が確認された．

血液生化学検査結果においては男女ともに，低栄養高齢者での血清総コレステロール値と血色素量が有意に低かった．血清総コレステロール値との関係はすでに同様の結果が Hu たち[33]の研究で示されており，低コレステロール血症群（hypocholesterolemia）の血清アルブミン値が有意に低いことを示している．総コレステロール低値は死亡リスク，特に心血管系以外の死亡との有意な関係が示されている[33,34]．したがって，低栄養高齢者に対しては血清アルブミン値を増加し，適正な血清総コレステロール水準を維持するために，栄養改善プログラムを提供することは必須と考えられる．

年齢を補正したうえで体力を比較した結果，男性では正常群に比べ低栄養群で握力と膝伸展力は有意に低かった（$P<0.001$）．この結果は，高齢者における血清アルブミン値と筋力の関係は，年齢，たんぱく質の摂取，運動，罹患率を補正しても血清アルブミン値と筋肉量には有意な関連性あることを示した Baumgartner たち（1996）の研究結果と一致している．一方，男性のみで有意な差がみられたのは，女性より男性で筋肉量が多いことがその理由として推測されるとしている（Pieterse et al., 2002）．また，Baumgartner たち[11]は，高齢者における血清アルブミン低値による日常生活の障害率の増加には，筋肉量減少（sarcopenia）が関係していることを示唆した．歩行能力には男女ともに両群間に有意差が見られなかったのは，歩行能力の場合は筋力と別にバランス能力との間に高い相関関係があるからだ[30,36]と思われる．

以上の結果に基づいて考えて見ると，男性の低栄養群では筋力低下の状況をそのまま放置すると生活機能の低下を招き，日常生活の自立度が容易に低下することが十分考えられる．一方，今回の分析結果では，女性では両群間に有意差がなかったが，女性は男性より加齢にともなう握力の低下が速いという結果や筋力の低下により日常生活の維持が困難となり[37]，転倒をはじめとする不慮事故を起こす可能性が高いこと[20]が指摘されている．従って，血清アルブミンの低い高齢者においては生活機能の維持や不慮の事故予防の観点からも栄養状態の改善や体力の維持･増進の手立てが極めて重要な予防戦略となる．

高齢者の低栄養対策として展開される介入プログラムは，低栄養状態とともに体力の改善がはかれるものではなければならない．すなわち，地域在宅低栄養高齢者を対象に，筋力や歩行能力の保持・向上について行った研究によれば，栄養サプリメント供給のみのプログラムは体重や BMI は有意に増加したが，体力増進には効果がなかった[38,39]．一方，栄養サプリメントと運動を並行したプログラムは筋力の向上に有意な効果があることが示されている[40]．すなわち，低栄養高齢者が地域で自立して生活するためには，栄養状態と体力の改善に効果的なプログラムの開発，および実施することが必要である．

最後に，本研究にはいくつかの限界がみられ，例えば，1）分析対象者が都市地域に居住する在宅高齢者のみであり，また母集団から無作為抽出法によって選定されたものではないこと，2）横断研究であり低栄養と関連する要因の間での因果関係を明らかにすることができないことなどである．しかし，1,700名以上の70歳以上の地域在宅高齢者を対象とした本研究において，血清アルブミンを指標とした栄養状態別の体力や血液生化学的データで差異がみられた結果から，低栄養高齢者を対象として展開される介入プログラムの開発において重要な示唆が得られたと考えられる．

今後，低栄養高齢者を対象に血清アルブミン値を高める栄養改善プログラムを実施し，果たして栄養状態の改善により体力の回復も可能なのかについて明らかにする予定である．

V．ま　と　め

本研究は、地域在宅高齢者における低栄養の割合および低栄養と健康状態，体力との関連について検討することを目的とした．その結果，分析対象者1,758名中，血清アルブミン値 3.8 g/dL 以下の低栄養高齢者は124名（7.1%）であり，1）女性より男性で低栄養の割合が有意に高く，また 2）子供と同居している高齢者より，一人あるいは高齢者夫婦で住んでいる高齢者のみの世帯で低栄養の割合が有意に高かった．

男性では低栄養群と正常群の間に，趣味の活動と健康度自己評価に有意差が見られた．また，血液生化学的所見からは，男女ともに低栄養群で，低コレ

ステロール血症(<169 mg/dL)と貧血(男<13 g/dL，女<12 g/dL)を示す割合が有意に高かった(P<0.05)．体力に関して比較した結果，男性では正常群に比べ低栄養群では握力と膝伸展力が有意に低かった．通常および最大歩行速度の場合も低栄養群で遅い傾向があったが有意差はなかった．また，女性では両群の間に握力，膝伸展力，および歩行能力の有意差が見られなかった．

以上より，低栄養状態にある高齢者では，生活習慣と健康状態が全般的に不良であり，握力と膝伸展力が低下していることが明らかとなった．したがって，高齢者が地域で自立した生活を営むために，低栄養高齢者においては低栄養状態とともに体力の改善する介入プログラムは必要である．

（受理日　平成16年10月７日）

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Osteoporosis Japan

地域高齢者における転倒と転倒恐怖感についての研究
－要介護予防のための包括的健診（「お達者健診」）調査より

鈴木隆雄　岩佐　一　吉田英世
金　憲経　古名丈人　杉浦美穂
吉田祐子

はじめに

高齢期の生活の質（QOL）あるいは日常生活動作能力（ADL）を低下させる大きな要因として，老年症候群があげられる。この老年症候群とは，老化が進行し身体および精神機能が低下した高齢者において，単純に疾患に帰すことのできない高齢者特有に発生するさまざまな障害を意味し，転倒(骨折)，失禁，痴呆，うつ状態，低栄養，生活機能低下，せん妄，寝たきりなどが含まれる[1)]。

なかでも転倒は頻度も高く，加齢に伴って増加し，かつ骨折という重篤な外傷をもたらすとともに，生活空間の狭小化をもたらし，いわゆる閉じこもりや身体の虚弱化を促進させる「転倒症候群」を容易に発生する。これらの多くの問題を含む高齢期における転倒予防は重要かつ緊急の課題となっている[2)]。

われわれは，地域在宅高齢者における老年症候群の代表的症状であり，かつ自助努力により相当の改善の見込まれる，1)転倒，2)失禁，3)低栄養，4)認知機能低下，および，5)生活機能(ADLおよび手段的ADL)低下などについて，それらの効果的スクリーニング方法の開発，および予防対策(介入)プログラムの確立を目指した包括的健診（以下「お達者健診」と称する）を都市部に居住する70歳以上の住民2000人以上を対象として実践してきた。本研究の目的は，そのなかで転倒の頻度や原因，転帰危険因子の分析および転倒恐怖感との関連性についての分析を行うことである。

1　研究方法

1）対象者

調査対象者，すなわち「お達者健診」対象者は東京都板橋区在住の70歳以上の在宅高齢者である。対象者は板橋区の住民基本台帳から無作為に抽出された高齢者約900名，および同区内5ヵ所にある老人保健福祉施設を利用している在宅高齢者約900名である。「お達者健診」を受診する者と非受診の者では当然バイアスの存在が考えられる。この点については受診者と非受診者の特性の比較をすでに報告している[3)]。

2）方　法

「お達者健診」東京都板橋区内5ヵ所の高齢者向け保健・福祉施設を中心として，対象者を会場に招待し，医学的健康調査および面接聞き取

Study on Fall and Fear of Falling in the Community Elderly

Takao Suzuki：Epidemiology and Health Promotion Research Group, Tokyo Metropolitan Institute of Gerontology, *et al.*

