表1　サルコペニア群と正常群の調査項目の比較

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/m²)	18.98±2.01	23.74±2.84	<0.001
筋肉量(kg)	26.92±2.61	31.73±3.16	<0.001
転倒率，%	26.5	16.4	<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

肪23.0%，大豆タンパク質17.0%)の飲料を毎日1回摂取する指導を10週間行った．その結果，運動群で筋力113.0±8.0%増加(非運動群3.0±9.0%増加，P<0.001)，歩行速度11.8±3.8%改善(非運動群1.0±3.8%増加，P＝0.02)，階段昇りパワー28.4±6.6%向上(非運動群3.6±6.7%向上，P＝0.01)，大腿筋面積2.7±1.8%上昇(非運動群1.8±2.0%減少，P＝0.11)であった．このように，虚弱高齢者の身体機能の改善には運動中心の複合介入は有効であり，栄養補充のみでは不十分であると指摘している．

2. 運動と必須アミノ酸補充の効果

1)一般的選定基準

サルコペニア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．今日広く採用されている制度の高い筋肉量評価法はDXA法であり，Baumgartnerら[12]は，DXA法によるカットポイント男性7.26 kg/m²，女性5.45 kg/m²を提案し，広く活用されている．一方，Chienらはbioelectrical impedance (BI)法によるカットポイント男性8.87 kg/m²，女性6.42 kg/m²を提案している[13]．

筋力指標としては握力，膝伸展力あるいは膝屈曲力を，Physical performance指標としては通常歩行速度，Timed Up & Go testを提案しているが，European Working Group on Sarcopenia in Older Peopleの報告[14]では，握力で男性30 kg未満，女性20 kg未満を，歩行速度で0.8 m/s未満を採用している．しかし，これらの基準を日本の地域在住高齢者に適用した場合，大変厳しい基準になっていることが判明したので，筆者は次の操作的選定基準を採用して対象者を選定した．

2)操作的選定基準

大都市部在住75歳以上の後期高齢女性1,399名の対象者の中から，サルコペニア高齢者を抽出するために先行文献で採用している基準に基づき，骨格筋量の減少はSMIを，筋力低下は膝伸展力を，歩行速度の低下は通常歩行速度を，sarcopenic obeseを除外するためにBMI減少を用いた．採用した選定基準は，「SMI＝6.42 kg/m²以下」で「膝伸展力＝1.01 Nm/kg以下」あるいは「歩行速度＝1.22 m/sec以下」，「BMI 22.0以下」で「膝伸展力＝1.01 Nm/kg以下」あるいは「歩行速度＝1.22 m/sec以下」である．これらの選定基準に該当する者をサルコペニアと操作的

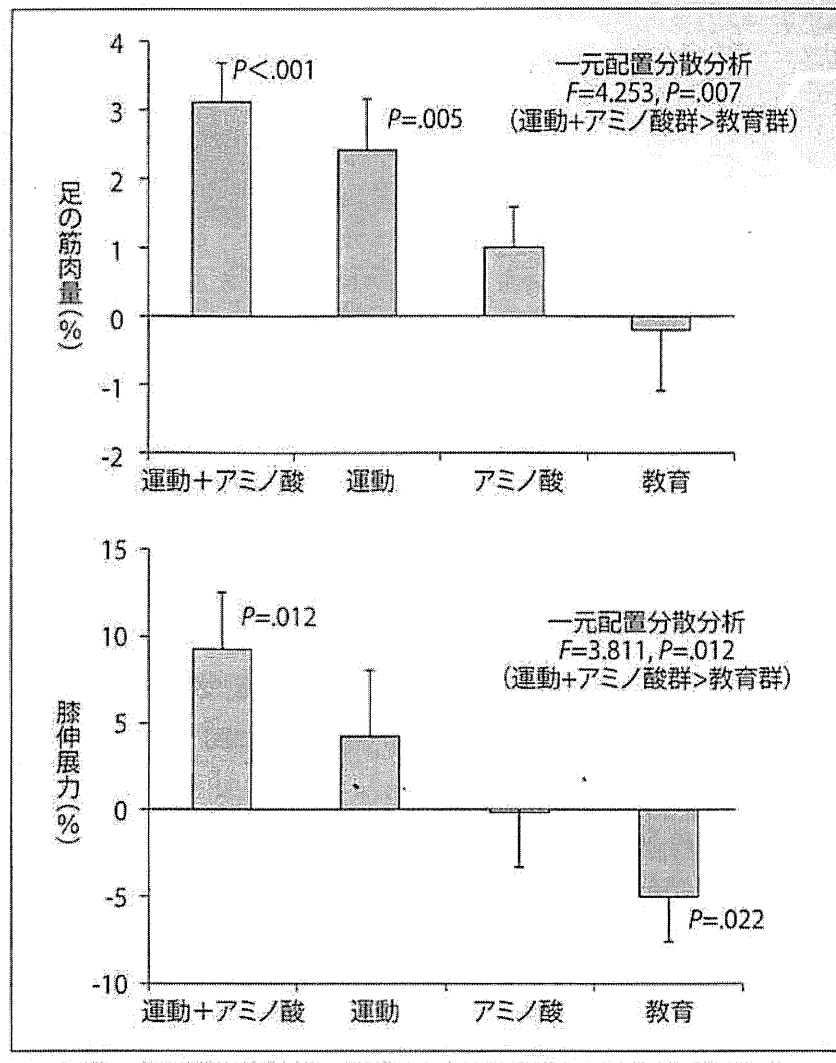

図3 介入後における足の筋肉量と膝伸展力の変化の群間比較
(文献15より改変)

に定義，304名(21.7%)を抽出し，サルコペニア高齢者の特徴および複合介入効果を調べた．

3)対象者の特徴

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．その結果，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，筋肉量は有意に低値を，健康度自己評価で健康だと回答した者の割合，定期的な運動習慣を持っている者の割合は低かった．既往歴においては，高血圧症，高脂血症は正常群より低い割合を示したが，骨粗鬆症の既往はサルコペニア群38.2%，正常群30.7%，60歳以降の骨折歴はサルコペニア群28.6%，正常群22.9%，過去1年間の転倒率はサルコペニア群26.5%，正常群16.4%といずれの項目においてもサルコペニア群が有意に高い割合を示した(表1)．以上のことから，サルコペニア高齢者は，転倒のみならず骨粗鬆症に伴う骨折危険性が高いことが示唆され，その予防策の早期確立が重要なポイントであることが強く示唆された．

4)運動＋栄養補充介入の実際

地域在住サルコペニア高齢者に対する運動，栄養補充の複合介入効果を調べるために，サルコペニアと認定された304名を事前に設けた選定基準に基づき，介入参加者155名，不参加者149名に分けた．介入参加者155名を無作為化比較試験(randomized controlled trial; RCT)により

表2　介入後の骨格筋量および身体機能の改善に対する介入群間の調整済オッズ比の比較(文献15より引用)

	介入†							
	健康教育群	アミノ酸群		運動群		運動+アミノ酸群	
従属変数*	基準	OR#	95% CI	OR#	95% CI	OR#	95% CI
四肢の筋肉量	1.00	2.21	0.73～6.98	2.65	0.86～8.71	4.63	1.44～9.08
通常歩行速度	1.00	1.83	0.62～5.55	3.02	1.31～6.72	4.31	1.39～10.77
膝伸展力	1.00	2.16	0.78～7.13	3.91	1.29～10.09	5.11	2.02～12.71
四肢の筋肉量+膝伸展力	1.00	1.39	0.49～3.97	2.33	0.78～7.08	4.30	1.52～10.65
四肢の筋肉量+通常歩行速度	1.00	1.70	0.63～4.68	2.13	0.76～6.10	4.83	1.70～9.60
膝伸展力+通常歩行速度	1.00	1.47	0.70～3.40	4.18	1.37～9.16	5.26	1.41～10.72

*従属変数：筋肉量と身体機能の変化：
1=向上，0=無変化あるいは低下.
#OR=調整済オッズ比；95% CI= 95%信頼区間

運動+栄養群38名，運動群39名，栄養群39名，対照群39名に分け，次の介入を行った[15].

