都市部在住高齢者における介護予防健診の不参加者の特徴

介護予防事業推進のための基礎資料（「お達者健診」）より

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目的　地域高齢者を対象に実施された介護予防健診への継続参加者と不参加者の特性を比較し，不参加の関連要因を検討した。また，老年症候群の改善介入教室の参加状況が健診への継続参加へ及ぼす影響について検討した。

対象と方法　2002年に東京都Ｉ区で実施された介護予防を目的とした健診（「お達者健診」）の参加者（1,712人）を対象とした。2年後の2004年に実施した健診に参加した者を「参加者」，参加しなかった者を「不参加者」の二群に分類し両群間における特性を比較した。また，健診への不参加の関連要因を明らかにするため，多重ロジスティック回帰分析を実施した。

結果　健診の参加率は，男性66.3%，女性67.3%であった。多重ロジスティック回帰分析の結果，男性では，認知機能が低い（Odds ratio（OR）＝2.19, 95% Confidence Intervals（CI）1.07－4.49），教育歴が低い（OR＝1.58, 95% CI 1.22－2.22），老年症候群がある（OR＝1.82, 95% CI 1.27－2.59）が，女性では，認知機能が低い（OR＝2.01, 95% CI 1.13－3.59），喫煙習慣がある（OR＝2.05, 95% CI 1.13－3.72），趣味習慣が無い（OR＝0.68, 95% CI 0.50－0.92）ことが健診への不参加に関連した。ついで，老年症候群の保有者のみを対象に不参加の関連要因を検討したところ，男女に共通して老年症候群の改善介入教室へ不参加である（男性 OR＝5.90, 95% CI 2.08－16.7，女性 OR＝2.64, 95% CI 1.57－4.45）ことが健診への不参加に関連した。

結論　健診に参加しない者は，男性では認知機能が低く，教育歴が低く，老年症候群の保有者であり，女性では，認知機能が低く，喫煙習慣があり，趣味習慣が乏しいという特徴が認められた。また，男女共に老年症候群の保有者であっても，介入教室に参加した者はその後の健診にも参加しやすいことが明らかとなった。

提言　健診への参加率を向上させるためには，個々の背景やニーズに合わせた周知法や健診内容の提示が必要である。

Key words：地域在住高齢者，健診不参加者特性，認知機能，介護予防

Ⅰ　緒　　言

高齢者の増加に伴い介護給付費の増大が見込まれていることから，高齢者の自立の維持・延伸を目的とし，平成18年から基本健康診査への基本チェックリストの導入や各種介護予防事業が展開されている[1]。しかしながら，平成18年の65歳以上人口に占める基本チェックリストの実施率は約23%，基本健康診査の受診率は約30%と参加率は低い[2]。そのため，全体的に参加率を底上げさせることが課題とされ平成19年3月の見直し案では，基本チェックリスト実施率を40～60%にするよう目標値を設定している[2]。

介護予防事業の目的は，加齢に伴う心身機能の低下の早期発見・早期対応であり，個人の健康状態を見極め適切な介護予防サービスを提供することにある。安定した介護予防サービスを展開するためには，まずその入り口の一つである健診への参加を促し，各事業への高い参加率を得る必要がある。そのためには，各事業への不参加者の背景を知り，それぞれに合った働きかけをすることが望ましい。

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高齢者を対象とした健診や健康調査への不参加者の特徴について報告した研究によれば，不参加者の特徴に，年齢が高い[3]，教育歴が低い[4]，疾病がある[4-7]，健康問題が多い[8]，主観的な健康感が低い[3,7,9]，認知機能が低い[4,8]，喫煙習慣がある[7,9]，町内会・老人クラブへの参加が低いことや趣味・生きがいを持つ割合が低い[10]ことが示されている。

このように健診や健康調査への不参加の要因として，主に心身機能の低さが示されており，本来介護予防の対象となりうる者が不参加であることが考えられる。また，健診不参加者はその後の生命予後が不良であることが報告されており[11]，不参加者に対する対応を含めた全体への介護予防対策を講ずることが急務である。

そこで本研究では，高齢者を対象に実施された介護予防健診の参加者を対象に，2年後に実施された健診への参加者と不参加者の背景要因を比較し，不参加者の特徴について明らかにすることを目的とした。また，健診をもとに実施された老年症候群の改善介入教室が，2年後の健診参加へ及ぼす影響についても検討した。本知見は今後の介護予防健診の参加率向上のための基礎資料として寄与するものである。

Ⅱ　研究方法

1.　対象

2002年10月1日時点で70歳以上であった東京都Ⅰ区（同区総人口506,478名，65歳人口割合16.9%）に在住する高齢者を対象に実施された介護予防健診（「お達者健診」）[3,12]に参加した1,784人（男性769人，女性1,015人）のうち，追跡期間中の死亡者39人，転出者33人を除く1,712人（男性728人，女性984人）を分析の対象とした。

健診への継続参加の関連要因の分析のため，2002年に実施されたベースライン健診の参加者を二群に分類し比較した。2年後（2004年）の健診に参加した場合を「参加群」，参加しなかった場合を「不参加群」とした。

2.　手続き

本研究における健診ならびに改善介入教室の流れについて示す。2002年および2004年に実施された「お達者健診」は，高齢者の老年症候群の早期発見（スクリーニング）・早期対応（介入プログラム）を目的とした介護予防健康診査である。健診では一般の医学健診に加え，身体機能測定，面接聞き取り調査を実施した。次いで，2002年に実施された健診結果に基づき，自助努力により改善可能である病態の老年症候群のうち，転倒，尿失禁（女性のみ），うつ，低栄養の保有者をそれぞれスクリーニングし，改善介入教室を実施した[13]。さらに2004年に同健診を実施した。（図1）

3.　分析項目

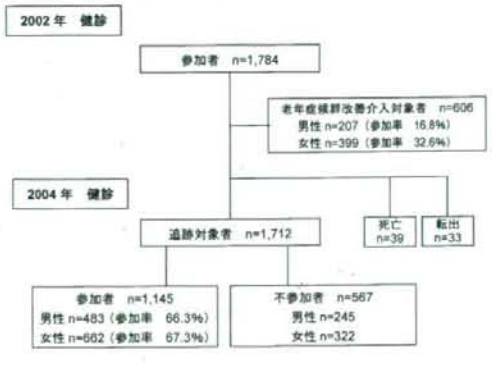
分析項目は，2002年のベースライン健診時における性，年齢，健康度自己評価，総合的移動能力[14]，外出頻度，疾病既往症の有無（高血圧既往，脳卒中既往，心臓病既往，糖尿病既往，高脂血症既往），治療中の疾病の有無，飲酒習慣の有無，喫煙習慣の有無，散歩・体操・運動習慣の有無，趣味や稽古ごとの有無，グループ活動の有無，居住形態（同居者あり，独居），教育歴（中等教育以上，初等教育以下），高次生活機能（老研式活動能力得点[15]），認知機能（Mini Mental State Examination; MMSE[16]），老年症候群（転倒，尿失禁（女性のみ），うつ，低栄養のうちいずれか1つ以上）の有無，体格指数（Body Mass Index; BMI），身体機能の項目として，握力，5 m歩行速度（通常歩行速度，最大歩行速度）[17]，座位膝伸展筋力，改善介入教室の参加状況であった。膝伸展筋力は，計測器に対象者の膝角度が90度になるよう座してもらい，足首の位置にHand-held Dynamometer（MUSCLATOR GT-30, OG GIKEN）のセンサーを設置し，最大で膝を伸展するよう指示し筋力を測定した。

分析にあたり，健康度自己評価については「非常に健康」，「まあ健康な方」を「健康」とした。総合的移動能力は「1人で外出できる」を「遠出可能」とした。外出頻度は「1日1回以上」を「毎日」とした。飲酒習慣の有無および喫煙習慣の有無は「飲む/吸う」を「あり」，趣味や稽古ごとは「ときどきする」，「よくする」を「あり」とした。認知機能は，カットオフ値を23/24点に設定した。

4.　分析方法

「参加群」と「不参加群」における特性の比較は，

図1　お達者健診の流れ



連続量についてはt検定，離散量についてはχ^2検定を用いた。健診への不参加の関連要因を明らかにするため，多重ロジスティック回帰分析（強制投入法）を実施した。従属変数を継続参加の有無，独立変数に年齢，教育歴，健康度自己評価，喫煙習慣，趣味習慣，認知機能，健康問題として老年症候群の有無，また身体機能として歩行速度，高次生活機能として老研式活動能力指標得点を投入した。次に，老年症候群の保有者を対象に，改善介入教室への参加の有無が健診参加に及ぼす影響について分析した。従属変数を継続参加の有無，独立変数に上記のモデルに加え，改善介入教室の参加の有無を投入した。