Key words： Fall, Fear of falling, Prevention of geriatric syndrome, Comprehensive health check-ups, Community elderly

東京都老人総合研究所疫学・福祉・政策研究グループ

表1　過去1年間の転倒経験者の性，年齢階級別内訳

	70～74歳	75～79歳	80＋歳	計
男性 (%)	51/404 (12.6)	63/345 (18.3)	30/178 (16.9)	144/927 (15.5)
女性 (%)	114/563 (20.3)	93/475 (19.6)	47/236 (19.9)	254/1274 (19.9)

り調査を実施した。「お達者健診」の実施にあたっては，受診者1人あたり1.5時間から2時間ですべての調査が終了するよう，会場内の安全と導線に配慮し会場設営を行った。

今回分析を行った転倒に関する特性あるいは要因については，以下の項目を中心として分析されている[3,4]。

①性および5歳階級による年齢階級

②身長，体重および体格指数 (kg/m^2)

③転倒について (過去1年間の転倒経験の有無，転倒回数，転倒の原因，転倒によるケガの状況，転倒恐怖感の有無，の5項目)

④外出頻度 (1日1回以上，2～3日に1回程度，1週間に1回程度，ほとんど外出しない，の4者択一)

⑤老研式活動能力指標(手段的ADL5項目，知的能動性4項目，社会的役割4項目の合計13項目)

⑥失禁の有無

⑦飲酒および喫煙の状況

⑧認知機能 (MMSE：30点満点による)

⑨身体運動機能(握力，膝伸展力，通常歩行速度，最大歩行速度，手伸ばし試験の5項目)

今回対象とした板橋区在住の70歳以上の高齢者は無作為抽出による対象者ではなく，先に報告したように，受診者としてのいくつかのバイアスは存在しているものの，本論文の研究テーマである「転倒経験」については受診者と非受診者間で有意な差を示していないことを明らかにしている[3)] (転倒経験者割合は受診者19.2%対非受診者18.6%：$\chi^2 = 0.04$，$p = 0.838$)。

2　研究結果

1) 転倒の発生率

各性および年齢階級別転倒者数(割合)は**表1**に示す。

転倒発生率について男女間では明らかな有意差を認めた ($\chi^2 = 7.02$，$p < 0.01$)。しかし，年齢階級別の発生率については，男性では加齢に伴う増加の弱い傾向が示されたが ($\chi^2 = 4.80$，$p = 0.09$)，女性では全く有意差はなく，各年齢階級ともほぼ20%で安定した発生率を示していた。転倒の発生回数については男女とも1～10回までばらついているが，1回のみの者は男性95名(66.4%)，女性171名(67.8%)であり，2回以上の複数回転倒者はそれぞれ48名，81名であった。

2) 転倒の原因と受傷状況

転倒時の状況あるいは原因については，男女とも「つまずいた」が圧倒的に多く，それぞれ35.4%，40.6%を占めている。次いで「滑った」あるいは「段差に気付かなかった」が続いている。それぞれの原因の割合に男女差は認められなかった。

転倒による結果あるいは受傷状況については，男女で受傷状況が明らかに異なっており，女性では「打撲」(34.7%)や「擦り傷」(25.2%)が多いが，男性では「何もなかった」が49.3%とほぼ半数を占め，女性よりも有意に割合が大きかった ($\chi^2 = 26.5$，$p < 0.001$)。また「骨折」については男性4.9%，女性11.0%であり，有意な性差を認めた ($\chi^2 = 4.35$，$p = 0.04$)。また女性の中には大腿骨頸部骨折を受傷した者が2名(1.0%)含まれていた。

表2　多重ロジスティック回帰分析によるオッズ比（95%信頼区間）

要因	カテゴリー／単位	男性	女性
転倒恐怖感	0＝あり，1＝なし	0.66（0.51–0.87）***	0.83（0.68–1.00）*
外出頻度	0＝週1回以上，1＝週1回以下	1.01（0.31–2.77）	0.81（0.31–1.83）
失禁	0＝あり，1＝なし	1.47（0.87–2.41）	1.14（0.08–1.59）
視力	0＝普通，1＝困難	1.29（0.57–2.62）	0.64（0.25–1.39）
喫煙	0＝吸う，1＝吸わない	0.85（0.54–1.28）	0.97（0.51–1.97）
飲酒	0＝飲む，1＝飲まない	0.86（0.67–1.10）	0.85（0.72–0.99）*
MMSE	0＝23以下，1＝24以上	0.30（0.07–0.90）	0.79（0.36–1.58）
年齢	歳	1.24（0.95–1.62）	0.83（0.67–1.03）
手段的自立	5点満点	1.00（0.71–1.43）	0.87（0.64–1.20）
握力	kg	0.96（0.93–0.99）**	0.96（0.92–0.99）*
最大歩行速度	m/sec	1.01（0.58–1.74）	0.69（0.43–1.12）
体格指数	kg/m^2	1.07（1.00–1.14）*	0.99（0.94–1.03）

数値は小数点第3位で四捨五入　$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$
目的変数は「転倒経験」の有無（0＝なし，1＝あり）

3）転倒恐怖感

「転ぶことが怖い」と感ずる転倒恐怖感については男性で367名（39.7%），女性で830名（65.2%）が感じており，女性で特に高く有意な性差を示していた（$\chi^2 = 149.9$, $p < 0.001$）。さらに，これら転倒恐怖感を有する者の中で日常の生活動作を「手伝ってもらう」者はそれぞれ15名（4.1%），52名（6.3%）であった。また「外出を控える」者はそれぞれ26名（7.1%），86名（10.4%）となっていた。これらについては有意な性差は認められなかった。

4）転倒発生に関する要因の分析

「お達者健診」での転倒に関連すると思われる調査項目（要因）別に転倒経験の有無（回数別）との単変量による分析では，男女ともに有意に関連のあった要因は，「転倒恐怖感」，年齢，老研式活動能力指標（総得点，および手段的自立，社会的役割の二つの下位尺度），握力，通常歩行速度，最大歩行速度の6項目であった。さらに男性では「外出頻度」，および老研式活動能力指標（知的能動性）の2項目が有意な関連性を示していた。

目的変数を転倒経験の有無とし，転倒経験と有意であった要因を説明変数の中心に，多重ロジスティック回帰分析を男女別に行った（表2）。その結果，転倒の発生と有意に関連のあった要因は，男性では「転倒恐怖感」，握力，および体格指数であり女性では「転倒恐怖感」，飲酒と握力が抽出された。したがって男女ともに共通であった関連要因は「転倒恐怖感」と握力という二つの項目が抽出された。

3　考　　察

わが国のような高齢社会における保健施策として疾病（特に生活習慣病）の予防と，寝たきりなどの介護を要する状態となることの予防（「介護予防」）を通じ，健康寿命の延伸を図ることが重点的な目標となる。

転倒の頻度に関するデータは国内でも数多くの報告がなされている。なかでも，調査方法や項目をほぼ標準化し，地域在宅高齢者を対象とした転倒の年間発生率の調査報告[5]によれば，沖縄の都市部データを除くと男性が16〜20%，女性が14〜23%となっていたが今回のデータもほぼ合致している。

転倒の有無に関連する要因の多重ロジスティック回帰分析モデルによる結果から，男女ともに「転倒あり」に有意な関連要因として面接質問項目からは「転倒恐怖感」のあること，身体機能測定データからは握力が低下していること

