

特集 介護予防をめぐる

転倒予防

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総合リハビリテーション

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転倒予防*

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はじめに

高齢者が日常生活上で介護の必要な状況となる原因は、脳血管疾患が最多であるが、それに次ぐものに、高齢による衰弱、転倒・骨折、認知症などがある¹⁾。そのため、転倒予防は、要介護状態の予防を検討する際には、きわめて重要な問題の一つと考えられる。2006年度から施行された改正

介護保険法においても、転倒予防は介護予防サービスの一つとして、大きな比重が置かれている。筆者らは、厚生労働省長寿科学総合研究事業「高齢者における効果的な転倒予防活動事業の推進に関する研究」において、自治体が行う転倒予防事業の内容や効果に関する調査を実施した。介護保険法が改正される前の状況であるが、本稿では、その結果の一部を紹介する。

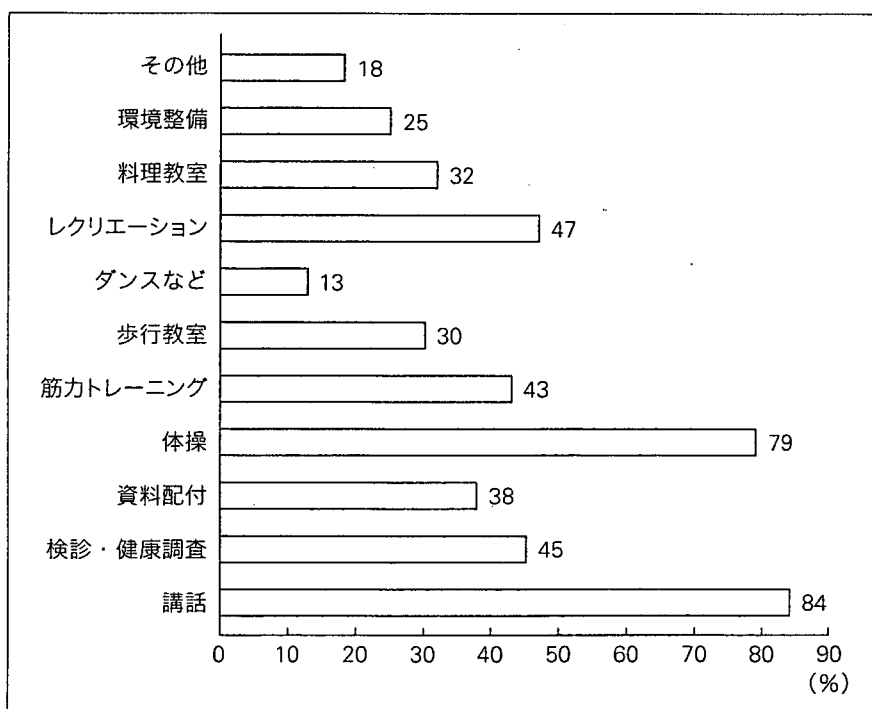


図 1 実施事業の内容 (151 市町村における割合) (文献²⁾引用)

* Prevention of falls.

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表 1 転倒予防事業の実態調査結果—「講話」

	転倒予防に関する講話	
	1.00	
	度数	列 (%)
開始年度		
1965～1988	3	2.5
1989～1993	2	1.7
1994～1998	16	13.3
1999～2003	99	82.5
実施期間		
1日	33	26.6
2日～1週間未満	15	12.1
1週間～1か月未満	9	7.3
1か月～3か月未満	12	9.7
3か月～6か月未満	9	7.3
6か月～1年未満	8	6.5
1年	30	24.2
その他	8	6.5
実施頻度		
ほぼ毎日	2	1.6
週2～4回程度	1	0.8
週1回程度	15	12.3
月2～3回程度	32	26.2
月1回程度	19	15.6
2～3か月に1回程度	17	13.9
その他	36	29.5
事業評価		
評価している	60	48.0
評価していない	65	52.0
継続希望		
継続希望あり	122	97.6
継続希望なし	3	2.4
来年度予定		
来年度実施予定あり	117	94.4
来年度実施予定なし	7	5.6

表 2 転倒予防事業の実態調査結果—「体操」

	体操	
	1.00	
	度数	列 (%)
開始年度		
1965～1988	6	5.2
1989～1993	6	5.2
1994～1998	12	10.4
1999～2003	91	79.1
実施期間		
1日	16	13.7
2日～1週間未満	7	6.0
1週間～1か月未満	4	3.4
1か月～3か月未満	17	14.5
3か月～6か月未満	13	11.1
6か月～1年未満	12	10.3
1年	40	34.2
その他	8	6.8
実施頻度		
ほぼ毎日	3	2.6
週2～4回程度	6	5.2
週1回程度	30	26.1
月2～3回程度	24	20.9
月1回程度	23	20.0
2～3か月に1回程度	8	7.0
その他	21	18.3
事業評価		
評価している	69	59.0
評価していない	48	41.0
継続希望		
継続希望あり	114	97.4
継続希望なし	3	2.6
来年度予定		
来年度実施予定あり	111	95.7
来年度実施予定なし	5	4.3

転倒予防事業の実態調査²⁾

1. 調査の概要

2000年に実施した転倒予防事業の全国調査³⁾で、転倒予防事業を実施していると回答した自治体から無作為に抽出した260市町村に調査票を郵送し、回答を求めた(2003年実施)。調査票は、前回調査で使用した調査票を改訂したもので、市町村の特性、転倒予防に対する担当者の認識、転倒予防事業の実施状況とその内容、事業(効果)評価の有無とその効果内容、などについて尋ねるものであった。

2. 結果

結果として調査に回答が得られたのは180市町

村であった(回答率180/260=69.2%)。95%の市町村が、「高齢者の転倒予防を目的とした保健事業」が重要と考えると回答した。この1年間に該当する事業を実施していた市町村は151(84%)であった(図1)。

転倒予防事業の内容では、「転倒予防に関する講話」(84%)と「体操」(79%)が多く、レクリエーションゲーム、「検診、健康調査」、「筋力トレーニング」がそれに次ぐものであった。いずれの活動も、開始年度は1999～2003年、実施期間は通年、継続希望・次年度予定はありとする市町村が多かった。

実施市町村の多かった「講話」と「体操」に関する結果の詳細を表1、2に示した。実施期間を

表 3 転倒予防事業の実態調査結果—「筋力トレーニング」

	筋力トレーニング	
	1.00	
	度数	列 (%)
開始年度		
1994～1998	6	9.5
1999～2003	57	90.5
実施期間		
1日	4	6.2
2日～1週間未満	2	3.1
1週間～1か月未満	5	7.7
1か月～3か月未満	11	16.9
3か月～6か月未満	19	29.2
6か月～1年未満	9	13.8
1年	10	15.4
その他	5	7.7
実施頻度		
ほぼ毎日	3	4.8
週2～4回程度	15	23.8
週1回程度	14	22.2
月2～3回程度	14	22.2
月1回程度	7	11.1
2～3か月に1回程度	3	4.8
その他	7	11.1
事業評価		
評価している	52	81.3
評価していない	12	18.8
継続希望		
継続希望あり	62	95.4
継続希望なし	3	4.6
実施予定		
来年度実施予定あり	60	93.8
来年度実施予定なし	4	6.3

1年と回答した市町村のなかには、1年間の事業計画の一つという意味で回答した所が少なからず含まれていた。したがって、「講話」は、年に1回のみ実施という市町村が最多と考えられた。また、講話を含む事業を一定期間継続する市町村では、1月に2、3回の頻度で実施する所が多かった。「体操」については、年に1回も少なくなかったが、1か月～3か月を筆頭に、一定の期間実施する市町村が多く、頻度としては、週に1回から月に1回まで、ある程度定期的に実施している傾向がみられた。

参考までに、改正された介護保険制度のなかで、予防介護サービスとしての注目度が高い「筋力トレーニング」についての結果も示す(表3)。開始

時期は遅い、実施期間は3か月～6か月が最多、体操よりも高頻度で実施されている、などの傾向がみられた。

なお、転倒予防事業に携わるスタッフについては、保健師が中心であり、97%以上の市町村で保健師が担当スタッフに含まれていた。理学療法士(PT)/作業療法士(OT)、栄養士、健康運動指導士が担当者に含まれる市町村は約6割だが、医師が含まれる所は約1/4であった。