①運動：運動群には週2回，1回あたり60分間の筋力強化と歩行機能の改善を目的とした運動指導を行った．運動指導は対象者の体力レベルが低く個人差が大きい点を考慮し，漸増負荷指導を行った．具体的な運動は，椅子体操，レジスタンス運動(ゴムバンド：黄色，赤色使用，Ankle-weight：錘0.50 kg，0.75 kg，1.00 kg，1.50 kg使用)，歩行・バランス運動を指導した．

②栄養：栄養補充群には，ロイシン42.0%，リジン14.0%，バリン10.5%，イソロイシン10.5%，トレオニン10.5%，フェニルアラニン7.0%，他5.5%組成のアミノ酸3 gを1日2回補充する指導(1日総補充量=6 g)を3カ月間実施した．

5)複合介入の効果

介入前後における四肢の骨格筋量は運動群(事前13.90±1.06 kg，事後14.19±1.33 kg)，栄養群(事前12.86±0.99 kg，事後13.03±1.10 kg)，運動+栄養群(事前13.25±1.35 kg，事後13.59±1.53 kg)の3群で有意な増加が観察され，サルコペニア高齢者の骨格筋量は運動のみならず栄養補充によって増える可能性が強く示唆された(図3)．

通常歩行速度は運動群(事前1.31±0.24 m/s，事後1.50±0.23 m/s)，栄養群(事前1.30±0.18 m/s，事後1.36±0.18 m/s)，運動+栄養群(事前1.27±0.25 m/s，事後1.43±0.29 m/s)の3群で有意な増加が観察された．

膝伸展力は運動+栄養群(事前1.15±0.27 Nm/kg，事後1.23±0.29 Nm/kg)のみで有意な向上が認められた(図3)．

サルコペニアは複合概念，つまり「筋肉量減少+筋力低下」あるいは「筋肉量減少+歩行速度低下」と定義されている．よって，介入効果を検証するときも，これらの概念に基づいた分析が必要である．表2に示したように，「下肢筋力+膝伸展力」改善のためにはアミノ酸補充あるいは運動単独の介入効果は不十分であり，「運動+アミノ酸補充」の複合介入で有効(OR=4.89，95% CI=1.89～11.27)であり，「下肢筋力+通常歩行速度」の改善にも「運動+アミノ酸補充」の複合介入が有効(OR=4.11，95% CI=1.33～13.68)であることを検証した．

おわりに

加齢に伴う筋肉量の減少は下肢部位が最も顕著であり，筋量減少に伴う筋力の衰え，あるいは身体機能の低下(サルコペニア)は身体的障

害，転倒・骨折率の上昇と強く関連している．サルコペニアと関連する要因は種々で複雑であるが，全メカニズムの完全解明までには至っていない現況である．しかし，からだの不使用と栄養不良は筋肉量の減少と密接に関わり，可変要因として注目が高まっている．骨格筋の不使用を解消するためには，漸増負荷レジスタンス運動が勧められ，その実践によって筋肉量や筋力の増大効果は認められている．一方，炭水化物を中心とする栄養補充によっては，虚弱高齢者の筋肉量や体力向上に不十分であり，ロイシン高配合の必須アミノ酸の補充によって，高齢者の筋肉量の増大有効は認められている．しかし，アミノ酸補充のみではサルコペニア高齢者の体力改善には不十分であるとの指摘も散見される．

本稿では，運動にロイシン高配合の必須アミノ酸を補充する複合介入によって，サルコペニア高齢者の骨格筋量の増大，筋力上昇，歩行機能の向上効果を検証した．今後，運動と他の栄養素の組み合わせによる効果検証の成果を期待する．

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シンポジウム

身体活動の指導からみた高齢者支援
—老年症候群の早期予防のための支援—

Comprehensive interventions for the prevention of geriatric syndromes in community-dwelling elderly

金　憲経
Hunkyung Kim

1．はじめに

ヒトの器官や機能は、適当に使えば発達し、使わなければ衰退・委縮するというルーの3法則通りに、不動、低運動、不使用は精神を含めた身体の諸機能低下や機能喪失を加速させる(図1：金ら、1999)。様々な機能が低下する高齢期には必ずしも、病気とは言い切れないような障害、即ち虚弱、認知機能の低下、尿失禁、それから低栄養など老年症候群と呼ばれる徴候も出現しやすくなっている（図2)。これらの老年症候群は生活機能を低下させ、自立を阻害する主要な要因である。高齢者が元気に高齢期を過ごせるよう老年症候群の予防を意図した支援が重要である。本シンポジウムでは高齢者の支援、特に身体的な側面と老年症状群の早期予防、特にサルコペニア、転倒骨折、尿失禁を中心に講演を行った。その中でも特に、最近話題になっているサルコペニアは、要介護状態の原因になっている虚弱と密接に関わっており、年齢が高くなるにつれてこの割合が増えていくという特徴がある（図3)。

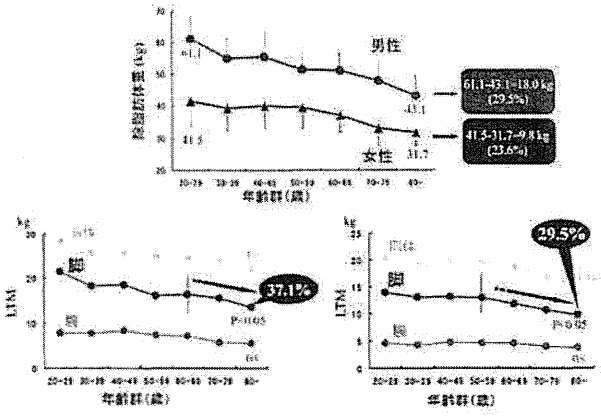
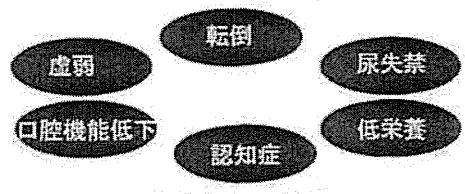


図1　DXA法によるLBM、LTM,の年代別の比較
(金ら, 1999)



有症率が高く、生活機能の自立を阻害する要因

老年症候群の早期予防・治療は高齢期における生活機能の自立、QOL向上のために必要な戦略

早期予防のための支援戦略は？

図2　老年症候群とは

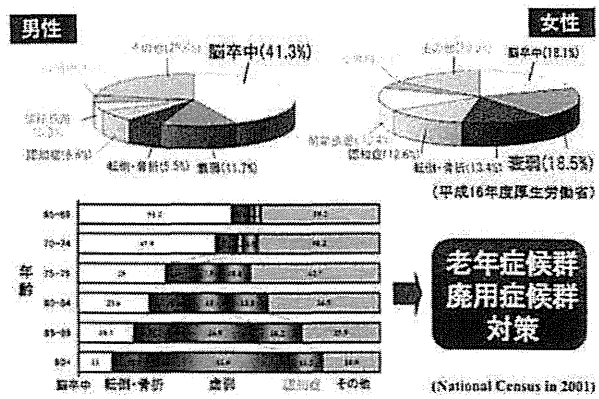


図3　背景：要介護状態の主な原因

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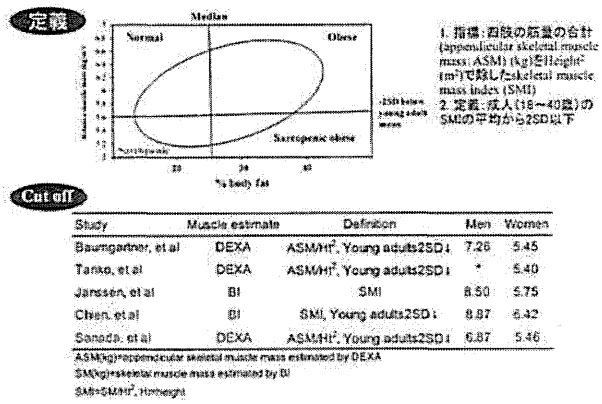
2．サルコペニアの定義

サルコペニアの操作的定義としてよく使われているものの一つとして、Baumgarterらによる New Mexico高齢者調査のデータを用いた定義がある（図4）。この定義は、二重エネルギーX線吸収（dual energy X-ray absorptiometry: DXA）法から得られた四肢の筋肉の量（appendicular skeletal mass: ASM）を身長（m）の二乗で除したskeletal muscle mass index（SMI）を指標としたものである。サルコペニアとは、成人（18～40歳）SMIの平均から2標準偏差（SD）以下に達した場合と定義し、加齢に伴う骨格筋量の減少を意味する言葉として1989年Rosenbergにより提唱され、現在老年医学分野で最も関心の高い領域の1つである。なお、サルコペニアには、サルコペニアとsarcopenic obeseの二つがあるが、今回は前者に焦点を当てて考える。



Study	Muscle estimate	Definition	Men	Women
Baumgartner, et al	DEXA	ASM/Ht², Young adults2SD↓	7.26	5.45
Tanko, et al	DEXA	ASM/Ht², Young adults2SD↓	*	5.40
Janssen, et al	BI	SMI	8.50	5.75
Chien, et al	BI	SMI, Young adults2SD↓	8.87	6.42
Sanada, et al	DEXA	ASM/Ht², Young adults2SD↓	6.87	5.46

ASM(kg):appendicular skeletal muscle mass estimated by DEXA
SM(kg):skeletal muscle mass estimated by BI
SMI=SM/Ht², Ht=height

図4　サルコペニアの定義及びcutoff values

3．サルコペニア予防のための支援

サルコペニアを評価する四肢の筋肉量は、DXA法とbioelectrical impedance（BI）法から求めているが、BI法がDXA法より高値を示す傾向になっている。BI法ではChienらがSMI男性8.87kg/m²、女性6.42kg/m²のカットポイントを提案している。もともとのサルコペニアは筋肉量減少の概念であったが、2010年European Working Group on Sarcopenia in Older Peopleは新たな診断基準を3つあげている（表1）。一つは筋肉の量の減少、二つは筋力の低下、もう一つは身体機能の低下の3つのカテゴリーを設定し、プレサルコペニア、サルコペニア、シビアサルコペニアに分け、プレサルコペニアは、筋肉の量だけ減少している症状、サルコペニアは筋肉の量の減少と筋力の低下、あるいは筋肉の量の減少と歩行速度の低下に分けている。シビアサルコペニアは筋肉の量の減少、筋力の低下、歩行速度も低下しているときを示している。サルコペニアは、特に年齢の影響を非常に受けやすいといえる。表2に示したサルコペニアの有症率は、70歳以下の場合は13.5～24.1%、80歳以上になる43.2%から60.0%の約半分がサルコペニアと判定される可能性がある。特に問題なのは身体的disabilityが非常に高いことに影響される。このような問題に関わっているサルコペニアの予防のためには、どのようなものがあるのかということになる。先ず、筋肉量の減少と関

表1　Sarcopenia: Current concepts

Sarcopenia has become a catch-all term that is now regularly defined as the age-related loss of skeletal muscle mass and strength.