の2項目が共通に抽出された。

地域高齢者の転倒恐怖感について調べたTinettiら[6]は，43%が転倒恐怖感を有し，19%が活動に影響があると報告している。また，Howlandら[7]は55%（146/266）が転倒恐怖感をもっており，恐怖感を有する者の中の56%（82/146）が転倒恐怖感のために活動が制限されると指摘した。わが国でも，転倒外来受診者におけるわれわれの研究からは，85.4%（35/41）が転倒恐怖感を有することが報告された[8]。

さらに，われわれの行った介護保険制度下における後期高齢期の要支援者の生活機能の特徴の分析的研究[9]からは，男性では93.1%，女性では93.8%が転倒恐怖感を有し，そのなかで転倒が怖くて外出を控える者は男性66.7%，女性60.4%と非常な高率に上っていることが明らかにされている。以上，先行研究や本研究結果から，われわれは，地域高齢者には老年症候群の包括的予防と基本的生活機能を高める支援のための健診が必要であるとともに，転倒および転倒恐怖感の解消を目指す介入プログラムの提供が必須であると結論した。

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Randomized controlled trial of exercise intervention for the prevention of falls in community-dwelling elderly Japanese women

Takao Suzuki[1], Hunkyung Kim[1], Hideyo Yoshida[1], and Tatsuro Ishizaki[2]

[1] Department of Epidemiology, Tokyo Metropolitan Institute of Gerontology, 35-2 Sakaecho, Itabashi-ku, Tokyo 173-0015, Japan
[2] Department of Health Economics and Quality Management, Kyoto University, Kyoto, Japan

Abstract Falls are common in elderly people. Possible consequences include serious injuries and the post-fall syndrome, with functional decline and limitation of physical activity. The present randomized controlled study sought to clarify the benefits of a combined long-term and home-based fall prevention program for elderly Japanese women. The subjects were individuals aged over 73 years, living at home in a western suburb of Tokyo, who had attended a comprehensive geriatric health check. Persons with a marked decline in the basic activities of daily living (ADL), hemiplegia, or those missing baseline data were excluded. Fifty-two subjects who expressed a wish to participate in the trial were randomized, 28 to an exercise-intervention group and 24 to a control group. Baseline data for age, handgrip force, walking speed, total serum cholesterol, serum albumin, basic ADL, visual and auditory impairments, self-rated health, and experience of falls did not differ significantly between the two groups. Beginning from June 2000, the intervention group attended a 6-month program of fall-prevention exercise classes aimed at improving leg strength, balance, and walking ability; this was supplemented by a home-based exercise program that focused on leg strength. The control group received only a pamphlet and advice on fall prevention.

The average rate of attendance at exercise class was 75.3% (range, 64% to 86%). Participants showed significant improvements in tandem walk and functional reach after the intervention program, with enhanced self confidence. At the 8-month follow-up, the proportion of women with falls was 13.6% (3/22) in the intervention group and 40.9% (9/22) in the control group. At 20 months, the proportion remained unchanged, at 13.6% in the intervention group, but had increased to 54.5% (12/22) in the control group, which showed a statistically significant difference between the two groups (Fisher's exact test; $P = 0.0097$). The total number of falls during the 20-month follow-up period was 6 in the intervention group and 17 in the control group. We conclude that a moderate exercise intervention program plus a home-based program significantly decreases the incidence of falls in both the short and the long term, contributing to improved health and quality of life in the elderly.

Key words exercise intervention · geriatric exercise · home-based exercise · fractures

Offprint requests to: T. Suzuki (e-mail: suzutak@tmig.or.jp)
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Introductions

A combination of osteoporosis and falls underlies most fractures in the elderly. In particular, falls account for 90% of the growing problem of femoral neck fractures [1]. Other forms of trauma such as bruises and sprains also have a high incidence, and a fear of falling (the "post-fall syndrome") leads to a marked decline in the activities of daily living (ADL) [2]. Falls are thus an important factor when considering quality of life (QOL) in the elderly. Predisposing risk factors include a gait deficit [3–12], visual impairment [13,14], the use of sedatives [4–15], and a history of falls [6–22]. In a long-term, longitudinal study of community-dwelling elderly people in Japan, "a history of a fall in the previous year" and "decreased free walking speed" were independent strong predictors of future falls [23]. Irrespective of age, maintaining muscle strength, balance, and walking ability seem to be important first steps in preventing falls.

An elderly person's gait is characterized by a decreased height of the swing phase and a decreased stride length [24], both changes probably increasing the individual's susceptibility to falls. Therefore, in addition to correcting visual acuity and eliminating adverse drug reactions, active correction of physical weakness, especially walking ability, should be a highly effective intervention both at individual and societal levels [25]. A recent review of 16 studies ranked the major risk factors for falls in the elderly, in descending order, as (1) muscle weakness, (2) a history of falls, (3) gait deficit, and (4)

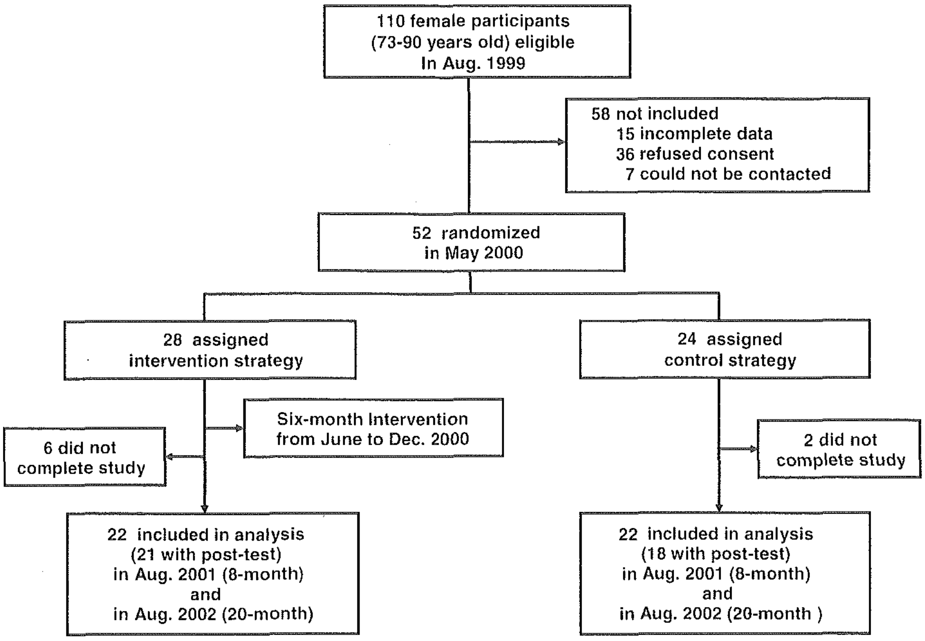

Fig. 1. Trial pofile

balance deficit [26]. The importance of addressing these risk factors as a practical preventive strategy has become widely recognized in Japan and elsewhere.

We therefore conducted a randomized controlled trial to examine the effectiveness of an intervention that aimed to improve overall physical function as a means of preventing falls. The two major goals of the intervention were (1) to improve muscle strength of the lower extremities and, thus, walking ability, and (2) to reduce the incidence of future falls through improvement of these physical attributes.