解析にはSPSS13.0J for Windowsを用い，危険率5%未満を有意差ありとした。

なお，本研究は東京都老人総合研究所の倫理委員会の審査を経て実施した。対象者には研究の主旨と個人情報の厳守について十分な説明を行い，調査協力の同意を得た。

Ⅲ　研究結果

健診の参加率は，男性66.3%，女性67.3%であった（表1）。健診参加群と不参加群の特性について比較したところ（表2），男性では参加群に比べ不参加群で，教育歴が初等教育の割合が高く（$P<0.001$），健康度自己評価が健康の割合が低く（$P<0.05$），老研式活動能力指標得点が低く（$P<0.05$），喫煙習慣ありの割合が高く（$P<0.05$），趣味ありの割合が低く（$P<0.05$），グループ活動ありの割合が低く（$P<0.05$），認知機能23点以下の割合が高く（$P<0.01$），老年症候群を保有する割合が高く（$P<0.001$），握力が弱く（$P<0.001$），膝伸展筋力が弱く（$P<0.01$），通常歩行速度および最大歩行速度が遅かった（$P<0.05$, $P<0.001$）。女性では参加群に比べて不参加群で，年齢が高く（$P<0.05$），教育歴が初等教育の割合が高く（$P<0.01$），健康度自己評価が健康の割合が低く（$P<0.05$），老研式活動能力指標得点が低く（$P<0.01$），外出頻度が毎日の割合が低く（$P<0.05$），喫煙習慣ありの割合が高く（$P<0.05$），趣味ありの割合が少なく（$P<0.001$），グループ活動ありの割合が少なく（$P<0.05$），認知機能23点以下の割合が多く（$P<0.001$），老年症候群を保有する割合が高く（$P<0.05$），BMIが高く（$P<0.01$），膝伸展筋力が弱く（$P<0.001$），通常歩行速度および最大歩行速度が遅かった（各々$P<0.001$）。

表1　対象者の主な特性

	男性 (n=728)	女性 (n=984)	全体 (n=1,712)
年齢　～74歳	42.6	42.6	42.6
75～79歳	37.5	37.2	37.3
80歳～	19.9	20.2	20.1
健康度自己評価；健康	83.8	75.8	79.2
総合的移動能力；遠出可能	96.8	93.6	95.0
飲酒習慣；あり	64.9	28.6	44.0
喫煙習慣；あり	25.7	5.0	13.8
運動習慣；あり	79.3	73.8	76.1
学歴；初等教育	30.1	32.2	31.3
居住形態；独居	10.6	36.5	25.5
老研式活動能力指標；点	11.8±1.7	12.1±1.4	12.0±1.5
老年症候群：あり	26.1	39.0	33.5
健診参加状況；参加	66.3	67.3	66.9

老年症候群；転倒，尿失禁，低栄養，うつ
（%，平均±SD）

健診への不参加の関連要因を総合的に検討するため多重ロジスティック回帰分析を行った（表3）。その結果，男性では，認知機能（Odds ratio（OR）=2.19, 95% Confidence Intervals（CI）1.07–4.49），教育歴（OR=1.58, 95% CI 1.22–2.22），老年症候群の有無（OR=1.82, 95% CI 1.27–2.59）が，女性では，認知機能（OR=2.01, 95% CI 1.13–3.59），喫煙習慣（OR=2.05, 95% CI 1.13–3.72），趣味習慣（OR=0.68, 95% CI 0.50–0.92）が健診への不参加に関連し，男性では，教育歴が低い，認知機能が低い，改善介入教室の対象であることが，女性では，喫煙習慣がある，趣味習慣が無い，認知機能が低いことが不参加になりやすいことを示した。

次いで，老年症候群保有者を対象に改善介入教室の参加の有無が2年後の健診参加へ及ぼす影響を検討した。その結果，男女共に介入教室の参加状況（男性OR=5.90, 95% CI 2.08－16.7，女性OR=2.64, 95% CI 1.57－4.45）が健診への不参加に関連し，男女共に改善介入教室に不参加の場合は2年後の健診へ不参加になりやすいことを示した。

Ⅳ　考　　察

本研究では介護予防健診の参加者を対象に，その後の同健診への不参加の関連要因について検討した。その結果，男女に共通して認知機能が低いこと，さらに男性では，教育歴が低い，老年症候群があることが，女性では，喫煙習慣がある，趣味習慣が無いことが不参加に関連した。また，老年症候群の保有者のみを対象に，老年症候群の介入教室への

表2　健診参加・不参加別にみたベースライン時の特性

	男性		女性	
	参加（n=483）	不参加（n=245）	参加（n=662）	不参加（n=322）
年齢　～74歳	45.1	37.6	44.9	37.9
75～79歳	35.0	42.4	37.3	37.0*
80歳～	19.9	20.0	17.8	25.2
居住形態；独居	9.3	13.1	37.8	33.9
学歴；初等教育	25.9	38.5***	29.2	38.4**
健康度自己評価；健康	86.1	79.1*	77.9	71.3*
老研式活動能力指標；点	11.9±1.5	11.5±1.8*	12.2±1.3	11.9±1.6**
外出頻度；毎日	80.7	80.3	81.7	75.7*
飲酒習慣；あり	64.8	65.2	28.9	28.0
喫煙習慣；あり	23.4	30.3*	3.9	7.2*
運動習慣；あり	80.7	76.5	75.4	70.4
趣味習慣；あり	70.1	62.8*	72.4	60.4***
グループ活動；あり	44.0	34.6*	46.4	38.0*
認知機能；23点以下	3.5	8.2**	3.8	9.4***
高血圧既往；あり	44.9	44.9	45.0	50.0
脳卒中等既往；あり	11.2	11.0	6.5	5.6
糖尿病既往；あり	10.6	11.0	5.4	7.1
高脂血症既往；あり	16.8	15.1	31.7	32.9
心疾患既往；あり	22.2	22.4	25.4	21.7
老年症候群：あり	21.5	35.1***	36.9	43.5*
BMI；kg/m^2	23.2±2.7	23.5±3.3	22.7±3.2	23.4±3.6**
握力；kg	30.9±6.5	28.9±6.3***	18.5±4.3	17.9±4.3
膝伸展力；Nm	78.2±23.9	71.4±24.3**	48.6±15.7	45.0±15.1***
通常歩行速度；m/s	1.24±0.24	1.19±0.26*	1.18±0.25	1.11±0.28***
最大歩行速度；m/s	1.95±0.39	1.82±0.39***	1.72±0.36	1.62±0.37***

* $P<0.05$, ** $P<0.01$, *** $P<0.001$. Tested by χ^2 test or t-test　　（%，平均±SD）
項目により欠損値あり

参加の影響を検討したところ，介入教室への不参加が，健診不参加に関連した。

健診不参加の関連要因を分析したところ，男女で認知機能の低さが健診不参加に関与していた。高齢者を対象とした健康調査への不参加者の特性の検討では，不参加者は認知機能が低いことが報告されており[4,8,18]，本研究の結果は先行研究に一致した。先行研究では認知機能に障害があり一度調査に不参加であっても，その後に自宅へ訪問するという方法により，参加率は上昇することが報告されている[8]。このように健診不参加者の中には，認知機能の低下により健診への参加の機会を逃しているケースがあることも考えられることから，認知機能低下も視野に入れ，電話連絡や自宅訪問または家族への連絡により参加を促すなどの工夫が必要であることが考えられた。

男性で教育歴の低さが健診不参加に関連した。教育歴は健診への不参加に関連することが報告されている[4]。教育歴が低い者は保健行動の実施率も低く[19]，教育歴の低さが保健行動の一環である健診受診行動に関与し，健診へ不参加になった可能性が考えられた。

女性で健診への不参加に喫煙習慣が関連していた。先行研究では健診の不参加に喫煙習慣が関連することが報告されている[7,9]。喫煙習慣がある者は，健診など保健行動に対する関心が低く，その結果健診に参加しにくいことが考えられた。

女性で趣味習慣が無いことが不参加の関連要因としてあげられた。健診への不参加者は趣味や生きがいを持つ割合が低いことが報告されている[10]。趣味やグループ活動の場では，様々な情報交換や社会交流が行われることが推測される。趣味やグループ活動に参加することにより保健行動に対する意識の高い参加者に誘導され，健診に参加する可能性が考えられた。

男性で老年症候群を保有することが健診への不参

表3　健診不参加に対する関連要因の分析

	男性（n＝718）	女性（n＝974）
	OR（95%CI）	OR（95%CI）
年齢	1.06(0.85～1.32)	1.11(0.91～1.36)
教育歴	1.58(1.12～2.22)**	1.16(0.85～1.57)
老研式活動能力指標得点	0.97(0.87～1.07)	0.96(0.87～1.07)
健康度自己評価	0.77(0.50～1.18)	0.85(0.62～1.18)
喫煙習慣	1.32(0.92～1.90)	2.05(1.13～3.72)*
趣味習慣	0.93(0.65～1.32)	0.68(0.50～0.92)*
認知機能	2.19(1.07～4.49)*	2.01(1.13～3.59)*
通常歩行速度	0.75(0.37～1.51)	0.59(0.32～1.08)
老年症候群の有無	1.82(1.27～2.59)**	1.25(0.94～1.66)

多重ロジスティック回帰分析（強制投入法），OR：Odds Ratio, CI：Confidence Intervals
従属変数：健診参加状況（0＝参加，1＝不参加）
独立変数：年齢（0＝～74歳，1＝75～79歳，2＝80歳～），教育歴（0＝中等教育以上，1＝初等教育以下），老研式活動能力指標得点（実数），健康度自己評価（0＝その他，1＝健康），喫煙習慣（0＝なし，1＝あり），趣味習慣（0＝なし，1＝あり），認知機能（0＝24点以上，1＝23点以下），通常歩行速度（実数），老年症候群の有無（0＝なし，1＝あり）
* $P<0.05$, ** $P<0.01$.

