第4節　高齢者におけるサルコペニアの発見と対処法の構築

Summary

- サルコペニアは，disability or mortality，転倒・骨折の予知因子である．
- 筋肉量を評価する精度の高い手法は，CT 法，MRI 法，DXA 法であるが，疫学調査の手法としては不向きである．大規模集団を扱う疫学研究では，形態測定値，BIA 法の採用も推奨される．
- サルコペニアと関連する要因は様々で複雑であるが，不活動や栄養など，可変要因の改善に焦点を当てた対処法の構築が有効である．
- サルコペニア高齢者の一つの特徴は，骨粗鬆症に伴う骨折危険性の高いことが挙げられる．
- サルコペニア高齢者における骨格筋の増加，体力の向上には，運動指導，栄養指導ともに有効であるとの知見を得た．

はじめに

中年期を過ぎると人間諸組織の機能が変化し，環境変化への適応能力の低下ないし機能喪失が徐々に増してくる．その背景要因に，身体の構成要素である体脂肪や除脂肪組織量（lean body mass：LBM）の変化が挙げられる（図1）[1]．中でも，加齢に伴って徐々に進行する骨格筋量の減少や筋力の衰えを意味する“sarcopenia”は[2]，disability or mortality，転倒・骨折の predictor であることが多くの疫学調査で指摘され[3,4]，その対処法をいかに立てるかは，介護予防，健康寿命の延長のために重要な課題である．

しかし，地域在住高齢者の中から，サルコペニア高齢者を発見し，適する対処法を立てることは容易な作業ではない．それは，サルコペニアの定義，骨格筋量の推定，採用する選定基準が研究者によって異なり，ゴールドスタンダードが確立されてないからである．

1．地域高齢者におけるサルコペニアの発見

サルコペニアは「骨格筋量の減少」を意味する概念であるが，サルコペニア高齢者を発見するためには，骨格筋量の正確な推定が必要である．筋肉量を評価する精度の高い手法は，computed tomography（CT）法，magnetic resonance imaging（MRI）法，dual energy X-ray absorpti-

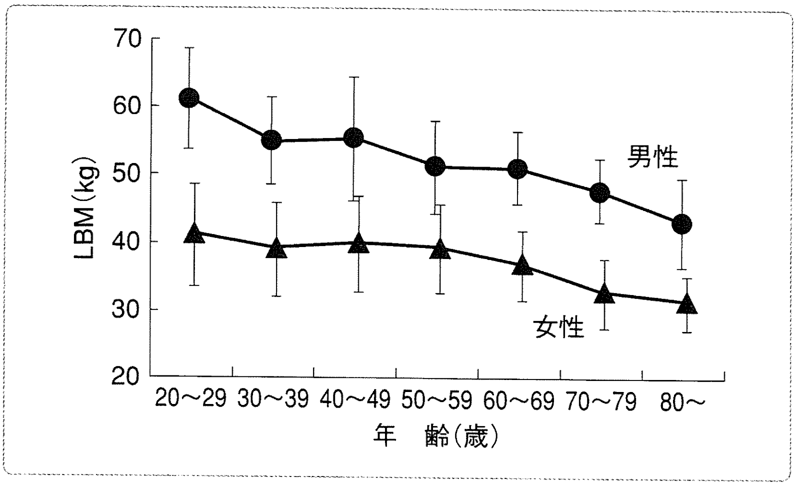

図1　DEXA 法による LBM の年代別の比較（文献1より引用）

ometry（DXA）法などが挙げられる．しかし，これらの測定には，高価な実験室装置や設備が要求され，計測に専門的な知識や資格が必要であり，大規模集団を扱う疫学調査の手法としては不向きである．骨格筋量を推定するための多様な手法が検討されているが，疫学研究に適用し得る代表的な方法を簡略に紹介する．

1）形態測定値による推定

形態測定値による筋肉量の評価については，1921 年の Matiegka[5]の試み以来，いくつかの研究が報告されている．1990 年，Martin ら[6]は，50〜94 歳の男性死体の筋肉量を妥当基準に設定し，筋肉量と四肢の周囲（前腕囲 $r=0.96$，大腿囲 $r=0.94$，下腿三頭囲 $r=0.84$，腕囲 $r=0.82$）との高い相関関係を示し，四肢の皮下脂肪厚値で補正すれば，精度が上昇することに着目し，男性の骨格筋量（total skeletal muscle mass：MM）を推定する次の式を提案している．

$$\mathrm{MM}=\mathrm{STAT}(0.0553\ \mathrm{CTG}^2+0.0987\ \mathrm{FG}^2+0.0331\ \mathrm{CCG}^2)-2445$$
$$[\mathrm{SEE}=1.53\ \mathrm{kg},\ R^2=0.97] \cdots\cdots\cdots(1)$$

MM＝骨格筋量(g)，STAT＝身長(cm)，CTG＝大腿前部皮下脂肪厚で補正した大腿囲(cm)，FG＝補正なしの前腕囲(cm)，CCG＝下腿三頭皮下脂肪厚で補正した下腿三頭筋囲(cm)．

Lee ら[7]は，20〜81 歳の男性 135 名，女性 109 名を対象に，MRI より求めた骨格筋量(skeletal muscle mass：SM，妥当基準）を形態側値より推定する皮下脂肪厚－周径囲（モデル 1），体重－身長（モデル 2）を開発し，提案している．

モデル1：

$$\mathrm{SM(kg)}=\mathrm{Ht}\times(0.00744\times \mathrm{CAG2}+0.00088\times \mathrm{CTG}^2+0.00441\times \mathrm{CCG}^2)+2.4\times 性-0.048\times 年齢+人種+7.8$$
$$[R^2=0.91,\ \mathrm{SEE}=2.2\ \mathrm{kg}] \cdots\cdots(2\text{-}1)$$

（性：男性＝1，女性＝0）（人種：アジア人＝－2.0，アフリカ系米国人＝1.1，白人・ヒスパニック人＝0）

モデル2

$$\mathrm{SM(kg)}=0.244\times 体重+7.80\times 身長\ 6.6\times 性-0.098\times 年齢+人種-3.3$$
$$[R^2=0.86,\ \mathrm{SEE}=2.8\ \mathrm{kg}] \cdots\cdots(2\text{-}2)$$

（性：男性＝1，女性＝0）（人種：アジア人＝－1.2，アフリカアメリカ人＝1.4，白人・ヒスパニック人＝0）

これらは，全身の骨格筋量を推定する式であり，推定式より求めた筋肉量に基づいたサルコ

表1　性・年齢・人種別にみたサルコペニアの有症率（文献4より引用）

年齢群（歳）	男性		女性	
	ヒスパニック (n=221)	白人 (n=205)	ヒスパニック (n=209)	白人 (n=173)
＜70	16.9	13.5	24.1	23.1
70〜74	18.3	19.8	35.1	33.3
75〜80	36.4	26.7	35.3	35.9
80＜	57.6	52.6	60.0	43.2

ペニア判定の試みはなかった．しかし，Baumgartner ら[4)]は，1993〜1995 年に地域在住高齢男女 808 名（男性 426 名，女性 382 名）の DXA 法より求めた四肢の骨格筋量（appendicular skeletal muscle mass：ASM）を，次の式より推定し，「ASM（kg）/身長^2（m^2）」の値が，18〜40 歳の健康成人の平均値の 2 SD 以下をサルコペニアと定義している．