Subjects and methods

Subject sample

Subjects (Fig. 1) were selected from participants in the Tokyo Metropolitan Institute of Gerontology Longitudinal Interdisciplinary Study on Aging (TMIG-LISA), which was launched in 1991 [27,28]. In August 1999, 110 women, aged 73 to 90 years, living in Koganei City, a western suburb of Tokyo, attended a comprehensive geriatric health examination at the last survey in TMIG-LISA. Fifteen individuals were excluded for the following reasons: muscle strength could not be determined in 5 subjects, 5 had poor mobility due to hemiplegia, 2 had poorly controlled blood pressure, and 3 had communication difficulties due to impaired hearing.

In May 2000, a pamphlet containing information on "Fall Prevention Exercise Classes" was mailed to the remaining 95 subjects. Responses were obtained from 88 individuals; 52 agreed to join the exercise classes and 36 declined to participate. After obtaining informed consent, we allocated the 52 respondents randomly to an intervention group (n = 28) or a control group (n = 24). We expected the number of dropouts to be greater in the intervention group than that in the control group. Baseline data (August 1999) for age, handgrip force, walking speed, physical performance test scores, degree of dependence in basic ADL (moving, eating, personal toilet, dressing, bathing), and history of falls did not differ significantly between the two groups (Table 1).

The intervention group attended an exercise-centerd fall-prevention program, and also undertook a home-based exercise program aimed at enhancing muscle strength, balance, and walking ability. The control group received only a pamphlet and advice on the prevention of falls. Participants provided written informed consent to participate in this study, which the Institutional Review Board and Ethics Committee of the TMIG approved (Accepted, no. 12, June 8th, 1998).

Variables measured

Interview

An interview assessed the individual's history of fractures and falls over the previous year, basic ADL, instrumental ADL, and subjective changes in physical strength.

Measurements of physical function

Based on the items reported as effective in screening for falls in the elderly [3,29,30], and considering their

Table 1. Comparison of physical performance parameters (mean ± SD values) and questionnaire variables (%) at baseline survey in 1999 between control and intervention groups

Variables	Control group (n = 24)	Intervention group (n = 28)	P value*
Age[a]	78.45 ± 4.42	77.68 ± 3.41	0.477
NWS[b]	1.19 ± 0.24	1.19 ± 0.28	0.995
MWS[c]	1.73 ± 0.35	1.72 ± 0.34	0.869
GS[d]	21.38 ± 6.12	21.21 ± 4.36	0.913
STO[e]	23.83 ± 21.02	26.46 ± 22.00	0.663
STC[f]	4.33 ± 2.1	5.18 ± 4.47	0.378
TW[g]	8.79 ± 2.67	8.39 ± 3.51	0.651
FR[h]	27.81 ± 3.73	28.49 ± 4.49	0.562
KEP[i]	48.01 ± 13.49	49.90 ± 14.93	0.408
Fall[j]	16.7%	14.3%	0.556
ADL[k]	94.4%	100.0%	0.462

* Control group vs intervention group by t-test (a–i), and Fisher's exact test (j, k)
[a] Average age (years)
[b] Normal walking speed (m/s)
[c] Maximum walking speed (m/s)
[d] Grip strength (kg)
[e] Stork stand time with eyes open (s)
[f] Stork stand time with eyes closed (s)
[g] Tandem walking (steps)
[h] Functional reach (cm)
[i] Knee extension power (Nm)
[j] Fall experience within 1 year preceding baseline (%)
[k] Independence of basic ADL (%)

validity, reliability, and objectivity, the following items were selected to estimate muscle strength, balance, and walking ability.

Anthropometry
Height and body mass were measured, and the percentage of body fat was estimated by an impedance method (body fat analyzer, TBF-305; Tanita Tokyo, Japan).

Handgrip force
The peak handgrip force of each hand was determined to 5 kN, using a hand-held Smedley-type dynamometer.

Stork stand (eyes open)
While standing on a square (0.4 × 0.4 m), the subject either foot while watching a point set at eye level 1 m away, and tried to maintain this posture. A stopwatch measured the duration in seconds up to a maximum of 1 min, the longer of two attempts being recorded.

Stork stand (eyes closed)
The test was repeated, but with the eyes closed. The time was recorded up to a maximum of 30 s, the better of two attempts being noted.

Walking speed
A flat walking path of 11 m was marked with tapes at the 3-m and 8-m points. A stopwatch measured the time taken to walk 5 m, from the time when the foot touched the ground after the 3-m line to when the foot touched the ground after the 8-m line. The participants first took the test by walking at normal speed, and then by walking as fast as possible. Walking tests at both normal and maximum speeds were repeated and the faster speed was recorded in each walking test.

Tandem walking
A 2.5-m tape was affixed to a flat floor. The subject was instructed "to walk step-over-step" (walk with the tip of one foot touching the heel of the other foot). Note was taken of whether the subject could complete the 2.5-m walk; if successful, the number of steps and the time taken were also recorded.

Knee muscle power
The knee extension power (N) was measured in the dominant leg, using a hand-held dynamometer. The subject was asked to sit on a chair with the knee bent at a right angle. The dynamometer was placed at the ankle joint. The muscle strength was measured as the peak force during isometric extension when the subjects were asked to extend the knee by their maximum leg power. The test was carried out two times and the higher of two measurements made on the dominant leg was recorded.

Functional reach
The subject stood sideways against a wall in a natural position, and stretched both arms to the height of the shoulders. The positions of the fingertips were taken as the zero point. Then one arm was lowered. With the body tilted forward as far as possible, the subject continued to stretch the arm parallel to the ground. The greatest distance of forward reach was measured. Three measurements were made, and the mean value was recorded [31,32].

Intervention program

The intervention program comprised ten 1-h exercise sessions held at the community center once every 2 weeks for 6 months. Because this amount of exercise was insufficient to maintain and develop muscle strength, it was supplemented by an individual exercise program which subjects could practice at home. Participation was noted on a "Falls Prevention Exercise Record Card", which was brought to each of the formal exercise classes for confirmation. The following exercises were used.

Basic exercises
Before training, subjects participated in 10 to 15 min of warmup and stretching exercises, consisting of finger joining and pushing, bending the fingers backward, shoulder rotation, waist rotation, upward stretching, and lateral bending of the arms, forward bending, and other similar exercises.

Muscle strengthening of legs, waist, and abdomen
The muscle strengthening routine consisted of bending and flexing the ankles, raising the heels, bending the knees, raising one leg while lying on the back, raising both legs and bending backwards and forwards (while lying on the back), raising the upper part of the body while lying on the stomach, raising both knees (while lying on the stomach), and other similar items.

Balance and gait training
Gait training consisted of standing on one leg, shifting weight laterally from one foot to the other foot, and anterior-posterior weight shifting, performed in a position similar to a fencing position [33]. It also included side stepping on alternate legs and tandem walking. A wall or chair was used to provide a safe support when needed.

Resistance exercise
Moderate resistance training included two kinds of exercise, i.e., using a dumbbell (0.5-kg to 1.5-kg weights) and a rubber band (light-to-medium-resistance band). The dumbbell exercise was performed in a standing and/or chair-sitting position, with pushing up and down or pulling up and down at a resistance that permitted four to eight repetitions.

Exercises using the rubber band (Thera-Band, Sakai, Tokyo) included horizontal stretching of both arms with the band in front, up-and-down stretching with the band above the head, and sideways, striding exercise, and others.