加に関与することが示された。老年症候群保有者は，転倒，尿失禁，うつ，低栄養の老年症候群のうち少なくとも一つの症候を持ち，心身の不都合があることを意味している。先行研究では疾病の数[5]や様々な健康問題[8]が不参加に影響することが報告されており，本研究の結果はこれらと類似の傾向を示した。

老年症候群の改善介入教室への参加の有無が，その後の健診参加に及ぼす影響について検討したところ，改善介入教室の参加の有無は，健診への参加状況に関連していることが示された。老年症候群を保有していても改善介入教室へ参加した者は，その後の健診へ参加しやすく，介入教室の参加が健診への参加を促進していることが示された。介入教室の不参加者は参加者に比べ，筋力や歩行機能が低く[13]，より虚弱が進みやすいことが推察され，これを抑止するためにも，健診や介入教室への参加促進が重要であることが考えられた。

本研究は，ベースラインの健診に参加した者を対象に，二回目の健診への不参加に関する二次的な選択バイアスに関する検討であり，一次的な選択バイアスに関する検討ではない。しかしながら，本知見における不参加者の特徴は，一般集団を対象とした一次的な選択バイアスの検討結果[4,7,8,10]と同様な傾向を示した。すなわち，健診に参加する程度に自立度が高い高齢者であっても，相対的に機能が低いことや社会活動が低いことなどがその後の健診不参加の関連要因であることが見出された。

本研究結果から考えられる健診への参加率向上のための対策法について述べる。第一に，対象者の認知機能が低下している可能性も視野に入れ，単に文書で通知するだけではなく，返答が無い場合は電話や自宅訪問および家族を介した通知を行うなど複数の勧誘方法を取り入れることが重要である。第二に，社会活動の場や高齢者が集まる場所などで参加者に健診への参加を促すこと，さらに参加者に近隣の高齢者や友人に健診開催に関する情報伝達を依頼するなど地域資源を活用した周知法が考えられる。第三に，老年症候群の改善介入教室への参加がその後の健診参加を促すことから，改善介入教室の募集の段階で積極的な勧誘を行うことが重要である。すなわち，老年症候群の介入対象者は非介入対象者に比べより虚弱が進みやすい集団であり，より重点的な働きかけが必要である。これらの対策は，単に健診参加率を向上させるだけではなく，長期の介護予防を視野に入れた対策につながることが考えられる。

本研究結果の限界について述べる。本研究の対象は，無作為抽出で抽出した者および公共の余暇施設利用者に対し健診参加への募集を行い，自主的に参加を表明した高齢者である。表1に示したように全体の約95%が単独で遠出可能と回答しているように，本研究の結果は，自立度の高い集団から得られた結果である。そのため，本知見は自立度の低い高齢者集団には当てはまらないことが考えられ，知見の一般化には注意を要する。また，本研究では健診不参加の理由について聴取を行っていない。健診不参加の理由には，行く手段が無い・元気だからという報告もあり[20]，心身の機能低下のみではないことが示されている。この点はさらに検討する必要がある。

V　結　　語

介護予防事業への参加率向上を目的とした対策法の検討のため，ベースライン健診の参加者を対象に2年後に実施された健診への不参加の関連要因を検討した。その結果，2年後の健診に参加しない者は，男性では認知機能が低く，教育歴が低く，老年症候群がある，女性では，認知機能が低く，喫煙習慣があり，趣味習慣がないという特徴が認められた。また，男女共に老年症候群を保有する虚弱傾向の高齢者であっても，老年症候群の改善介入教室に参加した者はその後の健診に参加しやすいことが示

された。これらのことから継続的な健診への参加率を向上させるため個々の背景に合わせた勧誘法の提示が必要であることが考えられた。

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Characteristics of non-participants in comprehensive health examinations ("Otasha-kenshin") among an urban community dwelling elderly: Basic research for prevention of the geriatric syndrome and a bed-ridden state

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Key words : Community-dwelling elderly, Non-participation in comprehensive health examinations, Cognitive function, Prevention of long-term care status

Purpose The present study was conducted to identify the characteristics of non-participants in secondary comprehensive health examinations among community-dwelling elderly.

Methods The subjects were 728 men and 984 women aged 70 years and over who had participated in comprehensive health examinations in 2002. Multiple logistic regression analysis was performed to assess the characteristics associated with non-participation in comprehensive health examinations after 2 years (in 2004).

Results The rates of participation in follow-up health examinations were 66.3% for men and 67.3% for women. Logistic regression analysis showed that male non-participants had low cognitive function (odds ratio (OR) = 2.19, 95% confidence interval (CI) = 1.07 − 4.49), low education (OR = 1.58, 95% CI = 1.22 − 2.22), and suffered from health problems (OR = 1.82, 95% CI = 1.27 − 2.59), and that female non-participants had low cognitive function (OR = 2.01, 95% CI 1.13 − 3.59), tended to be smokers (OR = 2.05, 95%, CI = 1.13 − 3.72), and had no hobby (OR = 0.68, 95% CI = 0.50 − 0.92).

Conclusion Poor cognitive function, health problems, and unfavorable lifestyle factors are related to non-participation in comprehensive health examinations.

Proposal It is necessary to devise various approaches to encourage participation of such individuals.

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Low Serum 25-Hydroxyvitamin D Levels Associated With Falls Among Japanese Community-Dwelling Elderly

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Low Serum 25-Hydroxyvitamin D Levels Associated With Falls Among Japanese Community-Dwelling Elderly

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ABSTRACT: Previous studies have shown that low serum 25-hydroxyvitamin D [25(OH)D] level is a risk factor for falls among the elderly in European and North American populations. We used a cross-sectional community-based survey to study the association of serum 25(OH)D level and falls among Japanese community-dwelling elderly. A total of 2957 elderly persons (950 men and 2007 women) 65–92 yr of age who participated in mass health examinations for the prevention of geriatric syndrome for the elderly underwent an interview, blood analysis, and physical performance testing. Experience of falls over the previous year was assessed in an interview. Physical performance tests of handgrip strength, stork standing time with the eyes open, and normal waking speed as risk factors for falls among the elderly were conducted. Serum albumin and 25(OH)D concentrations were analyzed. Mean 25(OH)D concentration was significantly lower in women than in men ($p < 0.001$). Women showed a significant decline of 25(OH)D level with increased age ($p < 0.001$). There was also a significant difference in the prevalence of 25(OH)D insufficiency [25(OH)D level < 20 ng/ml] between the sexes ($p < 0.001$). The rate of falls was significantly higher in the lowest quartile of 25(OH)D level in women ($p = 0.02$) and in women with 25(OH)D insufficiency ($p = 0.001$). Women also showed significant declines in all three fall-related physical performance tests. Multiple logistic regression analysis showed significant and independent associations between 25(OH)D level and experience of falls in women only ($p = 0.01$). Low 25(OH)D level was significantly associated with a high prevalence of falls in Japanese elderly women because of their inferior physical performance. Low serum 25(OH)D levels appear preventable and easily treated; there is an evident need for greater awareness to screen and thus prevent this condition.
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Key words: 25-hydroxyvitamin D, fall, physical performance, community elderly

INTRODUCTION

The importance of vitamin D for skeletal health is well known.[1,2] Through the regulation of calcium and phosphorus levels in the blood by promoting their absorption from food in the intestines, vitamin D promotes bone formation and mineralization for the development of a strong skeleton. Vitamin D deficiency, which can result from inadequate intake coupled with inadequate sunlight exposure, plays an important role in the development of osteoporosis because of the induction of a secondary hyperparathyroidism that mobilizes calcium from the bone.