事業の評価については、105市町村(69.5%)が何らかの評価をしていると回答した。また、効果評価をする市町村の約60%が「講話」と「筋力トレーニング」を、約50%が「体操」と「歩き方教室」を有効としていた(図2)。

3. まとめ

結論として、市町村の実施する転倒予防事業の内容としては、「講話」と「体操」が圧倒的に多かった。やはり、「転倒に関する話」と「身体を動かす体操」の組み合わせが転倒予防教室の定番と考えられる。さらに、自己申告的な要素の強い結果だが、「講話」と「体操」は、効果もあるとする市町村が多かった。この2つの活動が、実施可能性が高く、なおかつ、実施主体である自治体もある程度の評価をしているということになるであろう。

転倒予防事業の効果について⁴⁾

1. 研究の概要

地域における転倒予防を目的とした介入プログラムの効果については、これまでも研究がなされており、運動を中心としたプログラムに転倒予防効果があったとする報告がある^{5,6)}。われわれは、日本で一般的に実施されている転倒予防事業の効果を検討するために、前述の実態調査で実施市町村が多かった「講話」と「体操」を組み合わせたプログラムを、やはり回答の多かった実施期間である約2か月間行い、その効果を検討した。

具体的には愛知県豊田市若林地区で、65歳以上の在宅高齢者から参加者を募集し、転倒予防教室を実施した。教室は、1回2時間で、2週間に1回のペースで計5回実施した。教室の前半には、転倒予防と関連する講話を行った。これにより、プ

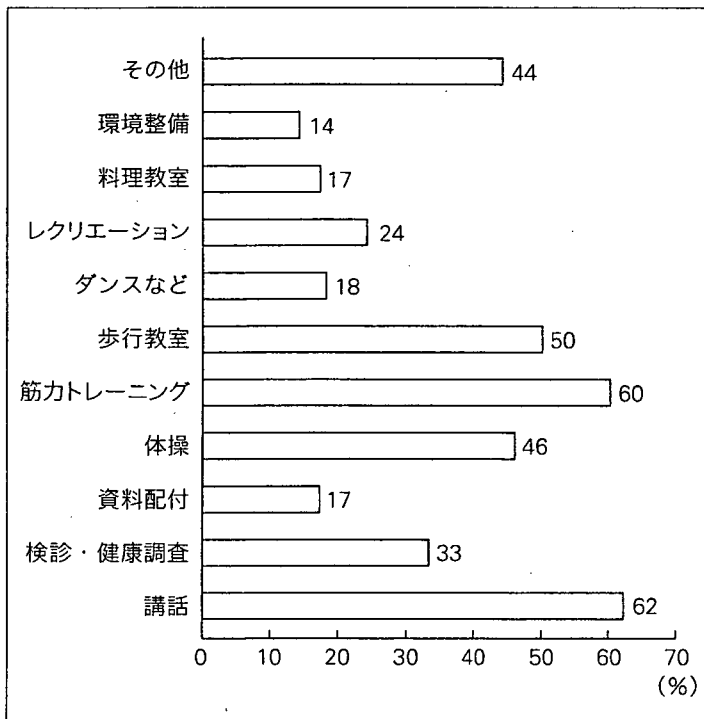


図 2 転倒予防事業の効果

各活動を実施し、さらに、効果評価もしていると回答した市町村数を分母とした場合の、効果ありとした市町村の割合(文献²⁾引用)

プログラム参加への動機付けを行うとともに、運動や転倒予防に関する参加者の知識の向上を図った。教室の後半では、筋力・持久力に有用とされる各種運動実践(ストレッチ、下肢・体幹を中心とした筋力トレーニング、リズム体操、歩行訓練)を行った。初回および最終回の教室の前半では、質問紙調査と体力測定を行い、転倒ならびに心身機能に関する指標を得た。

また、同地区の老人会の協力を得て、同じく 65 歳以上の高齢者に対照群を設定し、心身機能の変化について、教室参加者との比較分析を行った。

2. 結果

転倒経験と転倒恐怖感の比率の変化を、転倒予防教室参加群と対照群で比較し、直接的な転倒予防効果を検討した。結果としては、両群に差がなく、今回の教室の転倒予防に対する直接的な介入効果は確認できなかった(表 4)。ただし、今回は、教室終了後の転倒発生状況は検討していない。教室実施後の転倒について追跡調査を行い、その予防効果を検討することにより、異なる結果が得られた可能性はあるだろう。

表 4 転倒経験と転倒恐怖感に対する効果

転倒経験			
第 1 回測定 (過去 1 年 間の転倒)	第 2 回測定 (第 1 回測 定後の転倒)	介入群 (人)	対照群 (人)
あり	あり	1	0
あり	なし	6	4
なし	あり	1	1
なし	なし	9	10
n		17	15

($z = -0.48, ns$)

転倒恐怖感			
第 1 回測定	第 2 回測定	介入群 (人)	対照群 (人)
あり	あり	11	3
あり	なし	3	4
なし	あり	1	4
なし	なし	2	4
n		17	15

($z = -0.53, ns$)

次に、心身機能〔握力、開眼片足立ち、最大歩幅、10M 歩行歩数(普通歩および速歩)〕、転倒セルフエフィカシー(日常的な活動に対する自信の程度)、抑うつに対する教室の介入効果を、性、年齢、教育年数、入院歴、活動能力を調整して検討した。

その結果、介入群のみに統計学的に有意な転倒セルフエフィカシー得点の上昇および抑うつ得点の減少が認められ、心理機能に関する有意な介入効果が示された。

3. まとめ

市町村の転倒予防事業として一般的と考えられる内容の転倒予防教室を行い、その効果を検討した。転倒率や転倒恐怖感、あるいは各種身体機能に対する効果を確認することはできなかったが、心理機能すなわち転倒セルフエフィカシーや抑うつ症状の改善に有用である可能性が示された。費用対効果なども検討しなければ最終的な結論は出せないが、心理機能に対する有意な効果があったことを考えると、今回のような期間の限定された転倒予防教室にも、十分に実施意義はあると考え

られる。

なお、短期間の介入では、転倒予防に重要な筋力などの運動機能に十分な効果がみられないとする報告はこれまでもあることから⁷⁾、身体機能に有意な効果をもたらすには、今回の教室よりは長期のものが望ましいと考えられる。しかし、市町村などにおける事業として実施する場合には、ある程度期間が限定されてしまうことが避けがたい場合もある。そのときは、教室終了後に参加者が運動や勉強を継続できる工夫が重要となるだろう。

おわりに

最初にも述べたが、本稿の結果は、介護保険法改正前のものである。介護予防サービスとして転倒予防教室が実施可能となり、転倒予防事業は一層普及し、内容も豊富になり、効果の検証も進むと考えられる。転倒予防事業の変遷について、今

後さらに注目する必要があるだろう。

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ニュース News

鹿児島県内を含め、全国の授産施設で働く障害者から「働くほど負担増になる」など批判が噴出していた4月施行の障害者自立支援法。国は見直しを決め、県を通して各市町村への説明を進めている。早々の見直しに福祉行政への不信の声もあるが、「希望が見えてきた」と喜ぶ関係者が多い。

同法の施行により、施設内での作業による工賃から利用料を引かれると、手取りはゼロに近くなる障害者もいた。

見直しでは、工賃の月額が4万円以下の場合、施設利用料の負担を少なくした。厚生労働省社会・援護局の障害保健福祉部によると、食費などの負担額を支払っても、手元には少なくとも年間28万8,000円は残る計算だという。

同部は「障害者の働くことへのインセンティブ(誘因,刺激)を高め、より一層の配慮をする観点から今回の見直しとなった」としている。

厚労省は5月末に事務連絡の形で鹿児島県に見直

障害者自立支援法、施設利用料見直し

10月から、厚労省

しを通知。6月末にあった同省の障害保健福祉関係主管課長会議で具体的な数値を示した。県は7月中旬に見直しの内容を市町村に説明したほか、今月末にも説明会を開く。10月から実施予定だ。

県内の施設関係者は、制度の行方を慎重に見守る。

日置市の重度身体障害者授産施設「鹿児島太陽の里」の佐多京子理事長は「施行前から問題点が見えていたので、見直しが遅れたのは残念。ただ大勢の障害者が恩恵を受けることになり、希望が見えてきた。今後も利用者の生の声を訴えていきたい」と話している。