Tai Chi exercise
In China, one of the most popular forms of Tai Chi is the Yang style. A 24-form simplified Tai Chi, based on Yang's system, was developed in 1965 by a group of Tai Chi experts. The subjects performed three to five basic forms, i.e., hand-holding and departing, one-hand pushing, empty step, backward-step, and clouding [34,35]. The duration of exercise was increased progressively to 30 min in the last three sessions.

Home exercise
Subjects were instructed to undertake home exercise with two to three sets of the 15 exercises which they had learned in the last session. They were also advised to do the home exercises at least three times a week for about 30 min per day. Subjects were asked to record the exercise times and number of sets performed on a "Fall Prevention Exercise Record Card".

Post-intervention measurements and follow-up

An interview and blinded physical function assessments were conducted at the end of the 6-month intervention. During the first 8 months of follow-up, the home-based exercise program was mailed monthly to each subject, and the "Fall Prevention Exercise Record Card" was returned by the participant. The number of falls was assessed by interviews conducted 8 and 20 months after the intervention.

Data analysis

As shown in Fig. 1, a total of 8 subjects dropped out (6 in the intervention group and 2 in the control group) during the entire follow-up period, and they could not be assessed at the end of the 6-month intervention or traced for falling events during the 20-month follow-up period. One of 22 subjects in the intervention group and 4 of 22 subjects in the control group failed to undergo physical function assessment at the end of the 6-month intervention (post-intervention measurements), but could be traced only for falling events during the 20-month follow-up period. Thus, among the 52 participants enrolled in this study, 44 (22 from the intervention group and 22 from the control group) responded twice to the outcome survey at 8 and 20 months after the

6-month intervention, and the information about falling events could be traced during the 20-month follow-up period.

Data were analyzed on an intention-to-treat basis. Means and SDs were calculated for each variable, and differences between the intervention and control groups were tested by *t*-tests. In samples with unequal variance, a *t*-test with Welch's correction was used. Repeated measures two-way analysis of variance (ANOVA) was performed on outcome variables. Significant interactions were examined (Scheffe's post-hoc analysis) to determine if effects were greater in the exercise or control group. A χ^2 test assessed the frequency of pre- and post-intervention events for the intervention and control groups. The proportions of women with falls during the follow-up period, for the intervention and the control groups, were also compared by χ^2 tests, except when cell sample sizes in the contingency table were small, in which case Fisher's exact test was used. All subjects who provided follow-up data at any time point were included in the analysis.

Results

Among 110 elderly female community living residents, 52 (47.3%) were recruited to participate in the study and were assigned to either an exercise group or a control group. As shown in Table 1, there were no sigsnificant differences between the two groups at baseline.

Of the 52 participants, 8 (6 in the intervention group and 2 in the control group) dropped out during the 6-month intervention period. Among the 6 dropouts (24.1%) in the intervention group, 4 complained of lumbago ($n = 2$) or knee pain ($n = 2$) and withdrew at an early stage of exercise intervention, and the remaining 2 dropped out later because of relocation or hospitalization due to worsening of hypertension. Table 2 compares the physical performance and baseline questionnaire data between the subjects in the intervention and control groups who completed the trial (without the dropouts in each group). There were no variables showing significant differences between the two groups, including fall experience within 1 year preceding the baseline survey, which had been confirmed to be a very strong predictor for future falls in our previous community-based cohort study [23].

Two persons (8.3%) in the control group dropped out because they did not wish to participate in the post-intervention measurements or to keep in contact during the follow-up period. It was impossible to trace all dropouts for the information about falling events. After the post-intervention measurements, there were no more

Table 2. Comparison of physical performance parameters (means ± SD) and questionnaire variables (%) at baseline survey in 1999 between subjects in the control and intervention groups who completed the trial

Variables	Control group (n = 22)	Intervention group (n = 22)	P value*
Age[a]	78.64 ± 4.39	77.31 ± 3.40	0.272
NWS[b]	1.18 ± 0.25	1.24 ± 0.23	0.365
MWS[c]	1.72 ± 0.35	1.80 ± 0.25	0.408
GS[d]	20.82 ± 5.65	21.82 ± 4.63	0.524
STO[e]	25.09 ± 21.33	29.59 ± 22.77	0.502
STC[f]	4.23 ± 2.07	5.73 ± 4.70	0.181
TW[g]	9.00 ± 2.62	9.23 ± 2.60	0.774
FR[h]	28.02 ± 3.80	29.04 ± 4.25	0.404
KEP[i]	47.11 ± 13.45	52.62 ± 15.42	0.214
Fall[j]	18.2	18.2	1.000
ADL[k]	95.5	100.0	1.000

* Subjects who completed trial *vs* dropouts in the intervention group, by *t*-test (a–i), and Fisher's exact test (j, k)
[a] Average age (years)
[b] Normal walking speed (m/s)
[c] Maximum walking speed (m/s)
[d] Grip strength (kg)
[e] Stork stand time with eyes open (s)
[f] Stork stand time with eyes closed (s)
[g] Tandem walking (steps)
[h] Functional reach (cm)
[i] Knee extension power (Nm)
[j] Fall experience within 1 year preceding baseline (%)
[k] Independence of basic ADL (%)

dropouts in either the intervention group or the control group. Thus, the two groups did not differ in the follow-up rate (Fisher's exact test; $P = 0.262$) or in reasons for dropout. Table 3 compares the physical performance and baseline questionnaire data between the subjects who completed the trial ($n = 22$) and dropouts ($n = 6$) in the intervention group. There were two variables (i.e. normal walking speed and knee extention power) showing significant difference between the two groups.

Attendance rate

Individual rates of attendance at the fall prevention exercise classes ranged from 64% to 86%, with a mean of 75.3%. Fifteen subjects (53.6%) attended all ten sessions. Six subjects who attended none to three times were regarded as failing to master the exercise program; the reasons were refusal to participate after randomization because of lumbago ($n = 2$), knee pain ($n = 2$), relocation ($n = 1$), and hospitalization ($n = 1$). Among the 22 subjects who completed the intervention, 21 subjects (95.5%) participated in more than seven sessions.

Interview survey

Change in physical fitness

When subjects were questioned about perceived changes in physical fitness, 28.6% of the intervention group (6 subjects) responded "improved", 57.1% (12 subjects) reported "no change", and 14.3% (3 subjects) responded "worsened". No subject in the control group responded "improved"; most (61.1%; 11 subjects) indicated "no change", but 38.9% (7 subjects) responded that their condition had "worsened".

Basic activities of daily living (BADL)

Before the intervention, 100% of the intervention group and 94.4% (17 subjects) of the control group were independent in BADL. After the intervention, 85.7% (18 subjects) in the intervention group were still independent, but 14.3% (3 subjects) were impaired, as compared to 88.9% (16 subjects) and 11.1% (2 subjects), respectively, in the control group.

Subjective changes in physical strength and confidence in fall prevention

Some 66.7% of exercise-class participants perceived that walking had stabilized, and 55.6% perceived that their leg muscles had become stronger during the program. Moreover, 61.1% were confident that they were able to prevent falling by themselves.

Physical function measurements

Comparison between intervention and control groups

Before the intervention, there were no statistically significant differences in muscle strength, balance, or walking ability between the intervention and control groups. After the intervention, there were significant differences in tandem walking (intervention group versus control group, 10.7 ± 0.86 versus 7.3 ± 3.46 steps) and functional reach (33.5 ± 4.7 versus 28.0 ± 4.6 cm). Knee extension power, though significantly increased after intervention in the intervention group, showed no significant difference in the comparison of the two groups.

