McNemer's test. Fisher's exact test was used to compare the positive change in the DVS subgroup scoring 1–3 between the two groups. We compared differences in the improvement rate of walking and exercise frequency, and self-rated health between the groups using the Z-test. Interaction effects were analyzed using a two-way repeated measure analysis of variance. All data were analyzed using SPSS version 11.5 J for Windows XP, and the level of significance was set at 5%.

The study was approved by the Ethics Committee of Showa Women's University, Tokyo, Japan. All subjects provided written informed consent before being enrolled in the study.

Results

Baseline characteristics and attendance rate

Table 1 compares the baseline characteristics between the intervention and control groups. Compared with the

Table 2 Main outcomes in the intervention group and the control group

Outcomes		Intervention				Control				Between-groups
Food frequency, n (%)		Almost every day	3-4 days/ week	0-2 days/ week	P	Almost every day	3-4 days/ week	0-2 days/ week	P	P
Meat	Pre	12 (21.1)	21 (36.8)	24 (42.1)	0.002[a]	9 (25.7)	13 (37.1)	13 (37.1)	1.000[a]	
	Post	23 (40.4)	21 (36.8)	13 (22.8)		7 (20.0)	17 (48.6)	11 (31.4)		
Fish/Shellfish	Pre	23 (40.4)	23 (40.4)	11 (19.3)	0.020[a]	17 (48.6)	11 (31.4)	7 (20.0)	1.000[a]	
	Post	28 (49.1)	26 (45.6)	3 (5.3)		16 (45.7)	13 (37.1)	6 (17.1)		
Eggs	Pre	19 (33.3)	13 (22.8)	25 (43.9)	0.010[a]	10 (28.6)	12 (34.3)	13 (37.1)	0.527[a]	
	Post	24 (42.1)	20 (35.1)	13 (22.8)		8 (22.9)	14 (40.0)	13 (37.1)		
Milk	Pre	29 (50.9)	10 (17.5)	18 (31.6)	0.075[a]	20 (57.1)	6 (17.1)	9 (25.7)	1.000[a]	
	Post	35 (61.4)	8 (14.0)	14 (24.6)		19 (54.3)	8 (22.9)	8 (22.9)		
Soybean products	Pre	30 (52.6)	17 (29.8)	10 (17.5)	0.278[a]	17 (48.6)	11 (31.4)	7 (20.0)	0.822[a]	
	Post	34 (59.6)	15 (26.3)	8 (14.0)		16 (45.7)	12 (34.3)	7 (20.0)		
Green& Yellow vegetables	Pre	40 (70.2)	14 (24.6)	3(5.3)	0.491[a]	21 (60.0)	9 (25.7)	5 (14.3)	0.782[a]	
	Post	42(73.7)	13 (22.8)	2(3.5)		21 (60.0)	8 (22.9)	6(17.1)		
Potatoes	Pre	9 (15.8)	20 (35.1)	28 (49.1)	0.019[a]	8 (22.9)	13 (37.1)	14 (40.0)	0.225[a]	
	Post	15 (26.3)	25 (43.9)	17 (29.8)		6 (17.1)	12 (34.3)	17 (48.6)		
Fruits	Pre	42 (73.7)	9(15.8)	6(10.5)	0.029[a]	16 (45.7)	9 (25.7)	10 (28.6)	0.593[a]	
	Post	48 (84.2)	6:(10.5)	3 (5.3)		14 (40.0)	11 (31.4)	10 (28.6)		
Seaweeds	Pre	15 (26.3)	23 (40.4)	19 (33.3)	0.001[a]	7 (20.0)	17 (48.6)	11 (31.4)	0.674[a]	
	Post	28 (49.1)	21 (36.8)	8 (14.0)		10 (28.6)	13 (37.1)	12 (34.3)		
Fats & Oil	Pre	23 (40.4)	23 (40.4)	11 (19.3)	0.057[a]	13 (37.1)	12 (34.3)	10 (28.6)	0.858[a]	
	Post	33 (57.9)	16 (28.1)	8 (14.0)		10 (28.6)	17 (48.6)	8 (22.9)		
Food Frequency Score(FFS) mean ± SD	Pre		21.5 ± 3.7		0.000[b]		21.1 ± 5.4		0.631[b]	0.002[c]
	Post		23.9 ± 3.9				20.8 ± 4.3			
Dietary variety Score(DVS) mean ± SD	Pre		4.2 ± 2.3		0.001[b]		3.9 ± 2.9		0.328[b]	0.004[c]
	Post		5.4 ± 2.6				3.6 ± 2.2			
Positive change in DVS 1–3 Score group, n (%)			11 (55.0)				3 (18.8)			0.041[d]
		5-7 days	2-4 days	0-1 day	P	5-7 day	2-4 days	0-1 day	P	P
Walking, n (%)	Pre	35 (61.4)	7 (12.3)	15 (26.3)	0.664[a]	16 (45.7)	11 (31.4)	8 (22.9)	0.348[a]	n.s.[e]
	Post	31 (54.4)	17 (29.8)	9 (15.8)		14 (40.0)	10 (28.6)	11 (31.4)		
Exercise, n (%)	Pre	23 (40.4)	19 (33.3)	15 (26.3)	0.678[a]	17 (48.6)	6 (17.1)	12 (34.3)	1.000[a]	n.s.[e]
	Post	20 (35.1)	28 (49.1)	9 (15.8)		14 (40.0)	12 (34.3)	9 (25.7)		

Wilcoxon signed-rank test[a] for within-groups difference of categorical variables.
Student's t-test[b] for between-group difference of continuous variables.
Two-way Repeated-Measures ANOVA[c] for the time-by-group interaction of continuous variables.
Fisher's exact test [d] for between-group difference proportional variables.
Z-test[e] for between-group differences of improvement rate about categorical variables. P > 0.05; Z-score > 1.96.

control group, the intervention group had a significantly higher score (p = 0.014) for social roles on the TMIG Index of Competence, but no other significant differences were seen between the two groups. The participants were predominantly female (79.8%) as is typical for social programs in Japan [29], and all participants were previously unaware of the TAKE10! program. The mean attendance rate for the intervention classes was 68.1% (range 41– 95%). Eight subjects attended only the first general lecture on importance of dietary variety because of a lack of interest in the exercise programs (n = 3) and schedule conflicts (n = 5). Forty-one subjects (71.9%) participated in more than 3 sessions.

Outcomes measures

Compared to baseline, significant increases were seen in post-intervention food intake frequency for 6 food groups (meat p = 0.002; fish/shellfish p = 0.02; eggs p = 0.01; potatoes p = 0.019; fruits p = 0.029; and seaweed p = 0.001) , FFS (p = 0.000), and DVS (p = 0.001) in the intervention group, and interaction effects of FFS (F(1, 90) = 10.582, p = 0.002) and DVS (F(1,90) = 8.968, p = 0.004) were seen between the two groups. A significant difference was seen in the percentage of participants scoring 1–3 between the groups (p = 0.041) (Table 2), but no significant difference was observed between baseline and post-intervention in the control group (Table 2). Frequency of walking and stretching and muscle strengthening exercises did not change compared to baseline in either group and no significant differences were seen between two groups (walking, Z = 1.918; exercise, Z = 0.204) (Table 2).

Self-rated health was also significantly improved over baseline in the intervention group (p = 0.033), but no difference in the improvement rate was observed between the groups. Appetite and TMIG Index of Competence score did not change between baseline and post-intervention in either group (Table 3).

As shown in Tables 4 and 5, similar effects were observed for food intake frequency, FFS, DVS, and self-rated health in the crossover intervention group compared to the original intervention group. Compared to baseline, significant increases were seen in post-intervention food intake frequency for 8 food groups (meat p = 0.005; eggs p = 0.002; milk p = 0.021; soybean products p = 0.016; green & yellow vegetables p = 0.008; potatoes p = 0.003; fruits p = 0.013; and seaweed p = 0.011), FFS (p = 0.000), and DVS (p = 0.000) in the crossover intervention group. Self-rated health significantly improved (p = 0.025), and with regard to physical activity, frequency of walking did not change but frequency of exercise significantly improved in the crossover intervention group post-intervention.

Table 3 Secondary outcomes in the intervention group and control group

Outcomes		Intervention			*P*	Control			*P*	Between-groups
		mean ± SD				mean ± SD				*P*
TMIG Index of Competence	Pre	12.4 ± 1.1			0.083[a]	11.9 ± 1.4			0.571[a]	0.810[b]
	Post	12.5 ± 0.8				12.0 ± 1.5				
Self-maintenance	Pre	4.9 ± 0.2			0.146[a]	4.9 ± 0.3			0.422[a]	
	Post	5.0 ± 0.0				4.9 ± 0.2				
Intellectual activity	Pre	3.7 ± 0.6			0.279[a]	3.8 ± 0.5			0.763[a]	
	Post	3.9 ± 0.4				3.8 ± 0.5				
Social roles	Pre	3.8 ± 0.5			0.563[a]	3.3 ± 1.1			0.864[a]	
	Post	3.7 ± 0.6				3.2 ± 1.3				
		yes, n (%)			*P*	yes, n (%)			*P*	
Appetite	Pre	55 (96.5)			1.000[c]	32 (91.4)			0.625[c]	
	Post	56(100.0)				34 (97.1)				
		Very good n (%)	Good n (%)	Not good n (%)	*P*	Very good n (%)	Good n (%)	Not good n (%)	*P*	*P*
Self-rated health	Pre	7 (12.3)	41 (71.9)	9 (15.8)	0.039[d]	3 (8.6)	26 (74.3)	6 (17.1)	1.000[d]	n.s.[e]
	Post	12 (21.1)	40 (70.2)	5 (8.8)		3 (8.6)	26 (74.3)	6 (17.1)		

TMIG Tokyo Metropolitan Institute of Gerontology, *SD* standard deviation.
[a]Paired t-test for within-groups difference of continuous variables.
[b]Two-way Repeated-Measures ANOVA for the time-by-group interaction of continuous variables.
[c]McNemer's test for within-groups difference of proportional variables.
[d]Wilcoxon signed-rank test for within-groups difference of categorical variables.
[e]Z-test for between-group difference of improvement rate for categorical variables. P > 0.05; Z-score > 1.96.