始良町の身体障害者通所授産施設サン・ヴィレッジ始良の山之内浩子施設長は障害者の働きがいが考慮されたことを評価。一方で、「生活全般にわたる1割負担が重圧で、まだまだ暮らしにゆとりがない」と話している。

(南日本新聞・鹿児島 2006年8月16日)

Effect of regular exercise on homocysteine concentrations: the HERITAGE Family Study

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Abstract We investigated whether regular aerobic exercise could affect plasma total homocysteine (tHcy), and whether there were sex-related or racial differences in tHcy changes. Data were available for 816 black and white men and women, aged 17–65 years, 711 of whom completed a 20 week aerobic exercise training program. The tHcy concentration was measured in frozen plasma samples by an HPLC

method. In Blacks, tHcy did not change with exercise training [men -0.5 (SD 3.7) $\mu\text{mol/l}$, women 0.0 (2.2) $\mu\text{mol/l}$] but increased significantly in Whites (men $+0.3$ (1.7) $\mu\text{mol/l}$, women $+0.2$ (1.6) $\mu\text{mol/l}$). No sex-related differences were found in either racial group. Changes in tHcy correlated negatively with baseline homocysteine ($r = -0.40$, $P < 0.0001$). Homocysteine levels of the “High” (hyperhomocysteinemia) ($\geq 15 \mu\text{mol/l}$) group ($n = 30$) decreased significantly with regular aerobic exercise from 23.1 (12.1) to 19.6 (7.6) $\mu\text{mol/l}$. Homocysteine levels of the “Normal” group increased slightly from 8.2 ± 2.2 to $8.5 \pm 2.4 \mu\text{mol/l}$. Men exhibit racial differences for tHcy responses to exercise training. Regular aerobic exercise has favorable effects on individuals with hyperhomocysteinemia, but tHcy slightly increased in individuals within the normal range.

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Keywords Aerobic exercise training · Sex ·
Homocysteine · Hyperhomocysteinemia ·
Racial differences

Introduction

Elevated plasma total homocysteine concentrations (tHcy) are thought to contribute to atherosclerosis and thrombosis in several ways: (a) endothelial cell injury and endothelial dysfunction, (b) increased vascular smooth muscle cell growth, (c) increased platelet adhesiveness, (d) enhanced low density lipoprotein oxidation and deposition in the arterial wall, and (e) direct activation of the coagulation cascade (Fonseca et al. 1999). Epidemiological studies have shown that elevated tHcy are independently associated with an

increased risk of coronary artery disease (Langman et al. 2000; Ridker et al. 1999). Further, several observational studies have found that lowering tHcy was associated with reduced incidence of heart attack and strokes (Homocysteine Studies Collaboration 2002; Boushey et al. 1995; Schnyder et al. 2001).

Little information is available on the effect of exercise on tHcy. Although a few studies on endurance trained men (Konig et al. 2003) and untrained young women (De Cree et al. 1999) have shown that a single bout of intensive exercise acutely increased tHcy, long-term (6 months) regular exercise may be associated with a reduction in tHcy in young overweight and obese women (Randeve et al. 2002). These studies were, however, too small to provide conclusive evidence for an effect of regular exercise on tHcy.

An epidemiological study (Ganji and Kafai 2003) showed that both sex and race were important predictors of tHcy. The difference in tHcy between men and women was explained by alcohol consumption and blood concentrations of folate, vitamin B₁₂ (cyanocobalamin), creatinine and cotinine. On the other hand, racial differences are thought to be partly accounted for variation in allele frequency at the methylenetetrahydrofolate reductase gene (Cappuccio et al. 2002). To our knowledge, no data have been reported on race or sex differences for the changes in tHcy in response to exercise training. Therefore, the purpose of this study was to investigate the effects of relatively long-term regular exercise on tHcy in a large sample of black and white men and women.

Methods

Subjects

The HERITAGE Family Study was designed to define the role of the genotype in cardiovascular, metabolic and hormonal responses to aerobic exercise training. The aim, design and measurement protocol of the HERITAGE Family Study has been previously described in details elsewhere (Bouchard et al. 1995).

The present study is based on baseline data from 816 sedentary subjects, who were recruited and studied at four clinical centers. They came from families that included parents (aged ≤ 65 years) and adult offspring (aged ≥ 17 years). They were required to be sedentary at baseline, with a body mass index (BMI) < 40 kg/m² (a few cases with BMI ≥ 40 kg/m² were included with sufficient clinical justification), resting systolic blood pressure < 160 mm Hg, resting diastolic blood pressure < 100 mm Hg, plasma total cholesterol < 350 mg/dl, and

fasting plasma triglycerides < 500 mg/dl. Subjects who had renal, hepatic or cardiac disease, were diabetic, or had hypothyroidism, or were being treated with lipid-lowering, hypertensive or hypoglycemic drugs were excluded. The study relies also on data from the response to a 20 week aerobic exercise training program in 730 subjects (90 black men, 159 black women including 18 post-menopausal and 46 who were taking hormones, 236 white men, and 245 white women including 45 post-menopausal and 105 who were taking hormones). The study protocol was approved by the Institutional Review Board at each clinical center. The aim and design of the study were explained to all subjects before they gave written informed consent.

Measures

Body weight, height, waist and hip circumferences were measured according to standardized procedures (Wilmore et al. 1997), and BMI was calculated as body weight (kg) divided by height (m²). Body composition (fat mass and fat free mass) was estimated using the hydrostatic weighing technique. Details of the protocol of the hydrostatic weighing technique and body composition estimation are provided elsewhere (Wilmore et al. 1997).

Resting BP was measured using Colin STBP-780 automated units before 11 AM in the post-absorptive state (Rankinen et al. 2000). Subjects were asked to abstain from caffeine-containing or tobacco products for 2 h before measurements were made. Subjects rested for 5 min before the initial measurement. Blood samples were obtained after a 12 h fast. Cholesterol was determined in plasma by enzymatic methods (Despres et al. 2000).

The tHcy (the sum of homocysteine, homocystine, and homocysteine–cysteine mixed disulfides, free and protein bound) were measured in frozen plasma samples (-70°C) by an HPLC method (Durand et al. 1996). The intra- and inter-assay coefficients of variation for tHcy are 3.0% ($n = 12$) and 3.3% ($n = 50$), respectively. Plasma folate and vitamin B₁₂ concentrations were determined by means of radioimmunoassay using a commercial kit (SimulTRAC-SNB_B₁₂/Folate, ICN Diagnostics, Orangeburg, NY). The intra- and inter-assay coefficients of variation are 6.3% ($n = 20$) and 10.3% ($n = 14$), respectively, for folate, and 4.9% ($n = 20$) and 4.3% ($n = 14$), respectively, for vitamin B₁₂. Plasma vitamin B₆ (pyridoxal phosphate) concentrations were also determined by means of a radioimmunoassay using a commercial kit (Vitamin B₆ (³H) REA, American Laboratory Products Company, Windham, NH). The intra- and inter-assay coefficients

of variation for vitamin B₆ are 4.6% ($n = 9$) and 10.2% ($n = 8$), respectively.

Progressive maximal exercise tests to exhaustion were conducted both before and after the exercise training program on a stationary cycle ergometer (Ergo-Metrics 800S, SensorMedics, Yorba Linda, CA) connected to a SensorMedics 2900 metabolic cart.

Exercise training protocols

Each subject was trained three sessions per week for 20 weeks on stationary cycle ergometers that were computer controlled to automatically maintain the participant's target heart rates corresponding to heart rates associated with fixed percentages of the baseline VO_{2max} test (Skinner et al. 2000). The intensity and duration of the training program was adjusted each 2 weeks. Training began at a heart rate corresponding to 55% of each subject's baseline VO_{2max} for 30 min per session and progressed to an intensity of 75% for 50 min during the last 6 weeks. All training sessions were supervised on site.

Subjects were asked not to change their eating patterns (meals and supplement use) during the intervention period.

