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The Relationship between Physical Fitness and Ambulatory Activity in Very Elderly Women with Normal Functioning and Functional Limitations

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Abstract The effect of daily ambulatory activity on physical fitness has not yet been identified by quantitatively measuring the time spent on the intensity levels of ambulatory activity in elderly women over 75 with different functional capacity levels. The subjects consisted of 147 elderly women over 75 years old (82.8±4.3 years old) who were all capable of performing basic daily activities by themselves. Physical fitness was measured for 7 items (handgrip strength, knee extensor strength, postural stability, stepping, one-legged standing time with eyes open, 10 m walking, and the Timed Up and Go Test). The subjects wore a triaxial accelerometer for 2 consecutive weeks to measure their daily physical activities. The functional capacity level was assessed by the Tokyo Metropolitan Institute of Gerontology Index of Competence. The subjects were divided into two groups, a group with a score ≥10 points (high functional capacity group, n=59) and a score <10 points (low functional capacity group, n=88), and the relationship between physical fitness and physical activity was examined in both groups. In both the high and low functional capacity groups, 10 m walking, the Timed Up and Go Test, and one-legged standing time with eyes open significantly correlated with either the total steps/day or the ambulatory activity intensity. In the high functional capacity group, the knee extensor strength also significantly correlated with the total steps/day and moderate ambulatory activity. It is suggested that very elderly women with a reduced functional capacity should maintain their mobility by simply increasing their daily ambulatory activity. *J Physiol Anthropol Appl Human Sci 29(6): 211–218, 2010* http://www.jstage.jst.go.jp/browse/jpa
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Introduction

Japan has one of the highest average life expectancies and average active life expectancies in the world (World Health Organization, 2004). However, as the average life expectancy and average active life expectancy increases, the requirement for long-term care also increases, and this trend is especially prominent among women (Tsuji et al., 1995). Elderly women from 85–89 years old account for the highest percentage of persons requiring long-term care by sex and age (Ministry of Health, Labour and Welfare of Japan, 2007). Since a surge in the relative size of the very elderly population over 75 years old is expected in the future (National Institute of Population and Social Security Research, 2008), the strategies to prevent or shorten the period required for long-term care among very elderly women with a reduced functional capacity is considered to be important.

Regarding the lifestyle of the elderly, the physical activity (PA), which was assessed by questionnaire, has the strongest impact on active life expectancy while also influencing the onset of disability before death (Ferrucci et al., 1999). Many people who have a certified need for long-term care (CNLTC) also suffer a secondary functional decline caused by inactivity (Ministry of Health, Labour and Welfare of Japan, 2007b), and it is important to minimize the risk of these complications in order to maintain the mental, physical, and functional capacities. It is suggested that frail elderly persons (nursing home residents or day-care users) who actively perform PA should maintain a fairly good level of functioning (Shimada et al., 2002), and this applies to elderly persons with a reduced functional capacity.

Recently, a multicomponent exercise program (Taguchi et al., 2010) and an increase in the number of steps walked (Talbot et al., 2003) have together been reported to improve leg strength in elderly people with functional limitations. These studies suggest that long-term physical exercise of low-to-

moderate intensity and daily ambulatory activity (AA) are effective for maintaining and/or improving physical fitness and functional capacity in frail elderly persons. However, these studies do not clarify whether walking in daily life may also prevent or postpone a functional capacity disability (Keysor, 2003). Furthermore, precisely what kind of PA, which was based on the intensity of and time spent in daily walking, is effective for very elderly women with a reduced functional capacity for maintaining and/or improving their physical fitness and functional capacity remains to be elucidated. Activity monitoring based on accelerometry sensor is one of the useful methods for obtaining objective information on physical patterns and for estimating the related energy expenditure since it can continuously measure the intensity, duration, and frequency of daily activities. However, few reports have so far measured the time spent on the levels of PA intensity using an accelerometer to study the relationship with physical fitness in healthy independent elderly people (Aoyagi et al., 2009; Yoshitake et al., 2008; Gerdhem et al., 2008), and there are no reports on the study of very elderly women with a reduced functional capacity whose average age is over 80 years. Especially for an elderly person living at or near to their maximum functional level, it is suggested that a 10% to 20% increase in strength effectively postpones strength-related thresholds of performing daily tasks for another 10 to 20 years (Young, 1986). Therefore, it is important to measure the intensity and time spent on daily walking, and to ascertain the relationship between physical fitness and the time spent at AA intensity levels for maintaining and/or improving physical fitness and postponing the onset of disability in elderly people with functional limitations.