Table 4 Main outcomes in the crossover intervention group

Outcomes		Almost every day	3-4 days/week	0-2 days/week	P
Food frequency, n (%)					
Meat	Pre	6 (20.7)	15 (51.7)	8 (27.6)	0.005[a]
	Post	13 (44.8)	12 (41.4)	4 (13.8)	
Fish/Shellfish	Pre	12 (41.4)	11 (37.9)	6 (20.7)	0.197[a]
	Post	15 (51.7)	10 (34.5)	4 (13.8)	
Eggs	Pre	6 (20.7)	14 (48.3)	9 (31.0)	0.002[a]
	Post	16 (55.2)	10 (34.5)	3 (10.3)	
Milk	Pre	15 (51.7)	7 (24.1)	7 (24.1)	0.021[a]
	Post	22 (75.9)	2 (6.9)	5 (17.2)	
Soybean products	Pre	13 (44.8)	11 (37.9)	5 (17.2)	0.016[a]
	Post	21 (72.4)	6 (20.7)	2 (6.9)	
Green & Yellow vegetables	Pre	17 (58.6)	6 (20.7)	6 (20.7)	0.008[a]
	Post	24 (82.8)	4 (13.8)	1 (3.4)	
Potatoes	Pre	5 (17.2)	9 (31.0)	15 (51.7)	0.003[a]
	Post	14 (48.3)	8 (27.6)	7 (24.1)	
Fruits	Pre	11 (37.9)	9 (31.0)	9 (31.0)	0.013[a]
	Post	18 (62.1)	5 (17.2)	6 (20.7)	
Seaweeds	Pre	10 (34.5)	10 (34.5)	9 (31.0)	0.011[a]
	Post	16 (55.2)	10 (34.5)	3 (10.3)	
Fats & Oil	Pre	10 (34.5)	13 (44.8)	6 (20.7)	0.115[a]
	Post	15 (51.7)	10 (34.5)	4 (13.8)	
Food Frequency Score (FFS), mean ± SD	Pre		20.9 ± 4.5		0.000[b]
	Post		24.7 ± 5.1		
Dietary variety Score (DVS), mean ± SD	Pre		3.6 ± 2.3		0.000[b]
	Post		6.0 ± 3.2		
Positive change in DVS 1–3 Score group, n (%)			7 (53.8)		
		5-7 days	2-4 days	0-1 day	P
Walking, n (%)	Pre	12 (41.4)	10 (34.5)	7 (24.1)	0.090[a]
	Post	15 (51.7)	11 (37.9)	3 (10.3)	
Exercise, n (%)	Pre	13 (44.8)	10 (34.5)	6 (20.7)	0.026[a]
	Post	21(72.4)	4 (13.8)	4 (13.8)	

Wilcoxon signed-rank test[a] for within-groups difference of categorical variables.
Paired t-test[b] for within-groups difference of continuous variables.

Discussion

The TAKE10!® for Older Adults program at community centers appears to have improved dietary habits among community-dwelling older adults. In addition to the food intake frequency for 6 food groups, FFS and DVS were significantly increased in the intervention group, suggesting that the participants' dietary habits changed and that dietary variety was greater than before. Increases in the frequency of intake of high-protein foods and high-fiber foods were especially positive results and may help older Japanese adults to maintain good nutritional status. There were no changes in BMI ($p = 0.561$) or appetite ($p = 1.000$) seen in the intervention group, which indicates that it was the quality not quantity of food intake in their diets that changed. The fact that 55% of participants with a baseline DVS of 1–3 improved to a post-intervention score of ≥4 indicates their risk of a decrease in higher-level functional capacity had been lowered. In addition, the interaction effects of FFS and DVS and similar results seen in the crossover intervention group indicate the efficacy of this intervention program on dietary habits.

Physical activity and good nutritional habits are important to helping community-dwelling older adults avoid or delay the need for long-term nursing care [30]. Because of difficulties in evaluating nutritional programs for older

Table 5 Secondary outcomes in the crossover intervention group

Outcomes			mean ± SD		P
TMIG Index of Competence	Pre		12.0 ± 1.7		0.869[a]
	Post		12.0 ± 1.6		
Self-maintenance	Pre		4.7 ± 0.2		0.326[a]
	Post		5.0 ± 0.0		
Intellectual activity	Pre		3.9 ± 0.7		0.083[a]
	Post		3.7 ± 0.6		
Social roles	Pre		3.2 ± 1.4		0.846[a]
	Post		3.2 ± 1.2		
			yes, n (%)f		**P**
Appetite	Pre		28(96.6)		1.000[a]
	Post		28(96.6)		
		Very good, n (%)	**Good, n (%)**	**Not good, n (%)**	**P**
Self-rated health	Pre	1 (3.4)	23 (79.3)	5 (17.2)	0.025[b]
	Post	5 (17.2)	20 (69.0)	4 (13.8)	

TMIG Tokyo Metropolitan Institute of Gerontology, *SD* standard deviation.
[a]Paired t-test for within-groups difference of continuous variables.
[b]Wilcoxon signed-rank test for within-groups difference of categorical variables.

adults, few studies on such programs have been conducted to date. However, some studies have shown associations between dietary variety and nutritional status [23,24,31], quality of life [30,32], and physical and cognitive function [33,34]. It is clear that promoting dietary variety is one of the best ways to maintain proper nutritional status among older adults. Moreover, in a super-aging society like Japan, there is an urgent need for social programs that are easy to implement and follow and that do not require individual advice and attention from professionals.

It was interesting that frequency of walking and doing stretching and muscle strengthening exercises did not change even in the intervention group. Some possible reasons are that, first, the end point of this intervention was during the coldest time of year in Japan, and many people undoubtedly preferred to stay indoors. Second, at baseline, 78% participants were already in the habit of walking or engaging in exercise 5 days per week, and in this community attending radio calisthenics (*"rajio taisou"*) broadcasts in nearby parks is very popular. Third, 8 (14%) subjects did not participate in the sessions beyond the first lecture and another 8 (14%) subjects participated in fewer than 3 sessions, so they might not have been interested in our program and thus not have mastered the exercises enough to perform them at home without assistance. However, in response to the question in the post-intervention questionnaire "Did you do TAKE10 exercises at home?" 83% participants answered "Yes", and to "How many days did you do them a week?" 78% participants answered "every 2 days or more". In the winter, it is possible that some participants replaced their attendance of the radio calisthenics broadcasts with TAKE10 exercise as it was more difficult to go outside. In addition, significant differences were observed in the frequency of exercise in the crossover intervention group, suggesting the possibility of intervention effects on physical activity.

Self-rated health improved in the intervention group compared to baseline, although a significant difference in improvement rate was not seen between groups. Self-rated health is a global measure of health, and many studies have shown correlations with relative risk of mortality [35-38], well-being, and functional capacity [39]. For community-dwelling older adults, self-rated health is a possible indicator of quality of life. However, the observed effect may have been the result of not only attending this program, but also simply gathering together with other members of the community.

This study has several limitations. First, the study design was not an ideal randomized control trial. In order to eliminate transportation barriers to participation in this program, participants were assigned to groups according to their home address. In addition, to secure the same floor conditions at the 6 community centers, randomization was conducted before recruitment. Therefore, the two groups differed in the number of participants at baseline. However, as shown in Table 1, there were no significant differences between the two groups in the variables measured at baseline. Also, we compared the 3 baseline measures (sex, age, and TMIG Index of Competence) between the 6 clusters and no significant differences were seen. The sample size was less than the ideal 50 participants per group, and as the participants were recruited through the ward's bulletin, participants who enrolled might have been more motivated and health conscious. This might also explain the large percentage of female participants [29]. Other recruitment methods should be considered in future studies.

Although we did not examine behavioral stage and self-efficacy, we did find some behavior changes among the participants. In response to "Did your awareness of diet change after participating in this program?" 94% participants answered "Yes", indicating that behavioural stage or self-efficacy might have changed, although we did not evaluate this scientifically. In addition, we used the TAKE10!® Check Sheet and the TAKE10!® Calendar only as tools to motivate participants and not to measure outcomes. The tools could be used to evaluate behavioral aspects in future studies. Also, seasonal changes in participant behavior were not considered and the intervention program did not reflect this. The program started in autumn which is a good season for outdoor exercise, walking, and eating, but ended in mid-winter.