ASM(kg)＝0.248(体重)＋0.0483(身長)－0.1584(臀部囲)＋0.0732(握力)＋2.5843(性)＋5.8828
[R^2＝0.91，SEE＝1.58 kg]………(3)

この式より求めたサルコペニアのカットオフ値は，男性 7.26 kg/m^2，女性 5.45 kg/m^2と設定し，有症率を調べたところ（**表1**），70 歳以下の高齢者で 13.5〜24.1％の範囲であるが，80 歳以上になると 43.2〜60.0％に高まるとともに disability と密接に関連することを報告している．

Tanko ら[8)]は，18〜85 歳の女性 754 名を対象とした研究において，DXA 法より求めた 18〜39 歳の健康な女性 216 名の ASM（kg）/Ht^2（m^2）を基準値（6.8±0.7 kg）に用いている．この基準値の 2 SD 以下をサルコペニアと定義した時のカットオフ値は，ASM＝5.4 kg/m^2であり，ASM を推定する式を提案している．

ASM＝－13.3－0.005(年齢, 歳)＋0.11(体重, kg)＋16.1(身長，m)
[SEE＝1.7 kg，R^2＝0.76]…………(4)

この式に基づく有症率は，40〜49 歳で 3.3％，50〜59 歳で 3.8％と低いものの，60〜69 歳で 9.4％，70 歳以上で 12.3％と上昇することを報告している[6)]．

2）生体電気インピーダンス法（bioelectrical impedance analysis：BIA）による推定

ヒトの身体組成を，安全かつ迅速に測定できる BIA 法については，多くの研究者によってその妥当性が検証されていることから，多人数を対象にする疫学研究で汎用されている手法である．BIA 法をサルコペニア判定に適用するために，Janssen ら[9)]は，18〜86 歳の男女 388 名を対象に，MRI 法により求めた骨格筋量（SM）を妥当基準として，BIA 法に基づく骨格筋量の推定式を提案している．

SM mass(kg)＝（身長^2/R×0.401）＋(性×3.825)＋(年齢×－0.071)＋5.102
[R^2＝0.86，SE＝2.7 kg（9%）]………(5)

身長＝cm, R＝BIA レジスタンス（ohms），性（男性＝1，女性＝0），年齢＝歳．

さらに，この式より求めた SM と生活機能障害との関連性を検討しており，障害発生のハイリスクカットオフ値は，男性 8.50 kg/m^2以下（オッズ比 4.71），女性 5.75 kg/m^2以下（オッズ比 3.31）と提案している[10)]．

一方，Chien ら[11)]は，Janssen らの式を台湾在住の高齢者に適応して，18〜40 歳の基準値は，

表２　サルコペニア選定に用いた骨格筋量のカットオフ値

研究者	基準	男性	女性
Baumgartner, et al（1998）[4]	ASM/Ht^2，若年値の２SD 以下	7.26	5.45
Tanko, et al（2002）[8]	ASM/Ht^2，若年値の２SD 以下	*	5.40
Chien, et al（2008）[11]	SMI，若年値の２SD 以下	8.87	6.42
Janssen, et al（2000）[9]	SMI	8.50	5.75

ASM（kg）：appendicular skeletal muscle mass estimated by DXA，SM（kg）：skeletal muscle mass estimated by BIA，
SMI：SM/Ht^2，Ht：height

男性 10.87±1.00 kg/m^2，女性 7.88±0.73 kg/m^2 であることを示した．この基準値の２SD 以下をサルコペニアと定義し，男性 8.87 kg/m^2，女性 6.42 kg/m^{2}をカットオフ値と設定している．この基準によるサルコペニア有症率は，65 歳以上の男性 23.6%，女性 18.6%と報告している．

以上で紹介した地域高齢者の骨格筋量を推定する間接法は，周囲，皮下脂肪厚，身長，握力，BIA 法による抵抗値など簡単な測定値を利用すれば，骨格筋量の推定が可能な式である．

しかし，これらの式の採用に当たっては，杖使用者，車椅子使用者，変形性膝関節炎患者，あるいは脊柱弯曲を有する虚弱高齢者の形態を正確に測定できているかの問題がある．さらに，サルコペニアを判定するためのカットオフ値は研究者によって異なり，採用する定義によって有症率が異なる点を十分考慮すべきである（表2）．すなわち，地域高齢者におけるサルコペニア発見は容易なことではないという認識が必要である．

2．介入の組み立て方

サルコペニア対処法を構築するためには，サルコペニアの問題点，危険因子，サルコペニア高齢者の特性，取り組みの効果の把握が必要である．

1）サルコペニアの問題点と関連要因

サルコペニアには，性，年齢，身長，体重，BMI，膝の高さ，テストステロン，脂肪量，身体活動，ビタミン D など様々な要因が複雑に関わっていることが多くの研究で指摘されている[12]．サルコペニア予防策を構築するためには，多くの危険因子の中で，可変因子の改善を目的とした取り組みが有効である．Fiatarone ら[13]は，骨格筋の不使用と低栄養の改善に焦点を当てた介入が有効であると提案している．なぜならば，不活動が生理機能に及ぼす影響についてはベッドレスト実験でよく知られており，6〜7週間ベッドで安静をとらせると，筋中に多く含まれている窒素，カリウムの排泄量が増加し，筋の成分が臥床中に失われること，また，臥床中は特に下肢の筋力低下が著しく起こり，足関節背屈力は 13.3%，足関節低屈力は 20.8%低下するとともに，大腿囲および下腿囲が減少することを検証している[14]．反対に，虚弱高齢者でも筋力強化運動を実践すれば，筋力や歩行機能の改善効果が得られると報告している[15]．

一方，骨格筋量減少と栄養との関連性についても様々な角度から分析され，特に骨格筋蛋白質の分解量が合成量を上回ることによって，徐々に骨格筋量が減少するのである．したがって，骨格筋蛋白質の合成を促進するか，分解を抑制することにより，合成量が分解量を上回る