2010 European Working Group on Sarcopenia in Older People (EWGSOP) Suggested Criteria for the Diagnosis of Sarcopenia

Table. Criteria for the diagnosis of sarcopenia
1. Low muscle mass
2. Low muscle strength
3. Low physical performance

Table. EWGSOP conceptual stages of sarcopenia

Stage	Muscle mass	Muscle strength	Performance
Presarcopenia	↓		
Sarcopenia	↓	↓ or	↓
Severe sarcopenia	↓	↓	↓

Cruz-Jentoft et al. Age and Ageing 2010; 39: 412-423

表2　サルコペニアの有症率
(Baumgartner et al, Am J Epidemiol, 1998)

年齢群（歳）	男性 ヒスパニック (n=221)	男性 白人 (n=205)	女性 ヒスパニック (n=209)	女性 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

Associations of sarcopenia with physical disability or history of injury

	Men			Women		
	%	Odds ratio	95% CI	%	Odds ratio	95% CI
≥3 disabilities	16	3.66	1.42-10.02	33	4.08	1.52-11.31
>1 balance abnormality	28	3.23	1.13-9.74	8	1.77	0.48-5.75
>1 gait abnormality	25	1.87	0.94-3.74	21	1.12	0.43-2.73
Use of cane or walker	14	2.29	1.09-4.88	17	1.79	0.67-4.60
Fell during past year	22	2.58	1.42-4.73	31	1.28	0.60-2.67
History of bone fracture	11	0.52	0.20-1.25	24	1.31	0.56-2.89

係する要因は、性、年齢、疾病、筋委縮、内分泌機能の機能変化、不活動、栄養不良など様々なである。多様の危険因子の中で、不活動と栄養不良は適切な支援により変えることができる可変因子である。表３には、サルコペニア予防のための介入ポイントを示した。まず、運動である。Progressive Resistance Strength TrainingのHigh Intensity & High Volumeによって、高齢者の筋肉量のみならず筋力の上昇効果は多く検証されている。しかし、高強度・多量の運動を身体機能が低下しているサルコペニア高齢者にそのままの適用は困難であり、サルコペニア高齢者に対しては軽い運動で十分効果的であると提案されている（Taaffe DR, 2006）。

表３　サルコペニア予防のための介入のポイント

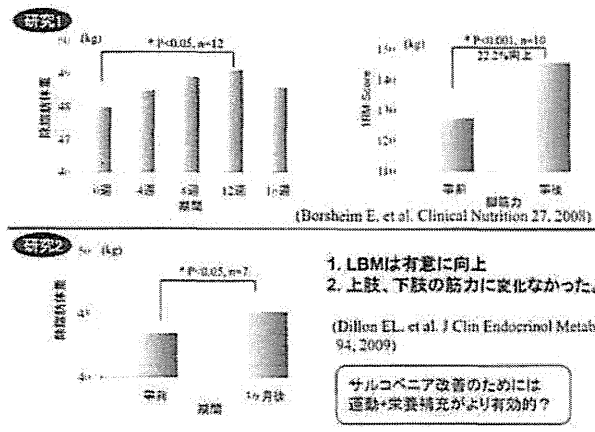
筋肉量減少の危険因子：性、年齢、身長、体重、BMI、内分泌機能の変化、不活動、不十分な栄養

可変因子　1. 不活動 → 運動
2. 栄　養 → アミノ酸

1. Progressive resistance strength training
1) 筋力
(1) Cochrane review(2009, Issue 3): 73介入の3059名のデータ分析
SMD=0.84, 95% CI=0.67-1.00: 筋力向上に効果的
(2) Peterson MD, et al (Ageing Res Rev, 2010)：47研究の1079名のデータ分析
筋力向上: 9.8-31.6 kg, 増加率(%): leg press (29.0), chest press (24.0), knee extension (33.0)
(3) Brost SE (Age Aging, 2004): 下肢筋力: 9～15%増加
2) 除脂肪体重
(1) Peterson MD, et al (Med Sci Sports Exerc, 2011): 49研究1328名のデータ分析:
LBM変化 1.1kg向上 (High-volume interventions)

2. Sarcopenia- Exercise as a treatment strategy -
Resistance training once or twice a week targeting the major muscle groups at moderate intensity is sufficient for improvement

もう一つは栄養である。特に必須アミノ酸に着目した研究が多く報告されている。筋肉量が減る背景には、筋タンパク質が減ることが関係している。高齢期になると筋タンパク質の合成力が低下し、分解力が促進されることで筋肉量が減少することが背景になっている。すなわち筋タンパク質の合成力を高めれば、分解を抑制でき、筋力の減少を抑制できることになる。今までの研究によりますと、必須アミノ酸の補充によって筋タンパク質の合成促進ができることを報告されている（図５）。必須アミノ酸の補充効果については異なる２つの研究成果が報告されている。一つは必須アミノ酸を補充すると筋肉の量も増えて筋力も増えるという報告がある。一方では、必須アミノ酸を補充すると筋肉



(Borsheim E, et al. Clinical Nutrition 27, 2008)

図５　必須アミノ酸補充の効果

の量は増えるが、筋力の変化はないという報告があるので、一層の研究が必要と言える。

著者らは、どのような取り組みがサルコペニア改善に有効かを検討するために、75歳以上の高齢者を対象に実施した包括的健診に参加した1,399名より次の基準を適用し、サルコペニア高齢者を選定した（図６）。すなわち、筋肉量が減少し筋力が低下している者、筋肉量が減少し歩行機能が衰えている者、もう一つはBMI22以下で筋力が低下している者、BMI22以下で歩行速度が低下している者を操作的にサルコペニアと定義した。このような対象は、骨密度が低く下腿三頭筋囲が細く骨粗鬆症既往が高いという特徴を示した（図７）。特に、転倒率は一般高齢者で16.4%に対して、サルコペニアの高齢者は、26.5%と非常に高くなっていることが明らかになった。さらに著者ら（2012）は、対象者を運動＋栄養、運動のみ、栄養のみ、それから

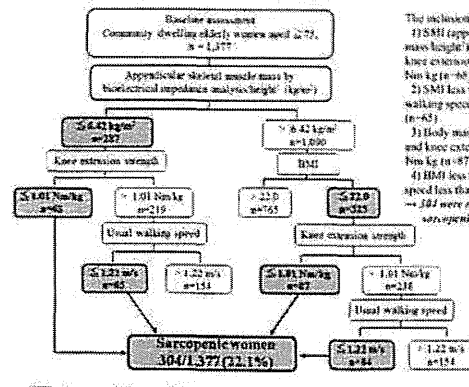


図６　Algorithm for the selection of women who were operationally defined as sarcopenia
(Kim H, Suzuki T, et al. JAGS 60: 16-23, 2012)

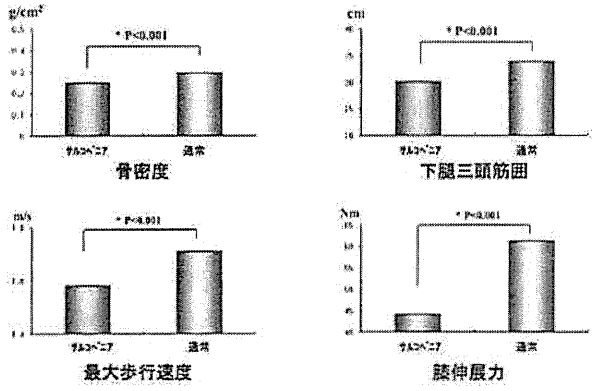


図7　サルコペニア判定者と通常者の測定値の比較

健康教育の４つのグループに分けて、３か月間介入を行った。なお、アミノ酸の場合はロイシンが42%パーセント含まれる錠剤一日３ｇを２回補充して一日６グラム補充する介入をした。その結果、図８に示したように、歩行速度はアミノ酸の補充だけでも、運動のみでも、運動＋アミノ酸も有意に改善されることが認められた。しかし、足の筋肉量と下肢筋力については、アミノ酸だけ補充をすると筋肉の量は有意ではないものの増加傾向を示し、運動の場合は有意に改善していることが認められた。また下肢筋力は、アミノ酸補充だけでは足筋肉量は増えても変化がない結果を示した。運動グループの場合は、筋肉の量が増えても力は改善しないことが認められた。運動と栄養の介入（運動＋栄養）によって、筋力は有意に改善されるという結果が得られた（図９）。また、サルコペニアは、筋肉の量の減少と身体機能低下という複合的な概念の定義である。実際に下肢筋肉量と膝伸展力の増加あるいは足筋力と歩行速度の有意な増加は、運動＋アミノ酸のみであり、アミノ酸補充あるいは運動だけでは有意な改善がなく、複合的に支援したときに有意に改善された。よって、サルコペニアを改善するためには運動と栄養の組み合わせによる複合的支援が有効であることが強く示唆された。

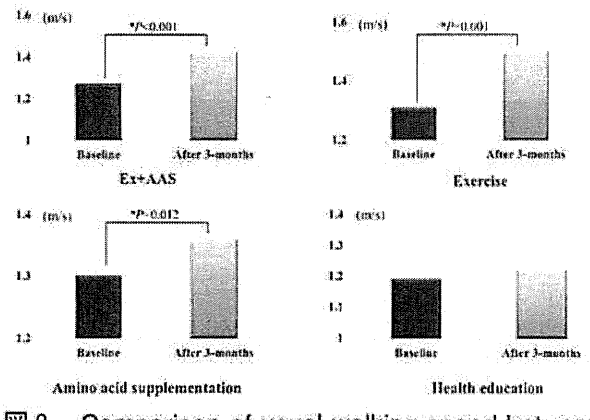


図8　Comparison of usual walking speed between exercise and amino acid groups.