In this study, we examined the relationship between physical fitness and the time spent at AA intensity levels as measured by accelerometers in very elderly women over 75 years old who maintained their functional capacity and those who did not, in order to identify the impact of daily AA on physical fitness.

Methods

Subjects

A request for cooperation with the survey was sent to day-care centers in Isahaya City, in Nagasaki Prefecture, and elderly subjects comprised women over 75 years old who use services provided by 17 centers which had agreed to take part in the survey. Many of them had a reduced functional capacity and had CNLTC (support only). Elderly persons who maintain a functional capacity included, in addition to people using day-care services but not CNLTC, participants in a community support project, as well as residents of the welfare facilities for the elderly (e.g., low-cost homes). The selection criteria for the subjects included being able to carry out basic daily activities independently, with people of clinically higher risk (e.g., people with disease whose conditions were severe or had been unstable in the last 6 months) and patients with dementia excluded. The subjects were selected by nurses and physical therapists based on interviews and medical records.

Anthropometric measurements

The height and weight were measured to calculate the body mass index (BMI).

Measurement of physical fitness

Physical fitness was measured for 7 items (handgrip strength, knee extensor strength (KE), postural stability, stepping, one-legged standing time with eyes open (OLST), 10 m walking (10MWT), and the Timed Up and Go Test (TUG)) with sufficient rest between items; the measurements were made by the physical therapist. The measurement method for each item is as described below.

Handgrip strength

The Smedley dynamometer (GRIP-D; TAKEI, Niigata, Japan) was used. The strength of both the left and right hands was measured twice each in a standing position, and the average of the best scores of each hand was used.

Knee extensor strength (KE)

In an upright sitting posture and with the knee flexion at 90° degrees, the maximum isometric muscle strength of both the left and right legs was measured twice each using a dynamometer (GF-300; YAGAMI, Nagoya, Japan), and the best scores of each leg were added up and the total was then multiplied by the leg length and converted into torque measurements, which were then divided by the weight, and the resulting figure was taken as the measured value.

Postural stability

The subjects were asked to stand on the platform of the GRAVICORDER (GS-11; ANIMA, Tokyo, Japan) for 1 min with their feet placed together. Subjects were asked to place their hands at their sides and try not to move during measurement. The width of the shift of the position of the center of foot pressure (total path length) was used as the index.

One-legged standing time with eyes open (OLST)

The length of time for which subjects were able to stand on one leg with their hands placed on their waist was measured using a stopwatch. The left and right legs were measured twice each, and the maximum length of time was taken as the measured value. However, the maximum measuring time was set at 60 sec.

Stepping

The subjects were instructed to step alternatively as quickly as possible with each leg while in a sitting position for 10 sec. The number of steps was counted using a step counter (SP-7; YAGAMI, Nagoya, Japan). The stepping rate of the left and right leg was calculated for the measured valued.

10 m walking (10MWT)

The subjects were asked to walk as fast as possible along a 10 m straight line, with a 1 m approach at both ends, making a total length of 12 m. The time required was taken as the measured value.

Timed Up and Go Test (TUG)

This study evaluated a slightly modified version of the "Get-up and Go" test originally devised by Podsiadlo and Richardson (1991). During testing, the subjects were asked to walk "at a maximum walking speed" instead of "at a normal walking speed," but it had been confirmed by a previous study (Hashidate and Uchiyama, 2005) that this modification would not result in the relationship between TUG test scores and functional capacity being significantly different from the one to be identified as a result of the original test.

In addition, subjects who were unable to walk by themselves, or who had extreme difficulty in doing so, were allowed to use a walking aid to measure 10MWT and TUG.