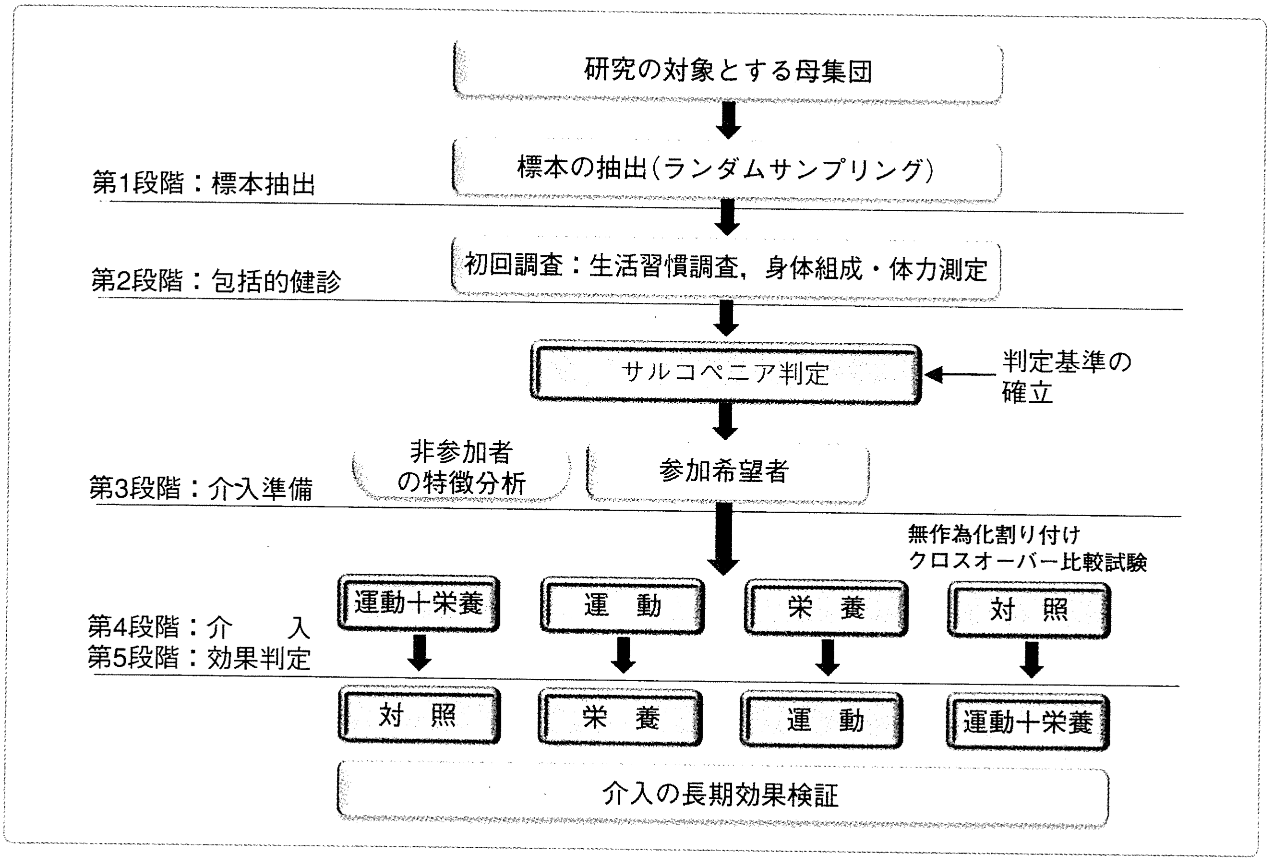

図２　大規模集団を用いた対処の構築手順

状態にできれば，筋量の減少を食い止める有効な対策となる．これらの背景に基づき，アミノ酸投与が骨格筋蛋白質代謝に与える影響について多く検討されている[16]．

2）対処の構築方法

対処が必要となった集団や個人に対し，介入実施の第一歩は，まず倫理委員会の承諾を得た上で，対象となり得る条件を持っている人に対し，対処の趣旨，目的，方法などの概略を説明し，対処への協力を依頼し，参加承諾を得ることである．

地域在住サルコペニア高齢者に対する対処法を確立するためには，概ね５段階の手続きが要求される．対処の標準的な手順を図２に示す．

①第１段階：無作為標本抽出

ⅰ）地域在住高齢者におけるサルコペニア有症率を検討するためには，悉皆調査がベストである．しかし，悉皆調査が不可能な大規模集団については，住民基本台帳などに基づく標本代表性を維持するため，性・年齢層化無作為標本抽出を推奨する．

ⅱ）抽出された標本に対して，調査研究への協力を要請する．参加承諾を得るためには，調査の趣旨，目的，方法などを詳細に説明し，参加意欲を高める．

②第２段階：初回調査準備および実施

ⅰ）初回調査参加者を確定する．

ⅱ）調査日数，スタッフ確保および事前訓練，調査項目，調査場所を確定する．

ⅲ）調査実施，緊急発生時の対応マニュアルなどを用意する．

ⅳ）調査結果の使用についての同意を得る．

③第３段階：介入準備

ⅰ）サルコペニア選定基準に基づき，サルコ

表3　サルコペニア群と正常群の調査項目の比較（文献17より引用）

項　目	サルコペニア群	正常群	p 値
年　齢（歳）	79.49±2.93	78.51±2.77	＜0.001
下腿三頭筋周囲（cm）	30.17±2.03	33.92±2.60	＜0.001
BMI（kg/m^2）	18.98±2.01	23.74±2.84	＜0.001
筋肉量（kg）	26.92±2.61	31.73±3.16	＜0.001
健康度自己評価，健康（%）	75.7	85.8	＜0.001
外出頻度，少ない（%）	4.6	2.5	0.051
運動習慣，有（%）	27.3	33.5	0.039
既往歴：有（%）			
高血圧	51.0	58.0	0.029
高脂血症	32.2	40.5	0.009
貧血症	4.6	2.2	0.022
骨粗鬆症	38.2	30.7	0.014
骨　折	28.6	22.9	0.038

ペニア高齢者を選定する．

ii）介入期間，頻度，時間，プログラムの内容を確定し，介入参加者を募集する．

iii）介入参加希望者を対象に説明会を開催し，プログラムの内容を具体的に説明する．介入最終参加者を決め，介入参加への同意を得る．

iv）無作為割付けにより群分けをする．群配置による不利益が生じないようにcrossoverモデルを採用する．不参加者の特性把握および不参加者に対する支援策を考える．

v）outcome measureを決める．

④第4段階：介　入

i）導　入：柔軟体操を中心とした軽い運動の指導によって，運動に慣れ，身体を動かす楽しさを感じ，運動に対する動機づけを高めることができる．個々人の特徴を把握し，無理のない範囲で指導する．

ii）展　開：筋力強化運動，各種器具（バンド，ダンベル，アンクルウエイト，ボール）を活用する指導を行い，運動幅を拡げる．

iii）定　着：運動の効果を意識し，習慣化を図る，目標到達度を自己評価する．

⑤第5段階：効果判定

i）短期効果判定および結果返却：体組成，身体機能，意識，老年症候群の変化について検討し，結果を返却する．

ii）長期効果判定：追跡期間の設定（3カ月，6カ月，1年，2年）および最終アウトカムについて評価する．

3）効果検証

加齢に伴って低下した筋肉量や筋力を回復させるためには，筋力強化運動が有効であることは多くの研究で指摘されている．一方，アミノ酸投与によって，筋蛋白質合成能力が促進される可能性も示唆されている．これらの研究を踏まえて，筆者らは，サルコペニアを単なる骨格筋量の減少という解釈にとどめず，骨格筋量の減少に伴う身体機能の低下，体格までも考慮し