Vitamin D deficiency results not only in impaired bone mineralization, but also in myopathy in the elderly.[3,4] It has also been shown recently to be associated with a decline of muscle strength,[5–8] sarcopenia,[7] and functional limitations and disability,[5,8] and probably because of these phenomena, with falls in the elderly.[9–11] We have studied and reported that concomitant low serum 25-hydroxyvitamin D [25(OH)D] and albumin were associated with decreased objective physical performance among Japanese community-dwelling elderly from a nutritional point of view.[12] However, falls were not taken into account in the previous study.

The aim of this study was to investigate the association between serum 25(OH)D levels and falls, and the associated physical performance among community-dwelling Japanese elderly who in some previous studies have been reported to have stronger muscle strength and lower fall rates than whites.[13,14] We hypothesized that low 25(OH)D levels (1) correlate with poor muscle strength, balance, and walking capability and (2) are consequently associated with the occurrences of falls among community-dwelling Japanese elderly.

MATERIALS AND METHODS

Subjects

The participants were 2957 residents (950 men and 2007 women) ≥65 yr of age living in Itabashi ward in Tokyo, Japan, who had participated in mass health checkups for the community elderly (Otasha-Kenshin) conducted in October/November 2004 and 2005. Otasha-Kenshin, which means "health checkups for successful aging" in Japanese, is a comprehensive mass health examination for commu-

The authors state that they have no conflicts of interest.

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nity-dwelling elderly that aims to prevent "geriatric syndrome" including falls and fractures, incontinence, poor oral health, mild cognitive impairment, depression, and undernutrition. The overall aim is to prevent the loss of independence and the need for long-term care in later life. Details of Otasha-Kenshin, including participant details, investigation methods, and its contents, have been described in our earlier papers.[15–17] None of the subjects analyzed in this study had a history of malignant diseases, current treatment of vitamin D, chronic renal failure, or other serious diseases affecting vitamin D regulation. All participants were essentially ambulatory, lived independently in their homes, and had sound functional capacity. Participants provided written informed consent to participate in the study, which was approved by the Institutional Review Board and Ethic Committee of the TMIG (Accepted No. 5, July 1, 2004).

Data collection

Interviews were conducted to assess the age, physical activity, and chronic disease conditions of subjects. History of chronic diseases was self-reported and included hypertension, stroke, heart disease, diabetes, and renal failure. Heart disease included angina pectoris, acute myocardial infarction, congestive heart failure, and various arrhythmias. Renal failure was defined as chronic renal failure under treatment including hemodialysis, which can affect the regulation and metabolism of serum vitamin D levels.

We also assessed fall experience over the previous year. A fall was defined as an unintentional change in position resulting in coming to rest at a lower level or on the ground. The subjects were asked about their falls in the same manner as in our previous study.[18] That is, they were asked the question, "Have you experienced any falls during the previous 12 months?" Those who reported one or more falls were asked about the circumstances and consequences of each fall (i.e., the time, reason and place of the fall, the presence or absence of injury, and whether they visited a doctor).

Previous population-based studies have confirmed that physical performance characteristics, including those based on handgrip strength, stork standing time with the eyes open, and normal walking speed, are risk factors for falls among the community elderly in Japan.[18–20] Moreover, these three variables have also been confirmed by a covariance structure model as the essential factors underlying physical performance measures for Japanese elderly living in a community.[21]

Handgrip strength

The peak handgrip force (kg) of each hand was measured by Smedley's hand dynamometer (Yagami, Tokyo, Japan). The test was performed twice, and the higher of the two measurements made on the dominant hand was recorded.

Stork standing

While standing on a square (0.4 × 0.4 m), each subject stood on one 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, and the longer of two attempts was recorded.

Normal walking speed

A flat walking path of 11 m was marked with tape at the 3- and 8-m points. A stopwatch measured the time taken to walk 5m, from the time when a foot first touched the ground after the 3-m line to when a foot touched the ground after the 8-m line. The participants were asked to take the test by walking at their normal or preferable speed. The test was repeated and the faster speed recorded.

Because of the possibility of a high correlation among the three physical performance tests, after confirmation by Pearson's correlation coefficient (r), normal walking speed was selected as the representative independent variable for the multiple logistic regression model.

Measurement of serum levels of albumin and 25(OH)D

Blood samples were collected in a nonfasting state and in a sitting position. Analyses were carried out centrally in one laboratory (Special Reference Laboratories, Tokyo, Japan). Serum 25(OH)D levels are commonly used as a measure of vitamin D status,[22–24] and these were measured with an RIT 2 kit (Dia Sorin, Stillwater, MN, USA). The RIT 2 method is based on an antibody specific to 25(OH)D; using this method, the CV was <1%. We summarized the serum 25(OH)D levels of these subjects into quartiles, and used the 25 percentile cut-off to compare groups of subjects with higher and lower 25(OH)D. Lower serum 25(OH)D was defined as 25.0 ng/ml (62.5 nM) or below for men and 21.0 ng/ml (52.5 nM) or below for women. For a definition of vitamin D insufficiency, based on studies performed in the United States and Australia[25,26] showing that a serum 25(OH)D level of at least 15–20 ng/ml is needed to achieve optimum PTH levels, we defined a 25(OH)D level of <20 ng/ml as insufficiency.

Statistical analysis

All data were analyzed with SPSS software for Windows, version 13.0 (SPSS, Chicago, IL, USA); the level of significance was set at 5%.

Means and SDs (for continuous variables) along with proportions (for categorical variables) were calculated for all participants. Differences between men and women were assessed using t-tests for continuous variables and χ^2 tests for categorical data. Differences in serum 25(OH)D levels were analyzed among the four age groups by one-way ANOVA in both sexes. Furthermore, comparisons of fall-related variables by 25(OH)D level were performed using analysis of covariance (ANCOVA) controlled for age in continuous variables, and Mantel-Haenszel χ^2 tests were used to adjust for age in categorical variables in both sexes.

To analyze the association of serum albumin and 25(OH)D level with physical performance (i.e., handgrip strength, stork standing time with the eyes open, and normal walking speed), multiple regression analysis was conducted with age adjustment. To study the association of falls and 25(OH)D levels, logistic regression analysis was

TABLE 1. CHARACTERISTICS OF STUDY PARTICIPANTS

Characteristics	*Male (n = 950)*	*[Min–Max]*	*Female (n = 2007)*	*[Min–Max]*	*p*
Age (yr, mean ± SD)	74.5 ± 5.1	[65–89]	75.4 ± 4.7	[65–92]	<0.001*
Fall experience over the previous year (yes, %)	103 (10.8)		372 (18.5)		<0.001†
Hand grip strength (kg, mean ± SD)	31.4 ± 6.6	[10–52]	18.8 ± 4.6	[1–38]	<0.001*
Stork standing time with eyes open (s, mean ± SD)	37.1 ± 22.5	[1–95]	35.8 ± 23.3	[1–88]	0.152*
Normal walking speed (m/s, mean ± SD)	1.23 ± 0.26	[0.40–2.08]	1.18 ± 0.29	[0.15–2.00]	<0.001*
Serum albumin (g/dl, mean ± SD)	4.35 ± 0.23	[3.4–5.0]	4.31 ± 0.21	[3.3–5.0]	<0.001*
Serum 25(OH)D level (ng/ml, mean ± SD)	28.5 ± 5.0	[8–42]	24.2 ± 4.9	[9–38]	<0.001*
Age group	(n)		(n)		
65–69	(173) 28.4 ± 4.5		(163) 26.8 ± 3.8		
70–74	(314) 28.5 ± 5.3		(763) 24.2 ± 4.6		
75–79	(320) 28.6 ± 4.9		(675) 24.0 ± 5.1		
80+	(143) 28.4 ± 5.5	$p = 0.97$‡	(406) 23.6 ± 5.3	$p < 0.001$‡	
Quartile [cut-off value of 25(OH)D for each percentile]	(ng/ml)		(ng/ml)		
25 percentile	25.0		21.0		
50 percentile	29.0		24.0		
75 percentile	32.0		28.0		
Insufficient (<20 ng/ml, %)	4.8		17.7		<0.001†

* Student's *t*-test for continuous variables between males and females.
† χ^2 test for categorical variables between males and females.
‡ ANOVA in both males and females.

conducted using "fall experience over the previous year" as a dependent variable and other variables [age, physical performance test, serum albumin, and 25(OH)D levels] as independent variables.