Our main outcomes on diet do not indicate the quantity of food consumed from each food group, and we did not evaluate participants' nutritional status using biochemical indicators. From our findings, we can estimate changes in dietary habits, but cannot indicate definite effects on health. In addition, it is necessary that good habits be maintained to observe the effects. However, we did not examine how long the behavioral changes continued following the intervention. We also did not measure how much physical fitness improved as a result of the exercise training undertaken by the intervention group. Further studies are therefore needed to confirm the effects of this program.

Ultimately, we consider this intervention program to be the first step toward introducing more healthy lifestyles to community-dwelling older adults, with its focus on improving their self-management abilities and aiming to increase the health status of the community as a whole. We believe the program can serve as an important form of social support that contributes to meeting present and future healthcare challenges. Personalized programs tailored to each individual's abilities, behavioral stage, and environment would be a good next step.

Conclusions

The social health program conducted at community centers incorporating the TAKE10!® for Older Adults program resulted in improved dietary habits—as measured by food intake frequency, FFS, and DVS—and may improve self-rated health among community-dwelling older adults.

Additional files

Additional file 1: Appendix 1. Contents of the TAKE10!® booklet.
Additional file 2: Appendix 2. The TAKE10!® Calendar.
Additional file 3: Appendix 3. The TAKE10!® Check Sheet.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MK, SKu, TF, SA, SKi, and TS developed the intervention program "TAKE10!® for Older Adults". MK, AM, SKu, and SKi contributed to the conception and design of this study. MK, SKu, and SA supervised and conducted the study. MK and AM interpreted the data and prepared the paper, and TS reviewed it for accuracy. All authors contributed to reviewing and approving the final version of the paper.

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―― 総　説 ――

高齢者の健康に関する科学的根拠を考える

Scientific Evidences on the Health of the Elderly

鈴木　隆雄

Takao Suzuki

長寿化と疫学的転換

日本人の平均寿命は，1960年代には欧米先進諸国とほぼ同じ程度であったが，その後高度経済成長による国民一人一人の経済状況の向上が，日常の生活のありよう（ライフスタイル）を大幅に変え，多くの面で健康状態の改善に結びついたことは明白な事実である。われわれ，日本人も含めて，近代化とともに寿命が伸長した過程は，疫学的転換（epidemiologic transition）として理論的に整理されている。それは感染症の撲滅を主要な原因とした死因構造の変化にともなう死亡率低下の過程である。理論の中では人類の死亡の歴史を四段階に分けている（表1）。このような疫学的転換は人々の生存確率を変え，ライフサイクルの姿をまったく違ったものにした。それによって人生の時刻表は大きく変わるとともに，社会経済全体をも変えることとなった[1~3]。

日本では少子化と長寿化が重なることにより，世界でも飛び抜けた人口高齢化を経験することになる。その中で長寿化は，より高い年齢層の割合を増大させる効果をもち，いわゆる高齢人口の高齢化を引き起こすことになる。具体的には，虚弱化が顕著となる後期高齢者の著しい増加である。もうひとつの見過ごすことのできない問題は，今後の高齢化率の伸びが著しく現れるのが大都市圏という点である。農村部などの地方と異なり，大都市圏には特有の高齢者を取り巻く環境（高齢者世帯や一人暮らし等）が存在し，今後のソーシャルサポート等の問題がより顕在化してくる。

本論では，このようなわが国の直面するいわば超高齢社会において，高齢者の健康水準がどういう状況にあるのか，高齢期における疾病予防と介護予防はどう調整しておくべきなのかなどの視点から，今後の健康福祉施策についての糸口を提示したいと考えている。

現在の日本人高齢者の健康水準の変容

東京都老人総合研究所（現・地方独立行政法人東京都健康長寿医療センター研究所）では，1991年から‘老化に関する長期縦断研究’（TMIG-LISA）を開始し，現在も毎年追跡している[4]。この長期縦断研究で設定したコホート（cohort）は，65歳以上の地域高齢者の集団で，1992～2002年の10年間のデータを用いて，1992年の古い高齢者集団と2002年の新しい集団との比較である。すなわち，新しい高齢者集団がどのくらい若返っているのかを探索的に分析すると，多くの身体機能や生活機能に関連する測定値について，2002年の65歳以上の高齢者での分布は，1992年の65歳以上の高齢者の分布に比べて右側（すなわち，より高い能力）にシフトしていることが明らかとなる。そこで，2002年の65歳以上の集団から，（測定値が低下し左に分布がシフトする）66歳以上のどの集団の分布が1992年の65歳以上の高齢者集団の分布と一致するか，つまり2002年の何歳以上の集団が1992年の65歳以上の集団と平均値に差がなく，分散にも差がない分布を示すかを，統計学的に検証した[5]。

その結果を示すデータが表2である。例えば握力については，1992年の65歳以上の集団の平均値と

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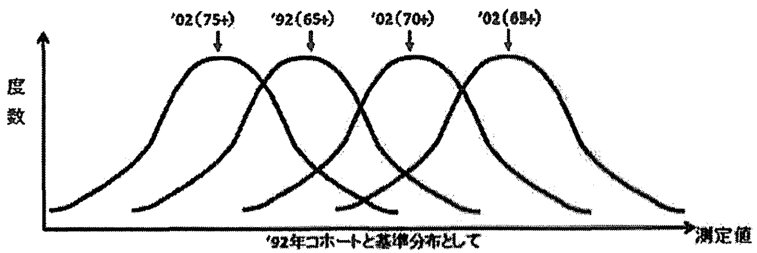
表1　疫学転換（Omran 1971, Olshansky & Ault; 1986）

Ⅰ．疾病蔓延と飢死の時代（the Age of Pestilence and Famine）
Ⅱ．慢性的疾病蔓延の終息期（the Age of Receding Pandemics）
Ⅲ．変性疾患（生活習慣病など）の時代（the Age of Degenerative and Man-Made Diseases）……戦後の先進国，平均寿命50年以上（～75年）
Ⅳ．変性疾患（生活習慣病など）遅延の時代（the Age of Delayed Degenerative Diseases……現代の先進諸国，平均寿命75年以上

表2　1992年コホートのデータと2002年コホートの年齢別層化データをマッチング



2002年コホートの年齢は，65歳以上の1992年コホートの測定値分布と類似している。

測定値	平均値±SD			統計値			
	1992（≦65歳）	2002（類似分布の年齢）		$F^{1)}$	p値	$t^{2)}$	p値
握力							
男性	30.2±6.9	69＋	30.0±6.6	1.925	0.166	0.278	0.781
女性	18.2±4.9	75＋	18.2±5.3	1.405	0.236	0.013	0.990
Stork standing(片足立ち)							
男性	36.6±24.0	69＋	36.8±23.0	5.155	0.024*	-0.127	0.899
女性	25.6±23.0	68＋	25.8±22.1	2.027	0.155	-0.167	0.868
通常歩行速度							
男性	1.16±0.27	76＋	1.17±0.30	1.861	0.173	-0.304	0.761
女性	1.00±0.27	76＋	1.00±0.27	0.030	0.863	-0.037	0.970
最高歩行速度							
男性	1.92±0.44	69＋	1.92±0.42	1.564	0.212	-0.012	0.990
女性	1.56±0.40	73＋	1.55±0.38	1.910	0.167	0.312	0.755

1) コホートの分散のF検定，2) 平均差のt検定，3) ＊ $p<0.05$

分散に有意差なく重なる集団は，2002年の男性69歳以上の集団および女性75歳以上の集団であることが分かる。このことは，今日の高齢者は10年前の高齢者に比べて，握力でみる限り男性は4歳若返り，女性は10歳若返ったことを意味している。バランスの能力を測定する'開眼片足立ち時間'においても，男性と女性でそれぞれ4歳と3歳若返っている。また通常歩行速度は，男性女性とも11歳若返っており，わずかこの10年間で大きな健康水準の変化が生じていることを示している。

今後，団塊の世代が高齢者集団を形成することになれば，これまでのさまざまなデータから類推して，より健康な（若返った）集団となることが予想される。したがって，今後高齢者のあらゆる面での制度や高齢者の健康を守る手立てを考えていくというときには，このような変化や，現状を考慮したも

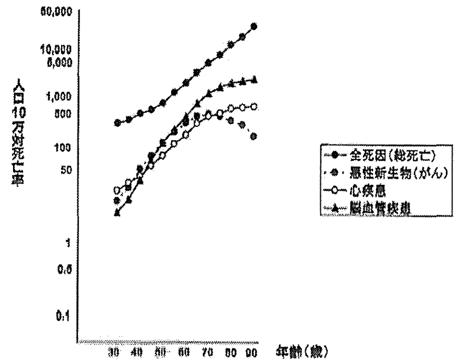


図1　1950（昭和25）年における男性年齢別，死因別死亡率（文献6）より）

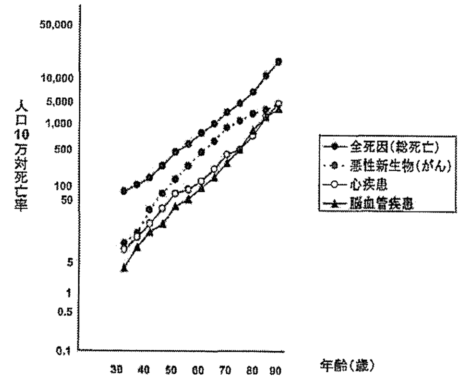


図2　2003（平成15）年における男性年齢別，死因別死亡率（文献6）より）

のでなければ意味がない。今後は'高齢者'として一括りにはできないことを念頭に置きながら，今後の政策や戦略を立てていかなければならない。

疾病予防と介護予防

生物には必ず死が訪れるが，縦軸に死亡率の対数をとると，加齢とともに総死亡率が直線的に上がる。これをGompertz曲線と呼んでいる。一方，個別の疾病死亡率に着目すると，Gompertz曲線と全く同じように平行に上がっていく場合（'並行型'），途中まで平行に上がっていってあるところで変曲点を示し乖離する場合（'乖離型'），あるいは全くGompertz曲線と無関係なまま平行に推移し高齢期から急速に上昇する場合（'急増型'），などに類型化できる[6]。