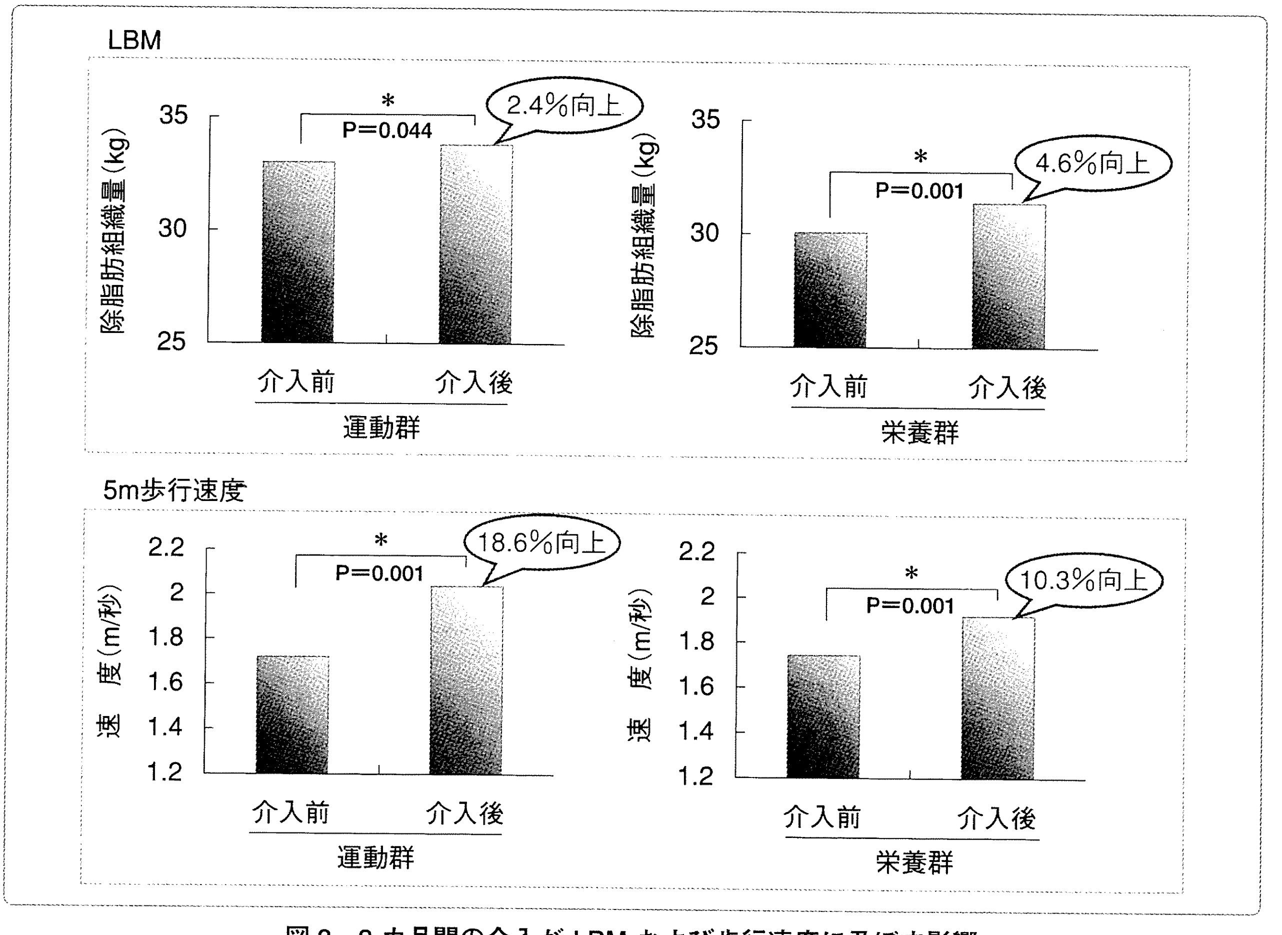

図3　3カ月間の介入が LBM および歩行速度に及ぼす影響

た概念を導入することが妥当であると判断した．この判断に基づき，大都市部在住 75 歳以上の後期高齢女性 1,399 名を対象に包括的健診を実施し，「骨格筋量の減少」，「BMI の低下」，「筋力あるいは歩行機能の低下」3 つの基準に該当する場合をサルコペニアと定義し，該当者 304 名（21.7%）を抽出し，対処法を構築した事例を紹介する．

① サルコペニア高齢者の特徴

サルコペニアと判定された 304 名と，サルコペニアと判定されなかった正常者 1,095 名の調査項目を比較したところ（**表 3**），サルコペニア群は正常群に比べて，年齢が高く，下腿三頭筋周囲，BMI，筋肉量が有意に低値を示し，高年齢の痩せ型で筋肉量が少ない者は，サルコペニアの可能性が高まることが示唆された．聞き取り調査項目においては，健康度自己評価，定期的な運動習慣を持っている者の割合は低く，外出頻度が少ない者の割合は高かった．一方，既往歴においては，貧血症，骨粗鬆症，骨折歴は有意に高い割合を示したが，高血圧症，高脂血症は正常群より低い割合を示している[17]．以上のことから，サルコペニアと判定された高齢者は活動量が少なく，自分の健康に対する自信感を喪失している者が多く，骨粗鬆症に伴う骨折危険性の上昇が示唆された．

② 取組みの実際と効果

サルコペニアと判定された 304 名について，「サルコペニア改善介入参加者」を募集し，参加希望者を RCT により運動群と栄養群に分けた．運動群には週 2 回，1 回当たり 60 分間の筋力強化と歩行機能の改善を目的とした包括的運動を，栄養群はロイシン高配合のアミノ酸 3 g を 1 日 2 回補充する指導を，3 カ月間実施した．介入

前後における身体組成，体力，老年症候群の改善の度合いを検討した．その結果，LBM は運動群で 2.4%，栄養群で 4.6%の有意な向上が観察された（図 3）．歩行速度は，運動群で 18.6%，栄養群で 10.3%の顕著な向上が確認され(図 3)，地域在住サルコペニアの改善には，運動のみならずアミノ酸補充も有効であることが示唆された．しかし，サルコペニア高齢者に多く観察される尿失禁は，運動群で 38.9%から 19.4%（P＝0.021）と有意に改善されたが，栄養群では有意な改善がみられなかった[18]．以上のことから，サルコペニア高齢者の LBM あるいは体力の改善を目的とした場合には，運動指導あるいは栄養補充の両方とも有効な手法であるが，サルコペニア高齢者に有症率の高い老年症候群の改善には，運動介入の効果が優れる可能性が示唆された．

おわりに

骨格筋量の減少に伴う筋力の衰えを意味するサルコペニアは，後期高齢者において有症率が上昇し，身体機能の障害や死亡と強く関連していることが指摘されている．サルコペニアと関連する要因は様々で複雑であるが，不活動や栄養など可変要因の改善に焦点を当てた予防策の効果を検討したところ，骨格筋量の増加，体力の向上には，運動指導，栄養指導ともに有効であった．しかし，サルコペニア高齢者に多くみられる老年症候群の解消には，運動指導がより有効であることが示唆された．

近年，サルコペニア高齢者を対象とした介入成果は報告されつつあるが，十分とはいえず，今後の研究成果に期待を寄せる．

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6

Behavioral Treatment for Geriatric Syndrome

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1. Introduction

Geriatric syndrome is a term used to capture complex clinical conditions such as frailty, falls and fractures, urinary incontinence, malnutrition, and declining mental health, which do not fit into discrete disease categories but are serious problems among the elderly population. They are highly prevalent in the elderly, especially in frail adults with low levels of functional capacity. These geriatric syndromes have a large effect on the development of disability, dependence, decrease in quality of life, morbidity, and mortality. Having multiple underlying factors involving impairments in multiple organ systems contribute to the occurrence of geriatric syndromes (Tinetti et al., 1995). Thus, prevention and treatment of geriatric syndromes such as frailty, falls, and urinary incontinence in its early stages are important strategies in maintaining health and independence among the elderly.

This chapter will focus on frailty, falls, and urinary incontinence, as they are the most common geriatric syndromes among community-dwelling elderly people.

1.1 Shared risk factors for distinct geriatric syndrome

A main feature of geriatric syndrome is that multiple risk factors contribute to their etiology. Research has suggested that vision and hearing impairment, anxiety, as well as upper and lower extremity impairments are associated with incontinence, falling, and occurrence of functional dependence.

