Measuring Physical Fitness Age, Physical Activity Level and Skeletal Muscle Cell Mass for Japanese Elderly

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Kyoto, Japan
Kyoto

2h16min by "Shinkansen" Super Express

Kyoto
Tokyo

515km
Emergence of aging/aged societies in the world

Average life expectancy (2005)

- Singapore: 81.6 years
- Japan: 82.9 years
For Healthy Aging…

Physical activity & Exercise

Diet
Fraility and Sarcopenia
Physical fitness, physical activity, and skeletal muscle

Fraility and Mortality

Frailty (Fried et al. 2001)

1. Unintentional weight loss:  
   \textit{Sarcopenia (loss of muscle mass)}

2. Weakness:  
   \textit{Lower muscle strength}

3. Poor endurance; Exhaustion  
   \textit{“Exhaustion” (self-report)}

4. Slowness:  
   \textit{Lower walking speed}

5. Low physical activity:  
   \textit{Lower daily physical activity}
Physical fitness, physical activity and skeletal muscle

Physical activity

Skeletal muscle

Physical fitness
Higher Physical fitness = Lower mortality

Cumulative overall mortality up to 13.8 years of follow-up in men according to quartiles of maximal oxygen uptake

VO2max

<27.6

27.6-32.2

32.3-37.1

>37.1 mL/kg/min

Physical capability and mortality

Systematic review and meta-analysis
Grip strength (14 study, n = 53,476)
Walking speed (5 study, n = 14,692)

The summary hazard ratio for the mortality comparing the weakest with the strongest quarter of:

Grip strength: 1.67
Walking speed: 2.87
Chair rise time: 1.96

Cooper et al. BMJ 2010 Sep 9;341:c4467
Various physical performance tests

Which is a good marker of aging?
Biomarker of Aging

Chronological age
(i.e. I am 32 years old. My grand father is 94.)

Biological age
better predict functional capacity at a later age than chronological age


Lower Forced expiratory volume \([FEV_1/Ht^2]\)
Higher Systolic blood pressure [SBP]
Lower Red blood cells [RBC]
Lower Albumin [ALBU]
Higher Blood urea nitrogen [BUN]
Establishing Physical Fitness Age using longitudinal data

The three steps of the selection process to identify the candidate fitness markers of aging.

Step 1: Cross-sectional analysis

The markers must have significant correlation with age.

Step 2: Longitudinal analysis

The longitudinal change of the markers must accord with cross-sectional trend with age.

Step 3: Stability analysis

The markers must have high stability between measurements.
Constructing an index of physical fitness age for Japanese elderly based on 7-year longitudinal data

122 healthy elderly adults aged 60 years and over underwent physical fitness test for 7 years between 2002-2008 at Kyoto Prefectural University of Medicine

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cross-sectional analysis</th>
<th>Longitudinal analysis</th>
<th>Stability analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men (n=52)</td>
<td>Women (n=70)</td>
<td>Men (n=52)</td>
</tr>
<tr>
<td>1. One leg stand with eyes open</td>
<td>-0.294*</td>
<td>-0.377**</td>
<td>-0.275*</td>
</tr>
<tr>
<td>2. One leg stand with eyes closed</td>
<td>-0.154</td>
<td>-0.208</td>
<td>-0.179</td>
</tr>
<tr>
<td>3. Functional reach test</td>
<td>-0.322*</td>
<td>-0.330**</td>
<td>-0.286*</td>
</tr>
<tr>
<td>4. Chair stepping</td>
<td>-0.160</td>
<td>-0.222*</td>
<td>-0.102</td>
</tr>
<tr>
<td>5. Trunk flexion</td>
<td>-0.151</td>
<td>-0.212</td>
<td>-0.150</td>
</tr>
<tr>
<td>6. Leg strength</td>
<td>-0.416**</td>
<td>-0.332**</td>
<td>-0.271*</td>
</tr>
<tr>
<td>7. Grip strength</td>
<td>-0.352**</td>
<td>-0.370**</td>
<td>-0.546**</td>
</tr>
<tr>
<td>8. Vertical jump</td>
<td>-0.529**</td>
<td>-0.580**</td>
<td>-0.456**</td>
</tr>
<tr>
<td>9. Shuttle stamina walk test</td>
<td>-0.352**</td>
<td>-0.460**</td>
<td>-0.205</td>
</tr>
<tr>
<td>10. 6-m walk (speed)</td>
<td>-0.223</td>
<td>-0.411**</td>
<td>-0.303*</td>
</tr>
<tr>
<td>11. 6-m walk (footsteps)</td>
<td>-0.309*</td>
<td>-0.391**</td>
<td>-0.291*</td>
</tr>
<tr>
<td>12. 10-m walk time</td>
<td>0.323*</td>
<td>0.389**</td>
<td>0.538**</td>
</tr>
<tr>
<td>13. Chair stand</td>
<td>0.234</td>
<td>0.354**</td>
<td>0.124</td>
</tr>
</tbody>
</table>

*P<0.05; **P<0.01
Scatterplots and regression lines of the five selected markers of physical fitness based on a cross-sectional data analysis. Results were obtained from 7-year longitudinal data of 70 older women.
FAS = -0.095 x Age + 5.89

FAS = -0.107 x Age + 7.89
Sex difference of physical fitness aging

**Fig. 6** Association between fitness age score (FAS) and chronological age in a longitudinal analysis of 52 older men. To aid interpretation, only the regression lines for FAS with age are shown in this figure.