RESULTS

The basic characteristics of the subjects, including age, handgrip strength, stork standing with the eyes open, normal walking speed, serum albumin level, and 25(OH)D level, are shown in Table 1. Mean ages were 74.5 ± 5.1 yr in men and 75.4 ± 4.7 yr in women ($p < 0.001$). Concerning fall experience, the numbers (percentage) of individuals who experienced a fall over the previous year were 103 (10.8%) in men and 372 (18.5%) in women. The prevalence of falls was significantly higher in women than men ($\chi^2 = 28.30$, $p < 0.0001$). The number of falls varied from one to five. Sixty-one men (59.2%) and 259 women (69.8%) had experienced only one fall, whereas 42 men and 113 women had recurrent falls of two or more times. The predominant cause of falling was "tripping" in both sexes, followed by "slipping" and "missing a step." The consequences of falling, that is, the conditions of injury, were clearly different between men and women. Although "bruise" (38.7%) and "scratch" (26.1%) were frequent among women, "no injury" accounted for nearly one half (44.7%) of men.

The mean 25(OH)D concentrations were 28.5 ± 5.0 ng/ml in men and 24.2 ± 4.9 ng/ml in women ($p < 0.001$). Only in women was there a significant decline of 25(OH)D concentration with increasing age by ANOVA ($p < 0.001$). Forty-six (4.8%) men and 356 (17.7%) women had a 25(OH)D level of <20 ng/ml (50 nM; $p < 0.001$).

Comparisons of the rate of fall experience over the previous year, average number of falls, physical performance tests, and serum albumin levels are shown in Table 2. Subjects who were judged as not appropriate for the tests because of high blood pressure, heart failure, lumbago, knee pain, etc., were excluded from the physical performance tests. Thus, the total number of subjects who underwent the physical performance tests was 2837 (917 men and 1921 women) in the handgrip strength test, 2519 (792 men and 1727 women) in the stork standing test, and 2044 (455 men and 1589 women) in the normal walking speed test. First, comparisons were conducted between the lowest quartile group (≤25.0 ng/ml in men and ≤21.0 ng/ml in women) and the higher groups. Both hand grip strength and stork standing time were significantly different in men, and all of the measurements were significantly different in women. Furthermore, for women only, the rate of fall experience and average number of falls were significantly higher in the lowest quartile group compared with the other groups ($p = 0.02$ for the rate and $p = 0.021$ for the number). Second, comparisons were conducted between the 25(OH)D insufficiency group (<20 ng/ml) and the normal group (≥20 ng/ml). Hand grip strength and serum albumin level in men, and all measurements except hand grip strength in women, were significantly different between these two groups. Stork standing time, normal walking speed, and serum albumin level were significantly lower in the 25(OH)D insufficiency group. As for rate of fall experience and average number of falls, only women showed that the 25(OH)D insufficiency group had a significantly higher rate ($p = 0.001$) and average number ($p = 0.006$) of falls than the normal group.

Table 3 shows the associations of serum concentrations of albumin and 25(OH)D with physical performance tests by multiple regression models adjusted for age. Serum 25(OH)D level showed significant association with all three variables in the physical performances of both men and women. However, serum albumin level showed significant association only with handgrip strength in both sexes.

Calculations of Pearson's correlation coefficient (r) were

TABLE 2. SERUM 25(OH)D LEVEL AND CHARACTERISTICS FOR MALES AND FEMALES

Characteristics	Male			Female		
	Lower (≦25.0 ng/ml) (n = 249)	*Higher (≧26.0 ng/ml) (n = 701)*	*p*	*Lower (≦21.0 ng/ml) (n = 576)*	*Higher (≧22.0 ng/ml) (n = 1431)*	*p*
Fall experience over the previous year (yes, *n*, %)	27 (10.8)	76 (10.8)	0.938*	129 (22.4)	243 (17.0)	0.020*
Average number of falls (times, mean ± SD)	2.1 ± 2.4	1.7 ± 1.1	0.422†	1.6 ± 1.2	1.4 ± 0.8	0.021[b]
Hand grip strength (kg, mean ± SD)	30.5 ± 6.7	31.7 ± 6.5	0.020[b]	17.9 ± 4.6	19.2 ± 4.6	0.002[b]
Stork standing time with eye open (s, mean ± SD)	34.6 ± 22.5	38.2 ± 22.5	0.046[b]	31.7 ± 23.5	37.7 ± 23.0	<0.001†
Normal walking speed (m/s, mean ± SD)	1.19 ± 0.26	1.25 ± 0.26	0.061†	1.12 ± 0.28	1.21 ± 0.27	<0.001†
Serum albumin (g/dl, mean ± SD)	4.34 ± 0.24	4.35 ± 0.26	0.616†	4.28 ± 0.23	4.33 ± 0.21	<0.001†
	Insufficiency (<20.0 ng/ml) (n = 46)	*Normal (≧20.0 ng/ml) (n = 904)*	*p*	*Insufficiency (<20.0 ng/ml) (n = 356)*	*Normal (≧20.0 ng/ml) (n = 1651)*	*p*
Fall experience over the previous year (yes, *n*, %)	3 (6.5)	100 (11.1)	0.454*	92 (25.8)	280 (17.0)	0.001*
Average number of falls (times, mean ± SD)	2.7 ± 0.6	1.8 ± 1.5	0.338†	1.7 ± 1.3	1.4 ± 1.5	0.006†
Hand grip strength (kg, mean ± SD)	28.5 ± 6.4	31.5 ± 6.5	0.003†	18.1 ± 4.7	19.0 ± 4.6	0.420[b]
Stork standing time with eye open (s, mean ± SD)	31.4 ± 22.9	37.5 ± 22.5	0.124†	29.8 ± 22.9	37.2 ± 23.2	<0.001†
Normal walking speed (m/s, mean ± SD)	1.16 ± 0.79	1.24 ± 0.26	0.138†	1.11 ± 0.29	1.20 ± 0.27	<0.001†
Serum albumin (g/dl, mean ± SD)	4.27 ± 0.26	4.35 ± 0.22	0.027†	4.27 ± 0.23	4.32 ± 0.21	<0.002†

* The Mantel-Haenszel χ^2 test adjusted for age.
† ANCOVA adjusted for age.

TABLE 3. ASSOCIATION OF SERUM ALBUMIN AND 25(OH)D LEVELS WITH PHYSICAL PERFORMANCE FOR MALES AND FEMALES

	Handgrip strength			*Stork standing time*			*Normal walking speed*		
	β	*SE*	*p*	β	*SE*	*p*	β	*SE*	*p*
Men									
Albumin	0.096	0.852	0.001	0.002	3.644	0.947	0.025	0.053	0.576
25(OH)D	0.067	0.037	0.020	0.075	0.152	0.030	0.111	0.002	0.012
Women									
Albumin	0.109	0.459	<0.001	0.037	2.502	0.106	0.045	0.030	0.051
25(OH)D	0.062	0.020	0.003	0.109	0.105	<0.001	0.143	0.001	<0.001

Values are adjusted for age. *p* values are derived from multiple regression analysis.
β, standardized regression coefficient.

carried out to confirm the correlation among the three physical performance tests. The results showed high and significant intercorrelation for these three variables; correlation coefficients were from 0.23 (handgrip strength and stork standing time) to 0.35 (stork standing time and normal walking speed) in men and from 0.31 (handgrip strength and stork standing time) to 0.47 (stork standing time and normal walking speed) in women, and all were significant at $p < 0.001$. Therefore, we adopted only "normal walking speed" to represent the physical performance tests as well as the independent variable for the final multiple logistic regression model.

Table 4 shows the associations of fall experience over the previous year with normal walking speed, serum albumin, and 25(OH)D levels by multiple logistic regression models with age adjustment. Normal walking speed (unit = 0.1 m/s) showed a significant protective effect against falls in

TABLE 4. MULTIPLE LOGISTIC REGRESSION MODEL OF FACTORS ASSOCIATED WITH FALL EXPERIENCE OVER THE PREVIOUS YEAR

Risk factor	Male			Female		
	OR	*95% CI*	*p*	*OR*	*95% CI*	*p*
Age (yr)	1.02	0.95–1.10	NS	1.02	0.99–1.06	NS
Normal walking speed (0.1 m/s)	0.87	0.77–0.97	0.015	0.92	0.88–0.97	0.001
Albumin (g/dl)	1.69	0.45–6.33	NS	1.60	0.88–2.90	NS
25(OH)D (ng/ml)	1.00	0.95–1.06	NS	0.97	0.94–0.99	0.010

Dependent variable was "fall experience over the previous year" (yes = 1, no = 0).
The unit of normal walking speed was transferred from meters per second to 0.1 m/s in this final multiple logistic regression model.
NS, not significant.

both men (OR = 0.87, 95% CI = 0.77–0.97) and women (OR = 0.92, 95%CI = 0.88–0.97). Serum 25(OH)D level (unit = 1 ng/ml) also had a significant and independent protective effect for falls found only in women (OR = 0.97, 95% CI = 0.94–0.99, $p = 0.01$).