The risk of each geriatric syndrome is greater with increasing number of predisposing factors possessed. Furthermore, incontinence and falling are associated with the occurrence of functional dependence. Geriatric syndromes; therefore, may contribute both indirectly, through shared risk factors, and directly to functional dependence in the elderly. One model unifying the concepts of geriatric syndromes has been proposed by Inouye et al., (2007) demonstrating that shared risk factors may lead to one or more geriatric syndromes, and eventually to frailty. Once frail, this may feedback to the development of more risk factors, which in turn may lead to other geriatric syndromes, further frailness, and ultimately disability, dependence, and even death.

Frailty can be defined as a condition in which three or more of the following criteria are present: unintentional weight loss, self-reported exhaustion, weakness, slow walking speed, and low physical activity (Fried et al., 2001). The prevalence of frailty is greater in women than men, and increases which age. Frailty status, or the presence of frailty can predict disability and adverse outcomes, where those who are frail have a significantly higher risk of further debilitation, specifically in mobility, activities of daily living (ADL) and falls, eventually leading to hospitalization and death (Fried et al., 2004) (Table 1).

	Hazard Ratios Estimated Over 3 Years Frail (Versus Not Frail)
Worsening mobility disability	1.50**
Worsening ADL disability	1.98**
Incident Fall	1.29**
First hospitalization	1.29**
Death	2.24**

**p ≤ .05
ADL= activity of daily living

Table 1. Frailty status predicting disability, falls, hospitalizations, and death over 3 years. (Fried, L.P.; Ferrucci, L.; Darer, J.; Williamson, J.D. & Anderson, G. (2004). Untangling the concepts of disability, frailty, and comorbidity: implications for improved targeting and care. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences,* Vol.59, No.3, pp. 255-263, by permission of the Gerontological Society of America.)

Falls are an especially serious problem among the elderly, as approximately 30% of community-dwelling older adults over the age of 65 experience falls every year. Falls are the leading cause of unintentional injury, functional decline, hospitalization, institutionalization, and increased healthcare costs. In order to prevent falls, a thorough understanding of the causes and risk factors for falls among the elderly is required for the development of effective preventative strategies.

Urinary incontinence, particularly in the elderly, is considered to be an important determining factor for admission into long-term care and has been associated with loss of independence, reduced quality of life, restricted social activities, increased anxiety and social isolation.

2. Risk factors

Many studies have demonstrated that geriatric syndromes are multifactorial, and shared risk factors including older age, cognitive impairment, functional impairment, and impaired mobility, are often associated with common geriatric syndromes of frailty, falls, and urinary incontinence. The identification and treatment of the risk factors that contribute to geriatric syndromes have been the focus in recent research.

2.1 Frailty

Frailty is highly prevalent in the elderly. Frailty often overlaps with (though is not synonymous with) comorbidity and disability, and is associated with several major chronic diseases such as cardiovascular disease, pulmonary disease and diabetes. Hence, treatments for frail older adults usually require specific care needs (Fried et al., 2004) (Fig. 1). With the presence of comorbid conditions, there may be competition between the treatments. The combinations of medications and treatment regiments may limit the desired effects of the treatments, or have adverse effects. Comorbidities lead to the over-use and mixing of prescription medication which is a risk factor for falls. Frailty, coupled with low bone mass is associated with increased risk of hip fractures which are a major threat to survival in the elderly. Research has shown that 17.4% of people who suffered hip fracture over the age of 65 died within 12 months of a fracture (Magaziner et al., 1989).

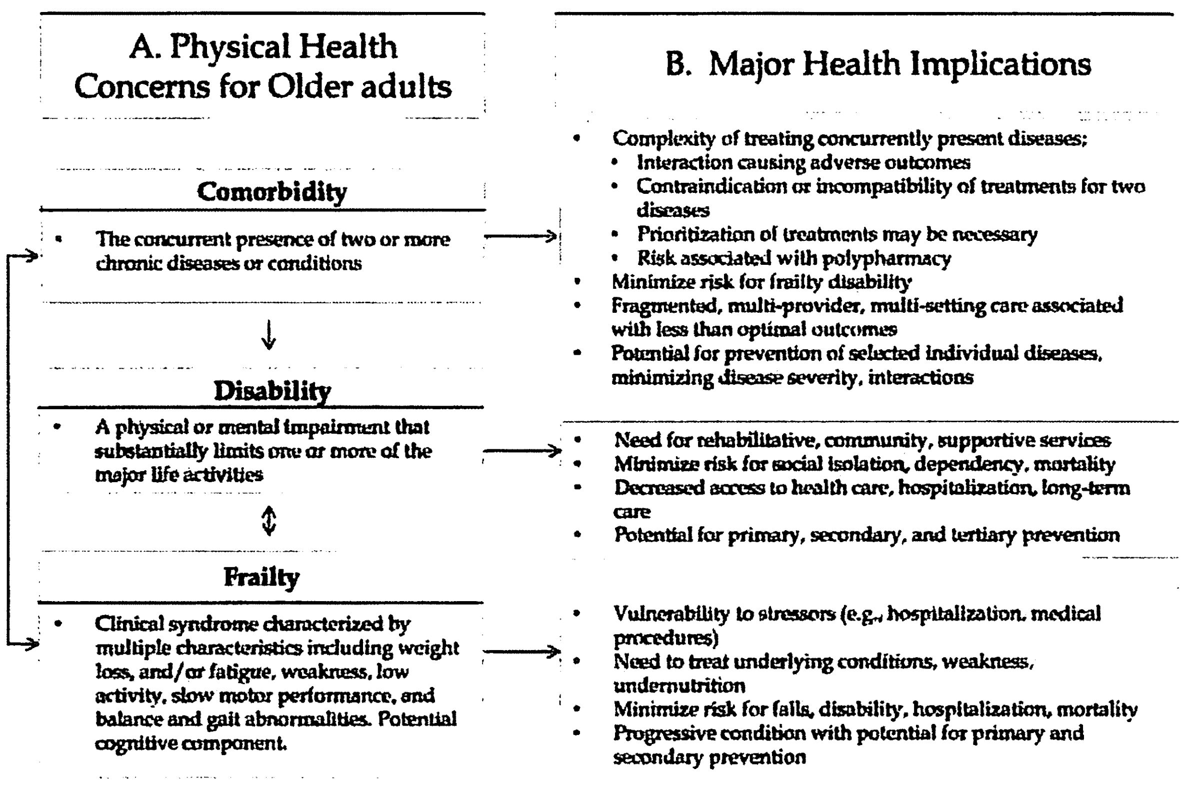


Fig. 1. Comorbidity, disability, and frailty: definitions and major health care implications. (Fried, L.P.; Ferrucci, L.; Darer, J.; Williamson, J.D. & Anderson, G. (2004). Untangling the concepts of disability, frailty, and comorbidity: implications for improved targeting and care. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, Vol.59, No.3, pp. 255-263, by permission of the Gerontological Society of America.)

There are numerous factors that contribute to muscle weakness and loss of muscle mass in aging adults such as chronic disease, a sedentary lifestyle, and under-nutrition, where some factors can be reversed with lifestyle changes, and others need specific medications and cannot be reversed. Xue et al. (2008) hypothesized the cycle of frailty, as many of these factors can theoretically be unified into a cycle associated with decreasing energetics and functional reserve (Fig. 2) The core elements of this cycle, including weight loss, sarcopenia, decrease in strength and walking speed, as well as low activity, are commonly identified as clinical signs and symptoms of frailty.