Statistical analysis

General linear model analyses were used to test for differences between men and women as well as between the two ethnic groups. Paired *t*-tests were used to assess differences between variables before and after the exercise training program. Multiple regression analyses with the forward stepwise method were performed to estimate the independent contributions of age, sex, race, menopausal status, taking hormones,

BMI, waist circumference, body composition, VO_{2max} , resting blood pressure, plasma levels of cholesterol, folate, vitamin B₆ and vitamin B₁₂ to the variations in tHcy at baseline and changes in tHcy in response to aerobic exercise training. The relationship between two measurements was assessed by Pearson and Spearman rank correlation coefficients. Based on a position statement of the American Heart Association, we classified subjects into two groups: subjects with tHcy in the normal range ($<15 \mu\text{mol/l}$, "Normal" group) and subjects with elevated levels or hyperhomocysteinemia ($\geq 15 \mu\text{mol/l}$, "High" group) (Malinow et al. 1999). Probability values below 0.05 were regarded as significant. The data were analyzed with the Statistical Analysis System (SAS), version 9.1.

Results

Physical and biochemical characteristics of subjects at baseline are presented in Table 1 ($n = 816$). Detailed values of anthropometric and body composition measurements (Wilmore et al. 1997), resting blood pressure (Rankinen et al. 2000), and plasma lipids (Despres et al. 2000) were presented in previous reports. The tHcy levels were higher in men in both ethnic groups, and were higher in Blacks in both sexes.

For the whole sample ($n = 711$), the mean change in tHcy was only $+0.1 \mu\text{mol/l}$ from baseline ($8.8 \pm 4.4 \mu\text{mol/l}$) to post-exercise training ($8.9 \pm 3.6 \mu\text{mol/l}$) ($P = 0.096$). Table 2 shows that tHcy did not change in Blacks but increased significantly in Whites. Vitamin B₆ remained unchanged, whereas vitamin B₁₂ decreased significantly in all groups. Folate increased significantly in black men only. When the changes were compared between the two ethnic groups, we found a

Table 1 Comparison of baseline data between men and women, and between Blacks and Whites

	Blacks		Whites		Race difference	
	Women ($n = 191$)	Men ($n = 111$)	Women ($n = 260$)	Men ($n = 254$)	Women	Men
Age (years)	33.0 (11.4)	32.9 (12.3)	35.1 (14.1)	36.2 (14.9)	0.089	0.028
Height (m)	1.62 (6.6)	1.76 (6.7) ^a	1.64 (6.4)	1.78 (6.3) ^a	0.041	0.01
Weight (kg)	74.4 (17.9)	84.6 (18.6) ^a	67.2 (13.6)	84.4 (16.2) ^a	<0.0001	0.907
BMI (kg/m ²)	28.2 (6.5)	27.4 (5.6)	25.1 (5.0)	26.7 (4.9) ^a	<0.0001	0.218
Homocysteine ($\mu\text{mol/l}$)	8.5 (4.2)	11.0 (7.2) ^a	7.7 (2.7)	9.4 (3.7) ^a	0.01	0.004
Folate (nmol/l)	12.0 (8.3)	12.0 (8.5)	16.6 (15.0)	14.1 (10.3)	0.001	0.034
Vitamin B ₆ (nmol/l)	40.6 (38.0)	64.9 (59.4)	56.2 (63.0)	60.9 (51.9) ^a	0.0001	0.763
Vitamin B ₁₂ (nmol/l)	332 (153)	328 (183)	286 (144)	289 (112)	0.0004	0.099
VO_{2max} (ml/min)	1,753 (365)	2,758 (490) ^a	1,912 (347)	3,026 (582) ^a	<0.0001	<0.0001

Data are expressed as mean (SD)

BMI body mass index, VO_{2max} maximal oxygen uptake

^a $P < 0.001$ significantly different from women

Table 2 Comparison of changes in measurements between men and women, and between Blacks and Whites

	Blacks		Whites		Race difference	
	Women (<i>n</i> = 151)	Men (<i>n</i> = 87)	Women (<i>n</i> = 243)	Men (<i>n</i> = 230)	Women <i>P</i> -value	Men <i>P</i> -value
Weight (kg)	−0.4 (2.9) ^a	−0.8 (3.1) ^a	−0.1 (2.1)	−0.3 (2.1) ^a	0.224	0.252
BMI (kg/m ²)	−0.2 (1.1)	−0.2 (0.9) ^a	−0.0 (0.8)	−0.1 (0.7) ^a	0.279	0.376
Homocysteine (μmol/l)	+0.0 (2.3)	−0.5 (3.8)	+0.2 (1.6) ^a	+0.3 (1.7) ^a	0.407	0.04
Folate (nmol/l)	+0.9 (9.6)	+2.8 (7.9) ^a	−0.7 (9.0)	−0.3 (6.9)	0.111	0.003
Vitamin B ₆ (nmol/l)	+3.3 (27.6)	+12.2 (76.2)	−1.5 (62.2)	+6.6 (64.7)	0.299	0.521
Vitamin B ₁₂ (nmol/l)	−17 (71) ^a	−14 (79) ^a	−23 (62) ^a	−18 (68) ^a	0.404	0.306
VO _{2max} (ml/min)	+336 (151) ^a	+411 (201) ^{a, b}	+349 (183) ^a	+450 (236) ^{a, b}	0.447	0.185

Data are expressed as mean (SD)

BMI body mass index, VO_{2max} = maximal oxygen uptake

^a Training response (post–pre) *P* < 0.05

^b *P* < 0.01 significantly different from women

significant difference in males for folate and homocysteine. No sex difference was found for any of the variables. After exercise training, the mean (SD) values of tHcy were 8.6 (3.4) μmol/l for black women, 10.8 (5.4) μmol/l for black men, 8.0 (2.4) μmol/l for white women, and 9.6 (3.4) μmol/l for white men. Sex and racial differences were identical to those at baseline.

We quantified the independent contributions of the variables considered here to the variance in tHcy. At baseline (Table 3), folate was the best predictor of tHcy in both sexes, and both races. Age, ethnicity and vitamin B₁₂ were also significant predictors of tHcy. When exercise training induced changes in tHcy were used as the dependent variable, baseline homocysteine levels, and changes in folate were the strongest predictors in the whole sample as well as in the sex and race subgroups (Table 3). Although VO_{2max} was not selected as a significant predictor, increases in VO_{2max} tended to associate with decreases in tHcy (*P* = 0.06) in the whole sample.

Figure 1 illustrates the relationship between baseline tHcy and change in tHcy in response to exercise training. Changes in tHcy were negatively correlated with baseline tHcy (Pearson correlation coefficient = −0.40, *P* < 0.0001 and Spearman rank correlation coefficient = −0.25, *P* < 0.0001).

Figure 2 displays individual tHcy data for the High group (*n* = 30) at baseline and after training. Mean values of tHcy decreased from 23.1 (SD 12.1) μmol/l to 19.6 (7.6) μmol/l (*P* = 0.01). After training, 21 (70%) individuals (3 black women, 9 black men, 3 white women, and 6 white men) decreased their tHcy. Eight of the 21 individuals decreased their tHcy to less than 15 μmol/l. On the other hand, in the Normal group (*n* = 681), only 8 (1%) individuals (2 black women, 3 black men, 1 white women, and 2 white men) increased their tHcy to more than 15 μmol/l. The Normal group

had a statistically significant increase in tHcy from 8.2 (2.2) μmol/l to 8.5 (2.4) μmol/l (*P* < 0.0001).

Figure 3 compares tHcy changes between the Normal and High groups. A significant (*P* < 0.0001) difference was observed between the Normal [+0.3 (1.5) μmol/l] and High [−3.5 (7.0) μmol/l] groups for the tHcy response to exercise training. The difference was still found after adjustment for age, sex, race and baseline tHcy (*P* = 0.0028). Folate levels increased significantly (+1.1 ± 3.0 nmol/l, *P* < 0.05) during the exercise training in the High group but remained unchanged in the Normal group. Vitamin B₁₂ levels did not change in the High group but decreased significantly (−16.5 ± 97.8 pmol/l, *P* < 0.0001) in the Normal group.