ここで重要なことは，生活習慣病についてみると，全く予防をしなかった場合の各疾患の死亡率パターンはすべて'乖離型'のパターンとなることである。その理由は病気の予防知識がなく全く予防対策がされない場合，その疾患で死亡するものは加齢とともに上昇し続けるが，ある一定のところまでいくと，いわばその疾病で死ぬべき人は全員死んでしまうために，それ以降は逆に死亡率は低下することになる。一方，逆に完璧に検診や生活指導などの予防対策をした場合，その疾患の死亡率はGompertz曲線と平行に上昇するのみである。その理由はその疾病を予防することによって，若年-壮年期の死亡が抑制されるために，総死亡と同じパターンを描くことになる。さらに疾病予防が飽和し，平均寿命の著しく進展する高齢社会では，'急増型'が顕著となってくる。それは転倒，誤飲・誤嚥，溺死・溺水，肺炎などの高齢者に特有に現れる老年症候群など，死亡数が急増するからである。

図1は1950年の男性の年齢別の死亡率である。直線を示すGompertz曲線に対して，がん，心疾患，脳血管疾患はすべて変曲点をもつ「乖離型」の死亡率パターンを示している。そして乖離の変曲点はおよそ70歳から75歳くらいのところに存在する。このことはきわめて重要な示唆を与えている。一方，図2は最近の死亡曲線である。Gompertz曲線は同じように直線化して変わっていないが，一方すべての生活習慣病死亡はおおよそ直線化してきていることは明らかで，このことは死亡曲線でみる限り，既に生活習慣病対策は飽和しているということを意味している。この50年の間に日本では営々と生活習慣病に対する地道な，そして着実な予防対策の取り組みによって，また医療技術の著しい発展によって，若年-壮年期の死亡を減らして世界に冠たる長寿国を生み出しきたのである。

では，いつまで生活習慣病の予防対策を行うのか？　答えは自明の理である。変曲点の前にやらなければ意味がない。予防対策が行われないために死亡が累積してゆくのは，変曲点の前なのである。変曲点以降は他の疾病死亡が優位となる。したがって

予防対策は，変曲点以前でなければ意味がないということになる。現代日本人は中年期における生活習慣病の一次予防をより一層進めなければならない。なぜなら，死亡率は下がっても発生率が下がっていないために，発症後要介護状態になる場合が多くなっていくことが容易に想定されるからである。発生率を下げるということは，病気を発症しないと同時に，要介護状態にならないということでもある。高齢期になっていかに不健康寿命を増加させないかが，喫緊の課題となる。先にも述べたが，疾病予防は変曲点の前が重要である。当然，介護予防は変曲点近傍（70歳頃）から特に重要となってくる。後期高齢者医療制度は，さまざまに議論を呼び，今後のあり方もまだ不安定要素を残している保険制度であるが，少なくとも疾病と介護を包括的に含む高齢者の健康づくりという視点からみて，‘後期高齢者’として一つの枠を作り，疾病予防と介護予防のまさに‘変曲点’としての機能をもたせるという意味において，今後も必要不可欠な制度だと考えられる。

介護予防の重要性

介護予防に関して，より具体的に対策方法を挙げるとすれば，‘老年症候群’をいかにして予防するかということである。例えば，老年症候群の代表的な症候である転倒は，最も重要かつ効果的な対象である。転倒は（骨粗鬆症と連動して）容易に大腿骨頸部骨折などの骨折をはじめとする外傷をもたらすだけでなく，たとえ外傷はなくとも転倒自体が高齢者に恐怖心を植え付け，その後の生活空間の狭小化やQOLを低下させて‘転倒後症候群’を引き起こす[7]。後期高齢者で独居高齢者や高齢世帯では，低栄養も問題となる。また，閉じこもりと密接に関連するのが尿失禁や足のトラブルである。尿失禁については軽度のものを含めると，高齢女性の3～4割に出現する。尿失禁によって友人と会うなどの社会活動性の制限がみられ，自信の喪失や閉じこもり状態へと移行する[8]。また，歯科領域では，口腔機能の減弱，すなわち咀嚼機能や嚥下機能の低下が食における QOL を低下させることはもちろんのこと，高齢期に特徴的な肺炎死亡を増加させる。

このような老年症候群の特徴は以下のようにまとめられる。

1）明確な疾病ではない（‘年のせい’とされる）。

2）症状が致命的ではない（‘生活上の不具合’とされる）。

3）日常生活への障害が初期には小さい（本人にも自覚がない）。

これらのことから，‘老年症候群’を有する高齢者であっても医療機関への受診は少なく，また医療側での対応も一定の水準がなく，対策に困難なのが現状である。しかし多くの老年症候群，特にそれらの初期には，自己の努力である程度予防していくことが可能である。特に最近では，わが国においても，これらの老年症候群の多くの症候に対して科学的に最も推奨される手法である無作為割付比較介入試験あるいはランダム化試験（Randomized Controlled Trial；RCT）によって，個々の症候に対する介入プログラムが有効であるか否かが確認されている。これらのRCTは論文化され，いずれも厳しいレビューのある学術雑誌に報告されている。数ある老年症候群の中で，転倒予防[9,10]，低栄養予防[11]，尿失禁予防[12]，足の変形による歩行障害の予防[13]，あるいはそれらの多くを複合して有する者に対する取り組み[14]，サルコペニアの予防[15]などはいずれもRCTを経て適切な介入が有効であることが示されている。

さらに，事項で詳述されているように，最近口腔機能の低下ともその関連性が疑われている，認知機能低下抑制に対する大脳刺激を含めた運動の効果検証のための RCT も実施され効果が確認されている[16,17]。

認知症予防

わが国のような高齢社会においては，認知症（予防）対策はきわめて重要な課題となっているが，われわれは国立長寿医療研究センターのある愛知県大府市との協働で，厚生労働省老人保健健康増進等事業の一環として，地域在住の高齢者を対象とする認知機能低下抑制に対する運動の効果検証をランダム化試験（RCT）により実施した。対象者は，軽度認知障害（mild cognitive impairment：MCI）の高齢者である。

実際の調査では，大府市在住の65歳以上の高齢

者に対し，一次調査（質問紙調査 n＝1,543），二次調査（認知機能検査 n＝135），三次調査（MRI 撮影 n＝126）を実施した。二次および三次調査で35名が除外基準に該当，あるいは参加を拒否し，最終的に100名のMCI高齢者が介入対象者として選択された。これらの対象者を健忘型MCIで層化して，無作為に健康講座群（対照群）と運動教室群（介入群）とに割り付けた（図3）。

調査では介入前後に認知機能検査，運動機能検査，MRI検査を全対象者に実施した。調査における評価項目を表3に示す。MRI検査では脳容量計測を行い，統計的パラメトリックマッピングにて標準脳に対する脳全体のなかで萎縮している領域の割合を求めた。

運動教室群の介入は，6カ月間，週2回，1回につき90分間，計40回実施した。介入の内容は，ストレッチ，筋力トレーニング，有酸素運動，脳活性化運動，行動変容技法による運動の習慣化とした。また，運動教室群の対象者には，歩数計の装着を促し，目標歩数への到達とストレッチ，筋力トレーニングの実施を毎日行うよう推奨した。一方，健康講座群には，介護や疾病予防に関する健康講座（60～90分間）を6カ月間に2回実施した。また，あわせて検査結果の説明を実施した。

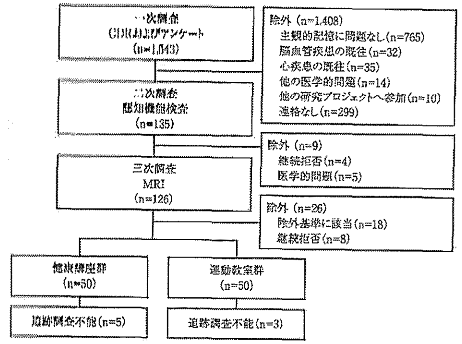


図3　研究の流れ

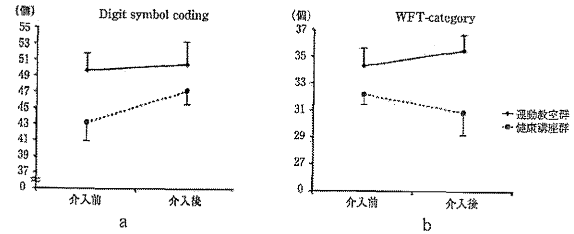


図4　全対象者の認知機能変化
a：digit symbol coding，b：word fluency test-category
いずれの項目も有意な交互作用を認めた。