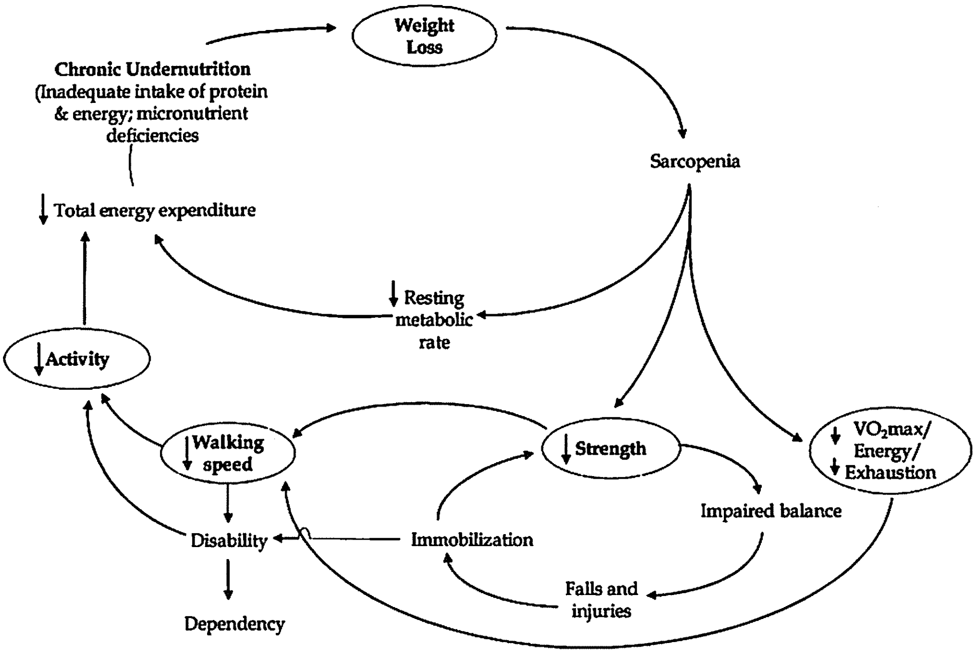


Fig. 2. Cycle of Frailty. (Xue, Q.L.; Bandeen-Roche, K.; Varadhan, R.; Zou, J. & Fried, L.P. (2008). Initial manifestations of frailty criteria and the development of frailty phenotype in the Women's Health and Aging Study II. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, Vol.63, No.9, pp. 984-990, by permission of the Gerontological Society of America.)

2.2 Falls

In the recent decade, several epidemiologic studies have identified risk factors for falls. While the classifications of these risk factors have not always been consistent, they are generally classified as intrinsic, extrinsic, and environmental. Intrinsic risk factors include muscle weakness, gait and balance deficits, functional and cognitive impairments, and visual deficits, extrinsic such as the use of four or more prescription medications and bifocals, and environmental factors, which include poor lighting, loose carpets, and lack of bathroom safety equipment (American Geriatric Society et al., 2001). Low vitamin D levels are also significantly associated with a high prevalence of falls in elderly women, as well as low physical performance (Suzuki et al., 2008) (Table 2).

The most common risk factors for falls are muscle weakness, history of falls, gait deficit, balance deficit, use of assistive device, visual deficit, arthritis, impaired ADL, depression, cognitive impairment, and older age (over 80 years old) (American Geriatric Society et al., 2001). The risk of falling increases linearly with the number of risk factors, from 8.0% with none to 78.0% with four or more risk factors (Tinetti et al., 1988). Furthermore, those who experience falls once have a greater chance of recurrent falls, which may lead to a fear of falling. Some older adults may then begin restricting activities both indoors and outdoors. Not only does this lead to a further lack of physical activity, but research has shown that older persons who restrict activity for fear of falling are more physically frail and have greater burden of chronic conditions and depressive symptoms compared with those who do not restrict activity despite their fear of falls (Murphy et al., 2002).

	Male			Female		
Risk Factor	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 (mg/ml)	1	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).
NS= not significant

Table 2. Multiple logistic regression model of factors associated with fall experience. (Suzuki, T.; Kwon, J.; Kim, H.; Shimada, H.; Yoshida, Y.; Iwasa, H. & Yoshida, H. (2008). Low serum 25-hydroxyvitamin D levels associated with falls among Japanese community-dwelling elderly. *Journal of Bone and Mineral Research*, Vol.23, No.8, pp. 1309-1317, by permission of the American Society for Bone and Mineral Research.)

2.3 Urinary incontinence

There is general agreement on the multifactorial nature of incontinence. Permanent incontinence also is typically the result of neurological damage or, intrinsic bladder or urethral pathology. However, incontinence is associated with several potentially reversible conditions. Lower urinary tract function, environmental factors, physical and cognitive function, psychological distress, mobility, manual dexterity, medical conditions, and medications may all have an effect on urinary incontinence status in the elderly (Landi et al., 2003). The incidence of urinary incontinence is typically higher in women than men, and those who experience incontinence are usually older with lower functional fitness levels for both sexes. Although there is a large amount of information regarding the mechanisms and treatment options for urinary incontinence, little is known about the potentially reversible causes of this condition in community-dwelling elderly people. Several of the known causes that may be reversible include urinary tract infections, as they can cause the urge to void quite frequently, physical restraints and drastic limitations in mobility, and environmental hazards.

Lifestyle and functional fitness are significantly associated with the onset of urinary incontinence in community-dwelling elderly people (Kim et al., 2004) (Table 3).

3. Treatment for geriatric syndrome

Declines in functional fitness such as walking speed, muscle strength and balance ability in the elderly are strongly associated with the development of geriatric syndromes. Hence, exercise focusing on strength, balance, and mobility improvement, even into advanced age, is usually offered as a strategy for the reduction of frailty, falls, and urinary incontinence in the elderly.

Sex	Variable		OR	95%CI
Male	Age (per 1 yr)		1.23	1.11-1.38
	Plasma albumin (per 0.1 g/dl)		0.70	0.54-0.88
	Smoking status	non-smoker	1.00	
		previous smoker	1.53	0.56-4.59
		current smoker	2.33	0.82-7.61
Female	Grip strength (per 1 kg)		0.92	0.86-0.98
	Social role (per 1 point)		1.81	1.19-2.73
	BMI (per 1 kg/m^2)		1.10	1.01-1.20
	Smoking status	non-smoker	1.00	
		current smoker	7.53	1.36-41.63

Table 3. Multiple logistic regression model of risk factors associated with the onset of urinary incontinence

3.1 Frailty

Aging is characterized by a gradual decrease in muscle mass and muscle strength, which contributes to declines in physical function, increased disability, frailty, and loss of independence. Out of many factors associated with the development of frailty, muscle disuse and nutritional deficiencies are the factors that are potentially reversible or preventable through interventions and a more active lifestyle (Fiatarone et al., 1994).

3.1.1 Nutritional supplementation

Declines in muscle mass are related to declines in muscle protein synthesis rates in older adults. In order to resist and reverse the effects of muscle protein synthesis declines, protein or more specifically, amino-acids, have been the focus of research. Investigators have found that leucine enriched essential amino-acid mixtures are primarily responsible for amino-acid-induced muscle protein anabolism in the elderly. Amino-acid supplementation can increase muscle mass in this population; however, an increase in muscle mass is not always accompanied by an increase in muscle strength (Dillon et al., 2009). Essential amino-acid supplementation alone is probably insufficient in increasing muscle strength. Carbohydrate-rich supplements have also been examined for any effects on muscle strength and muscle mass. However, supplements rich in carbohydrates are inadequate for the purpose of increasing muscle mass and strength (Fiatarone et al., 1994). Vitamin D supplementation, which will be discussed further (see section 3.2.1) has also been shown to increase strength.