**Fig. 7** Association between fitness age score (FAS) and chronological age in a longitudinal analysis of 70 older women. To aid interpretation, only the regression lines for FAS with age are shown in this figure.
Sex difference of physical fitness aging

Similar trends for
1. Biological aging
2. Physical fitness aging
3. Muscle mass aging
4. Activity energy expenditure aging

Biological determinants of longevity and morbidity. Individual longevity might be determined by the rate of biological aging, and individual frailty might be determined by physical fitness, which was measured by the extent of maximum reserve capacity.

Although women prototypically have less physical strength/health than men at their peak in early adulthood, the rate of decline across their remaining life span is lower than that of their male counterparts.

Nakamura et al. 2008
Longitudinal change of physical fitness age

Data between 1980-1984
Longitudinal change of FAS (the slope) and mortality

Probability of Survival

Time, year

Increasing FAS
Maintaining FAS
Decreasing FAS

Log-Rank $P = 0.004$

$\Delta$ Physical fitness score

- $<-0.46$
- $-0.46 - 0.30$
- $>0.30$

7th Dec 2012
Recommend “Physical fitness test battery”

- One leg stand with eyes open
- Functional reach test
- Vertical jump
- 10-m walking time
- In addition:
  - Grip strength
  - Sit-to-stand test
  - Knee extension strength
  - Timed up and go test
Physical fitness, physical activity and skeletal muscle
Introduction

Previous researches have shown that physical inactivity increases the risk of coronary heart disease (Batty 2002), stroke (Lee et al. 2003), chronic obstructive pulmonary disease (Garcia-Aymerich et al. 2006), mobility disability (Ip et al. 2012; Landi et al. 2007), falling (Gregg et al. 2000) and cognitive impairment (Middleton et al. 2011) and increases the risk of all-cause mortality (Manini et al. 2006) in the elderly.

Physical activity energy expenditure (PAEE) can be obtained most accurately using doubly labeled water (DLW) method
Calculating total energy expenditure (TEE)
Physical activity level (Activity energy expenditure) and mortality

Kaplan-Meier Survival Plots and Mortality Rates by Tertiles of Physical Activity Level

Health ABC Study. (Pittsburgh & Memphis) n = 302. (aged 70-79 years)
DLW method was analyzed at Schoeller’s Lab.

Physical activity energy expenditure measured by DLW was associated with lower risk of cognitive decline.
Faculty of the doubly labeled water method seminar
San Diego in 2010

Dale A. Schoeller (USA)
John Speakman (UK)
Klaas Westerterp (Netherlands)
Gertjan van Dijk (Netherlands)
Peter Walter (USA)
Yosuke Yamada (JAPAN)

IRMS in my Lab.
for DLW method
and other stable isotope analysis
International collaboration of DLW study for elderly cohort

Japan
Kyoto-Kameoka Study
over 150 elderly aged 65-90 years

USA
Health ABC Study
over 270 elderly aged 70-79 years and
Second DLW study at 80-89 years for subgroup

Some data has been obtained from African countries

The DLW data is lacking for Asian countries.
We are strongly looking for the collaborators in Asia.
Limitation of DLW method

The DLW method cannot be employed widely owing to the costs of the isotopes and the methodological effort involved.

The DLW method does not provide any information about the type and duration of different physical activities.

Practical, but accurate methods are required.
Tri-axial accelerometer (triAC)

Actimarker
Panasonic, Japan

Matsumura Y et al. (2004)
Examples of triAC during moderate walking:

- **x** (anteroposterior): Acceleration data showing slight fluctuations.
- **y** (mediolateral): More pronounced fluctuations compared to **x**.
- **z** (vertical): Least fluctuation compared to **x** and **y**.

**Graph:**
- Horizontal axis: Time [s] (0 to 5).
- Vertical axis: Acceleration (1 G = 9.8 m/s²).

**Observation:**
- The **x** axis shows the least variation.
- The **z** axis shows the most regular pattern due to the vertical motion.
- The **y** axis exhibits the highest variability, indicating significant mediolateral motion.