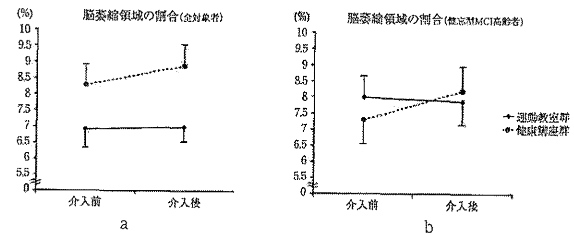


図5　MRI指標による脳萎縮の割合
a：全対象者における脳萎縮の割合，b：健忘型MCI高齢者における脳萎縮の割合．
有意な交互作用は健忘型MCI高齢者のみにみられた。

表3 評価項目

	検査項目	介入前	介入後	介入中
認知機能検査	Mini mental state examination	○	○	
	Alzheimer's Disease Assessment Scale-cognitive subscale	○	○	
	Clock drawing test	○	○	
	Wechsler memory scale-logical memory I	○	○	
	Wechsler memory scale-logical memory II	○	○	
	Rey-Osterrieth Complex Figure Test -模写	○	○	
	Rey-Osterrieth Complex Figure Test - 3分後再生	○	○	
	Rey-Osterrieth Complex Figure Test -30分後再生	○	○	
	Digit symbol	○	○	
	Trail making test-part A	○	○	
	Trail making test-part B	○	○	
	Stroop test I	○	○	
	Stroop test III	○	○	
	Word fluency test-category subscale	○	○	
	Word fluency test-letter subscale	○	○	
	Digit span forward	○	○	
	Digit span backward	○	○	
脳形態・機能検査	Volumetric MRI	○	○	
	FDG PET (n=26)	○	○	
	NIRS (n=24)	○	○	
運動機能検査	握力	○	○	
	膝伸展筋力	○	○	
	片脚立位	○	○	
	5 m 歩行時間（通常）	○	○	
	6分間歩行距離	○	○	
日常活動状況	老研式活動能力指標	○	○	
	International physical activity questionnaire	○	○	
	Life space assessment	○	○	
心理状態	Medical outcome scale short form-8	○	○	
	Geriatric depression scale	○	○	
一般健康状態	転倒状況	○	○	
	疾病状況	○	○	
	服薬状況	○	○	
プロセス評価（運動教室群のみ）	教室出席回数			○
	運動時間			○
	歩数			○
	運動前後の脈拍数			○

本RCTの主要な結果の概要は以下のとおりである。

1）運動教室群の38名（78%）が40回の介入の80%以上の出席をした。5名（10%）の対象者は30%以下の出席であった。運動教室実施中の有害事象はなかった。

2）認知機能における介入前後の群間比較（全対象者）において，Digit Symbol (DS) および Word Fluency Test（WFT)-category において有意な交互作用が認められた（図4）。

3）健忘型MCI高齢者の介入前後の認知機能の群間比較では，MMSE，WMS-I total，WFT-category，WFT-letter において有意な交互作用が認められた。さらに脳容量測定についての検証も行ったが，その結果，介入前後の比較において脳萎縮領域の割合が，健康講座群で全対象者および健忘型MCI高齢者の両方の分析にて有意に上昇し，群間比較では健忘型MCI高齢者の分析において交互作用が認められた[16,17]（図5）。

今後の高齢社会で認知症をいかに予防するかがもっとも大きな課題の一つとなることは確実であるが，現時点ではMCI高齢者の認知機能低下を抑制することによって認知症（特にアルツハイマー症）発症を先送りすることの可能性について，ようやく科学的エビデンスが提示されたところであり，今後，歯科的な視点から，口腔機能と認知機能の関連性なども含めて，さらなるエビデンスの積み重ねと，より効率的・効果的介入手法の開発が急がれる。

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Research Article

Divergent Significance of Bone Mineral Density Changes in Aging Depending on Sites and Sex Revealed through Separate Analyses of Bone Mineral Content and Area

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Bone mineral density (aBMD) is equivalent to bone mineral content (BMC) divided by area. We rechecked the significance of aBMD changes in aging by examining BMC and area separately. Subjects were 1167 community-dwelling Japanese men and women, aged 40–79 years. ABMDs of femoral neck and lumbar spine were assessed by DXA twice, at 6-year intervals. The change rates of BMC and area, as well as aBMD, were calculated and described separately by the age stratum and by sex. In the femoral neck region, aBMDs were significantly decreased in all age strata by an increase in area as well as BMC loss in the same pattern in both sexes. In the lumbar spine region, aBMDs decreased until the age of 60 in women, caused by the significant BMC decrease accompanying the small area change. Very differently in men, aBMDs increased after their 50s due to BMC increase, accompanied by an area increase. Separate analyses of BMC and area change revealed that the significance of aBMD changes in aging was very divergent among sites and between sexes. This may explain in part the dissociation of aBMD change and bone strength, suggesting that we should be more cautious when interpreting the meaning of aBMD change.

1. Introduction

Bone mineral density (aBMD) decreases with age [1] and it is the most significant and widely used index for the diagnosis of osteoporosis and for considering the effects of medication in its treatment [2]. When an aBMD decrease is found, the cause is usually considered to be a decrease in bone mineral content (BMC) in the region measured. ABMD is equivalent to BMC divided by an area. Since areal BMD depends both on bone mineral content and bone dimensions, it is difficult to interpret unambiguously [3]. Dimensional changes occur in long bone by aging [4–6], the shape of the bone, and conditions like osteophytes or vertebral fracture in lumbar spine [7–9] are well known. These can affect the measuring area of DXA examinations, and naturally their results. However, a longitudinal epidemiological DXA study on aging considering the effect of the area has not been carried out on a large scale, although there have been cross-sectional studies [10–17]. This study was performed in order to reconsider the significance of aBMD change and aging in different anatomical locations, by analyzing the longitudinal changes of both components of aBMD, namely, BMC and the area, and comparing the differences in sex. A large cohort for longitudinal studies of local inhabitants was used for this study.

2. Materials and Methods

2.1. Subjects. The subjects were selected among people who participated in both the 1st and 4th waves of the National Institute for Longevity Sciences Longitudinal Study of Aging (NILS-LSA). Details of the NILS-LSA are presented elsewhere [18]. It is a biannual examination checking the physical and mental condition of ordinary Japanese people, so as to clarify the effect of aging. It is conducted by the National Center for Geriatrics and Gerontology (NCGG), in Japan. The National Institute for Longevity Sciences (NILS) is a research section of NCGG. The participants were chosen randomly from the residents of Obu city and Higashiura-cho, in Aichi prefecture, Japan. For this study, data from 1167 persons were analyzed (59.2 ± 10.9, mean ± SD). Participants were 594 men and 573 women, whose ages ranged from 40 to 79 at the time of the 1st wave. The 1st and 4th waves were from November 1997 to April 2000, and June 2004 to July 2006, respectively.

2.2. Measurements of Bone Mineral Density. Areal bone mineral densities (aBMD) were measured using Hologic QDR4500, both at the 1st and 4th wave. Only one DXA scanner was used. Data on the right femoral neck (Figure 1) and the lumbar spine (L2–4) were used for the analysis. Coefficients of variance of the DXA instrument for aBMD were 1.3% (femoral neck), 1.0% (trochanter), and 0.9% (L2,1–4) [19]. ABMD is equivalent to BMC divided by an area, so the following formula was used for the theoretical calculation: aBMD (g/cm^2) = BMC (g)/Area (cm^2). Therefore, not only aBMD values but also those of BMC and the area measured were used for the analysis in the three different regions above. The annual change rates (CR) were calculated by the following formula. CR (%) = (the values in the 4th−the values in the 1st)/the values in the 1st × 100/6. The CRs of aBMD, BMC, and the area measured were calculated and described separately by the age stratum of 40s, 50s, 60s, and 70s and by sex. All who were 40 to 49 years at baseline belonged to the 40's age stratum, and so forth. Data are presented as the mean ± SD, including those in figures. The study protocol was approved by the Committee on Ethics of Human Research of the National Institute for Longevity Sciences. Written informed consent was obtained from each subject.

2.3. Statistical Analyses. The statistical analyses were made to test for significance of change (versus no change) in each subgroup defined by age decade and sex, using paired *t*-tests. Also, the trend analyses according to the increase of the age stratum were made for each subgroup using a general linear model procedure. Gender difference was checked for each subgroup. All analyses were conducted using SAS Ver. 8.2 (SAS Institute, Cary, NC, USA).

3. Results

Characteristics of subjects were shown in Table 1.

The change rates (CR) from the first to fourth what were expressed as an annual rate. Mean variation between the two DXA measurements was 6 years.