3.1.2 Exercise

Exercise in elderly individuals may potentially modify risk factors for age-associated reductions in muscle mass (Liu & Latham, 2009). Research has shown that high intensity resistance training is effective in counteracting muscle weakness and physical frailty in elderly people. More specifically, exercise interventions focused on the major muscle groups that are crucial for performing functional activities, are especially important for the reversal of muscle weakness.

Extensive research has confirmed that doing resistance training two to three times a week can improve physical function and functional limitations, and also reduce disability and muscle weakness in older people. Resistance training in elderly people produces increases in strength from 9 to 15% (Borst, 2004), and about 1.1 kg in lean body mass (Peterson et al., 2011). While more improvements are seen with high intensity and volume resistance training, moderate intensity exercises are also beneficial, and are much safer for aging adults. Exercise prescriptions must be of a safe intensity, duration and frequency to avoid further injury and complications (Taaffe, 2006) (Table 4).

Combinations of both exercise and nutritional supplementation have also been studied by researchers. Amino-acid supplementations alone have beneficial effects such as increasing walking speed, and exercise itself also has beneficial effects of improving physical function. Exercise and amino-acid supplementation together have significant effects in enhancing muscle mass, strength and functional fitness. The combination of high resistance exercise and a high carbohydrate mixture containing small amounts of soy protein is effective in the enhancement of muscle strength. High resistance exercise alone increases both muscle mass and strength, while the carbohydrate supplementation alone does not (Fiatarone et al., 1994). Further research is still needed to investigate which supplementations coupled with exercise, or alone, are most effective.

Resistance training program recommendations	
Exercises	8-10 that target the major muscle groups
Repetitions	8-12 per set. When able to achieve 12 repetitions, increase resistance so that 8 repetitions are possible
Sets	Minimum of 1, preferable 2-3 per exercise with 1-2 minutes rest between sets
Frequency	1-3 days per week with at least 48 hours between sessions
Velocity	2-3 seconds concentric and 2-3 seconds eccentric. Some sets of rapid concentric movements can also be included
Breathing	Normal breathing on each repetition (no breath holding)
Duration	Less than 1 hour

Table 4. Resistance training program recommendations. (Taaffe, DR. (2006). Sarcopenia—exercise as a treatment strategy. *Australian Family Physician*, Vol.35, No.3, pp. 130-134. ©2011 *Australian Family Physician*. Reproduced with permission from The Royal Australian College of General Practitioners. Text and images copyright of *Australian Family Physician*. Permission to reproduce must be sought from the publisher, The Royal Australian College of General Practitioners).

3.2 Falls

The development of effective preventative strategies to reduce the fall rate in community-dwelling elderly people who are at risk of falling require a better understanding of the modifiable risk factors for falling. Among the numerous risk factors for falling, those that are considered modifiable include muscle weakness, impairments in balance and gait, and the use of multiple prescription medications. These risk factors can be modifiable through behavioral strategies such as muscle strengthening exercises, balance and gait training, and education about nonpharmacologic treatments to reduce the number of prescription medications used (Tinetti et al., 1994). Furthermore, the occurrence of falling rises with increasing number of risk factors present; therefore, strategies targeted to reduce these modifiable risk factors may be effective in the prevention of falls.

3.2.1 Vitamin D supplementation

In several trials of older individuals at risk for vitamin D deficiencies, vitamin D supplementation improved strength, function, and balance in a dose-related pattern. A high daily vitamin D supplementation dose (about 700-1000 IU) can reduce the risk of falls by approximately 20%; although small doses (less than 400 or 700 IU) may not be sufficient to reduce falls (Bischoff-Ferrari et al., 2009).

3.2.2 Exercise

Falls in older people are not purely random events but can be predicted by assessing a number of risk factors. Some of these risk factors such as decreased muscle strength, impaired balance, and gait deficit can be modified using exercise; whereas poor vision, and psychoactive medications require different strategies. Exercise can be used as a fall prevention intervention on its own or as a component of a multifaceted program. The pooled estimate of the effects of exercise was that it reduced the rate of falling by 17.0% (Sherrington et al., 2008). Home-based and tailored group exercise classes seem to be effective in reducing falls by improving balance and muscular strength. Also, while home hazard management (e.g. removing tripping hazards) and vision screening are not markedly effective in reducing falls when used alone, they add value when combined with an exercise program (Day et al., 2002).

3.2.3 An exercise-based falls prevention program

Exercise programs designed for fall prevention in elderly people should address three major areas - strength, balance and gait. People at high risk of falling due to muscle weakness, balance impairment, and gait deficit should be instructed to perform low or moderate intensity exercise containing safe and simple movements at entry level.

Strength training

A moderate-intensity strength training program aimed to reduce falls should target the major muscles such as the tibialis anterior, soleus, quadriceps femoris, iliopsoas, tensor fasciae latae, and sartorius (Fig. 3). Tripping is a leading cause of falls in community-dwelling elderly people, responsible for up to 53% of falls in this population (Blake et al., 1988). Trips may be associated with weakness of the tibialis anterior muscle, which would cause low toe-clearance or walking in a "shuffling" manner where the toes do not lift off the ground sufficiently to avoid small obstacles that may cause trips.

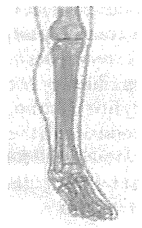
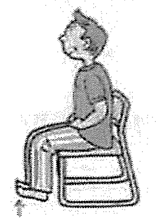
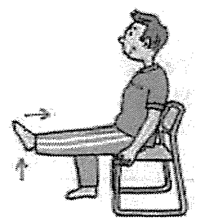
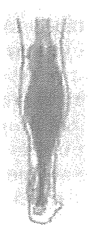
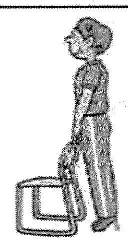
Target Muscle	Exercise	Exercise Description
Tibialis Anterior 	Seated Toe Raises 	Place hands in comfortable position while seated. Lift toes of both feet as high as possible with the heels still on the floor. Hold for 3-5 seconds, breath normally, and slowly lower toes to the floor. Perform 8-10 repetitions. Remind participants to not rock the body back when raising toes.
Quadriceps 	Seated Knee Extension 	Lift one leg still bent at the knee while inhaling, and extend the leg without "locking" the knee (keep knee slightly bent) while exhaling. Bend the knee again, with the hip still flexed, and place the foot on the floor. Perform 8-12 repetitions, and repeat on the other side. Remind participants to not lean back while lifting the leg, or extending the knee.
Soleus and Gastrocnemius 	Heel Raises 	Stand tall with feet flat, shoulder-width apart. Hold on to back of a chair for support. Slowly lift both heels off the floor while exhaling. Hold for 5-10 seconds, breath normally, and slowly lower the heels to the floor. Repeat 10 times.

Fig. 3. Examples of lower extremity strength training exercises.

Balance and gait training

Training is crucial for the improvement of balance in the elderly, and static as well as dynamic and lateral balance exercise have been recommended for reducing falls. Balance exercises progress from holding on to a stable supporting structure such as a chair, to performing the exercises independent of support. Not all elderly people will necessarily start at the first level of each exercise or be prescribed all the balance exercise such as one-leg standing, tandem stance, tandem walking, and side step (Fig. 4).