DISCUSSION

Maintenance of physical performance in old age is an important factor not only for a healthy and independent life in the community but also a way to prevent falls that can lead to a marked decline in activities of daily living (ADLs). A national survey in Japan has shown that the annual frequency of falls is >20% in those >65 yr of age and that ~10% of these falls result in fractures.[27]

This study showed that the proportion of people who reported falls in the previous year increased with age and that falls were more common in women than in men.[20] These findings are consistent with the results of other studies of falls among community-dwelling elderly.[28–32] Aoyagi et al.[33] reported that the proportion of falls in the previous year after age standardization for Japanese was about one half of that of whites. Furthermore, the incidence of hip fracture among Japanese elderly was found to be much lower than that reported for whites in North America and Europe.[34] This difference is probably partly the result of the lower fall rate among Japanese, suggesting that both ethnicity (genetics) and lifestyle (environmental) factors may be involved.[14] Recently, some studies have shown that lower serum vitamin D level is a risk factor for falls and fall-associated physical performance among the elderly.[9,10,35] At present, however, there are few studies on the association between serum 25(OH)D level and falls in Japanese community elderly, whose frequency of falls is less than that observed in Europe and the United States.[6–8,13]

In this study, we found that there were significant sex differences of 25(OH)D level on average and in a pattern of decline along with aging; namely, women had significant lower serum 25(OH)D levels at any age group and showed remarkable declines with aging. One of the reasons for this sex difference may be general inactivity and lower intake of vitamin D from daily food among Japanese elderly women compared with men. One Japanese national survey showed that, compared with 39.1% of men, 32.6% of women engage in physical activity for at least 30 min two or more times a week.[36] Our previous study also reported that women had significantly lower rates of regular sports activity than men (13.8% versus 21.5%).[37] Furthermore, we recently reported that one of the significant predictors for cessation of regular activity was "female sex" as well as "smoking" and "slow walking speed" from a population-based, 2-yr follow-up study.[38] The national survey also showed that women took smaller amounts of vitamin D than men (8.6 ± 9.0 versus 8.9 ± 10.0 μg/d on average). In particular, for elderly respondents ≥70 yr of age, the average intake of vitamin D in women (8.6 ± 9.0 μg/d) was much less than that in men (10.3 ± 10.1 μg/d).[36] These factors of physical inactivity and lower intake of daily vitamin D in elderly women may have caused their observed higher frequency of 25(OH)D insufficiency compared with men. It is known that the main source of vitamin D in humans is considered to be through the skin, where vitamin D is produced during exposure to UVB sunlight.[39,40] In our study, to avoid any seasonal variation of serum 25(OH)D, data collection was carried out only during autumn (October/November), which meant that serum 25(OH)D levels would be almost stable and at an average throughout the year among a normal Japanese population.[41]

The range of serum 25(OH)D levels was 8–42 ng/ml in men and 9–38 ng/ml in women. Although it is still uncertain what an optimal 25(OH)D level is, it has been suggested that the range of 25(OH)D levels should be 32–100 ng/ml, with a lower limit somewhere between 15 and 36 ng/ml.[41–43] In this study, we defined a 25(OH)D level of <20 ng/ml as insufficiency. From this, we judged that the prevalence of 25(OH)D insufficiency was significantly predominant in women (17.7%) compared with men (4.8%; $p < 0.001$). Studies concerning the prevalence of 25(OH)D insufficiency in various populations have been challenged because of the lack of standardization of assays and different cut-off points.[44] A comparison of serum 25(OH)D level between hip fracture patients and nonhip fracture controls in Japan showed that average serum 25(OH)D concentrations were significantly different: 17.8 ng/ml in hip fracture patients and 25.8 ng/ml in nonhip fracture controls.[45] Furthermore, 62% of the hip fracture patients ($N = 50$) had 25(OH)D insufficiency, defined as having a serum 25(OH)D concentration <20 ng/ml. In this context, the elderly whose 25(OH)D levels were <20 ng/ml can be considered to be in insufficiency and at high risk of a hip fracture, which indeed has increased sharply during last two decades in Japan.[46]

In comparisons of serum 25(OH)D levels and fall-associated variables between the group of participants in the lowest quartile and the groups of the three other higher quartiles of serum 25(OH)D level, all variables but normal walking speed in men were significantly lower in the lower 25(OH)D group than in the higher group. Our findings are consistent with the results from a Swedish population-based study of 986 community-living elderly women[47] that showed that the lower 25(OH)D group was significantly correlated with inferior gait speed, inferior balance test, and lower knee extension/flexion strength results, all of which are fall-associated variables.

The rate of fall experience over the previous year by serum 25(OH)D level was significantly different only in women [i.e., 22.4% in the lower 25(OH)D group and 17.0% in the higher group ($p = 0.02$) and also 25.8% in the insufficiency group and 17.0% in the normal group ($p = 0.001$), respectively]. The average numbers of falls were also significantly different between the lower and higher groups ($p = 0.021$) and between the insufficient and normal groups ($p = 0.006$), respectively. This finding that lower serum 25(OH)D level or 25(OH)D insufficiency status is associated with falls among elderly women is consistent with many previous studies.[3,4,11] However, there is a controversy about which type of vitamin D [i.e., 25(OH)D or $1,25(OH)_2D_3$] is associated with fall risk. Faulkner et al.,[48] who examined the relationship of vitamin D supplementation and the serum concentration of vitamin D metabolites

with falls in older white, community-dwelling women (n = 389) in the Unites States, reported that only the higher serum $1,25(OH)_2D_3$ concentration was associated with a lower fall risk but that 25(OH)D concentration was not associated with falls. In our study, as one of the study limitations, serum $1,25(OH)_2D_3$ was not assessed in the participants undergoing the mass health examination.

Further analysis on the association of serum albumin and 25(OH)D levels with the fall-associated variables in this study showed that only serum 25(OH)D level had a significant association with all three fall-associated variables in both sexes. On the other hand, serum albumin had a significant association only with handgrip strength in both sexes. The mechanism connecting serum albumin and muscle mass or power is not clear.[49,50] However, serum albumin concentration may be a marker of the protein status of an individual, with lower values indicating a diminished protein reserve and stimulated catabolic processes leading to muscle break down and also muscle strength decline.[50] Thus, low serum albumin, even within a normal range, is independently associated with weaker muscle strength and future decline in older men and women.[51,52]

Serum 25(OH)D concentration is an important determinant of muscle mass and sarcopenia. In an observational study of community-dwelling elderly in the Netherlands, incident sarcopenia, defined as a minimum of 40% decline in muscle strength and 3% decline in muscle mass, was found to be twice as likely among 25(OH)D-deficient elderly [25(OH)D level < 10 ng/ml] than among elderly with a 25(OH)D level of >20 ng/ml.[7] With respect to the role of vitamin D in muscle strength, the majority of the actions of vitamin D are mediated through $1,25(OH)_2D_3$ binding to nuclear vitamin D receptor (VDR) that can directly modulate the transcription of the gene possessing a functional binding site for VDR in its regulatory region.[8,53] Therefore, muscle strength seems to be influenced by the VDR genotype in the muscle cell. With the use of specific restriction endonucleases, several VDR polymorphisms have been determined. In nonobese, older women, a 23% difference in quadriceps strength and a 7% difference in grip strength between two homozygote types of a restriction site have been found.[54] The action of vitamin D is affected by allelic variance of the VDR. A genomic study on VDR polymorphism has shown that Japanese women had much lower frequency of homozygote BB (1.4%) than white women (16.7%).[55] In this context, if the VDR polymorphism affects not only the BMD but also muscle strength of elderly women, Japanese women in general may have an advantage with respect to their lower frequency of falls and associated hip fractures.

As for the association of serum 25(OH)D level and fall experience over the previous year by multiple logistic regression models, even after the adjustment of other fall-associated variables, serum 25(OH)D level was independently associated with falls in women as well as normal walking speed in this study. A considerable number of population-based studies have also been conducted on walking ability in relation to the occurrence of falls in the elderly.[56–60] Increased body sway, uneven distances, and uneven timing during walking were identified as risk factors for falls.[61,62] The authors have previously reported that both fall experience over the previous year and a decline in walking speed were very strong predicators of the occurrence of frequent falls in a 5-yr follow-up cohort study among Japanese community-living elderly.[18] Muscle function or strength as the single most important component for walking ability has been consistently identified as a risk factor for hip fractures as a consequence of falls in the elderly. Subclinical 25(OH)D insufficiency is also considered to be an important risk factor for hip fractures in elderly people in both white[63,64] and Japanese[45] populations. We have suggested that elderly women with lower 25(OH)D levels and with a significant decline in their fall-associated variables tend to decline in walking capability and be more vulnerable to falls even in elderly populations of Japanese women, whose fall rate has been reported to be low.