3.1. Femoral Neck Region. ABMDs significantly decreased in all age strata both in women (−1.1 ± 1.1% in 40s, −1.2 ± 0.9% in 50s, −1.0 ± 0.9% in 60s, and −0.8 ± 1.1% in 70s, all $P < 0.01$) and in men (−0.4 ± 0.8% in 40s, −0.5 ± 0.7% in 50s, −0.6 ± 0.9% in 60s, and −0.6 ± 1.0% in 70s, all $P < 0.01$) (Figures 2(a) and 2(b)). These declines were caused not merely by the decrease of BMC in most of the age strata (in women, −0.7 ± 1.4% in 40s, −0.8 ± 1.2% in 50s, and −0.4 ± 1.2% in 60s, all $P < 0.01$, and in men, −0.2 ± 0.9% in 50s and −0.2 ± 1.1% in 70s, with $P < 0.01$ and $P < 0.05$, resp.), but also by the constant or significant increase of the area measured (in women, 0.4 ± 1.1% in 40s, 0.5 ± 1.1% in 50s, 0.6 ± 1.2% in 60s, and 0.5 ± 1.5% in 70s, all $P < 0.01$, and in men, 0.4 ± 0.6% in 40s, 0.3 ± 0.8% in 50s, 0.4 ± 0.8% in 60s, and in 0.4 ± 0.8% in 70s, all $P < 0.01$). This trend was the same in both sexes. The change rates (CR) of the aBMD and BMC, however, were different between women and men in their 40s, 50s, and 60s (Table 2). The CR became higher (in absolute value) only in women according to age in aBMD and BMC (P trend = 0.0126 and 0.0027, resp.). As for the CR of the area, no significant trend according to age was observed in both sexes, and no sex difference was observed (Table 2).

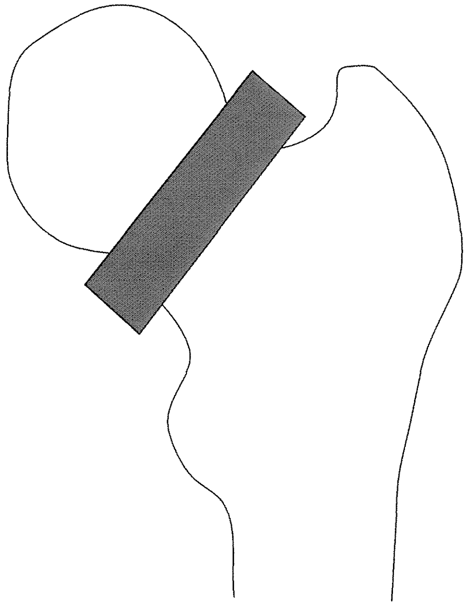

FIGURE 1: Femoral neck region of interest, derived from the Hologic QDR 4500 Operator's Manual.

3.2. Lumbar Spine Region. ABMDs significantly decreased in women in their 40s, 50s, and 60s (−1.1 ± 1.2% in 40s, −1.0 ± 0.9% in 50s, and −0.2 ± 1.1 in 60s, with $P < 0.01$, $P < 0.01$ and $P < 0.05$, resp.) (Figure 3(a)). At earlier ages, these declines were caused by a significant decrease in BMC (−1.2 ± 1.5% in 40s and −1.2 ± 1.2% in 50s, both $P < 0.01$) accompanied by a small but significant decrease in the area. After their 60s, however, no further decrease in BMC occurred, and the small but significant increase of aBMD was caused by the significant increase in the area.

The patterns of aBMD changes were much different in men. BMDs significantly increased in the 50s, 60s, and 70s (0.3 ± 0.8%, 0.5 ± 1.5%, and 0.3 ± 1.0%, all $P < 0.01$) due to

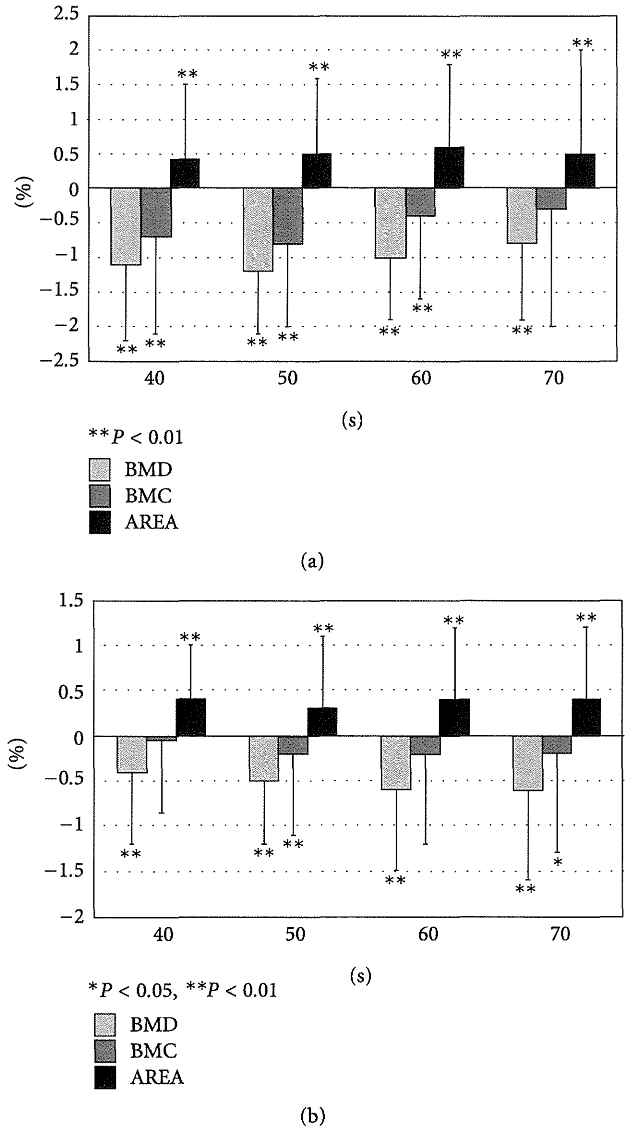

Figure 2: (a) Changes in the femoral neck region by age group in women. Results are the mean (±SD) CR of four different age strata. $^{**}P < 0.01$. (b) Changes in the femoral neck region by age group in men. Results are the mean (±SD) CR of four different age strata. $^{*}P < 0.05$, $^{**}P < 0.01$.

the significant increase of BMC (0.5 ± 1.0% in 50s, 1.0 ± 3.4% in 60s, and 0.4 ± 1.2% in 70s, all $P < 0.01$) (Figure 3(b)). The areas significantly increased in every age stratum (0.1 ± 0.5% in 40s, 0.2 ± 0.5% in 50s, 0.4 ± 1.2% in 60s, and 0.2 ± 0.6% in 70s, all $P < 0.01$). Since the increase of BMD occurred after the 50s, the rates of BMC increase surpassed those of the area. The change rates (CR) of the aBMD, BMC, and area were different between women and men in their 40s, 50s, and 60s (Table 2). And in women the CR increased according to age in aBMD, BMC, and area (P trend <0 .0001, P trend <0.0001, and P trend = 0.0115, resp.). The CR increased in men according to age in aBMD and BMC (P trend= 0.006 and P trend = 0.027, resp.), but not in area (Table 2).

Table 1: Characteristics of subjects.

	Women	Men
Age (years)	56.5 ± 9.9	57.9 ± 9.9
Height (cm)		
All	152.2 ± 5.7 (n = 573)	165.4 ± 5.9 (n = 594)
40s	154.9 ± 5.0 (n = 168)	168.7 ± 5.5 (n = 148)
50s	153.3 ± 4.8 (n = 179)	166.3 ± 5.7 (n = 183)
60s	150.4 ± 5.6 (n = 147)	164.0 ± 4.7 (n = 162)
70s	147.0 ± 5.0 (n = 79)	161.0 ± 5.2 (n = 101)
Weight (kg)		
All	53.0 ± 8.0 (n = 573)	62.8 ± 8.5 (n = 594)
40s	54.1 ± 8.0 (n = 168)	66.4 ± 8.8 (n = 148)
50s	53.7 ± 7.4 (n = 179)	63.5 ± 8.1 (n = 183)
60s	53.0 ± 8.0 (n = 147)	61.2 ± 7.8 (n = 162)
70s	49.1 ± 7.9 (n = 79)	58.8 ± 7.5 (n = 101)
BMI (kg/m^2)		
All	22.9 ± 3.2 (n = 573)	22.9 ± 2.6 (n = 594)
40s	22.5 ± 3.3 (n = 168)	23.3 ± 2.6 (n = 148)
50s	22.9 ± 3.2 (n = 179)	23.0 ± 2.5 (n = 183)
60s	23.4 ± 3.1 (n = 147)	22.8 ± 2.7 (n = 162)
70s	22.7 ± 3.1 (n = 79)	22.6 ± 2.5 (n = 101)
BMD at 1st wave		
Femoral neck (g/cm^2)	0.7 ± 0.1	0.8 ± 0.1
Trochanter (g/cm^2)	0.6 ± 0.1	0.7 ± 0.1
Lumbar spine (L2–4) (g/cm^2)	0.9 ± 0.2	1.0 ± 0.2
BMC at 1st wave		
Femoral neck (g)	3.2 ± 0.6	4.0 ± 0.7
Trochanter (g)	6.0 ± 1.3	8.7 ± 1.6
Lumbar spine (L2–4) (g)	38.1 ± 9.3	50.7 ± 10.0
Area at 1st wave		
Femoral neck (cm^2)	4.6 ± 0.3	5.3 ± 0.3
Trochanter (cm^2)	10.2 ± 1.2	12.8 ± 1.4
Lumbar spine (L2–4) (cm^2)	42.3 ± 3.9	51.3 ± 4.5

Values are mean ± SD.

4. Discussion

ABMD is equivalent to BMC divided by an area, but when we encounter cases of BMD decline, we simply consider the decline of the BMC at the measured sites without

Table 2: P trend according to age strata and P value of sex difference analyses of subgroup.