Discussion

We found that the 20 week aerobic exercise training program reduced significantly tHcy (−3.5 μmol/l, *P* = 0.01) in those with elevated tHcy at baseline. Moreover, a significant difference in tHcy changes remained between the Normal and High groups even after adjustment for age, sex, race and baseline tHcy (*P* = 0.0028). Boushey et al. (1995) have reported that about 10% of the population's coronary artery disease risk was attributable to tHcy, and Ueland et al. (2000) found that an increase of 5 μmol/l in tHcy could be associated with a 20% increased risk of cardiovascular disease. Schnyder et al. (2001) found that lowering tHcy from 11.1 to 7.2 μmol/l reduced significantly the rate of coronary restenosis after angioplasty and decreased the incidence of major adverse cardiac events. In a more recent study, lowering tHcy by 25% (3 μmol/l) was associated with an 11% lower ischemic heart disease and 19% lower stroke risk (Homocysteine

Table 3 Results of multiple regression analysis

Independent variable	Homocysteine at baseline					Independent variable	Homocysteine training response				
	Beta	F	P	Partial R ²	Model R ²		Beta	F	P	Partial R ²	Model R ²
[All]											
Folate	-0.18	118.1	<0.0001	14.2	14.2	B_homocysteine	-5.36	72.8	<0.0001	10.5	10.5
Sex ^a	-0.1	77.4	<0.0001	8.4	22.6	ΔFolate	-0.04	21.5	<0.0001	3.0	13.5
Age	0.002	73.8	<0.0001	7.3	29.9	Age	0.02	7.9	0.005	1.1	14.6
B ₁₂	-0.17	44.9	<0.0001	4.2	34.1	B_folate	-0.78	8.9	0.003	1.2	15.8
Race ^b	-0.04	18.6	<0.0001	1.7	35.8	B_VO _{2max}	0.0004	11.4	0.0008	1.5	17.3
						ΔB12	-0.002	4.5	0.036	0.6	17.9
						B_B6	-0.004	4.4	0.036	0.6	18.5
[Male]											
Folate	-0.23	65.6	<0.0001	16.7	16.7	B_homocysteine	-5.9	44.4	<0.0001	13.4	13.4
Age	0.002	48.3	<0.0001	10.8	27.5	ΔFolate	-0.05	15.3	0.0001	4.4	17.8
B ₁₂	-0.16	14.6	0.0002	3.1	30.6	ΔB12	-0.004	5.7	0.018	1.6	19.4
Race	-0.05	13.4	0.0003	2.8	33.4	Age	0.03	4.1	0.044	1.2	20.6
Fat%	0.002	8.6	0.004	1.7	35.1	B_VO _{2max}	0.0006	5.9	0.015	1.6	22.2
						B_folate	-0.9	5.1	0.025	1.4	23.6
[Female]											
Folate	-0.15	60.3	<0.0001	13.6	13.6	B_homocysteine	-4.61	32.2	<0.0001	8.9	8.9
B ₁₂	-0.18	35.9	<0.0001	7.4	21.0	ΔFolate	-0.03	8.9	0.003	2.4	11.3
Age	0.002	22.1	<0.0001	4.3	25.3	B_B6	-0.84	6.2	0.013	1.6	12.9
Race	-0.03	6.8	0.009	1.3	26.6	ΔB6	-0.003	4.9	0.028	1.3	14.2
						Age	0.02	5.3	0.021	1.4	15.6
[Blacks]											
Folate	-0.26	50.9	<0.0001	17.4	17.4	B_homocysteine	-8.0	61.0	<0.0001	25.0	25.0
Sex	-0.17	34.3	0.0001	10.3	27.7	ΔFolate	-0.05	8.4	0.004	3.3	28.3
Age	0.002	21.9	0.0027	6.0	33.7	ΔB6	-0.006	5.4	0.021	2.1	30.4
B ₁₂	-0.17	14.6	0.0096	3.8	37.5						
Cholesterol	0.02	4.2	0.041	1.1	38.6						
[Whites]											
Folate	-0.16	66.2	<0.0001	12.4	12.4	B_homocysteine	-0.03	42.0	<0.0001	8.8	8.8
Age	0.002	61.3	<0.0001	10.2	22.6	ΔFolate		10.2	0.0015	2.1	10.9
Sex	-0.07	45.0	<0.0001	6.8	29.4	Sex		9.2	0.0026	1.8	12.7
B ₁₂	-0.17	42.2	<0.0001	5.9	35.3	B_B6		9.8	0.0019	1.9	14.6
Resting DBP	0.002	7.0	0.008	1.0	36.2	B_folate		6.8	0.009	1.3	16.0
						Age		12.1	0.0006	2.3	18.3
						ΔB6		4.4	0.036	0.8	19.1

^a 1 = men, 2 = women

^b 1 = blacks, 2 = whites

Studies Collaboration 2002). Therefore, our observation that tHcy can be lowered by regular exercise in those with high levels is coherent with a number of studies indicating that it may reduce significantly the risk of events in individuals with hyperhomocysteinemia.

Sex difference

The tHcy concentrations are known to be higher in men than in women (Ganji and Kafai 2003; Carmel et al. 1999; Fukagawa et al. 2000; Lussier-Cacan et al. 1996; Morris et al. 2000; Nygard et al. 1995). Ganji et al. (2003) and Carmel et al. (1999) found that the sex-related difference could be explained by alcohol consumption, and concentrations of plasma folate, vitamin B₁₂, creatinine and cotinine. Folic acid and vitamin B₁₂ are involved as co-factors in metabolic

pathways catalyzed by the enzymes 16,2methylene-tetrahydrofolate reductase and methionine synthase, respectively, whereas vitamin B₆ is a cofactor for cystathionine beta synthase (Kang et al. 1992). A number of studies have shown inverse relationships of tHcy with plasma/serum levels of folate, vitamin B₆ and vitamin B₁₂ (Robinson et al. 1998; Selhub et al. 1993). Moreover, differences in rates of homocysteine remethylation (Fukagawa et al. 2000) and estrogen concentrations (Morris et al. 2000) may also contribute to the homocysteine sex dimorphism. Remethylation is one of the major pathways for homocysteine metabolism. In remethylation, homocysteine is salvaged by acquisition of a methyl group from N⁵-methyl-tetrahydrofolate in a vitamin B₁₂ dependent pathway or from betaine in a pathway occurring primarily in the liver (McKeever et al. 1991). Fukagawa et al. (2000) and

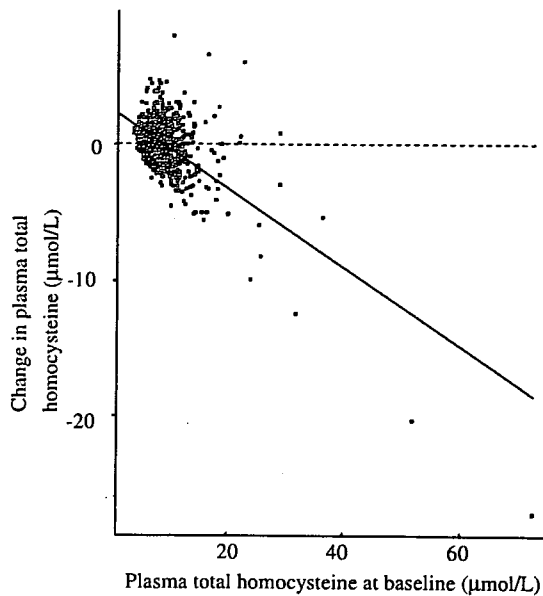


Fig. 1 Association between baseline homocysteine and regular exercise-induced changes in homocysteine. Pearson correlation coefficient = -0.40 ($P < 0.0001$), Spearman correlation coefficient = -0.25 ($P < 0.0001$)

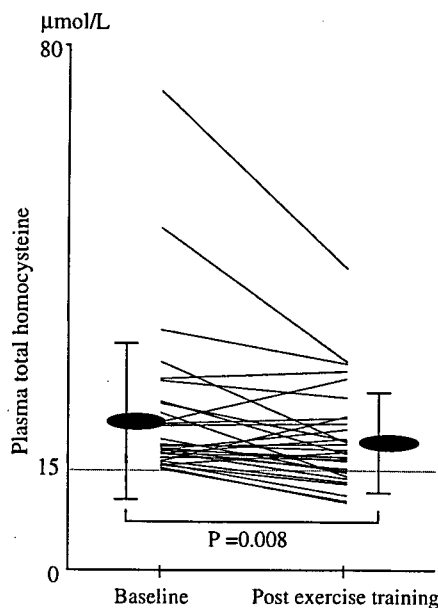


Fig. 2 Plasma total homocysteine levels in the High group at baseline and post-exercise training. Vertical lines indicate means (filled circle) and SD

McKeever et al. (1991) found that the remethylation rate was significantly higher in women than in men. They concluded that the sex-related difference is partially explained by homocysteine remethylation rates. Morris et al. (2000) found that higher estrogen concentrations

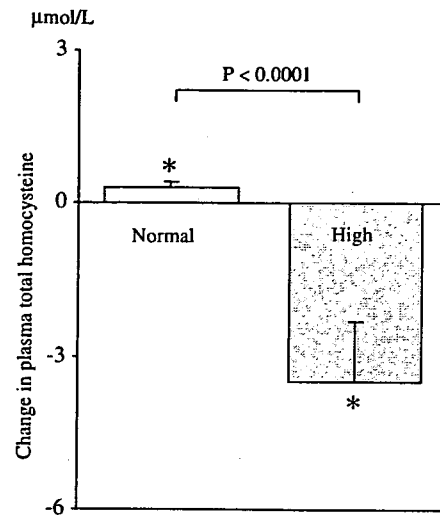


Fig. 3 Comparison of changes in plasma homocysteine levels between the “Normal” and “High” groups. Data are expressed as means \pm SEM. * $P < 0.01$, within group difference (pre vs post)

are associated with lower tHcy, independent of nutritional status and muscle mass.

