developed through learning, training, and experience (23). In our study, manual dexterity, finger dexterity, and motor coordination were considered to be cerebral functions based on the psychomotor skill of complex activities involving cooperative movements of the fingers, hands, and arms. Psychomotor skills decrease with age (24), therefore we expected and found that these three cerebral functions were correlated with age more than the other three cerebral functions.

In order to assess dementia in the elderly, Hasegawa's Dementia Rating Scale (25) is often used in Japan, and the Mini-Mental State Examination (26) and PGC-MSQ (Philadelphia Geriatric Center Mental Status Questionnaire) (27) are used throughout the world. Unfortunately, it is usually difficult to diagnose early dementia using the conventional tests (28), although early diagnosis of dementia is important because recent advances in medicine have developed drugs that are expected to prevent or delay mental dysfunction (29, 30).

We tried to estimate cerebral function using the GATB. This battery of tests was developed by the USA Employment Service to measure cognitive, perceptual, and psychomotor work-related abilities (13). This instrument, commonly used for vocational counseling purposes in a government related setting, is a standardized test that measures a broad spectrum of aptitudes, many of which on a priori grounds, would be expected to be sensitive to central nervous system dysfunctions (31). We believed that the signs of early dementia that are not detected by using the ordinary tests might be found as decreased performance on tests that evaluate the higher cerebral functions such as the GATB. To assess the usefulness of the GATB as a tool to detect early dementia, an easy and rapid way is to compare the scores of subjects who have and do not have early dementia. However, it is difficult to detect subjects with early dementia with any other detective tools. To detect the signs of early dementia, therefore, a longitudinal study that follows subjects who have no dementia or hidden dementia with some possible detective tools is needed. The subjects in this study have high ADL and seem to have no obvious dementia. A follow-up study will be required to evaluate the validity of the GATB as a detective tool of early dementia.

Sasaki et al. reported that the mental health condition estimated by the GHQ scores is not related to age (32). Berkman et al. reported that age is associated with only a few symptoms of depression in physically healthy older persons, but older men and women with major disabilities and serious chronic conditions had substantially more symptoms of depression than those with no limitations (8). However, our results in independent-living elderly women showed significant positive correlations between age and severe depression and social dysfunction. Jorm reported that aging is associated with an intrinsic reduction in susceptibility to anxiety and depression (33), and Ohta observed that depression increased with age although marked changes were not found in the GHQ scores (34). However, we found a positive correlation between age and depression scores in the GHQ sub-scale, although no correlation was found between age and anxiety/insomnia scores. Aging decreases the social roles played by individuals although our subjects were independent-living women without any disabilities, and furthermore, aged individuals tend to have higher scores of social dysfunction on the GHQ sub-scales.

The physical strength requiring coordinated muscular movements of the legs, for example, the time to stand up and sit down, was significantly correlated with many cerebral functions. The physical strength necessary for simple tasks but requiring muscular movements of the fingers and hands such as grip strengths and tapping score was also significantly associated with many cerebral functions. To maintain good cerebral function, it is generally believed that it is important to stay physically strong. Kimura et al. reported that the regional cerebral blood flow in the frontal, parietal and occipital cortices of rats increases during slow walking (35). A hypothesis could be set forth that physical training to maintain the muscular strength of the legs, fingers and hands is

effective in maintaining good cerebral functions. Intervention studies that make the subjects continue physical training over a certain period are required to check the hypothesis.

We also found significant correlations between physical strength and the mental health as estimated by the GHQ scores. Body balance was negatively correlated with somatic symptoms and anxiety/insomnia. The task requiring muscular leg strength such as vertical jump height were significantly negatively correlated with severe depression scores. The mental health condition will affect everyday activities, and also physical strength. However, physical training to maintain body equilibrium or muscular leg strength could have a good effect on the mental health condition.

In conclusion, our cross-sectional study of 151 independent-living elderly women showed that physical strength, cerebral function and mental health condition were very closely interrelated. Physical strength and cerebral functions tended to decrease with age, and social dysfunction and severe depression on the GHQ sub-scales also tended to worsen with age. In order to seek effective ways to increase and maintain the QOL of the elderly, a causal relationship between physical strength and cerebral function or mental health condition should be examined by longitudinal studies with an intervention of physical training in elderly people.

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