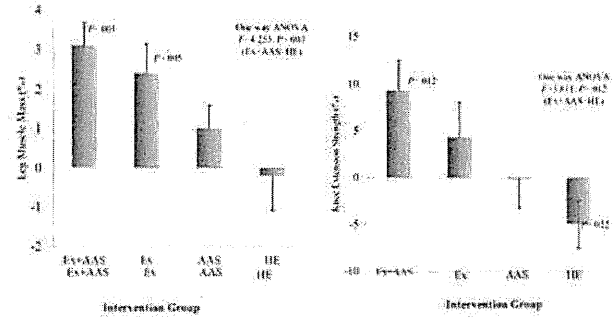


図9　Mean(±SE) changes in leg muscle mass and knee extension strength after exercise (Ex), amino-acid supplementation (AAS), both (Ex+AAS), or health education (HE). Bars indicate the average changes from baseline to after the 3-month interventions.
(Kim H, Suzuki T, et al. JAGS 60: 16-23, 2012)

4．転倒・骨折予防のための支援

転倒の危険因子には、身体機能と非常に強くかかわっている（表４）。転倒は、歩行中に60%発生し、特に大腿骨頸部骨折は要介護状態あるいは寝たきりに繋がりやすく場合によっては死亡原因にもなる。高齢者にとって最も深刻な大腿骨頚部骨折の引き金の90%は転倒であり、特に横に転ぶことが大きなリスクファクタ

表４　転倒危険因子の相対的危険度

危険因子	相対危険度
筋力の虚弱	4.4
転倒歴	3.0
歩行障害	2.9
バランス障害	2.9
補助器具の使用	2.6
視力障害	2.5
関節炎	2.4
ADL障害	2.3
うつ病	2.2
認知機能障害	1.8
年齢80歳以上	1.7

(AGS., JAGS. 2001)

ーになっており、身体づくりの中でも特に横に転びにくい体づくりが必要である。もう一つは、歩くときの「つまずき」が転倒の40%を占めていることに着目すべきである（図10）。転倒予防のための体づくりのポイントは歩行機能の向上とつまずき改善である。つまり、大腿四頭筋、下腿三頭筋、腸腰筋、大腿筋膜張筋、縫工筋等々の下肢筋を鍛えて歩行能力の改善を、前脛骨筋を鍛えてすり足改善を図ることが必要である。これらに重点を置いた運動を支援することによって、転倒率は、約20%軽減させることができると多くの研究で指摘されている（図11）。

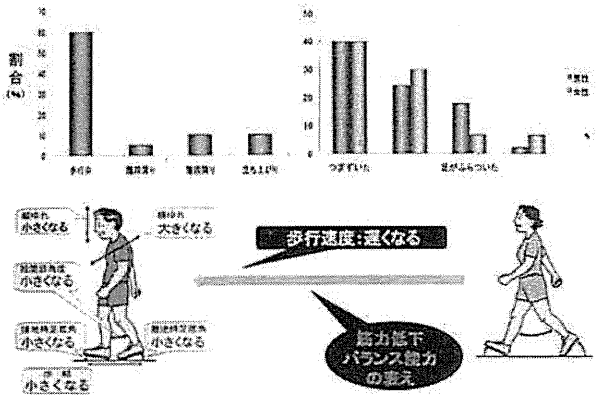


図10　転倒時の動作

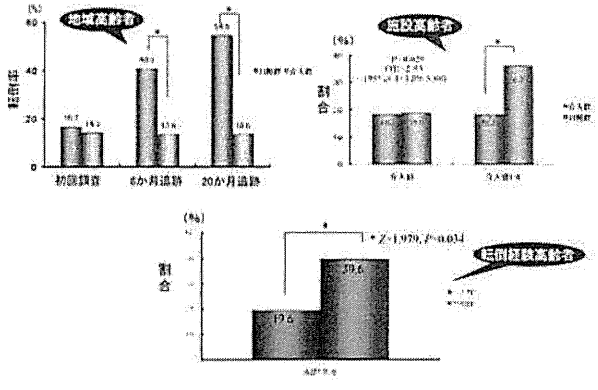


図11　介入後追跡期間中の転倒率の推移

5．尿失禁予防への支援

尿失禁は高齢者に多く（図12）、社会生活に種々の影響を及ぼす。尿失禁予防としてはこれまでに骨盤底筋運動が主流であったが、肥満が尿失禁のリスクファクターであることにも注目

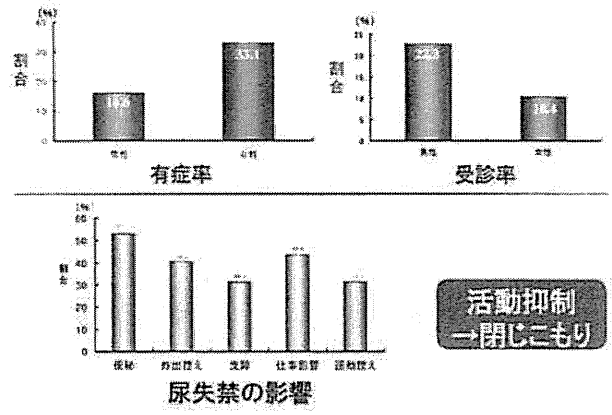


図12　地域高齢者の尿失禁の有症率と受診率

すべきである。すなわち、今までは骨盤底筋だけ鍛えるのが尿失禁予防の主流であったが、腹部過剰脂肪は骨盤底筋に過負荷を与える要因として、骨盤底筋を緩める原因であることを考慮すべきである（図13）。著者ら（2007）は、腹圧性尿失禁者に対して骨盤底筋運動プラス、腹部脂肪減少運動を組み合わせる介入を行った。その結果、対象の54.5%が完治した（図14）。さらに、尿失禁が完治することは、外出を控える者は運動指導前44.8%が指導後13.8%に減り、近所付き合い・知人友人との付き合いに支障がある者は運動指導前34.5%が指導後10.3%に減り、社会活動の復活に繋がることが示唆された（図15）。

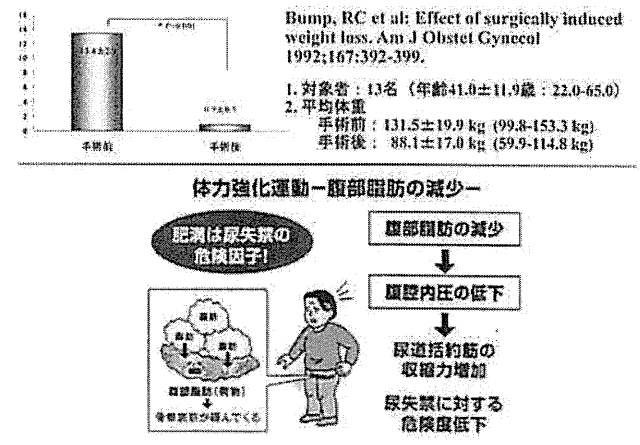


図13　尿失禁改善と肥満の改善との関連性

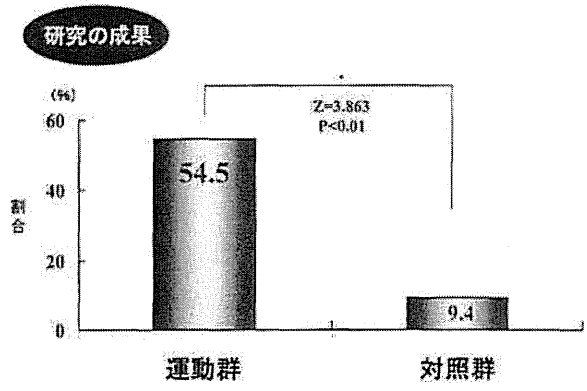


図14　3ヶ月間の運動指導による尿失禁完治率
Kim H, et al., JAGS: 2007.

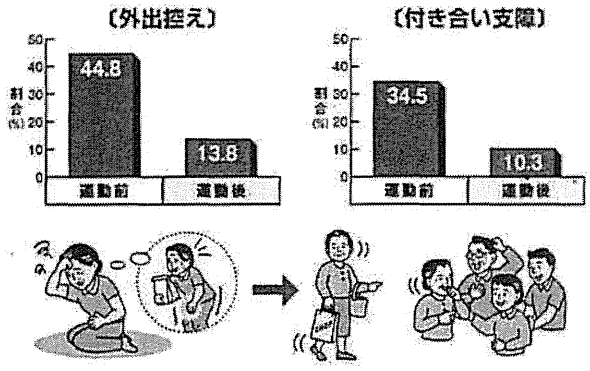


図15　運動指導後の外出控え・付き合い支障の変化

6．まとめ

体育研究者や指導者が虚弱高齢者に支援するとき、健康な期間、できればdisabilityの期間を短くする支援が必要である。なかでも支援の中心になっているのは運動であるが、運動＋栄養運動、運動＋他の要因を取り入れた方が、より効果的になると思っている。

プロフィール　金 憲経（Kim Hunkyung）
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慶北大学校（韓国）卒業、筑波大学大学院体育科学研究科修了　博士（体育科学）
研究等：虚弱高齢者の生活機能の改善を目指す介入、高齢者の転倒予防を目指す介入、介護予防を目的とした虚弱高齢者の尿失禁改善、等など