In the Hordaland Homocysteine Study (Nygard et al. 1995), tHcy levels were 19% higher in men ($10.8 \mu\text{mol/l}$) than in women ($9.1 \mu\text{mol/l}$) in middle age participants but only 11% (men $12.3 \mu\text{mol/l}$ and women $11.0 \mu\text{mol/l}$) in elderly subjects. Although our data also indicated that baseline tHcy was higher in men than in women, there was no difference in exercise-induced changes in tHcy between men and women.

Racial differences

Several studies (Carmel et al. 1999; Ganji and Kafai 2003; Morris et al. 2000) have reported that Whites have 7–8% higher tHcy than Blacks. For instance, Ganji and Kafai (2003) found that tHcy was 8% higher in Whites ($10.4 \mu\text{mol/l}$) than in Blacks ($9.6 \mu\text{mol/l}$). Carmel et al. (1999) speculated that the higher tHcy in Whites might be explained by their lower vitamin B₁₂ status compared with Blacks. On the other hand, the third National Health and Nutrition Survey in the United States (Jacques et al. 1999) found no racial difference in tHcy.

The present study indicates that baseline homocysteine levels were higher in Blacks than in Whites, and differences were also found for the training changes in homocysteine levels between Black and White men. Several investigators have reported that folate and vitamin B₁₂ were predictors of blood homocysteine concentrations (Koehler et al. 2001; Morris et al. 2000).

Using multiple regression analyses, folate was found to be the strongest predictor of homocysteine in the present study. Our results also showed that folate levels were higher in Whites than in Blacks although vitamin B₁₂ levels were higher in Blacks.

The present study has some limitations. First, since the primary goal of the HERITAGE Family Study is to study the role of genotype in the responsiveness to regular exercise, a control group was not deemed necessary. Second, subjects were asked not to change their eating patterns during the 20 week intervention period, but we have no direct assessments of folic acid, vitamin B₆ and B₁₂ intakes over the duration of the exercise protocol.

In summary, we have examined the effects of exercise training on tHcy concentrations in both sexes and in Blacks and Whites. Baseline tHcy is higher in men than in women, consistent with previous studies. However, no difference between men and women was found for the changes in tHcy levels as a result of regular exercise. Baseline tHcy was higher in Blacks than in Whites, and in men, differences were also found for the changes in tHcy between the two ethnic groups. Twenty weeks of regular exercise reduced tHcy in individuals with baseline hyperhomocysteinemia, although tHcy slightly increased in individuals who were in the normal range of tHcy at baseline.

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A novel exercise for improving lower-extremity functional fitness in the elderly

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ABSTRACT. Background and aims: Many falls in the elderly are caused by tripping. After tripping, a certain level of lower-extremity functional fitness is necessary, in order to make protective responses and to avoid falling. The purpose of this study was to test whether our new exercise program (a square-stepping exercise: SSE) would improve lower-extremity functional fitness in the elderly. **Methods:** Fifty-two individuals aged 60-80 years were divided into two groups (non-randomized control design); SSE (n=26) and controls (n=26). Lower-extremity functional fitness was defined as standing up from a lying position (agility), chair-stand in ten seconds (leg power), walking round two cones (locomotion speed), sit-and-reach (flexibility) and single-leg balance with eyes closed (balance). The SSE group participated in a six-month regimen of SSE once a week. SSE was performed on a thin mat of 250 cm by 100 cm, partitioned into 40 small squares (25 cm each side). SSE included not only forward steps but also backward, lateral and oblique steps, and step patterns were progressively made more complicated. Controls maintained their usual lifestyles. **Results:** In the SSE group, significant improvements were observed in agility, leg power, locomotion speed, flexibility and balance. No significant changes were detected in any tests in the control group. **Conclusions:** The SSE program improved lower-extremity functional fitness, lack of which constitutes a risk factor for falls in the elderly. This program should be tested further to determine if it can effectively reduce the incidence of falls in the elderly.

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INTRODUCTION

In Japan, a national survey found the incidence (per 10,000 per year) of hip fracture in 1997 was 17.3 (men) and 40.8 (women) in persons 60-69 years old, and

57.4 (men) and 147.8 (women) in those 70-79 years old (1). Falls are the most common cause of hip fractures, leading to decreased mobility, restriction to bed, and/or death; in addition, not only hip fractures but also minor injuries such as joint dislocation, lacerations and bruises are also caused by falls (2). As well as fall-associated injuries, falls may lead to an increased fear of falling which can restrict social activities, thereby decreasing independence and overall quality of life.

An interview-based community survey (3) reported that 35% of older residents had suffered one or more falls in the preceding year, and that 53% of the falls had been caused by tripping. Other causes, much less common, were dizziness (7.8%), black-out (6.4%) or accident (5.2%). For many elderly people, impact velocities at the ground after tripping were within one standard deviation of the estimate of the mean impact velocity needed to fracture a femur (4). Falling sideways, which is often observed after slipping, is also associated with the incidence of hip fractures (4, 5); the impact velocity after slipping also reaches the estimated femur fracture velocity (4). Therefore, the prevention of falls caused by elderly persons tripping or slipping is one of the most important areas for maintaining independence and quality of life in this age group.

Effective interventions for preventing falls should include quick stepping in any direction and the generation of enough force at push off to support the whole body following a trip or slip (6). Quickness (reaction speed/agility) and power in the lower extremity, which have been implicated as factors influencing falls, decrease with age (2, 7-10). In most elderly people, the ability to respond quickly and forcefully may be impaired, leading directly to falling. To the best of our knowledge, there are few studies concerning the development of an intervention program to improve speed and power in the lower extremities of the elderly. This study aimed at developing a novel exercise program for improving lower-extremity

Key words: Fall, risk, slip, square-stepping exercise, trip.

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functional fitness in the elderly, and to assess its effects on fall-related risk factors.

METHODS

Study design

An age- and gender-matched, six-month intervention and non-randomized control trial was conducted in Gifu, the capital city of Gifu Prefecture, located in the centre of Japan.

Participants

Participants in the exercise group were recruited in two ways. One was by direct mailing to pensioners who had an account in the Juroku Bank (Gifu, Japan). Approximately 38,000 letters were sent to people who lived in the area around the building in which the exercise program was conducted. Another procedure was to use leaflets, which were placed in the main office and 60 branch offices of Juroku Bank in Gifu Prefecture. The mailer or leaflet, besides our program, also contained information on several free-of-charge culture classes for the elderly, such as Chinese conversation and "shogi" (Japanese chess) classes. Persons receiving the mailer or leaflet could attend and choose any class from the list, including our program.

Twenty-six people aged 60-80 years agreed to participate in the study (6 men, 20 women). To lower the risks of accident by exercise, five consecutive low-intensity exercise sessions (60 minutes each) over a period of 10 weeks were given to participants before the study. These exercise sessions mainly consisted of stretching the lower extremities while sitting or lying on a mat, and calisthenics for the upper extremities while in a standing position. Participants then engaged in the pre-test and square stepping exercise (SSE) program (see below) for six months without interruption, but were not encouraged to engage in any other new forms of exercise. Once an exercise group was identified, age- (± 3 years) and gender-matched controls were selected at random from among cohort members of another surveillance program, in which elderly individuals aged 60 or more living in the city attended as participants of another research program focused on aging and lifestyle. Controls were asked to maintain their lifestyles for six months and to refrain from engaging in the SSE program or any other new form of exercise. Individuals who were living in care facilities, who were regularly exercising twice or more weekly, had a history of illness or a condition that would affect balance (e.g., stroke or Parkinson's disease), or were unable to participate safely in the exercise program, were excluded.