Monitoring daily ambulatory activity

The daily AA was monitored using a waist-mounted triaxial accelerometer (Active style PRO HJA-350IT; OMRON, Kyoto, Japan). The subjects received accelerometers on the day of the test. Their activity from the time they got up until going to bed was continuously monitored for fifteen days. Of 13 days, with the 1st day and the 15th day being excluded, only those days with an activity time of ≥500 min/day were analyzed, and those with <7 days to be submitted for analysis were excluded as subjects. Items for analysis were the total steps and the time spent in AA (total, low, and moderate intensity), with all these indicated as an average value per day. The activity intensity was classified according to the measurement range of the accelerometer (intensity from 1–8), with the range of 1–2 (<about 3 METs) as low intensity and the range of 3–5 (about 3–6 METs) as moderate intensity. The high intensity activity (the range of 6–8) converted into average activity time was <1 min/day for all subjects and this was excluded from analysis. Previous reports have already estimated the validity of the accelerometer used in this study for identifying the type and intensity of various activities (Oshima et al., 2010; Ohkawara et al., 2007).

Functional capacity

The Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC) was used as the index of functional capacity. This index was developed to measure the high-level functional capacity of elderly people (Koyano et al., 1987), and its validity and reliability have already been confirmed (Koyano et al., 1991). The TMIG-IC index is widely used in Japan and it is assumed that a score of ≥10 points represents more or less independent functioning in daily life, while a score of <10 points indicates a higher risk of having functional difficulty in daily life (Fujiwara et al., 2003). Therefore, in this study, the subjects were classified into two groups, the high functional capacity group (TMIG-IC score of ≥10 points, HFG) and the low functional capacity group (TMIG-IC score of <10 points, LFG), and the relationship between physical fitness and PA was examined by group.

Statistical analyses

The physical characteristics of HFG and LFG were compared using an unpaired *t*-test, while a χ^2 test was used to identify the existence of subjects who had CNLTC and who had diseases. As the results of the Shapiro-Wilk test demonstrated that measurements of all activity items did not have a normal distribution, the relationship between physical fitness and PA was analyzed using Spearman's rank correlation coefficient. The statistical software SPSS 12.0J for Windows was used and all statistics were processed at a significance level of less than 5%.

Ethical issues

The details of the study were explained to all subjects and their family members in advance, and written consent was obtained from each subject. In addition, the study was approved by the Ethical Committee of the National Institute of Fitness and Sports in Kanoya.

Results

Physical characteristics

All data were obtained from 147 subjects (average age: 82.8±4.3 years). Characteristics of HFG (n=59) and LFG (n=88) are listed in Table 1. There was no significant difference between the 2 groups for age, height, weight, and BMI. However, the percentage of subjects who had CNLTC and disease were both significantly higher in LFG ($p<0.01$, Table 2).

Daily ambulatory activity

The average steps/day was significantly higher in HFG (2,416±2,055 steps/day) than in LFG (1,275±1,313 steps/day). The time spent in AA was 36.8±24.0 min/day in HFG and 24.4±18.8 min/day in LFG. Most AA was low intensity in both groups (Table 3).

Table 1 Comparison of characteristics between HFG and LFG

		HFG (n=59)	LFG (n=88)	*p* value
TMIG-IC	(scores)	11.6±1.1	6.9±2.0	<0.001
Age	(years)	82.0±3.6	83.4±4.6	0.054
Height	(cm)	145.0±6.1	144.3±6.9	0.486
Weight	(kg)	50.5±8.2	49.1±9.1	0.354
BMI	(kg/m^2)	23.9±3.0	23.6±3.7	0.521

Values are means±*SD*. n: Number of subjects. *p* values evaluate two groups (HFG and LFG) differences. HFG: High functional capacity group. LFG: Low functional capacity group. TMIG-IC: Tokyo Metropolitan Institute of Gerontology Index of Competence. BMI: Body mass index.

Table 2 Comparison of characteristics between HFG and LFG

	HFG (n=59)	LFG (n=88)
Persons who had CNLTC**	42 (n=25)	85 (n=75)
Support level 1	35 (n=21)	51 (n=45)
Support level 2	7 (n=4)	25 (n=22)
Care level 1	0 (n=0)	9 (n=8)
Persons who had chronic disease**	46 (n=27)	81 (n=71)
Bone and joint disease	25 (n=15)	50 (n=44)
Respiratory and circulatory disease	12 (n=7)	8 (n=7)
Neurological disease	2 (n=1)	9 (n=8)
Cerebrovascular disease	0 (n=0)	9 (n=8)
Others	7 (n=4)	5 (n=4)

Values are the percentages. n: Number of subjects. Significant difference between HFG and LFG (**: $p<0.01$). HFG: High functional capacity group. LFG: Low functional capacity group. CNLTC: Certified need for long-term care.