A relevant issue regarding the role of 25(OH)D in physical performance is that vitamin D supplementation has been reported to be significantly effective in maintaining or improving physical performance and preventing falls among the elderly. In a recent randomized and multiple-dose study, Broe et al.[65] reported that a high dose of vitamin D (800 IU/d) reduced the risk of falls dramatically by 72% lower (adjusted-incidence rate ratio) than participants taking a placebo over the same 5-mo period in a nursing home. However, the question of which type of vitamin D supplementation (i.e., either cholecalciferol or calciferol) is more effective at reducing falls among community-living elderly is still controversial. The association of vitamin D supplementation with better physical performance related to the risk of falls and/or reduced falls is unclear at present. For example, a meta-analysis of five randomized controlled trials provided some evidence that vitamin D supplementation might reduce falls,[10] whereas the results of a second meta-analysis of four randomized controlled trials of vitamin D found no such evidence.[66]

Our findings suggesting that there are significant relationships between serum 25(OH)D and fall-associated physical performance and with falls themselves could provide guidance about how to prevent falls and fractures, particularly hip fractures resulting from falls among community-living elderly. Two such countermeasures are to improve muscle strength, especially in the lower extremities, and to enhance balance ability.[67,68] For example, from a randomized controlled exercise intervention trial for Japanese community-dwelling elderly, we have proven that a moderate exercise intervention program in addition to a home-based program significantly improved fall-associated variables and, consequently, decreased the incidence of falls for 1.5 yr after the intervention.[67]

Another countermeasure would be to maintain a high level of serum 25(OH)D by adequate intake of foods containing vitamin D, supplementation, and exposure to sunlight. Incidentally, fish consumption seems to play an important role in maintaining adequate vitamin D nutrition among elderly Japanese.[69] In general, these countermeasures seem to be consistent with the traditional Japanese lifestyle. Our earlier study using risk factor analysis of hip fractures in elderly Japanese showed that such a traditional

Japanese lifestyle, including living on Japanese tatami mats and eating fish daily, was strongly associated with a decrease in the risk of hip fractures.[14] Living on Japanese tatami mats, including futon-style bedding, seems have great benefits for preventing falls and hip fractures by continuously strengthening the muscles of the hip girdle and lower extremities by sitting, squatting, and frequent standing over the course of many years. Furthermore, consumption of dark-meat fish, which is rich in vitamin D, also seems to be beneficial for maintaining adequate 25(OH)D levels in the elderly, especially in the winter season.[69]

Before detailing our final conclusions, some limitations of our study must be considered. (1) The subjects analyzed were not selected randomly from the study population; as well, they were relatively healthy elderly persons who were able to travel from their homes to the health checkup venue. As a result, elderly persons with lower physical functional capacity were excluded. (2) Plasma $1,25(OH)_2D_3$, albumin-corrected calcium, and PTH, which would provide information on the extent of any primary vitamin D deficiency,[8,48,70] and creatine clearance that may affect the metabolism of vitamin D through the kidney,[71] were not assessed in this study. It is well known that increased secretion of PTH is associated with decreased serum 25(OH)D levels, which may commonly occur in the elderly. However, according to a survey on the nutritional status of vitamin D among Japanese community-dwelling elderly, Nakamura et al.[72] reported that only 1.8% of the subjects had elevated intact PTH levels. (3) We did not analyze the genotype of the VDR that could influence muscle strength and, likely, the fall rate as well. (4) This study was cross-sectional and therefore did not provide cause/effect relationships, although we showed a significant correlation between physical performance and serum 25(OH)D levels in Japanese community-dwelling elderly. Therefore, a longitudinal follow-up study and controlled clinical trials would seem necessary to confirm the role of serum 25(OH)D in falls and its association with the physical performance of the elderly.

In conclusion, our findings showed that a lower serum 25(OH)D level was significantly associated with fall experience over the previous year and with fall-associated variables in Japanese women whose fall rate has been reported to be about one half that of white women. This indicates that serum 25(OH)D level has a common and positive relationship with the occurrence of falls in elderly women, and probably beyond any genetic background represented by VDR phenotype differences and anthropometric and nutritional differences.

Muscle weakness or sarcopenia, frailty, and falls, all of which can be frequent among the elderly and therefore are often categorized as geriatric syndrome, have a major impact on the elderly in terms of both morbidity and mortality. The connections between these items related to geriatric syndrome and 25(OH)D has been well established by many population-based epidemiological studies including this one. Such geriatric syndromes could be prevented by both exercise interventions and adequate levels of serum 25(OH)D; these would help maintain good physical performance and functional capacity for a high quality of life among community-dwelling elderly.

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Square-Stepping Exercise and Fall Risk Factors in Older Adults: A Single-Blind, Randomized Controlled Trial

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Background. Decreased fitness of the lower extremities is a potentially modifiable fall risk factor. This study aimed to compare two exercise programs—square-stepping exercise (SSE), which is a low-cost indoor program, and walking—for improving the fitness of the lower extremities.

Methods. We randomly allocated 68 community-dwelling older adults (age 65–74 years) to either the SSE or walking group (W group). During the 12-week regimen, the SSE group participated in 70-minute exercise sessions conducted twice a week at a local health center, and the W group participated in outdoor supervised walking sessions conducted weekly. The W group was instructed to increase the number of daily steps. Prior to and after the program, we obtained information on 11 physical performance tests for known fall risk factors and 3 self-reported scales. The fall incidence was followed-up for 8 months.

Results. At 12 weeks postregimen, significant differences were observed between the two exercise groups with respect to leg power (1 item), balance (2 items), agility (2 items), reaction time (2 items), and a self-reported scale (1 item); the SSE group demonstrated a marked improvement in the above-mentioned items with Group × Time interactions. Significant time effects were observed in the tests involving chair stands, functional reach, and standing up from a lying-down position without Group × Time interactions. During the follow-up period, the fall rates per person-year in the SSE and W groups were 23.4% and 33.3%, respectively ($p = .31$).

Conclusion. Although further studies are required, SSE is apparently more effective than walking in reducing fall risk factors, and it appears that it may be recommended as a health promotion exercise in older adults.

Key Words: Functional fitness—Walking—Fall risk—Health status.

WALKING is a widely accepted exercise (1) and is used as a means to develop functional fitness in population-based fall prevention programs (2). However, older adults may experience difficulty in walking in unfavorable weather conditions such as rain, wind, cold, or heat waves. Furthermore, the fear of injury, disease, accident, and crime may prevent them from walking outdoors (3,4).

Considering that older adults face these situations in daily life, we have attempted to develop a square-stepping exercise (SSE) that they can easily perform indoors, composed of movements similar to walking (Figure 1) (5). Walking involves only forward-stepping movements, whereas SSE involves varied movements in multiple directions and is performed on a thin mat (100 × 250 cm) that is partitioned into 40 squares (25 cm each). As suggested in previous studies, corrective steps in certain directions are necessary for recovering balance after tripping in order to prevent a fall (6–8). Therefore, it appears logical to hypothesize that the functional ability of the lower extremities is improved to a greater extent with SSE than with regular walking; thus, SSE is more effective in preventing falls. This study aimed to compare the effects of SSE and regular walking on the fall risk factors in older adults.

Methods

The Institutional Review Board of the Kawage Health Center approved the research protocol. All persons provided written informed consent prior to enrollment in the study. The study complied with the CONSORT (Consolidated Standards of Reporting Trials) checklist for randomized controlled trials.

Participants

Persons aged 65–74 years ($n = 2164$) were recruited from Kawage, Mie, Japan. A letter containing information regarding the schedule of the exercise sessions was sent to 700 noninstitutionalized persons (350 women and 350 men) who were randomly selected community residents from the town of Kawage. After consenting to participate, each person was randomly allocated to either the SSE or walking group (W group) by a public health nurse who used a computerized random number generation program in which the numbers 0 and 1 corresponded to the two groups, respectively. The walking and SSE sessions were conducted on different days. The presence of severe neurological or cardiovascular diseases or mobility-limiting orthopedic conditions was considered as an exclusion criterion.