The Juroku Bank and the University of Nagoya cooperated in the Revitalization of Physical and Social Activities of the Elderly Project and approved the study. All participants gave their informed consent before participating.

Outcome measures

Outcome measures were changes in functional fitness related to the risks associated with falling. Fallers are more likely to report difficulty rising from a bed or chair, and to have some form of gait abnormality (11). Lower limb weakness and poor tandem-walking ability have emerged as significant predictive factors among multiple clinical and functional falling risk factors (12). Gehlsen et al. (13) reported that functional fitness in those with a history of falls was lower than in those with no history of falls. In that study, functional fitness items included static balance (one-leg balance test), dynamic balance (backward-walking test), hip, knee and ankle joint strength, and hip and ankle flexibility tests.

From these studies, we assumed that agility, leg power, locomotion speed, flexibility and balance would be elements of functional fitness related to the risk of falls. Further, in the present study, five functional fitness tests were selected to match each element: standing up from a lying position (agility), chair-stand in 10 seconds (leg power), walking round two cones (locomotion speed), sit-and-reach (flexibility), and single-leg balance with eyes closed (balance). Details of the measurements of these fitness items have been reported elsewhere (14, 15). In standing up from a lying position on a signal, participants were asked to stand up as quickly as they could, to a stable erect position from a lying position. The process of moving to the standing position depended on each participant's customary method. Performance time was assessed in terms of time needed to reach a stable erect position. In the item of chair-stand in ten seconds, participants were asked to repeat the exercise of fully standing up and then fully sitting on a chair as many times as possible within ten seconds. During the measurement, participants crossed their arms at the wrists and held them to their chests. Walking round two cones was measured as follows: two cones were placed 1.8 m on both sides of and 1.5 m behind the chair. Participants rose from the chair, walked to the right going inside and round the back of the cone, returned to a fully seated position on the chair, stood up and walked round the left cone, and returned to a fully seated position. One trial consisted of two complete circuits (total distance about 16.8 m). Performance time was recorded in units of 0.1 seconds. In the test of sit-and-reach, participants were asked to sit on the floor and push the plastic cursor forward slowly as far as possible with their middle fingers and without bending their knees. Performance was recorded as the maximum distance between toes and middle fingers; the farther forward the fingers, the greater the performance distance. The reference position, 0 cm, was at the level of the toes. Participants performed twice and the better (further) score indicated by the cursor was noted.

Descriptive variables, such as age, height, weight and attendance rate in the exercise program, were recorded.



Fig. 1 - Square stepping exercise.

Exercise intervention

Based on the mechanism and direction of falls, and on ladder training drills designed for athletes, we developed our SSE program and used it for the intervention described here. SSE was performed on a thin mat of 250 cm by 100 cm, partitioned into 40 small squares (25 cm each side). A smaller mat, 200 x 80 cm, also partitioned with smaller squares (20 cm each side), was prepared for shorter participants (i.e., those less than 150 cm in height). Participants were required to step in the length direction (250 or 200 cm), basically without treading on the lines making up the squares. The SSE program included forward, backward, lateral and oblique steps, and step patterns were progressively made more complicated (Fig. 1).

One hundred and nineteen step patterns were developed and categorized into Junior (8 patterns), Basic (19), Semi-Regular (17), Regular (26), Senior (35) and Master (14) patterns, according to difficulty. Examples of Junior, Basic, Regular and Master patterns are shown in

Fig. 2. Junior patterns consisted of easy steps, i.e., forward steps only. For Basic patterns, lateral steps were added to the Junior patterns. Further, oblique and backward steps were added in the Semi-Regular patterns; somewhat complicated oblique and backward steps were added in the Regular patterns; complicated lateral, oblique and backward steps were added in the Senior patterns; and much more complicated steps were added in the Master patterns.

There were some options, so that step patterns in each category were more complicated. Many patterns required a wide stance over one or two squares. Some patterns had bilateral symmetry, which led participants to grasp the pattern image easily. Each pattern consisted of two to 16 steps; participants were asked to repeat the step pattern until they got to the end of the mat. Once a pattern was performed, a mirror-imaged pattern was then also performed.

The exercise group participated in a six-month regimen of SSE once a week. Each SSE class consisted of 10-min warm-up activities, such as walking and mild stretching, 30-min SSE, 10-min whole-body light resistance training, and 10-min cool-down. To familiarize participants with SSE, only Junior patterns were used for the first month. From the second month, Junior patterns were performed as the warm-up. Participants were encouraged to try some new patterns in the Basic or more complicated categories. Essentially, a one-step pattern was repeated 3-5 times and then the mirror-image pattern was repeated the same number of times. If participants could not step a pattern smoothly, they repeated it until it was accomplished, and then they progressed to a new step pattern. The Basic and more complicated category patterns which included lateral, oblique and backward steps were carefully introduced, because many participants needed a long time to learn each new pattern. During the SSE program, step patterns drawn on leaflets or boards were not provided. Participants were asked to learn the pattern by watching an instructor's movements.

Participants were also asked to go forward on the mat one-way, to pass back by the mat walking normally, and then to stand in a line for the next stepping exercise: this meant that the number of steps did not differ among participants. Raising the heels was a recommended option: this made it more difficult for participants to step the patterns and ensured improvements in agility, locomotion speed and balance. Although step cadence was not determined, participants stepped slowly at first and then were able to step faster after some practice. For example, in the Basic pattern shown in Fig. 2, participants stepped at approximately 1 step/sec. They needed some time to remember where they should place their feet during the steps, and so took 20 to 30 seconds in one direction. After some practice, they could step out the patterns at approximately 2 steps/s: and took 20 or fewer seconds to complete.

Junior				Basic				Regular				Master			
	2			4	2	1	3		6	1	5	2	6	5	1
		1		4	2	1	3		4	2	3	8	4	3	7
	2			4	2	1	3		6	1	5	16	12	11	15
		1		4	2	1	3		4	2	3	10	14	13	9
	2			4	2	1	3		6	1	5	2	6	5	1
		1		4	2	1	3		4	2	3	8	4	3	7
	2			4	2	1	3		6	1	5	16	12	11	15
		1		4	2	1	3		4	2	3	10	14	13	9
	2			4	2	1	3		6	1	5	2	6	5	1
		1		4	2	1	3		4	2	3	8	4	3	7

Fig. 2 - Examples of Junior, Basic, Regular and Master patterns of square stepping exercise. Steps were performed according to numbers, from lower end of each figure to upper end. Odd and even numbers indicate location of right and left feet, respectively.

In each SSE class, participants gathered in a room in a Juroku Bank branch building; no transportation was provided. The floor of the venue in which classes was held was fitted with a thin carpet. Two instructors concurrently taught all SSE participants.

Statistical analysis

Data are presented as means ±SD. The overall design employed a 2 (group) by 2 (time) repeated-measures format. Repeated-measures techniques were conducted to determine time-by-group interactions. Before this, the Kolmogorov-Smirnov test was applied to determine if data on each test significantly differed from normal distribution. The Levene test was then used to verify the assumption that variances were equal across groups. When significances in these tests were found, the Wilcoxon signed-rank test for paired data was used. Two kinds of correlation coefficients in the SSE group were also calculated: the first between baseline data and the pre-post change for

each test; the second between the change in one test and the change in another test. These coefficients were calculated by: (i) Pearson's correlation analysis, when data were similar to normal distribution, and (ii) Spearman's correlation analysis when data were significantly different from normal distribution. All statistics were computed using SPSS version 11.5.1 J. The level of significance was set at α= 0.05.

RESULTS

The baseline characteristics of the two groups were very similar (Table 1). Data of the SSE group in agility, leg power, locomotion speed, flexibility and balance measures were comparable with those of the control group at the beginning of the study (Table 2). Average attendance in the SSE program was 92% (±7.9, range= 75-100%). In the exercise group, no participants discontinued involvement or claimed knee or back pains that had not already existed at the start of the study. No falls or injuries

Table 1 - Baseline characteristics of participants.