Table 3 Comparison of physical fitness and ambulatory activity between HFG and LFG

Measurements		HFG (n=59)	LFG (n=88)
Handgrip strength	(kg)	17.9±4.0	15.1±4.0
Knee extensor strength	(Nm/kg)	2.10±0.69	1.61±0.87
Postural stability	(cm)	121.6±53.4	163.0±95.8
OLST	(sec)	11.9±15.1	6.0±8.4
Stepping	(times/10 sec)	66.1±14.3	56.9±15.6
10 m walking	(sec)	9.0±3.5	14.6±10.6
Timed Up and Go Test	(sec)	10.2±3.4	15.1±8.4
Steps	(steps/day)	2,416±2,055	1,275±1,313
Ambulatory activity time			
Total	(min/day)	36.8±24.0	24.4±18.8
Light	(min/day)	29.6±16.6	22.5±16.5
Moderate	(min/day)	7.2±11.2	1.9±4.0

Values are means±SD. n: Number of subjects. HFG: High functional capacity group. LFG: Low functional capacity group. OLST: One-leg standing time with eyes open.

Relationship between physical fitness and ambulatory activity

In HFG, steps/day and moderate AA were significantly correlated to KE ($p<0.05$), OLST ($p<0.05$), 10MWT ($p<0.01$), and TUG ($p<0.01$), and Total AA was to 10MWT ($p<0.01$) and TUG ($p<0.01$), and Light AA was to TUG ($p<0.05$), respectively (Table 4). On the other hand, in LFG, steps/day, total AA, Light AA and moderate AA were all significantly correlated to OLST ($p<0.05$), 10MWT ($p<0.05$), and TUG ($p<0.05$), respectively (Table 5).

Discussion

As far as we know, our investigation is the first to attempt to examine the relationship between physical fitness and the time spent at AA intensity levels as measured by accelerometers in very elderly women over 75 years old who maintained their functional capacity and those who did not, in order to identify the impact of daily AA on physical fitness.

Table 4 Relationship between physical fitness and ambulatory activity in HFG

Measurements	Steps	Ambulatory activity time		
		Total	Light	Moderate
Handgrip strength	0.137	−0.091	−0.176	0.206
Knee extensor strength	0.277*	0.159	0.028	0.475**
Postural stability	−0.132	−0.221	−0.212	−0.239
OLST	0.323*	0.233	0.193	0.312*
Stepping	0.169	0.078	0.006	0.245
10 m walking	−0.681**	−0.415**	−0.235	−0.789**
Timed Up and Go Test	−0.716**	−0.475**	−0.326*	−0.782**

Spearman's rank correlation coefficient. Significant correlations: ** $p<0.01$, * $p<0.05$. HFG: High functional capacity group. OLST: One-leg standing time with eyes open.

Table 5 Relationship between physical fitness and ambulatory activity in LFG

Measurements	Steps	Ambulatory activity time		
		Total	Light	Moderate
Handgrip strength	0.142	0.102	0.076	0.146
Knee extensor strength	−0.018	−0.034	−0.045	0.055
Postural stability	−0.157	−0.159	−0.132	−0.185
OLST	0.396**	0.257*	0.222*	0.317**
Stepping	0.069	0.078	0.058	0.1
10 m walking	−0.486**	−0.313**	−0.269*	−0.463**
Timed Up and Go Test	−0.450**	−0.284**	−0.246*	−0.434**

Spearman's rank correlation coefficient. Significant correlations: ** $p<0.01$, * $p<0.05$. LFG: Low functional capacity group. OLST: One-leg standing time with eyes open.

In this study of very elderly women with LFG, no relationship was observed between AA and KE, but there was a significant relationship between balance ability and mobility (10MWT, TUG). On the other hand, in HFG, it was found that AA was significantly related to KE, balance ability, and mobility, with the relation to mobility being particularly higher. These results suggest that the difference in daily AA affects the relationship between physical fitness and mobility.