		P trend according to age strata		Sex difference analysis			
		women	men	40s	50s	60s	70s
Femoral neck	BMD	0.0126	0.1682	<0.0001	<0.0001	<0.0001	0.0982
	BMC	0.0027	0.2519	<0.0001	<0.0001	0.0298	0.7122
	Area	0.2084	0.9947	0.9436	0.0434	0.0987	0.2391
Lumbar spine	BMD	<0.0001	0.006	<0.0001	<0.0001	<0.0001	0.815
	BMC	<0.0001	0.027	<0.0001	<0.0001	<0.0001	0.4277
	Area	0.0115	0.3383	<0.0001	<0.0001	0.0052	0.0986

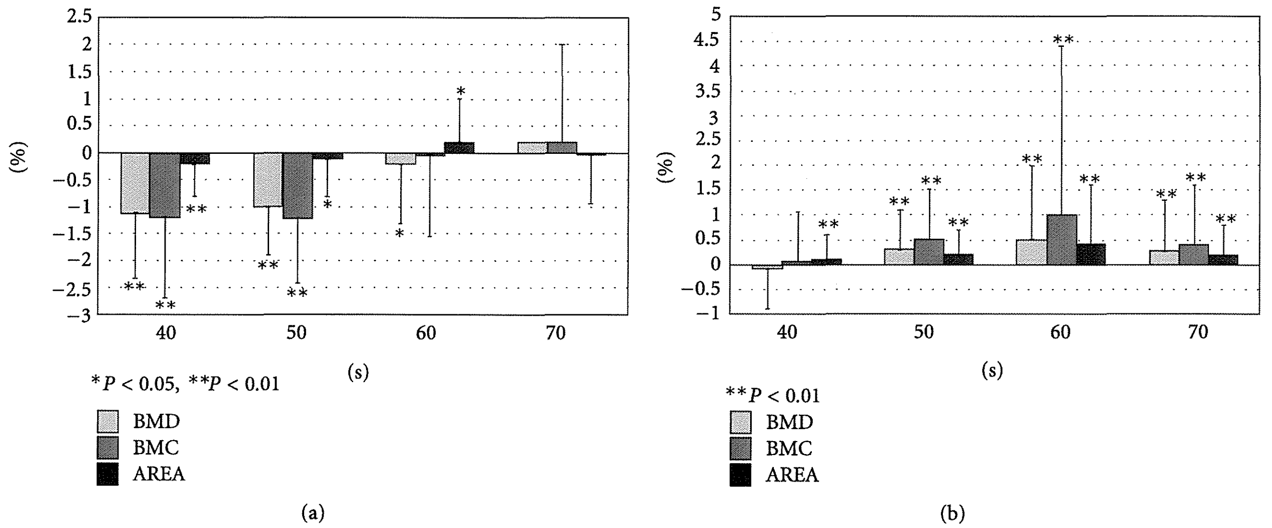

Figure 3: (a) Changes in the lumbar spine region by age group in women. Results are the mean (±SD) CR of four different age strata. $^{*}P < 0.05$, $^{**}P < 0.01$. (b) Changes in the lumbar spine region by age group in men. Results are the mean (±SD) CR of four different age strata. $^{**}P < 0.01$.

incorporating the change of the area (or size), which may represent the change of the shape in the region. The present study demonstrated that in the femoral neck, the aBMD decline in aging occurs not only due to the decline of BMC, but also due to the increase in the area, for both men and women. In fact, the increase of the femoral neck area represents the physiological compensating effect of the weakened bone tolerance [4, 20–23], caused by BMC decline. This may be one of the reasons for the dissociation between the strength of the bone and aBMD values. The widening (or enlargement) of the femoral neck in elderly persons has been demonstrated by the hip structure analyses of DXA [10, 13–15], by computed tomography [23–26], or utilizing both [27, 28]. The annual change rates of aBMD in our study in the femoral neck region were around −1% in women (Figure 2(a)) and 0.5% in men (Figure 2(b)). This is almost equal to the level of the large population-based cohort in Hiroshima Japan, −1.14% in women, and −0.38% in men [29]. In the lumbar spine, however, a sexual difference was observed in the changes of aBMD and those of BMC or the area as well. The increase in BMC together with the area may be explained by the osteophyte formation found to be more marked in elderly men [7, 9]. This type of change, osteophyte formation, occurs also in women but later. The significant area increase in women may derive from the osteophyte formation in advanced age. The reason for the significant decrease in the areas in women in their 40s and 50s is unclear at the moment. More detailed studies, using CT scans, are warranted to elucidate the mechanism of the sex difference in the spinal region.

From this perspective, the meaning or significance of aBMD change should be diverse depending on the sites measured and gender. Moreover, the apparent decrease of aBMD may not simply represent the weakness of that measured region (e.g., in the femoral neck), since the greater diameter can make the cylindrical structure stronger [21].

The limitation of this study is that the measurements were carried out by the ordinary DXA method without using elaborate software like hip structure analysis or CT. DXA has an inherent inaccuracy [30–32]. If body composition or weight changed during the followup, it is possible that BMD is inaccurately measured, namely, it may be over- or underestimated. Also, the size measuring by DXA was not very accurate for volumetric analysis. But our method disclosed the differences among sites and between sexes, particularly in terms of longitudinal effect, which have been little investigated.

The strength of our study is its random selection of our samples from people in the local community with very little bias in the process. NILS-LSA is one of the few major epidemiological studies investigating the aging mechanism that is designed to select subjects in a completely random manner. The results of this study should therefore reveal characteristics of the entire Japanese population.

In summary, we investigated the meaning of aBMD changes in aging through separate analyses of BMC and area change. The results revealed that the significance of aBMD changes were very divergent among the sites measured, and between sexes. This may explain the dissociation of aBMD change and bone strength, which encourages one to be more cautious when interpreting the meaning of aBMD change.

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ORIGINAL ARTICLE

Why not use your own body weight to prevent falls? A randomized, controlled trial of balance therapy to prevent falls and fractures for elderly people who can stand on one leg for ≤15 s

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Abstract

Background Maintaining or improving motor (balance) ability is essential to extending the healthy lifespan of elderly people, and developing effective and efficient strategies to prevent falls of elderly people is an urgent. The purpose of this study was to determine the effects of balance exercise on fall and fracture prevention for elderly people with poor balance.

Methods A 6-month, randomized controlled trial was conducted to verify whether one-leg standing with eyes open for a total of 1 min, three times a day (dynamic flamingo exercise) prevents falls and fractures. Setting and participants were elderly people ≥75 years of age and one-leg standing time ≤15.0 s living in their own home. They were visiting orthopaedic clinics for orthopaedic handicaps. Subjects with poor balance were allowed to hold on to something. If a subject's lifted leg touched the ground during the exercise, they were allowed to lift it again and continue so that they stood on one leg for a total of 60 s.

Results The dynamic flamingo exercise group (410 people; 86 men, 324 women) and the no exercise group (455 people; 78 men, 377 women) were compared. After dynamic flamingo exercise for 6 months, significant differences were seen in the increase in one-leg standing time with eyes open (men right/left, women right/left), in the improvement in independence in daily living (women), number of people who fell during the 6 months (women),

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and adverse events (women). The number of fractures was not significantly different for men or women.
Conclusions Dynamic flamingo exercise prevents falls but no significant difference was demonstrated in fracture prevention in elderly women with poor balance.

Introduction

As the aging of society accelerates, a very important question is how to maintain daily living functions in elderly people so that they can spend their remaining life comfortably. Elderly people with underlying osteoporosis are susceptible to fractures of the proximal femur, and their mortality 1 year after a fracture is high (10–27 %) [1–3]. Prevention of proximal femur fractures is believed to be beneficial for extending the healthy life span of elderly people. One-third of elderly people ≥65 years of age are said to fall once a year [4], and more than half of these need to be hospitalized for trauma accompanying the fall [5]. Strategic development and implementation of effective and cost-efficient means of preventing falls of elderly people is a pressing global health challenge. Sherrington et al. [6]. conducted a systematic review and meta-analysis of the most effective methods for fall prevention, and concluded that effective methods are training for ≥50 h during trials, training in standing on both legs with narrow bases of support, or center of gravity balance control training standing on one leg. Walking training was not included among the most effective methods. Selection of methods with superior cost performance must also be considered in exercise training [7].

Haeney [8] listed three elements related to the growth and deterioration of bone: genetics, endocrine activity, and mechanical stress. As seen from this, mechanical stress is a crucial element for bone metabolism. Bone density of the proximal femur of astronauts returning to earth after a space flight of 6 months, during which time there is little mechanical stress, requires a long period of approximately 900 days to return to its original level [9]. Various kinds of exercise therapy are recommended, but this exercise therapy must combine three basic rules:

1. dynamic loading;
2. short duration; and
3. customary mechanical loading environment [10].

To prevent fractures of the proximal femur caused by minor trauma when osteoporosis is a background factor, it is necessary not only to prevent falls but also to apply loads to the proximal femur to increase its density and to improve bone quality and strengthen the bone.