Comparison of measurement changes between the intervention and control group

In comparison of measurements before and after the intervention, the intervention group developed significant gains in tandem walking (pre-intervention versus post-intervention: 9.24 ± 2.66 versus 10.67 ± 0.86 steps), functional reach (29.27 ± 4.22 versus 33.52 ± 4.70 cm), and knee extension power (52.12 ± 15.62 versus 56.81 ± 11.71 Nm; Fig. 2). The control group, in contrast, developed a significant decrease in handgrip force (pre-intervention versus post-intervention: 22.17 ± 5.57 versus 20.22 ± 4.21 kg), with no significant changes in any of the other variables.

Proportion of women with falls in each group, and numbers of falls during follow-up

Before the intervention, 16.7% (4 of 24 subjects) in the control group and 14.3% (4 of 28 subjects) in the intervention group had experienced falls (no significant difference). At the 8-month follow-up, the proportion of women with falls in the control group had increased to 40.9% (9 of 22 subjects), but had decreased to 13.6% (3 of 22 subjects) in the intervention group (Fisher's exact test, $P = 0.0883$). At the 20-month follow-up, the proportion of women with falls in the control group had increased to 54.5% (12 of 22 subjects), but remained unchanged, at 13.6% (3 of 22 subjects), in the intervention group (Fisher's exact test, $P = 0.0097$; Fig. 3). The number of falls sustained during the 20-month follow-up period was 6 in the intervention group and 17 in the control group. No subject in either group sustained a fracture.

Discussion

A Japanese national survey showed that the annual frequency of falls was greater than 20% in subjects aged over 65 years; approximately 10% of these falls resulted

Table 3. Comparison of physical performance parameters (means ± SD) and questionnaire variables (%) at baseline survey in 1999 between subjects who completed the trial and dropouts in the intervention group

Variables	Completed trial (n = 22)	Dropouts (n = 6)	P Value*
Age[a]	77.31 ± 3.40	79.00 ± 3.41	0.293
NWS[b]	1.24 ± 0.23	0.99 ± 0.36	0.047
MWS[c]	1.80 ± 0.25	1.41 ± 0.44	0.089
GS[d]	21.82 ± 4.63	19.00 ± 2.28	0.164
STO[e]	29.59 ± 22.77	15.00 ± 15.34	0.153
STC[f]	5.73 ± 4.70	3.17 ± 2.99	0.220
TW[g]	9.23 ± 2.60	5.33 ± 4.89	0.111
FR[h]	29.04 ± 4.25	26.04 ± 5.18	0.182
KEP[i]	52.62 ± 15.42	39.95 ± 7.33	0.011
Fall[j]	18.2	0.0	0.357
ADL[k]	100.0	100.0	—

*Subjects who completed the trial *vs* dropouts in the intervention group by t-test (a–i), and Fisher's exact test (j, k)
[a] Average age (years)s
[b] Normal walking speed (m/s)
[c] Maximum walking speed (m/s)
[d] Grip strength (kg)
[e] Stork stand time with eyes open (s)
[f] Stork stand time with eyes closed (s)
[g] Tandem walking (steps)
[h] Functional reach (cm)
[i] Knee extension power (Nm)
[j] Fall experience within 1 year preceding baseline (%)
[k] Independence of basic ADL (%)

in fractures [36]. Over 80% of femoral neck fractures in the elderly are caused by falls, and these usually require long-term hospitalization. Proposed methods of preventing fractures include increasing bone mineral density, preventing falls, and using appliances. Bone mineral density may be increased by either pharmacotherapy or exercise. However, most reports suggest that, in practice, it is difficult to use exercise for fracture prevention [37]. On the other hand, many studies agree that by strengthening the muscles and improving balance, exercise training can prevent falls that often cause fractures.

Walking ability is particularly important in preventing falls. Our recent 5-year follow-up study [23] showed that the incidence of falls was 26.3% in the group with a slow normal walking speed (0.96 m/s), compared with 11.4% in the group with a fast normal walking speed (1.28 m/s). Furthermore, a 1-m/s increase in walking speed lowered the risk ratio to 0.2 (95% confidence interval; 0.08 to 0.52) after adjusting for other variables. According to The Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT) study [38,39], muscle training and environmental modification were the most effective methods of preventing falls in the elderly. Gardner et al. [40] reviewed 11 randomized controlled trials based on a total of 4933 subjects aged over 60 years. Five of these trials found that exercise significantly reduced the incidence of falls or the risk of falling. Close et al. [41] conducted a randomized controlled trial on subjects aged over 55 years who were attending an emergency department because of falls, providing not only medical evaluation but also evaluation and interventions from the occupational therapy viewpoint. They achieved not only a reduced incidence of falls but also a reduction in the percentage of hospital admissions, indicating the effectiveness of practical approaches. Rubenstein et al. [42], in a randomized controlled trial, reported that, even for fall-prone elderly men with chronic impairments, a group exercise program (three times per week × 12 weeks) could significantly improve isokinetic strength, endurance, and gait, which resulted in a significant reduction of fall rates in the intervention group.

The types and intensities of exercise used in our study were chosen so that they could be implemented by the subjects themselves, at home. Home-based exercise is already known to be effective in preventing falls [43,44]. As a first outcome of our trial, we noted several perceived changes in functions. Over 50% of subjects in the intervention group perceived increased muscle power in their legs and approximately 70% also perceived greater stability when walking. Over 60% became

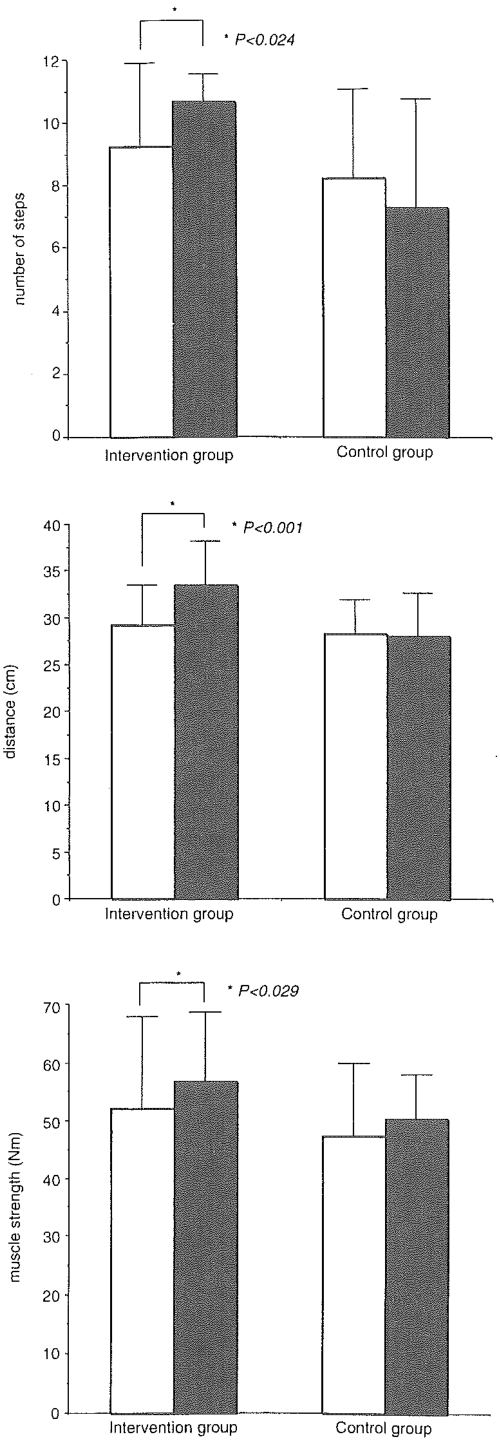

Fig. 2. Comparisons of physical performance parameters (number of steps in tandem walking, distance of functional reach, and muscle strength in knee extension power) in between intervention and control groups after 6-month intervention (paired *t*-test was used separately for both groups). *While bars*, pre-test; *black bars*, post-test