Physical characteristics

The average of age did not differ significantly between the two groups. The percentage of people having CNLTC and that had a disease were 42% and 46%, respectively, in HFG and 85% and 81%, respectively, in LFG, with both being significantly higher in LFG. From these results, it was assumed that the two groups had different characteristics in terms of functional capacity and disease. In particular, it was found that more than 80% of the subjects in LFG had CNLTC (in most cases, support level) for several diseases or disability.

Daily ambulatory activity

The steps/day were significantly higher in HFG (2,416±2,055 steps/day) than in LFG (1,275±1,313 steps/day). In the National Health and Nutrition Survey Japan, 2006 (Ministry of Health, Labour and Welfare of Japan, 2006), the total steps/day of very elderly women over 75 years old was 3,273±3,116 steps/day, and up to 44.8% of them took less than 2,000 steps/day. In addition, in a study of the elderly similar to our LFG in terms of age and level of disability, the steps/day were reported to be no more than 1,000 steps/day (Taguchi et al., 2010). Because the steps/day in the present study, in both HFG and LFG, were less than the average steps/day of elderly women in general in previous reports, it was assumed that the subjects in this study were elderly people with fewer daily AA.

A high value standard deviation of the total steps/day, which indicates the large interindividual variation in the total steps/day, was observed on both HFG and LFG in this study. The results of our study were similar to those of the National Health and Nutrition Survey Japan, 2006 (Ministry of Health, Labour and Welfare of Japan, 2006), and in this report the large interindividual variation is assumed to be associated with chronic illnesses and disabilities, and characteristics of elderly women over 75 years old. Recently, Tudor-Locke et al. (2009) reviewed the steps/day pertinent to free-living special people living with chronic illness and disability and has demonstrated that the steps/day varied in these people. Therefore, it is likely that chronic illnesses and disabilities bring about large interindividial variations in the steps/day in this study (Asai et al., 2001).

Some reports have indicated that a pedometer or accelerometer may underestimate the actual steps taken by elderly people who have disease and walk at a slow speed, as with the subjects in this study (Storti et al., 2008; Elsworth et al., 2009). However, it has also been reported that a triaxial accelerometer would be better suited than a pedometer to count shuffling steps and slow speed, such as patients with Parkinson's disease (Dijkstra et al., 2008) and, furthermore, that a piezoelectric sensor can accurately calculate the number of steps taken by an individual at slow speed (Melanson et al., 2004). The triaxial accelerometer (piezo-type) was used in the present study, and it was confirmed that this accelerometer could calculate the number of steps when subjects were walking at 0.4–0.5 m/s in our pilot study (not reported). Therefore, although the possibility that the number of steps in this study may have been underestimated compared to general elderly people is not ruled out, it is nevertheless assumed that the results appropriately reflected the level of AA of the subjects in this study.

Relationship between physical fitness and ambulatory activity

Recently, physical activity has been suggested as one of the highest priorities for preventing and treating disease and disability in older adults in the American College of Sports Medicine (ACSM) and American Heart Association (AHA) recommendations (Nelson et al., 2007). ACSM/AHA has recommended moderate-intensity (3 METs) aerobic activity, but it is uncertain whether such moderate-intensity activity is actually necessary for maintaining physical fitness in very elderly people with normal functioning and functional limitations.

Regarding LFG, both the total steps and the time spent in AA significantly correlated with OLST, 10MWT, and TUG, but not with KE. On the other hand, in HFG, it was found that OLST, 10MWT, TUG, and KE significantly correlated with either the steps/day or the time spent in AA; moreover, these correlation coefficients tended to be higher, in comparison to LFG. These results suggest that, regardless of the level of functional capacity, the daily AA was associated with mobility, and additionally, as the steps/day increases and the percentage of the high intensity walking also increases (Yoshitake et al., 2008), and thus the relevance to leg strength and mobility becomes higher.