European Journal of Clinical Nutrition (2013), 1–7

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ORIGINAL ARTICLE

Accuracy of segmental multi-frequency bioelectrical impedance analysis for assessing whole-body and appendicular fat mass and lean soft tissue mass in frail women aged 75 years and older

M Kim and H Kim

BACKGROUND/OBJECTIVE: We aimed to examine the accuracy of segmental multi-frequency bioelectrical impedance analysis (SMF-BIA) for the assessment of whole-body and appendicular fat mass (FM) and lean soft tissue mass (LM) in frail older women, using dual-energy X-ray absorptiometry (DXA) as a reference method.
SUBJECTS/METHODS: All 129 community-dwelling Japanese frail older women with a mean age of 80.9 years (range, 75–89 years) from the Frailty Intervention Trial were recruited. The agreements between SMF-BIA and DXA for whole-body and appendicular body composition were assessed using simple linear regression and Bland–Altman analysis.
RESULTS: High coefficients of determination (R^2) for whole-body FM ($R^2 = 0.94$, s.e. of estimate (SEE) = 1.2 kg), whole-body LM ($R^2 = 0.85$, SEE = 1.4 kg), and appendicular FM ($R^2 = 0.82$, SEE = 1.1 kg) were observed between SMF-BIA and DXA. The R^2 coefficient for appendicular LM was moderate ($R^2 = 0.76$, SEE = 0.8 kg). Bland–Altman plots demonstrated that there was systematic (constant) bias (that is, DXA minus SMF-BIA) with overestimation of whole-body FM (bias = −1.2 kg, 95% confidence interval (CI) = −1.5 to −0.1) and underestimation of whole-body LM (bias = 2.1 kg, 95% CI = 1.8–2.3) by SMF-BIA. Similar, the appendicular measurements also demonstrated systematic bias with overestimation of appendicular FM (bias = −0.3 kg, 95% CI = −0.5 to −0.1) and underestimation of whole-body LM (bias = 1.5 kg, 95% CI = 1.4–1.7) by SMF-BIA. In addition, the individual level accuracy demonstrated a non-proportional bias for whole-body LM ($r = 0.08$, $P = 0.338$) and appendicular FM ($r = 0.07$, $P = 0.413$).
CONCLUSIONS: SMF-BIA had acceptable accuracy for the estimation of whole-body and appendicular FM and LM in frail older women, although SMF-BIA underestimated LM and overestimated FM relative to DXA.

European Journal of Clinical Nutrition advance online publication, 6 February 2013; doi:10.1038/ejcn.2013.9

Keywords: body composition; bioelectrical impedance analysis; sarcopenia; frailty

INTRODUCTION

Frailty is an important and common geriatric syndrome that is described as a status of increased vulnerability resulting from the loss of complexity in resting dynamics involving multiple physiological systems with advancing age.[1] The prevalence of frailty increases with age, from 3.9% at 65–74 years to 11.6% at 75–84 years and to 25% in people older than 85 years. In addition, frailty is more prevalent in women than in men.[1] Sarcopenia is a loss of skeletal muscle mass and size that occurs with aging.[2] Although many definitions of sarcopenia have been reported,[3–5] current definitions focus on loss of appendicular skeletal muscle mass as well as low muscle strength and low physical performance.[6] The European Working Group on Sarcopenia in Older People consensus definition of sarcopenia is based on three stages: the presarcopenia stage involves low muscle mass with normal muscle strength and physical performance; the sarcopenia stage involves low muscle mass and either diminished muscle strength or physical performance; and severe sarcopenia combines all three factors.[6] Several pathophysiological overlaps between sarcopenia and frailty have been observed.[7] Thus, age-related loss in muscle mass and strength are a major component in the development of frailty in the elderly.[8,9] Moreover, frailty is associated with a decline in muscle mass and quality and a parallel increase in fat mass (FM).[10] Measurement of body composition, including FM and muscle mass in older populations provide important information about their nutritional status. Therefore, the understanding of the body composition of frail elderly populations is an important part of clinical assessment with a goal of optimal prevention and treatment strategies.

Dual-energy X-ray absorptiometry (DXA) is an accepted method for the estimation of whole-body and segmental body fat and fat-free mass (FFM), which includes lean soft tissues and bone minerals.[11–13] However, DXA has disadvantages for use in clinical settings, such as the high cost of equipment, risk of radiation exposure and lack of access to instruments. For clinical use, bioelectrical impedance analysis (BIA) has been used as an attractive alternative method.[4,14,15] BIA is a portable, non-invasive, easy to use and convenient method for the patient, and it is also relatively inexpensive compared with other methods.[16] Of the BIA devices developed over the years, segmental multi-frequency (SMF)-BIA devices have advantages

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Author contributions: Both authors designed the study together. MK developed the study concept and design, analysed and interpreted the data, and prepared the manuscript. HK recruited subjects, assisted with statistical analysis and reviewed the manuscript for accuracy.
Received 17 September 2012; revised 19 December 2012; accepted 21 December 2012

over single-frequency BIA devices (50 kHz).[17–19] SMF-BIA avoids the problems encountered in single-frequency BIA by employing both low- and high-frequency electric currents.[20] In recent years, SMF-BIA has been shown to be valid in the estimation of body composition using DXA as a reference standard.[21–23] However, these results were obtained from analysis of healthy populations.

To our knowledge, SMF-BIA has not been evaluated in the assessment of total and appendicular body composition in a specifically targeted frail elderly population. Therefore, the aim of this study was to examine the accuracy of SMF-BIA for the assessment of whole-body and appendicular body composition using DXA as a reference method in frail Japanese women aged 75 years and older.

MATERIALS AND METHODS

Subjects

The subjects were 129 community-dwelling Japanese frail older women with a mean age of 80.9 years (range, 75–89 years). The study population was recruited from participants in the Frailty Intervention Trial (clinical trials registry, number: JMA-IIA00069). The baseline assessment was conducted on 1835 women aged 75 and older at the Tokyo Metropolitan Institute of Gerontology. Three hundred thirty-one were defined as frail, according to Fried's frailty phenotype with the presence of three or more of following criteria: weight loss, weakness, exhaustion, slowness and low physical activity.[1] In the present study, the five different components of the frailty indicators were evaluated as: (1) weight loss: either, answering 'yes' to the question, 'In the last 6 months, have you lost $>2\sim3$ kg unintentionally?' or a body mass index (BMI) <18.5; (2) weakness: hand grip strength <19.0 kg; (3) slowness: usual walking speed <1.10 m/s; (4) exhaustion: answering 'yes' to at least one of two questions, 'I felt that everything I did was an effort' or 'I could not get going'; (5) low physical activity: answering 'true' to at least three of the following four statements, 'I regularly take walks less than once a week,' 'I do not exercise regularly,' 'I do not actively participate in hobbies or lessons of any sort,' and 'I do not participate in any social groups for elderly people or volunteering.' Two hundred (60.4%) of the frail older women were excluded because they were classified into the exclusion criteria or declined participation. The exclusion criteria were: (1) severe knee or back pain; (2) severely impaired mobility; (3) impaired cognition (Mini-Mental State Examination score <24); (4) missing baseline data; and (5) unstable cardiac conditions, such as ventricular dysrhythmias, pulmonary oedema or other musculoskeletal conditions. Of a total of 131 frail older women who participated in the intervention study, body composition was measured in 129 subjects, using SMF-BIA and DXA. The anthropometric assessment of the subjects was conducted at the Tokyo Metropolitan Institute of Gerontology. The participants read and signed the informed consent forms that were approved by the institutional review board before testing. The Clinical Research Ethics Committee of the Tokyo Metropolitan Institute of Gerontology approved the study protocol.

Experimental design

The study model was a cross-sectional analysis of baseline data from the Frailty Intervention Trial. The subjects were instructed to refrain from exercise for 12 h and to refrain from eating for 3 h and drinking for 1 h before the measurements.[24] Subject body composition was measured by SMF-BIA and DXA. Both investigations were performed on the same day 2 h apart.

Anthropometric measurements

With the subjects wearing light clothes and no shoes, body weight was measured to the nearest 0.01 kg using DXA equipment, and height was determined to the nearest 0.1 cm using a fixed-wall-scale measuring device. BMI was calculated as body weight in kilograms divided by height in metres squared. The calf circumference was measured at the point of greatest circumference.

Dual-energy X-ray absorptiometry (DXA)

As a reference method, DXA (QDR-4500 A scanner; Hologic, Waltham, MA, USA) was used for the measurement of whole and regional body composition, including FM, lean soft tissue mass (LM), bone mineral content and bone mineral density. The subjects were positioned for whole-body scans according to the manufacturer's protocol. The subjects lay in a supine position on the scanner table with their limbs close to their bodies. Their body compositions were analysed manually using DXA analysis software (version 9.03 D; Hologic, Waltham, MA, USA). The segmental analyses of the total body into arm, leg and trunk segments were separated manually with anatomical landmarks by the DXA analysis software. Appendicular skeletal muscle mass[25] was calculated as the sum of the LM of both the right and left arms and legs, with the assumption that all non-fat and non-bone tissue was skeletal muscle. Appendicular muscle index was defined as ASM/body height.[23] The subjects were measured while wearing only a standard light cotton shirt to minimise clothing absorption. The DXA machine was calibrated daily against a spine phantom supplied by the manufacturer before testing. In addition, weekly calibration procedures were performed on a density step phantom. The precision error for bone mineral density and bone mineral content were 0.20–0.77% for the spine phantom. Our laboratory assessment of seven subjects demonstrated that the coefficients of variation for FM, LM and bone mineral content with repeated examinations were $<3.0\%$.