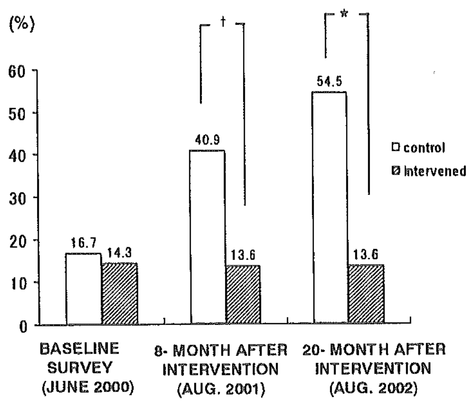

Fig. 3. Changes in proportions of women with falls (%), 8 and 20 months after intervention, in control (*white bars*) and intervention (*black bars*) groups. Fisher's exact test, $^{\dagger}P < 0.1$; $*P < 0.05$

confident that they themselves could prevent falls, indicating an important psychological benefit from the program.

A second outcome was a significant improvement in dynamic balance and muscle strength in the lower extremities. Deficits in skeletal muscle strength, balance, and gait, being major causes of frailty and risk factors for falls, are equivalently and potentially reversible by exercise training. Binder et al. [45], in a randomized controlled trial, showed that intensive exercise training could improve those physical functions even in frail and impaired community elderly. In our study, it appears that an exercise class even once every 2 weeks is very effective in enhancing physical function in ambulatory individuals aged over 73 years, provided that it is supplemented by a home-based exercise program.

A third outcome was a significant reduction in the incidence of falls in the intervention group. This may translate into a smaller number of fractures, with resulting decreases in medical expenditure. In the control group, the cumulative incidence of falls was more than 50% over the 20-month follow-up period, a figure consistent with previous reports on the incidence of falls among elderly Japanese [13,36]. The beneficial effect of the intervention apparently continued not only over the short term (8-month follow-up) but also over the longer term (20-month follow-up).

In our study, there were some methodological weakness. First, the number of subjects was not sufficiently large, so that the incidence of falls during the follow-up period may have been influenced by chance. Second, the dropout rate of more than 20% in the intervention group may have produced a type-I error, as already reported by McMurdo et al. [46]. The high dropout rate in our randomized controlled trial may have reduced the statistical power to detect a significant effect of the interventions for fall prevention among the elderly. In spite of these limitations, this first randomized controlled intervention study for prevention of falls among the community elderly in Japan suggests beneficial effects of long-tem moderate exercise to improve physical activity and to reduce the incidence of falls. A large-scale study is needed to confirm the present results and to evaluate the most effective exercises for the prevention of falls.

The general conclusion to be drawn from this study is that the incorporation of exercises in daily life is important in maintaining an appropriate level of physical function in the elderly. Integrating exercises in daily life can strengthen muscles in the legs, waist and abdomen, improve balance, and increase the individual's self-confidence.

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Authors:

Hiroyuki Shimada, PhD, PT
Shuichi Obuchi, PhD, PT
Taketo Furuna, PT
Takao Suzuki, MD, PhD

Affiliations:

From the Department for Prevention of Dependence on Long-Term Care (HS, SO) and the Department of Epidemiology and Health Promotion (TF, TS), Tokyo Metropolitan Institute of Gerontology, Tokyo, Japan.

Correspondence:

All correspondence and requests for reprints should be addressed to Hiroyuki Shimada, PhD, PT, Department for Prevention of Dependence on Long-Term Care, Tokyo Metropolitan Institute of Gerontology, 35-2 Sakae-cho, Itabashi-ku, Tokyo 173-0015, Japan.

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Research Article

New Intervention Program for Preventing Falls Among Frail Elderly People

The Effects of Perturbed Walking Exercise Using a Bilateral Separated Treadmill

ABSTRACT

Shimada H, Obuchi S, Furuna T, Suzuki T: New intervention program for preventing falls among frail elderly people: The effects of perturbed walking exercise using a bilateral separated treadmill. *Am J Phys Med Rehabil* 2004;83:493–499.

Objective: To determine the effects of a perturbed walking exercise using a bilateral separated treadmill in physically disabled elderly.

Design: Participants of the study were 32 long-term care facility residents and outpatients aged 66–98 yrs. Participants were randomly assigned to a usual exercise group or to a treadmill exercise group. Perturbed gait exercise on a treadmill continued for 6 mos. Number of falls and time to first fall during a 6-mo period, balance and gait functions, and reaction time were evaluated before and after intervention.

Results: The treadmill exercise group showed significant improvement in balance and reaction time when compared with the usual exercise group. Number of falls in the treadmill exercise group was 21% lower than that in the usual exercise group. However, this difference was not significant. No significant differences were seen in time to first fall.

Conclusions: Gait training with unexpected perturbation seems to have a beneficial impact on physical function in disabled elderly individuals. The results suggest that this program may be used as an exercise intervention to reduce falls in institutional settings.

Key Words: Falls, Intervention, Walking, Treadmill, Elderly

Many studies have assessed the efficacy of exercise intervention to prevent falls in elderly individuals, and the effects of these interventions are well recognized. However, subjects in the majority of these studies were community-dwelling elderly people[1–11] and did not include the institutionalized elderly with serious functional impairment.[12,13] Thus, the efficacy of exercise for preventing falls in institutionalized elderly is uncertain.

Previous studies have shown that exercises such as resistance, balance, and gait training seem to be effective.[14] Among these, tai chi is considered to be particularly effective.[15] Maintaining balance while performing the slow motions of tai chi helps to strengthen postural stability. However, most falls are the result of unexpected perturbation, such as stumbling or slipping while walking.[16] Furthermore, studies using unexpected perturbation clearly showed that dynamic balance while walking and static balance while standing are not necessarily related.[17,18] We therefore consider instant reactions to unexpected perturbation to be important in preventing falls and consequently invented a treadmill that continuously and randomly generates unexpected perturbation while walking.[19]

The purpose of this study was to determine the effectiveness of treadmill gait training in institutionalized disabled elderly and in those who regularly visit rehabilitation facilities with a high risk of falls. We also investigated the effects on balance function, gait function, and reaction time.

METHODS

Subjects. For this study, 124 frail elderly people who were either residents or outpatients of a geriatric health services facility and who were receiving rehabilitation as of November 2001 underwent a screening evaluation. In all of these subjects, muscle weakness and decreased balance and gait functions were present, and all subjects were at high risk for falls. All were disabled seniors who required public support through Japanese long-term care insurance screening.

Of the 124 subjects screened, 70 were excluded because they could not walk for ≥3 mins at a speed of 0.5 km/hr on a treadmill, 19 were excluded because they could not participate in the exercise program due to recognizable dementia, and three were excluded because of health problems. Thus, 32 subjects met the inclusion criteria for participation, and informed consent was obtained. This study conformed to the Helsinki Declaration.