Other studies (Aoyagi et al., 2009; Yoshitake et al., 2008) of general elderly people over 75 years old reported that both the steps/day and time spent in moderate intensity activity have a significant positive correlation with both KE and maximum walking speed. In addition, a 5-year follow-up study (Rantanen et al., 1997) of elderly women in general who were 75 years, showed that an increase in daily PA caused an increase in KE, while a decrease in PA caused a decrease in KE. Additionally, in middle-aged and older women, it was shown that the greater the steps/day, the greater the percentage of the time spent in moderate-intensity AA, thus making its relevance higher (Yoshitake et al., 2008; Yamamoto et al., 2007). These factors thus support that, in HFG, both the steps/day and the moderate intensity AA significantly correlated with leg strength and mobility.

On the other hand, a study (Puthoff et al., 2008) of elderly people with minor disabilities demonstrated that both the steps/day and the total walking distance per day were significantly related to leg strength or power. Although the study included elderly men and made no reference to the intensity of the AA, the findings suggested that people with more daily AA had stronger leg strength. It is certain that, for elderly people with disabilities, the disability as well as its severity have no small impact on their physical fitness. However, as the frequency of going outdoors amongst the elderly tends to decrease, they also simultaneously suffer secondary functional decline caused by inactivity (disuse syndrome), leading to the assumption that inactivity may have a large impact (Tsuneyoshi et al., 2008). In fact, previous studies (Rand et al., 2009; Mudge and Stott, 2009) of middle-aged and older people after stroke reported that people with more daily PA had higher mobility. In addition, in a study (Talbot et al., 2003) of elderly people with osteoarthritis of the knee, it was observed that leg strength and walking ability had improved by increasing some 1,000 steps/day. These studies suggest that daily AA effectively maintains and improves physical fitness even for elderly people who have a disease or

disability.

As a significant relationship was observed in this study between mobility and AA in 2 groups of different levels of functional capacity and disability, it is assumed that, for a majority of very elderly women, regardless of disability level, daily AA has a large impact on their mobility. It has been suggested that a program using exercise intervention would be necessary to maintain and improve the physical fitness and physical functional capacity of frail elderly persons (Taguchi et al., 2010; Worm et al., 2001), but no relationship between the steps/day and the physical fitness or mobility has yet been demonstrated. However, Taguchi et al. (2010) implemented a multicomponent program of low-to-moderate intensity exercises for 12 months and reported that not only did the KE of the people who had CNLTC improve but their walking ability had also been maintained; they thus adopted a walking equivalent to 3 METs as an exercise program. For elderly around 80 years of age and very elderly persons with a significantly reduced physiological reserve, even an activity that has more or less 3 METs, such as walking, may have a moderate-to-higher exercise load (Paterson et al., 2007; Young, 1986). In LFG, there was a significant relationship with OLST. To stand on one leg for sustained periods, leg muscle strength plays a critical role in especially elderly persons with reduced leg strength (Kasahara et al., 2001). This would imply that AA plays a role in maintaining leg strength in LFG. From these findings and those of the present study, AA which is below 3 METs is assumed to not worsen pain and/or inflammation and it is recommended for frail older women with a reduced functional capacity as a means to maintain and improve mobility, and that this effect can also be expected even with a slower walk or with a walking aid.

Limitations and summary

There are several limitations in this study. First, as the relationship between physical fitness and PA was examined from a cross-sectional study in nature, it was difficult to prove any causal relationship. Consequently, it would be possible that changes in mobility and leg strength may have affected daily AA. Second, the subjects in this study were all women, and it is not clear whether the results of this study could also apply to very elderly men. Furthermore, this study did not sufficiently consider the influence of disease and disability, as well as their severity. Therefore, a study including only male subjects and examining each disease or its severity will be necessary in the future, using a longitudinal or an interventional study.

In summary, for very elderly women who maintain their functional capacity, a relationship was confirmed between daily AA and physical fitness (mobility and leg strength), in that the higher the AA intensity became, the stronger the relationship with physical fitness became. Therefore, it is assumed that the daily AA may effectively maintain and improve not only mobility, but also leg strength, and its effect will further increase when the percentage of brisk walking increases. In addition, for very elderly women with a reduced functional capacity, it was found that the longer the activity time even with slow walking, the higher their mobility became. Therefore, it is assumed that simply increasing the AA may improve maintenance mobility.

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