Segmental multi-frequency bioelectrical impedance analysis (SMF-BIA)

SMF-BIA was performed with a body composition analyser (InBody 720, Biospace Co. Ltd, Soul, Korea). A tetra-polar 8-point tactile electrode system was used. The system separately measured the impedance of the subjects' right arm, left arm, trunk, right leg and left leg at six different frequencies (1, 5, 50, 250, 500 and 1000 kHz) for each body segment. In accordance with the manufacturer's guidelines, subjects wiped the bottom of their feet with a proprietary electrolyte tissue before standing on the electrodes embedded in the scale platform of the respective analysers. The subjects were instructed to stand upright and to grasp the handles of the analyser, thereby providing contact with a total of eight electrodes (two for each foot and hand). In our study, the within-day coefficient variances for six different frequencies evaluated in nine subjects were 0–1.9%. Proprietary equations from the manufacturer were used to estimate whole and regional body composition variables.

Statistical analysis

The data are expressed as means, s.d., and range (minimum–maximum). A paired Student's *t*-test was used to compare the difference in body composition measurements between the SMF-BIA and DXA. To assess the agreement in body composition parameters of whole-body measurements of FM and LM and appendicular measurements of FM and LM as measured by SMF-BIA and DXA, linear regression and Bland–Altman analyses were conducted. Simple linear regression analyses were performed with DXA body composition parameters as the dependent variable to determine whether the regression line differed significantly from the line of identity. In the Bland–Altman plots,[26] the systematic bias was calculated as the mean difference between methods, and the 95% limits of agreement were calculated as the bias ± 2 s.d. of the differences between methods. As there was evidence of proportional bias for body composition parameters, a Pearson's correlation was performed to quantify the bias observed in the Bland–Altman plots. Multiple regression analysis was performed to determine physical variables that influenced the bias of appendicular LM between DXA and SMF-BIA. The independent variables were age, body weight, height and appendicular LM as determined by DXA. Statistical analyses were performed using the IBM SPSS software version 20 (SPSS Inc., Chicago, IL, USA) and the SigmaPlot software version 12.0 (Systat Software Inc., Chicago, IL, USA). For all tests, statistical significance was set at $P<0.05$.

RESULTS

The characteristics of the frail older women subjects are described in Table 1 with means ± s.d. and ranges. Table 2 describes the body composition parameters obtained by using SMF-BIA and DXA. The means of the body composition parameters estimated by SMF-BIA and DXA were significantly different ($P<0.01$), except for the segmental FM in both legs ($P>0.05$).

Figure 1 displays the results of simple linear regression analyses for whole-body FM and LM, in addition to the appendicular FM and LM parameters as determined by SMF-BIA and DXA. The

correlations between SMF-BIA and the body composition parameters estimated by DXA for whole-body FM and LM and appendicular FM were high ($r > 0.9$, all $P < 0.001$). High coefficients of determination (R^2) for whole-body FM ($R^2 = 0.94$, s.e. of estimate (SEE) = 1.2 kg or 8%), whole-body LM ($R^2 = 0.85$, SEE 1.4 kg or 6%) and appendicular FM (R^2 0.82, SEE 1.1 kg or 15%) between SMF-BIA and DXA were observed. The R^2 coefficient for appendicular LM was moderate ($R^2 = 0.76$, SEE – 0.8 kg or 6%).

In addition, agreements between the two methods were assessed using Bland–Altman plots at the individual level (Figure 2). There was a narrow limit of agreement on the Bland–Altman plots for the whole-body FM and LM and the appendicular FM and LM measurements. Almost all individual plots were within the 95% limit of agreement (mean difference ± 2 s.d.). There was systematic (constant) bias (that is, DXA minus SMF-BIA) with the overestimation of whole-body FM (bias = – 1.2 kg, 95% confidence interval (CI) = 1.5 to – 0.1) and the underestimation of whole-body LM (bias = 2.1 kg, 95% CI = 1.8–2.3) by SMF-BIA. Proportional bias was noted for whole-body FM measurement, with overestimation of the whole-body FM (SMF-BIA) increasing with increasing whole-body FM ($r = -1.42$, $P < 0.01$). However, the Bland–Altman plots indicated no significant proportional bias in whole-body LM measurement ($r = 0.08$, $P = 0.338$). Similarly, the appendicular parameters were systematically biased, with the overestimation of appendicular FM (bias = – 0.3 kg, 95% CI = – 0.5 to – 0.1) and the underestimation of whole-body LM (bias – 1.5 kg, 95% CI = 1.4–1.7) by SMF-BIA. In contrast, the Bland–Altman plots indicated no significant proportional bias in appendicular FM measurement ($r = 0.07$, $P = 0.413$). In addition, proportional bias was noted for appendicular LM measurement, with SMF-BIA tending to underestimate the appendicular LM in the lower range ($r = -1.42$, $P < 0.01$).

In a multiple regression analysis, age ($\beta = 0.051$), body weight ($\beta = -0.055$), height ($\beta = -0.091$) and appendicular LM as determined by DXA ($\beta = 0.302$) were significant contributors to the appendicular LM bias between DXA and SMF-BIA (all, $P < 0.05$) (data not shown). The R^2 in the multiple regression model was 0.421, indicating that 42.1% of the variability in the appendicular LM bias was explained by all variables ($P = 0.001$).

Table 1. Characteristics of the subjects

	Mean ± s.d.	*Range*
Age, years	80.9 ± 2.9	75.0–89.0
Body weight, kg[a]	48.5 ± 8.2	29.2–72.4
Height, cm	146.4 ± 6.0	132.2–161.8
BMI, kg/m^2	22.6 ± 3.5	15.6–31.4
<18.5	32 (24.8)	
18.5–24.9	80 (62.0)	
≥25.0	17 (13.2)	
Calf circumference, cm	32.4 ± 3.0	25.7–41.3
<31.0	46 (35.7)	
Whole-body bone mineral content, g	1111.1 ± 254.0	978.1–1880.1
Whole-body bone mineral density, g/cm^2	0.75 ± 0.10	0.59–1.37

Abbreviation: BMI, body mass index.
Values are means ± s.d., number (%).
[a]Weight derived from whole-body mass measurement by dual X-ray absorptiometry.

DISCUSSION

To our knowledge, this is the first investigation to compare the assessment of whole-body and appendicular body composition from SMF-BIA to DXA device-based measurements in a community-dwelling elderly population of frail women Japanese aged 75 years and older. In particular, our study examined the accuracy of SMF-BIA in the heterogeneous population. Our findings indicate that there was good agreement between the two methods for the estimation of whole-body and appendicular body composition in frail older women subjects, but SMF-BIA underestimated LM and overestimated FM relative to DXA. Moreover, the Bland–Altman plots at the individual level demonstrated non-proportional bias for whole-body LM and appendicular FM.

Table 2. Body composition parameters as determined by DXA and SMF-BIA

Body composition parameters	*DXA*		*SMF-BIA*		*Difference*[a]	
	Mean ± s.d.	*Range*	*Mean ± s.d.*	*Range*	*Mean ± s.d.*	*P-value*[b]
Whole-body measurement						
FM, kg	14.7 ± 5.1	4.4–30.3	16.0 ± 5.7	4.2–33.6	– 1.2 ± 1.5	0.001
LM, kg	32.7 ± 3.6	24.1–42.0	30.6 ± 3.5	23.0–41.5	2.1 ± 1.4	0.001
Percentage of FM, %	29.6 ± 5.9	13.2–41.8	32.0 ± 7.0	12.6–49.7	2.5 ± 2.8	0.001
Segmental body mass measurement						
Right arm FM, kg	1.0 ± 0.4	0.3–2.6	1.7 ± 0.5	0.4–3.0	– 0.2 ± 0.2	0.001
Left arm FM, kg	1.0 ± 0.4	0.3–2.5	1.2 ± 0.5	0.4–3.1	– 0.2 ± 0.2	0.001
Trunk FM, kg	6.7 ± 2.7	1.6–15.5	7.6 ± 3.1	0.9–17.1	– 0.8 ± 1.0	0.001
Right leg FM, kg	2.6 ± 2.0	0.6–5.0	2.9 ± 0.8	0.9–4.7	0.1 ± 0.5	0.177
Left leg FM, kg	2.6 ± 0.9	0.6–4.9	2.6 ± 0.8	0.9–4.7	0.0 ± 0.5	0.816
Appendicular FM, kg	7.2 ± 2.6	1.8–13.6	7.5 ± 2.5	2.6–15.2	– 0.3 ± 1.1	0.001
Right arm LM, kg	1.6 ± 0.2	1.1–2.2	1.4 ± 0.3	0.7–2.1	0.2 ± 0.2	0.001
Left arm LM, kg	1.6 ± 0.2	1.0–2.2	1.4 ± 0.3	0.70–2.1	0.2 ± 0.2	0.001
Trunk LM, kg	16.4 ± 2.0	11.7–21.7	13.7 ± 2.0	9.0–18.2	2.7 ± 1.0	0.001
Right leg LM, kg	5.1 ± 0.6	3.8–6.9	4.5 ± 0.8	2.9–7.0	0.6 ± 0.4	0.001
Left leg LM, kg	5.1 ± 0.6	3.7–7.1	4.5 ± 0.8	3.0–7.2	0.6 ± 0.4	0.001
Appendicular LM, kg	13.4 ± 1.6	10.0–18.0	11.9 ± 2.0	7.7–18.3	1.6 ± 0.9	0.001
Appendicular skeletal muscle index, kg/m^2[c]	6.3 ± 0.7	4.8–8.1	5.5 ± 0.7	4.0–7.9	0.8 ± 0.5	0.001

Abbreviations: DXA, dual X-ray absorptiometry; FM, fat mass; LM, lean soft tissue mass; SMF-BIA, segmental multi-frequency bioelectrical impedance analysis.
Values are means ± s.d. [a]Mean difference between DXA and BIA (that is, DXA minus SMF-BIA), mean (s.d.) [b]P-values for paired *t*-test between DXA and SMF-BIA. [c]Appendicular lean soft tissue mass (kg)/height (m^2).