The 32 subjects were randomly divided into two groups: a usual exercise group (n = 14), which continued the same exercise regimen they had previously been doing, and a treadmill exercise group (n = 18), which did the treadmill gait exercises in addition to their usual exercise program. Subject demographics are listed in Table 1. No significant differences in demographic data were noted between the two groups.

TABLE 1
Characteristics of usual exercise and treadmill exercise groups at entry into study

	Usual Exercise Group (n = 14)	Treadmill Exercise Group (n = 18)	Difference P Value
Age, yrs[a,b]	83.1 ± 6.4	81.8 ± 5.9	0.837
Sex, Female	11	14	1.000
Height, cm[a,b]	143.9 ± 8.8	143.3 ± 9.1	0.841
Weight, kg[a,b]	48.4 ± 7.2	50.0 ± 8.6	0.381
Body mass index[a,b]	23.4 ± 3.1	24.1 ± 2.7	0.738
Falls during previous 12 mos	10	11	0.712
Use of psychotropic drugs	2	4	0.672
Diagnosis			
Stroke	3	1	0.295
Parkinsonism	3	1	0.295
Arthritis of the knee	2	6	0.412

[a]Data provided as mean ± standard deviation; other items indicate number of subjects.

[b]The Mann-Whitney test was used to compare differences in characteristics between usual exercise and treadmill exercise groups; other items used the χ^2 test.

Experimental Procedures. Before commencement of their respective exercise programs, both groups underwent a pre-intervention evaluation consisting of inquiries about number of falls, a physical performance examination, and a questionnaire survey. After the initial evaluation, the treadmill exercise group began a 6-mo-long treadmill gait exercise program. Both the usual exercise group and the treadmill exercise group continued their usual exercise programs consisting of stretching, resistance training, group training, and outdoor gait training. A postintervention evaluation was conducted for both groups at 6 mos after intervention (Fig. 1).

Examination Items. On initial evaluation, we asked the subjects about the number of falls they had experienced during the year before commencement of the current exercise intervention. The number of falls experienced by the subjects during and at

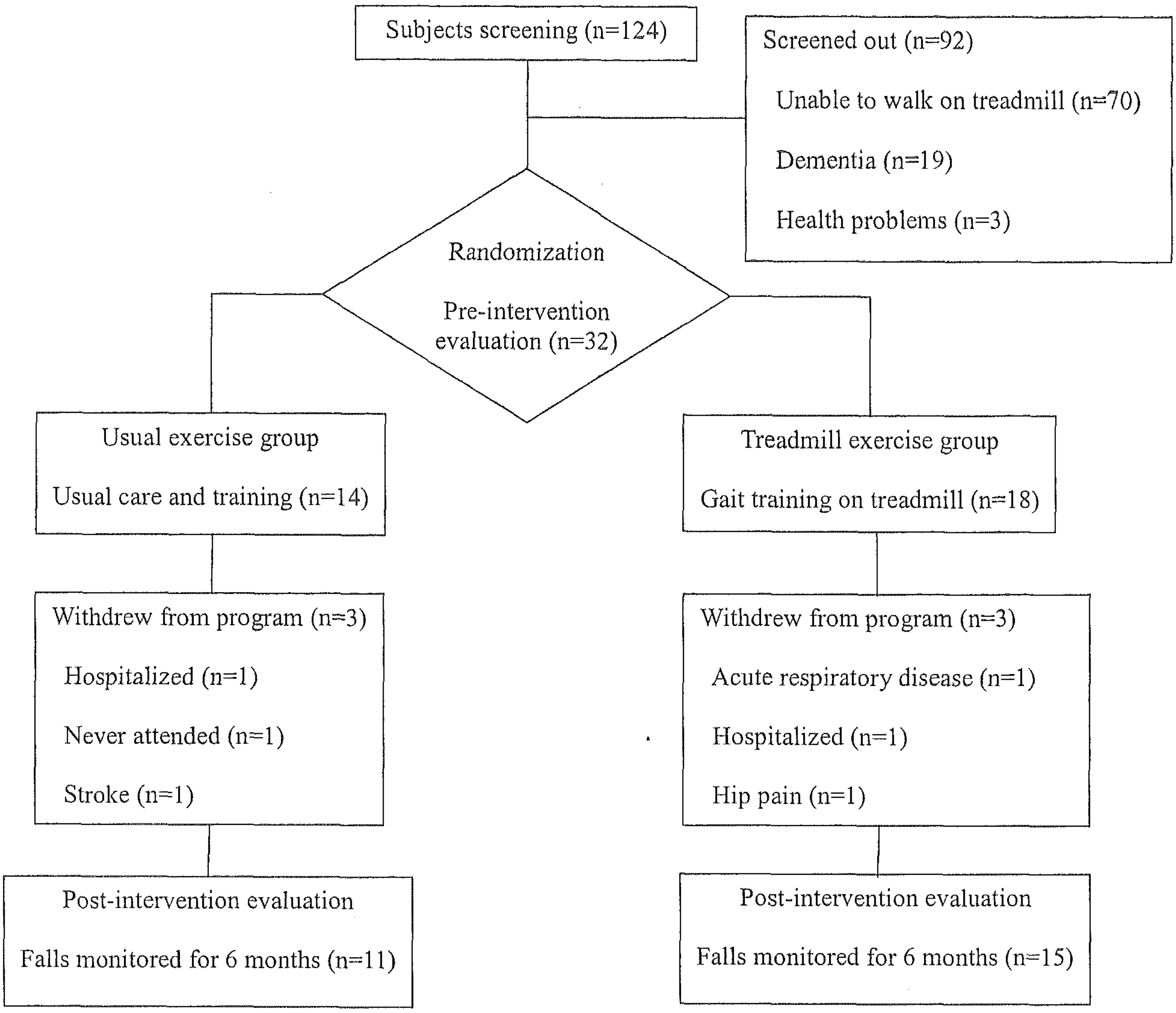

Figure 1: Flow chart showing subjects, timing of randomization and intervention, and outcomes.

the conclusion of the study was also determined from nursing staff reports and monthly subject self-reports. When the number of falls differed in the monthly reports recorded by staff and subjects, the larger number was used.

Physical function was examined by evaluating the subject's balance, gait, and reaction time. Balance was evaluated by measuring one-leg standing time and the Functional Reach Test.[20] One-leg standing time was measured twice on both the right and left legs, and the average of the four performances was reported as the one-leg standing time. The Functional Reach Test was performed twice with the upper limbs reaching as far forward as possible, and the maximum length of the two tests was reported as the functional reach for the subject.

Walking speed was measured to evaluate gait performance. Walking speed was measured over a 10-m walking distance at a comfortable pace. Time was measured using a stopwatch.

Reaction time to an auditory stimulus (100 Hz) was measured using Whole Body Reaction Type-II (Takei, Japan). Subjects placed their finger on a switch to enable depression of the switch on receiving an auditory stimulus. Reaction time was measured under two conditions: while walking (RT walking) on a treadmill (Hitachi, Japan) at 50% of the subject's maximum walking speed and while walking at 50% of the subject's maximum walking speed with the speed of either the right or left treadmill belt randomly decreasing by 60% once every 5 secs (RT perturbed-walking). This deceleration over 500 msecs was intended to mimic slipping. Reaction tests were conducted five times for each test condition, with the average of the five trials being reported as the reaction time for each particular test condition. Before recording reaction times, all subjects were allowed to practice under each set of conditions ten times.

Intervention Method. Gait training on the treadmill was conducted in eight different phases. At the begin-