The results of a large scale study, known as the Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT) trials, suggest that exercise interventions (flexibility, resistance, balance) and Tai Chi for elderly people reduce the risk of falls (Province et al., 1995). To evaluate the effect of Tai Chi on functional fitness and falls, it is necessary to analyze the characteristic movements of Tai Chi. Tai Chi consists of a series of smooth movements linked together in a continuous sequence of whole body weight-shifting, with a low center of gravity. Also, Tai Chi movements involves shifting the weight forward and standing on one foot while lifting the other foot an inch off the floor, which contributes to the improvement of static balance. Moreover, the safe completion of the steps requires an adequate amount of dynamic balance, postural strength, and lateral stability (Li et al., 2004). Participants in the FICSIT trial were instructed on correct foot placement and posture, standing in a semi-squat position, which requires substantial lower extremity strength. These movements are directly or indirectly related to improvement of functional fitness.

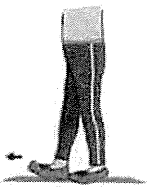
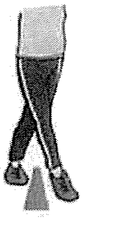
Target Balance Type	Exercise	Exercise Description
Static Balance	One-Leg Stand 	Stand tall with feet flat, shoulder-width apart. Lightly hold on to back of a chair for support or place hands on the hips. Slowly lift one foot off the floor while exhaling. Hold position for 10 seconds, breath normally, and slowly lower the foot to the floor. Repeat by lifting the other leg. Perform 2-3 sets per day.
Dynamic Balance	Tandem Walk 	Stand tall with feet flat on the floor, near a wall or railing for safety. Place one foot directly in front of the other foot, allowing the heel of the front foot to touch the toes of the back foot. Repeat with the other foot. Continue for 10 steps.
Lateral Balance	Cross Step 	Place a piece of tape or draw a line (refrain from anything that may cause trips) on the floor. Begin by standing with both feet together on one side of the tape. Lift the foot farther from the tape, and place it forward (diagonal) on the other side of the tape in a cross-fashion. Shift weight to the front foot, cross the other foot and place on the other side of tape. Note: Both feet do not come together. Continue for 10 steps.

Fig. 4. Examples of balance and gait exercises.

3.3 Urinary incontinence

The common treatments for urinary incontinence include surgery, drug therapies, and behavioral treatments. Behavioral treatments such as pelvic floor muscle (PFM) exercises and bladder training are recommended as a first line of treatment in the management of urinary incontinence, because of the potential benefits with few risks and no side effects. Urinary incontinence is usually classified into three different types: stress, urge, and mixed. Stress incontinence is urine leakage associated with increased abdominal pressure such as coughing, sneezing, laughing, heavy lifting, standing, running, or other types of physical activity. Urge incontinence is leakage associated with running water, or an urge to void and not being able to reach the toilet in time. Mixed urinary incontinence is when characteristics of both stress and urge incontinence types are present.

3.3.1 Pelvic floor muscle exercise

PFM exercises (Fig. 5), initiated by Kegal in 1948, is hypothesized to enhance urethral resistance by increasing the strength and endurance of the periurethral and perivaginal muscles and by improving the anatomic support to the bladder neck and proximal urethra (Kegel, 1948). These exercises are the preferred treatment for stress incontinence but have recently been recommended for urge or mixed incontinence because of reflex bladder inhibition associated with pelvic floor muscle contraction. The efficacy of PFM exercises in improving urine leakage has been validated by many investigators, and the improvement rate has been reported to range widely from 17 to 84% (Bo, 1995).

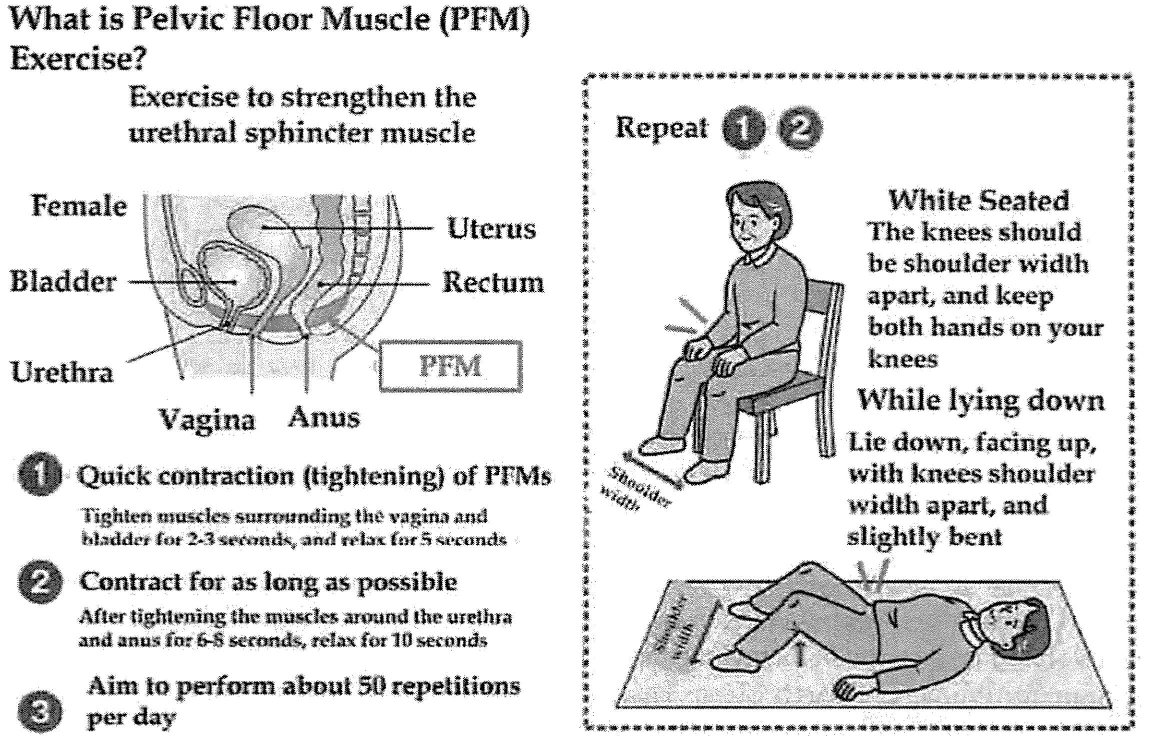


Fig. 5. Pelvic floor muscle exercise for the prevention of urinary incontinence.

At the beginning of PFM training, it is important to teach the elderly people participating in a training program, the structure of the PFM in order to gain awareness of these muscles. The participants should be taught that straining the abdomen would increase the abdominal pressure and would exert load on the PFM. Training should focus on how to exert force on the PFM without excessively straining the abdomen. Most exercise regimens are designed to strengthen the fast and slow-twitch fibers located at the pelvic floor. PFM exercise programs often incorporate alternations of fast contractions, usually held only for about three seconds, sustained contractions, where the participants would hold the contraction for about six to eight seconds, and ten-second relaxation periods between the contractions. The PFM exercises are usually performed in the seated, lying, and standing positions with the legs apart, and the emphasis placed on training of the PFM and relaxing of the other muscles.

The durations of the exercise training periods vary between 3 weeks and 6 months. Bladder training appears to have its greatest efficacy at 6 weeks; PFM exercise appears to be best between 11 to 12 weeks; and combined bladder training and PFM exercise seems to be most effective between 8 to 12 weeks of training (Wyman et al., 1998) (Fig. 6).