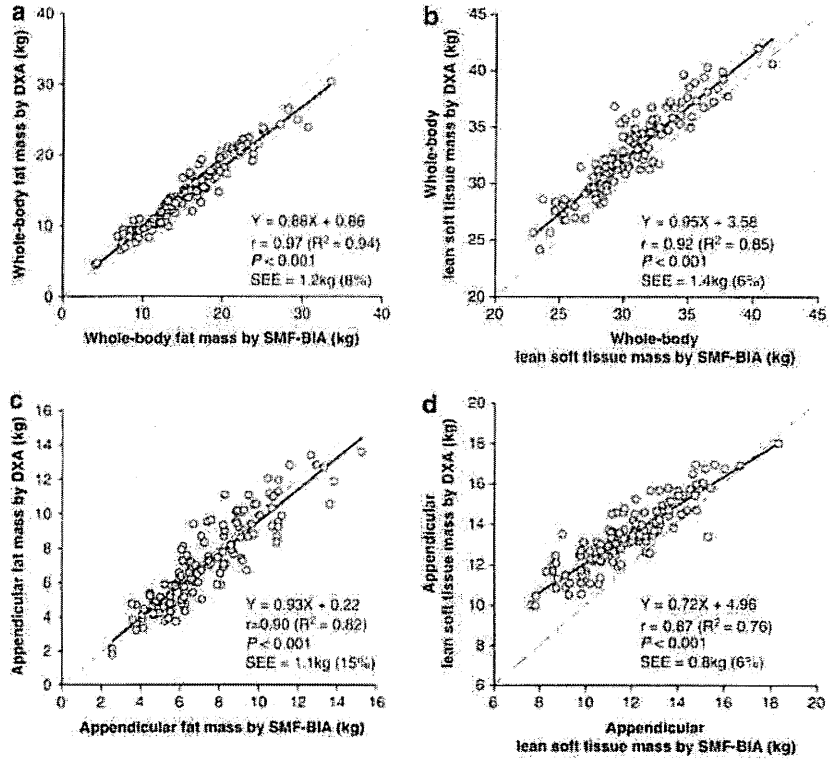

Figure 1. Linear regression between SMF-BIA and DXA. (**a**) Whole-body fat mass, (**b**) whole-body lean soft tissue mass, (**c**) appendicular fat mass and (**d**) appendicular lean soft tissue mass. SEE, s.e. of estimate; solid lines, regression line; dotted lines, identity line.

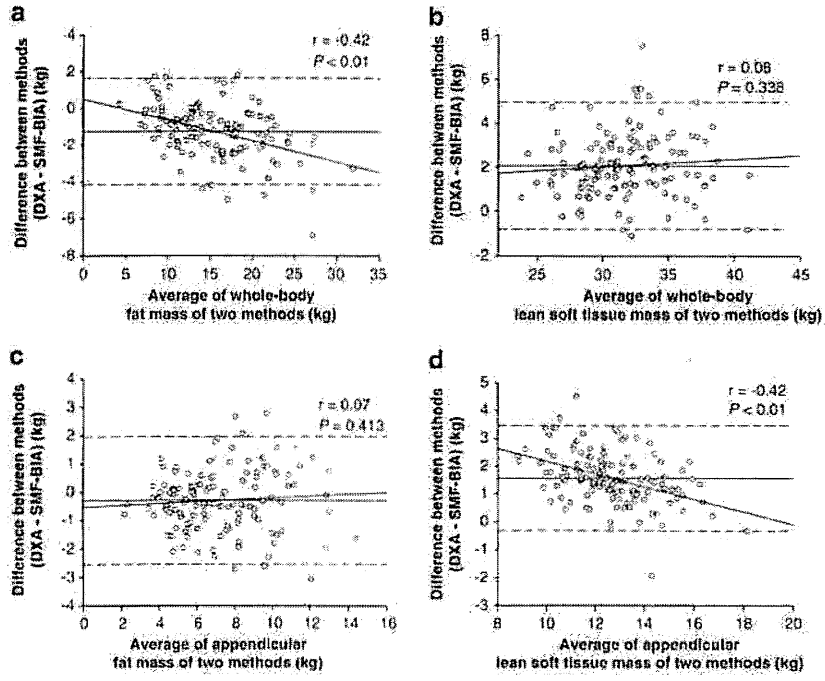

Figure 2. Bland–Altman plots comparing: (**a**) whole-body fat mass, (**b**) whole-body lean soft tissue mass, (**c**) appendicular fat mass and (**d**) appendicular lean soft tissue mass by SMF-BIA and DXA. Solid lines, bias (mean difference); dotted lines, limits of agreement (mean difference ± 2 s.d.).

Previous studies have demonstrated that SMF-BIA provides a valid estimation of body composition using DXA as a reference standard.[21–23] Ling *et al.*[22] reported that SMF-BIA (InBody 720, Biospace Co. Ltd) had a good agreement with DXA (the same device as used in this study, the Hologic QDR-4500A) in the assessment of total body composition of 484 general middle-aged

Dutch subjects. In that study, the coefficients of determination for whole-body FM ($R^2 = 0.94$) and whole-body FFM ($R^2 = 0.95$) in linear regression equations with adjusted gender was significantly greater. Anderson *et al.*[18] found that whole-body FM ($R^2 = 0.95$) and LM ($R^2 = 0.88$) measured with SMF-BIA in 25 women aged 18–45 years had a high correlation and small SEE when using DXA (Lunar DPX-iQ2288) as a reference standard. Houtkouper *et al.*[27] reported that an SEE of 2.0–2.5 kg in men and 1.5–1.8 kg in women is considered ideal in the FFM as calculated by the BIA equations. Whole-body LM, as measured by DXA, is bone mineral-free LM (total FFM − total bone mineral content). Previous studies have reported good correlations between DXA-derived LM and skeletal muscle mass when MRI was used as the criterion ($r = 0.94–0.97$).[11,28–30] Chen *et al.*[11] reported that DXA-derived LM was highly correlated with MRI-derived whole-body skeletal muscle mass ($r = 0.94$) in 101 older women aged 50–79 years. Our study found that the Bland–Altman plots indicated no significant proportional bias in whole-body LM measurement. Therefore, SMF-BIA may provide a valid method for assessing whole-body body composition, particularly for the whole-body skeletal muscle mass, assuming that the LM from DXA is skeletal muscle mass in the frail older women.

We found in our study that SMF-BIA underestimated whole-body LM and overestimated whole-body FM relative to DXA (see Figure 1). In our study, a subanalysis of the FFM indicated that SMF-BIA underestimated the whole-body FFM (bias, 1.2 kg, 95% CI, 0.9–1.5) (data not shown). These results are consistent with a previous study. The method's bias indicated that SMF-BIA underestimated whole-body FFM and overestimated whole-body FM in women with a mean age of 61.2 ± 6.4 years and a mean BMI of 26.1 ± 4.4 kg/m^2.[22] However, Völgyi *et al.*[31] demonstrated the validity of SMF-BIA compared with DXA (GE Lunar Prodig) in 86 Finnish women aged 37–81. These researchers observed that SMF-BIA overestimated FFM in normal and overweight groups by 3.2 and 2.9 kg, respectively. Discrepancies between studies are most likely due to differences in the specificity of subject populations (for example, age, gender, body shape, ethnic groups). In our study, SMF-BIA was used to analyse body composition (InBody 720 device). The measurement of FFM with an InBody 720 device was estimated as TBW/0.73. In addition, FM was calculated as the difference between total body weight and FFM. However, FFM hydration of 0.73 has been shown to be remarkably stable in healthy individuals.[32] The change of FFM hydration has been controversial because of the presence of systematic differences in regards to growth, aging, adiposity, gender, body size and acute or catabolic illness.[33] Heymsfield *et al.*[34] suggest that FFM hydration increases slightly in old age, resulting in a slight, systematic decrease in FFM density. Physiological ageing is associated with several changes that may affect water balance and expose older adults to the risk of dehydration. These changes include a decline in renal function and thirst perception and a reduction of TBW.[35] Thus, SMF-BIA may lead to underestimation of FFM with DXA in the dehydrated state. The extracellular water to intracellular water (ECW/ICW) ratio is a parameter of cellular hydration state. The ECW/ICW ratio ranges from 0.80–1.20 in healthy adults.[33] However, elderly patients displayed chronic cellular dehydration associated with relative extracellular overhydration, which was not evidently related to ageing because healthy elderly volunteers and healthy adults had similar water space distributions.[36] Notably, overhydration is a frequent consequence of organ failures such as kidney impairment, heart failure, chronic obstructive pulmonary disease and liver disease.[37–41] Basrends *et al.*[38] reported that chronic obstructive pulmonary disease patients with extreme FFM wasting are characterised by an increased ECW/ICW ratio despite the relative sparing of FM. Therefore, SMF-BIA is dependent on proprietary regression equations to estimate conductor volume (for example, FFM). As these equations have been formulated from healthy populations, they may contribute to error in body composition measurements in specific populations.