Standing on one leg with the eyes open for 1 min 3 times a day (dynamic flamingo (DF) therapy [11]), uses the fact that one-leg standing places a load on the femoral head that is 2.75 times greater than the load on one leg when standing on two legs. This exercise theory is based on the finding, for the elderly, that the total load on the femoral head when standing on one leg with eyes open for 1 min is equivalent to the total load placed on the femoral head on one side from walking for 53.3 min (160/3 min) [12]. DF therapy has points in common with Tai Chi exercise, which is reported to be effective in preventing falls [13, 14]. It is also reported to be effective in increasing bone density in the proximal femur [15, 16]. DF therapy is exercise that uses the body's own weight as mechanical stress, and it requires no special equipment. It is also a very simple exercise therapy that does not require special exercise instruction. A randomized trial was conducted for 6 months to determine whether this DF therapy is, in general, effective in preventing falls and fractures for elderly people with an orthopedic handicap who live at home. If this therapy were to be effective in fall prevention, it may be beneficial in preventing femoral neck fractures by increasing bone density in the femoral neck and preventing falls.

Subjects

The subjects were men and women ≥75 years of age who lived at home and visited an orthopedic clinic or hospital for an orthopedic handicap and who could stand on one leg, both right and left, with the eyes open for ≤15 s (the Ministry of Health, Labor, and Welfare of Japan designates men and women ≥75 years of age who can stand on one leg with eyes open for ≤15 s as having musculoskeletal ambulation disability symptom complex). The time of one-leg standing with eyes open for the left and right legs is measured with the subject standing on one leg with both hands placed at the hips until the subject takes a hand off his or her hip or the other leg hits the floor. The subject is first allowed one attempt as practice, and the second attempt is measured using a stopwatch to the first decimal place. The time of one-leg standing with eyes open was measured for up to 20 s for each leg for elderly individuals

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aged ≥75 years, and those with a time ≤15 s for both legs were allocated to the Entry group. To ensure accuracy in judgments of the effect of one-leg standing exercise training, subjects were usually people with the ability to communicate and those who could continue training. It had been recommended to these people that they participate in exercise without DF therapy. After presenting a written explanation, consent was obtained from the subjects in writing for participation in the clinical study. People with Parkinson's disease or other conditions that made them susceptible to falls, people with artificial joints, and people with cognitive disorders were excluded. From April 2007 until March 2010, 1,788 subjects were recruited (exercise group 889, non-exercise group 899; Fig. 1; flow diagram: trial profile [17]). Those who did not meet the stipulations were excluded, as were subjects with no responses for dominant leg, weight, height, and other items on a questionnaire. Next, those for whom there was no report at the end of the 6 months were excluded. Final reports were collected for 483 people in the exercise group and 524 in the no exercise group. Of these, those with items with no responses in the report were excluded. The comparative

Fig. 1 Flow diagram trial profile

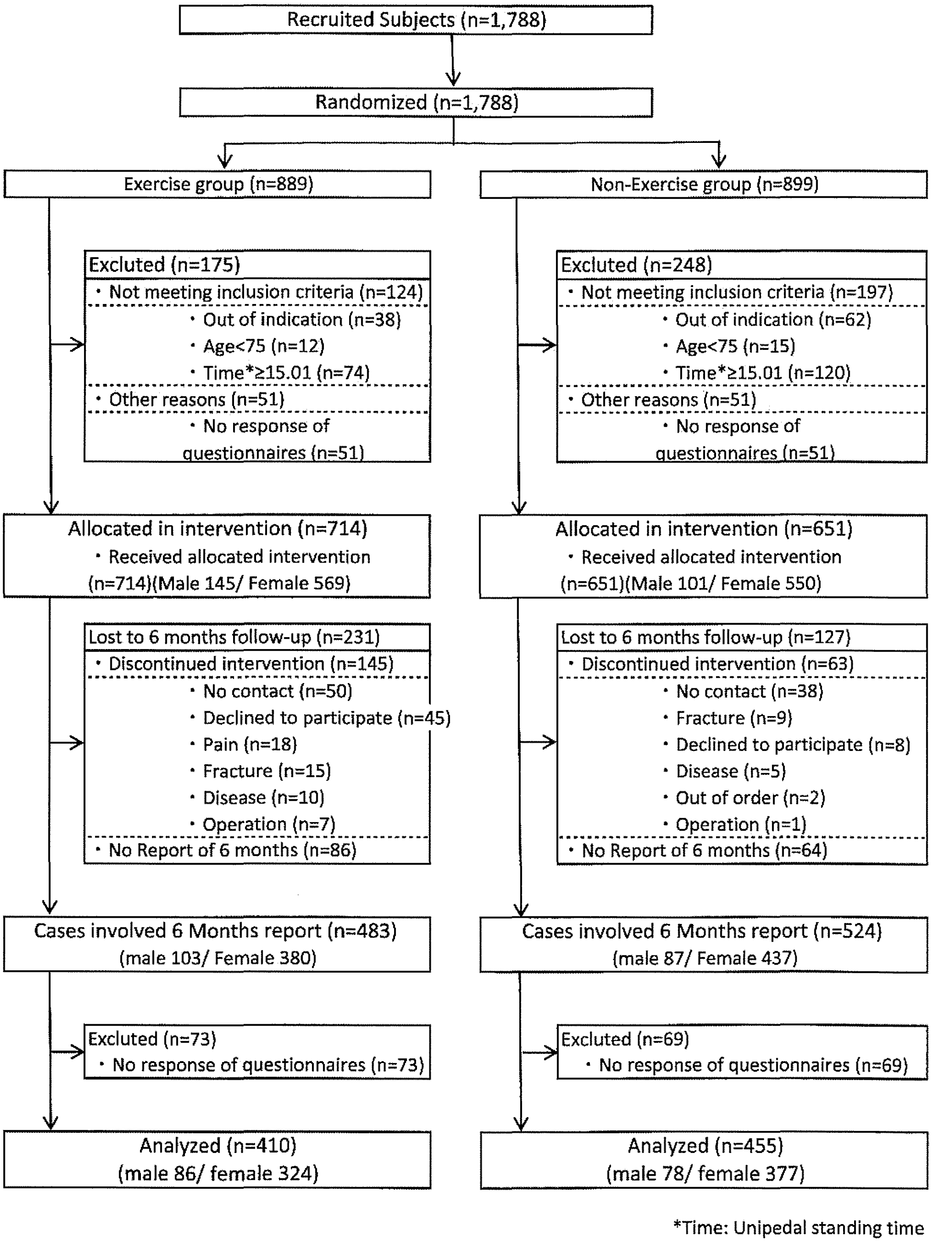

Table 1 Diagnosis of subjects at baseline survey between exercise group and non-exercise group (the first diagnosis name described on report sheet)

Female				Male	
Exercise group		Non-exercise group		Exercise group	
Diagnosis	*N*	Diagnosis	*N*	Diagnosis	*N*
OA (knee)	97	OA (knee)	97	Spondylosis deformans	24
Osteoporosis	72	Osteoporosis	90	LCS	14
LSD	31	LCS	45	OA (knee)	13
LCS	30	LSD	40	Osteoporosis	6
Spondylosis deformans	18	Vertebral fracture	22	Cervical spondylosis	5
Painful shoulder	10	Cervical spondylosis	21	LDD	4
Cervical spondylosis	8	Non-vertebral fracture	12	Diabetes meritis	4
Hypertension	7	Rheumatic arthritis	10	Lumbar spondylosis	3
Vertebral fracture	6	Painful shoulder	8	Painful shoulder	3
MAD	5	LDD	7	Vertebral fracture	2
Low back pain	4	Heart disease	4	etc.	8
CTS	4	OA (shoulder)	3	Total	86
Non-vertebral fracture	4	MAD	2		
LDD	3	OA (hip)	2	Non-exercise group	
Lumbar disc hernia	3	Low back pain	2	Diagnosis	*N*
Cranial infarct	3	etc.	13	LCS	16
Rheumatic arthritis	2	Total	378	OA (knee)	15
CDD	2			Spondylosis deformans	13
Scoliosis	2			Osteoporosis	8
Rotator cuff injury	2			Cervical spondylosis	8
etc.	11			Painful shoulder	4
Total	324			Lumbar disc hernia	3
				Rheumatic arthritis	3
				Gout	2
				etc.	6
				Total	78

Exercise group versus non-exercise group

OA osteo arthritis, *LSD* lumbar spondylosis deformans, *LCS* lumbar canal stenosis, *MAD* musculoskeletal ambulation disability symptom complex, *CTS* carpal tunnel syndrome, *LDD* lumbar disc degeneration, *CDD* cervical disc degeneration, *N* number

analysis was finally conducted with 410 people from the exercise group (86 men, 324 women) and 455 people from the no exercise group (78 men, 377 women).

The ailments diagnosed in each group are listed in Table 1. Among women in both groups, osteoarthritis of the knee was the most common ailment (97 subjects). Among men, spondylosis deformans was the most common in the exercise group (24 subjects), and lumbar canal stenosis was the most common in the no exercise group (16 subjects).

Methods

Application for approval of this study was made to the Ethics Committee of the School of Showa University, and the randomized, controlled trial (RCT) was conducted for 6 months after approval was obtained. To prevent feelings of unfairness among participants, random allocation to the intervention group (exercise group) or control group (non-exercise group) was conducted at the institution level, meaning that all participants attending the same institution belonged to the same group. The following randomization method was applied. The 10 × 5 (= 50) random number tables with 5 × 5 (25) numbers were prepared and 2 ten-faced dice (one green, one yellow) were thrown to decide which table to use. Two six-faced dice were then thrown to select the number within the chosen random number table to decide whether the institution would be designated an exercise or non-exercise institution. Dice were repeatedly thrown in this manner until the target number of facilities had been allocated to each group.