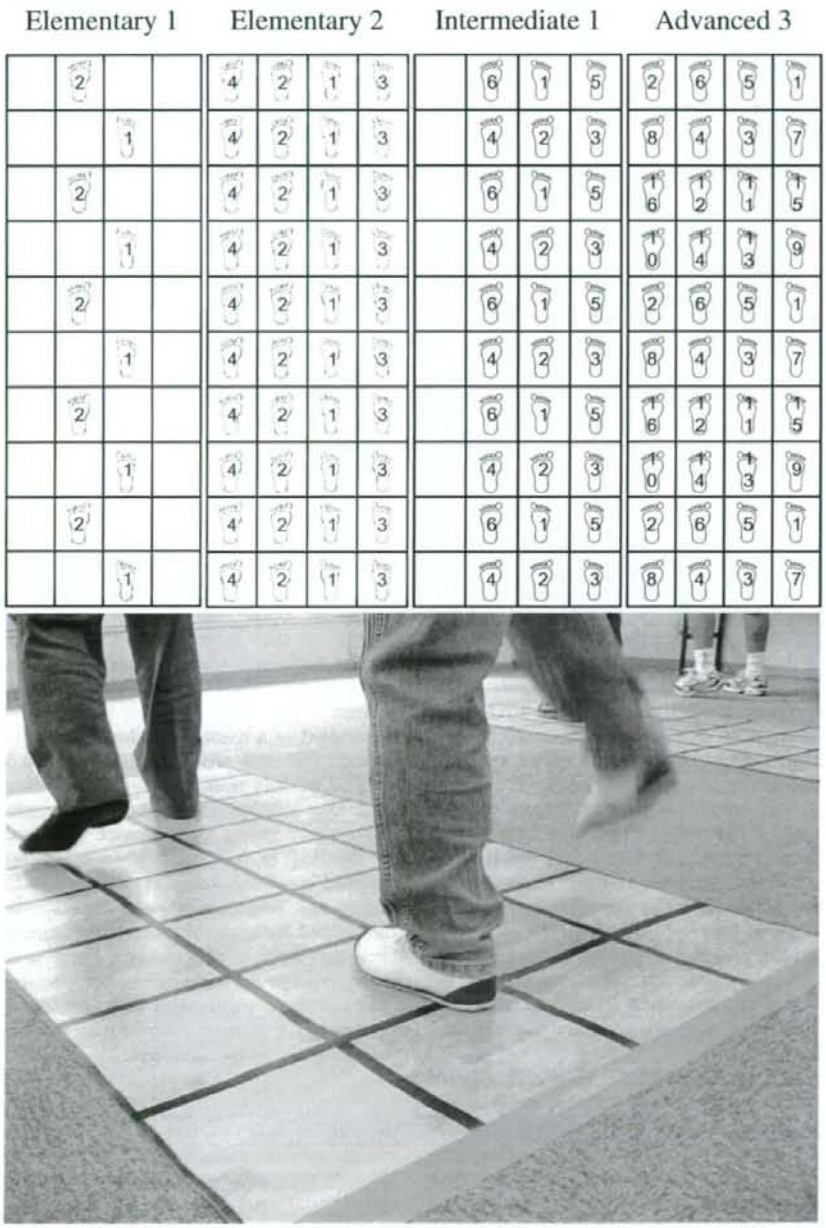

Figure 1. *Top:* Examples of the square-stepping exercise patterns in Elementary 1 and 2, Intermediate 1, and Advanced 3 categories. *Bottom:* Square-stepping exercise.

Outcome Measures

At baseline, the persons completed a questionnaire on vision (5-point Likert scale: 1 = poor and 5 = excellent, higher scores indicate better vision) (9,10); common medical conditions (from among 21 possible common medical conditions such as cerebrovascular disease, hypertension, and heart disease); medication use (yes or no); exercise frequency (4-point Likert scale: 1 = not at all, 2 = once or twice a month, 3 = once a week, and 4 = two or more times a week); and occurrence of falls in the previous year (yes or no). In addition, body weight and height were measured. Body fat was estimated by bioimpedancemetry (HBF-354; Omron Healthcare Co., Ltd., Kyoto, Japan).

The physical performance tests for the fall risk factors

were adopted from previous studies and included the following items: number of chair stands in 30 seconds (11), leg extension power (12), single-leg balance with eyes closed (5), functional reach (13), forward/backward tandem walking over a 20-foot distance (14), standing up from a lying-down position (5), stepping with both feet in 10 seconds [persons stepped as quickly as possible for 10 seconds by using a 60 × 55 cm stepping sheet (TKK 5301; Takei Scientific Instruments Co. Ltd., Niigata, Japan)], walking around two cones (5), vertical jump reaction time after a light signal (simple reaction time) (15), and weight transfer time recorded while stepping in the forward/backward/right/left direction after a light signal (choice reaction time) (16). These tests were conducted by individuals who were unaware of the study group assignment (such as public health nurses other than those involved in the randomization, exercise instructors other than those who served in the regimens, and university students who had specialized in exercise gerontology). Each test was measured by the same staff preregimen and postregimen.

Self-reported scales consisted of the fear of falling (17), perceived health status (18), and pleasure during exercise (using a line scale: left end = not pleasant "0" and right end = very pleasant "100"; higher scores indicate considerable pleasure).

The occurrence of falls and trips was also measured during the 8-month follow-up period at the end of the program. A fall was defined as a sudden unintentional change in position that caused an individual to land at a lower level, that is, on an object, the floor, or the ground, due to reasons other than sudden-onset paralysis, epileptic seizures, or overwhelming external forces (19). A trip was defined as the act of stumbling over an object without landing on any part of the body. Trips may cause false-positive results because some individuals may report a trip as a fall (20); therefore, the persons were explained the difference between a fall and a trip and were instructed to record the occurrence of falls and trips separately on a daily basis. All the persons received a prepaid postcard at the beginning of each month, which they returned at the beginning of the subsequent month. A telephonic or face-to-face interview was conducted to ascertain the reported occurrence of falls and trips.

Pedometers (Walking Style HJ-710IT; Omron Healthcare Co.) were provided to the persons of each group one week prior to the study. During the first week, as a pre-regimen, the persons were instructed to continue their routine daily activities and were advised against performing any new exercises. During the period between preregimen and postregimen, they were instructed to wear the pedometers at all times when awake except when bathing. The recorded number of steps also included those completed during all the exercise sessions.

Exercise Regimen

The SSE group participated in the supervised group sessions twice a week over the 12-week period at the Kawage Health Center; each session comprised 15 minutes of warm-up activities such as stretching and calisthenics, 40 minutes of SSE, and 15 minutes of cool-down activities. A detailed description of the SSE method has been provided in another study (5). In brief, SSE was performed on a thin felt mat (100 × 250 cm) that was partitioned into 40 squares (25 cm each). The persons were instructed to walk (step) from one end of the mat to the other according to the step pattern provided (Figure 1). When the persons reached the end of the mat, they were instructed to return to their start positions by walking normally off the mat and then stand in line for the next stepping. The SSE included forward, backward, lateral, and oblique step patterns. After the persons became familiar with each of these step patterns, they were instructed to walk with their heels lifted, that is, on their toes, without treading on the frames of the squares. Each step pattern was repeated 4–10 times to ensure that the persons could complete the pattern, and was followed by the introduction of a more complex step pattern. In total, 196 step patterns were developed and categorized (based on progressively increasing levels of complexity) into 8 categories (Elementary, 1–2; Intermediate, 1–3; and Advanced, 1–3). The persons were encouraged to concentrate in order to successfully perform each progressively more complicated step pattern. Step cadence was not determined; therefore, the persons performed the pattern at their preferred pace. Although they required 15–20 seconds to complete each step pattern initially, they eventually completed each pattern in < 15 seconds.

The persons in the W group were instructed to attend an outdoor supervised walking session at the Kawage Health Center once a week for 12 weeks. These sessions were structured in a manner similar to that of the SSE sessions except that SSE was substituted with a long-distance 40-minute outdoor walking session. Furthermore, the W group was also instructed to increase the number of daily steps, particularly during long-distance walking.

The SSE ($n = 32$) and W ($n = 36$) groups were further divided into 2 subgroups ($n = 16$ and 18 for the SSE and W subgroups, respectively), and the respective sessions were conducted for each subgroup from December 2004 through February 2005 (winter season). These sessions were always supervised by the same instructors who were certified in first aid and were encouraged to report any negative signs or symptoms that they observed in the persons during the sessions due to the exercises.

Statistical Analysis

An outcome analysis was performed using the intention-to-treat principle, and only two-tailed tests of significance were used. All baseline characteristics were compared between the groups by using the Student t test except for sex, vision, medications (proportion of medicated persons), exercise frequency, and falls in the last year because these characteristics were assessed using the chi-square test. Analysis of covariance (ANCOVA) was used to determine the effect of the exercise program on each of the outcome measures by using the baseline characteristics as covariates. For both groups, the proportional hazards models were used to determine the relative hazards associated with the first fall, and these relative hazards were calculated using the Cox model. SPSS 11.5 software (SPSS Inc., Chicago, IL)