This study measured coefficients of determination for appendicular FM ($R^2 = 0.82$) and appendicular LM ($R^2 = 0.76$) between SMF-BIA and DXA. Our findings are supported by previous studies that indicate SMF-BIA has excellent agreement in the measurement of the segmental LM as both the right and left arms when using DXA as the reference method (interclass correlation coefficient $\geqslant 0.83$).[22] Anderson *et al.*[21] found that the measurement of appendicular LM by SMF-BIA devices (InBody 720 and InBody520) was moderately to strongly associated ($R^2 = 0.62–0.87$) with DXA in men and women aged 18–49. In our study, the appendicular FM was in better agreement between SMF-BIA and DXA than the appendicular LM. To our knowledge, no comparative studies exist that evaluate the accuracy of assessing the segmental body composition at the individual level by SMF-BIA (InBody 720 device) in a population of elderly subjects.

In the present study, despite the significant SMF-BIA overestimation of appendicular FM and the underestimation of appendicular LM with DXA, the Bland–Altman plots indicated a non-proportional bias in appendicular FM measurement. However, we observed a proportional bias in appendicular LM, with SMF-BIA tending to underestimate appendicular LM in the lower range (see Figure 2). These results are in contrast to the results of previous studies evaluating SMF-BIA in healthy adults. Anderson *et al.*[21] found a non-proportional bias for appendicular LM as measured by two types of SMF-BIA devices in 25 women with a mean BMI of 26.1 kg/m^2 and aged 18–45. These different findings are probably the result of methodological differences, with the previous data confined to small subject numbers dispersed over a wide age range. In particular, the findings may be the result of a combination of physical factors such as different body sizes. Bedogni *et al.*[17] found that eight-polar SMF-BIA was precise and gave accurate estimates of TBW in healthy subjects with a BMI range from 18.5–29.9 kg/m^2. In our study population, the prevalence of underweight subjects (BMI values below 18.5 kg/m^2) in the frail older women population was 24%, with a TBW-to-body weight ratio of 44.8%. Thus, the Fried's definition includes weight loss criteria.[1] We found that in multiple regression analysis, the age, body weight, height and appendicular LM determined by DXA were associated with the bias of appendicular LM between DXA and SMF-BIA among the frail older women subjects. Therefore, SMF-BIA may tend to underestimate appendicular LM in the lower range as underweight when using DXA as the reference method.

Our study has some limitations. First, although DXA is a validated 'gold standard' reference method, it is still only an estimate of body composition. Therefore, validation against DXA is not the most accurate analysis possible.[42–44] However, it is included as a reference method because of its wide availability and previous validation. Second, it is likely that the focus of our study on frail older women in communities may not be applicable to populations in nursing homes, hospitals and other institutions. Finally, the hydration status of the study subjects was not determined before the body composition assessment.

In conclusion, the present study confirmed that SMF-BIA had acceptable accuracy in the estimation of whole-body and appendicular FM and LM in frail women subjects aged 75 years and older, although SMF-BIA underestimated LM and overestimated FM relative to DXA. In addition, the individual level accuracy revealed non-proportional bias for whole-body LM and appendicular FM measurement. This may suggest that SMF-BIA can be used in intrapersonal comparisons, with the understanding that SMF-BIA measurements will include errors. Our findings indicate that SMF-BIA would be useful for community-based research in measuring body composition in frail older women populations. Future research efforts should examine the validity of the SMF-BIA models in predicting body composition changes in frail elderly populations with diverse body shapes and compositions.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

We are deeply grateful to the study participants and to the staff of the Tokyo Metropolitan Institute of Gerontology for their cooperation.

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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).

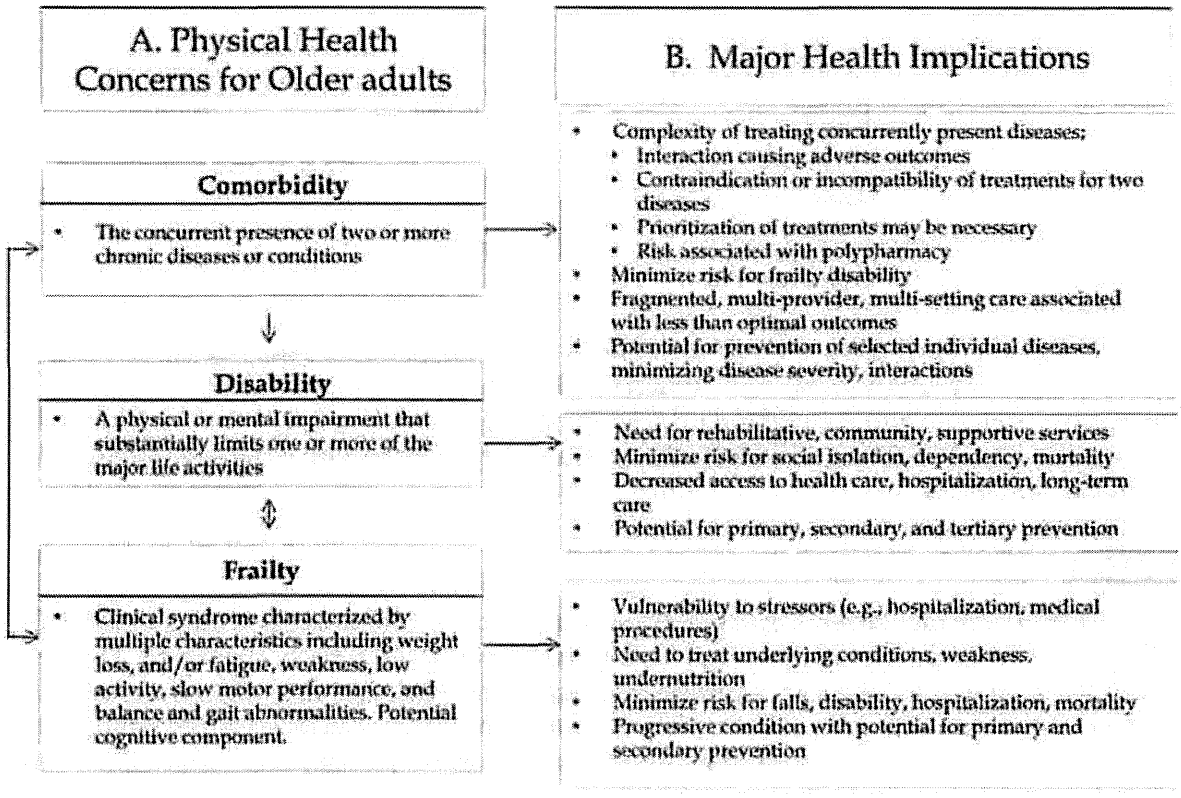

Fig. 1. Comorbidity, disability, and frailty: definitions and major health care implications. (Fried, L.P.; Ferrucci, L.; Darer, J.; Williamson, J.D. & Anderson, G. (2004). Untangling the concepts of disability, frailty, and comorbidity: implications for improved targeting and care. *The Journals of 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.

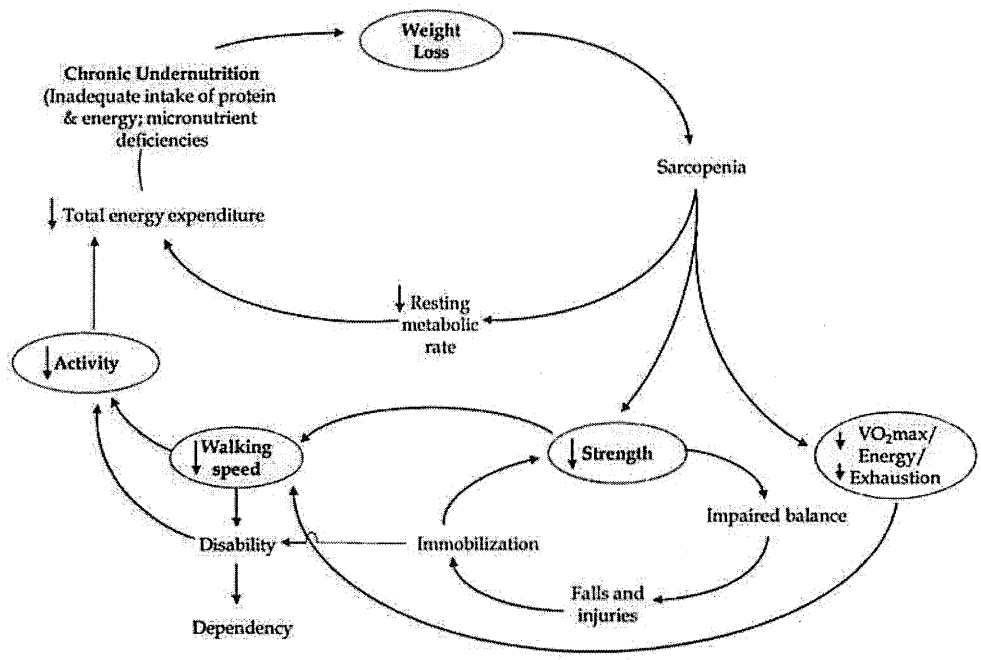

Fig. 2. Cycle of Frailty. (Xue, Q.L.; Bandeen-Roche, K.; Varadhan, R.; Zou, J. & Fried, L.P. (2008). Initial manifestations of frailty criteria and the development of frailty phenotype in the Women's Health and Aging Study II. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, 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).