Measure	Control (n=26)	Exercise (n=26)
Age (yrs)	68.3±6.3	67.5±4.9
Height (cm)	151.4±6.3	148.5±4.3
Weight (kg)	52.5±9.3	53.2±7.0

resulted directly from the exercises. Of all the participants in the exercise group (n=26), one achieved only the Basic pattern, ranked as the second easiest category, by the time the six-month intervention was over. He could step Basic patterns easily and safely, but had difficulty in stepping the more complicated ones. Two other participants achieved Semi-regular patterns. Of the remaining participants, 14, 4 and 5 could step Regular, Senior and Master patterns, respectively, at the end of the six-month regimen. Compliance among controls was 100%, i.e., no controls engaged in any new form of exercise, they all maintained their lifestyles, and attended pre- and post-measurement sessions.

A repeated-measure ANOVA revealed a significant group-by-time interaction for standing up from a lying position ($p<0.01$). Univariate follow-up analysis revealed that the significant agility increases were attributable to the SSE program (Table 2). The exercise group experienced

a decrease of 0.39 seconds in this measurement. Walking round two cones and sit-and-reach had significant group-by-time interactions ($p<0.05$). Participants in the exercise group had a significant decrease in walking time (-1.4 s) and a significant increase in sit-and-reach (+5.8 cm). Kolmogorov-Smirnov tests revealed that data for chair-stand in 10 seconds and single-leg balance with eyes closed could not be assumed to be normally distributed. Therefore, Wilcoxon signed-rank tests were applied to these data, in which scores for chair stand (+1.8 n/10 s) and single-leg balance (+4.6 s) increased significantly in the exercise group. The control group exhibited no significant improvement in any of the five measures.

Correlation coefficients between baseline data and changes in each test are shown in Table 3a. They range from -0.45 to 0.27, accounting for 1.4-20.3% of variance; none achieved significance level ($p<0.05$) except for sit-and-reach. Correlation coefficients between the change in one test and the change in another test were not statistically significant. All coefficients were 0.37 or less in absolute value (Table 3b), which accounted for approximately 13.7% or less of each variance.

DISCUSSION

These results demonstrate improvements in agility, leg power, locomotion speed, flexibility and balance resulting from the six-month regimen of our square-stepping

Table 2 - Functional fitness at pre- and post-treatment and comparison of changes in variables.

Functional fitness related to risk of falls	Measurement item	Control group		Exercise group	
		Pre	Post	Pre	Post
Agility	Standing up from a lying position (s)	3.26±0.93	3.70±1.42	3.39±1.20	3.00±0.90 ^a
Leg power	Chair-stand in 10 seconds (n)	8.8±2.6	7.6±4.3	7.5±2.2	9.3±2.6 ^b
Locomotion speed	Walking round two cones (s)	22.6±3.4	22.9±4.8	21.2±3.5	19.8±3.6 ^a
Flexibility	Sit-and-reach (cm)	3.2±8.8	4.2±11.0	3.7±13.9	9.5±11.0 ^a
Balance	Single-leg balance with eyes closed (s)	11.0±15.5	6.7±9.1	9.3±11.7	13.9±15.6 ^b

Significances by Kolmogorov-Smirnov test were found in leg power and balance; Group-by-time interactions were found in agility, locomotion speed and flexibility by ANOVA; ^aSignificant main effect of time; ^bSignificant difference by Wilcoxon signed-rank test.

Table 3 - Correlation coefficients: (a) between baseline data and change in each test and (b) between change in one test and change in other test.

	(a)	(b)				
		1	2	3	4	5
1. Standing up from a lying position	0.27	1	0.27	0.21	0.37	0.16
2. Chair-stand in 10 seconds	-0.12		1	0.17	0.30	-0.14
3. Walking round two cones	0.24			1	0.17	0.15
4. Sit-and-reach	-0.45 [*]				1	0.06
5. Single-leg balance with eyes closed	0.12					1

Spearman's correlation coefficients were calculated when sit-and-reach or single-leg balance with eyes closed were included as independent variables; Other coefficients calculated by Pearson's analysis; ^{*} $p<0.05$.

exercise (SSE) program. In addition, the attendance rate was relatively high and there were no accidents during the SSE program. Therefore, we believe that it is an effective, practical means of decreasing the risk factors for falling in apparently healthy elderly people.

Standing up from a lying position, which we defined as agility, was significantly improved. This task requires a combination of quick response and whole-body movement. Whole-body movement during the test needs control over the center of gravity of the body, or dynamic balance. There are no published reports of changes in time or dynamic balance in standing up from a lying position as a result of an exercise intervention in the elderly, but it has been hypothesized that reaction time (2, 7) and dynamic balance (6, 16, 17) are major determinants of this test item. In previous studies, increases in reaction time are associated with high risk factors for falls (2, 7). The twelve-month prospective study of Nevitt et al. (2) found that those who had an increase in 0.75 or more seconds in hand-reaction time showed 1.8 times the relative risk of falls than those who had an increase of 0.74 seconds or less. In addition, anterior body mass carriage following a trip needs dynamic balance to control the whole body to avoid falling (6, 16, 17). Therefore, improving agility (standing up from a lying position) probably provided some reduction in risk factors for falls.

The increase in the test of chair-stand in 10 seconds probably reflected the improvement in participants' leg power (14) even though it was not assessed directly. A number of studies have identified a lack of muscular strength or power as risk factors for falling (18, 19), especially trip-induced falls (20). For example, being unable, or taking more than 2 seconds, to rise from a chair without using one's arms was associated with an increased risk of injury (2); fallers show a significant decrease in the strength of knees and ankles compared with non-fallers (21). Hip flexion joint torque from a sitting to standing position, which is related with leg power, may also be an important factor for quick chair-stand movement (22).

A low walking speed is also considered as a risk factor for falling (23-25). In the prospective study of Taylor et al. (25), a decrease of 0.22 m/sec in maximal walking speed over ten years was associated with an increase in hip fracture risk (RR 1.25, 95% CI 1.17-1.33). In the present study, the speed of walking round two cones changed from 0.79 m/sec before the program to 0.85 m/sec at the end of the program. Although a decrease in falls in itself cannot be attributed to a change of only 0.06 m/sec, the improvement in this test probably provided some improvement in risk factors for falls. Also, this improvement may play a distinct role in falls, by improving neuromuscular function, so that the SSE program influences an individual's speed, coordination and protective responses during a fall (23).

Increases in hip joint flexibility, which was measured by the sit-and-reach test in this study, should result in decreasing the risk factors for falls (13). The increase in the present study (about 6 cm) was slightly higher than our expectations, because some recent reports have found that exercise intervention that did not focus on flexibility showed an increase of about 3 cm; in these, exercise frequency or duration were not very different from those of our study (26, 27). This improvement may be due to the leg and hip stretching exercise that was provided in every warm-up period. We also told participants that doing sufficient stretching could prevent falls and injuries from occurring in the SSE program, which made them concentrate on stretching and thus improving sit-and-reach scores. A previous study (13) showed that those who had fallen three or more times in the previous year had significantly lower hip-joint flexibility than those who had had no falls. It is probable that hip-joint flexibility is related to stability and mobility in the elderly. Those with lower hip joint flexibility could not walk smoothly with a certain stance, and had great difficulty in maintaining their stability and placing the foot as a support for their bodies when a trip occurred.

Postural instability has also been cited as a risk factor for falls in the elderly (2, 12, 13, 16, 25, 28). It was hypothesized that single-leg balance with eyes closed, defined as balance, would be improved due to the stepping imposed by the SSE program with raised heels. Raised heels, which for safety reasons was not added until participants were familiar with a step pattern, probably afforded neuromuscular stimulation to the exercisers. Shigematsu et al. (29) demonstrated increases in single-leg balance with eyes closed in women aged 72-87 years who participated in a three-month dance-based aerobic exercise. They performed movements that extended, flexed, abducted, adducted and rotated the leg and foot, such as side-stepping, fast walking, forward-backward stepping and heel rises. Participants in the present study performed steps similar to those of the dance movements of Shigematsu et al.

These findings indicate that individuals in the exercise group were able to move their whole body more quickly and accurately after the exercise program. This may have clinical meaning, given that the leg movement in the front, side or oblique directions after tripping or slipping is appropriately carried out, and the center of gravity of the body is controlled to avoid falls. Since only 1.4-20.3% of the variance of the changes in each test could be explained by the initial levels, it is suggested that all persons, independently of their initial performance on any test, could benefit from our SSE program in at least one fitness element.

The present study was conducted with non-randomized allocation of participants. However, it may be difficult for persons who are transitioning to frailty or who are already frail to attend an SSE program. Therefore, our results may