**Conclusion:**
- The data illustrates the dynamic changes in acceleration during walking, emphasizing the variability in the mediolateral direction.
Relationship between acceleration and oxygen consumption

\[ K_m = \sqrt{\frac{1}{n-1} \left[ \left( \sum_{i=0}^{n} x_i^2 + \sum_{i=0}^{n} y_i^2 + \sum_{i=0}^{n} z_i^2 \right) - \frac{1}{n} \left( \sum_{i=0}^{n} x_i \right)^2 + \frac{1}{n} \left( \sum_{i=0}^{n} y_i \right)^2 + \frac{1}{n} \left( \sum_{i=0}^{n} z_i \right)^2 \right]} \]

\[ K_m : \text{standard deviation of the vector norm of the composite acceleration for a minute} \]

\( r^2 = 0.89 \)

Instructed walking speed [m/min]
- * 40
- ▲ 60
- ■ 80
- × 100
- ○ 120
- ● 140
- + 160

(oxygen consumption (\( V_{O_2} \))
3.5 ml/kg/min
= 1 MET)

Matsumura et al. (2004)
Agreement with DLW measurements

a) Traditional uniAC

b) triAC (Actimarker, Panasonic)

Yamada et al. 2009 EJAP
Limitation of accelerometers

Although researchers have attempted to discriminate several movements using accelerometers, these devices are unable to record the type of activities or to provide an accurate measure of intensity for several types of activities.
## Simplified Physical Activity Record (sPAR)

<table>
<thead>
<tr>
<th>Activity</th>
<th>METs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sleeping time and rest periods</strong></td>
<td></td>
</tr>
<tr>
<td>Walking slowly</td>
<td>2.3</td>
</tr>
<tr>
<td>moderate</td>
<td>2.8</td>
</tr>
<tr>
<td>speedy to fast</td>
<td>3.9</td>
</tr>
<tr>
<td>Bicycling slowly (&lt;15 km/h)</td>
<td>3.2</td>
</tr>
<tr>
<td>moderate (15-20 km/h)</td>
<td>4</td>
</tr>
<tr>
<td>fast (20-23 km/h)</td>
<td>6</td>
</tr>
<tr>
<td>Driving a car</td>
<td>2.5</td>
</tr>
<tr>
<td>Riding in a bus, train or car</td>
<td>1.3</td>
</tr>
<tr>
<td><strong>Daily life activities</strong></td>
<td></td>
</tr>
<tr>
<td>(Including work related activities and housekeeping)</td>
<td></td>
</tr>
<tr>
<td>Sedentary activities (eating, reading, watching TV)</td>
<td>1.3</td>
</tr>
<tr>
<td>Standing activities (self care)</td>
<td>2.1</td>
</tr>
<tr>
<td>Taking a bath by oneself</td>
<td>2.9</td>
</tr>
<tr>
<td>Housekeeping with standing (cooking, washing)</td>
<td>2.5</td>
</tr>
<tr>
<td>Standing (moderate working)</td>
<td>3</td>
</tr>
<tr>
<td>Standing with some walking</td>
<td>3.5</td>
</tr>
<tr>
<td>Gardening (light work)</td>
<td>2.7</td>
</tr>
<tr>
<td>Home repair, painting, tiling</td>
<td>4</td>
</tr>
<tr>
<td><strong>Leisure time activities</strong></td>
<td></td>
</tr>
<tr>
<td>Sedentary activities (tea ceremony, knitting)</td>
<td>1.5</td>
</tr>
<tr>
<td>Standing activities (singing, playing instrument)</td>
<td>2.7</td>
</tr>
<tr>
<td><strong>Sports activities</strong></td>
<td></td>
</tr>
<tr>
<td>Bowling, Gateball, Baseball</td>
<td>3.1</td>
</tr>
<tr>
<td>Gymnastics, tai chi</td>
<td>3.1</td>
</tr>
<tr>
<td>Table tennis, tennis, badminton, volleyball</td>
<td>5.2</td>
</tr>
<tr>
<td>Golfing, Aerobic, Ballroom dancing</td>
<td>3.5</td>
</tr>
<tr>
<td>Jogging slowly, bicycling</td>
<td>4.3</td>
</tr>
<tr>
<td>Swimming, hill climbing, soccer, jogging speedy</td>
<td>9</td>
</tr>
</tbody>
</table>

**Example of records**

<table>
<thead>
<tr>
<th></th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Walking slowly</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bicycling slowly (&lt;15 km/h)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing (moderate working)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gardening (light work)</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bland and Altman plots

Range of Limits of Agreement for TEE, 868 kcal/d; PAEE, 781 kcal/d
Table 4 A summary of studies comparing TEE and PAEE measured using the DLW method in which TEE and PAEE were estimated using conventional methods in the elderly or the adults including participants aged 60 year and over

<table>
<thead>
<tr>
<th>Methods</th>
<th>Mean difference (MJ day(^{-1}))</th>
<th>Range of limits of agreement (MJ day(^{-1}))</th>
<th>N</th>
<th>Age (year)</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PAEE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACCtri</td>
<td>0.03</td>
<td>3.03</td>
<td>14 M, 18 F</td>
<td>75 ± 6</td>
<td>This study</td>
</tr>
<tr>
<td>ACCuni-Lifeorder</td>
<td>−0.91*</td>
<td>3.84</td>
<td>14 M, 18 F</td>
<td>75 ± 6</td>
<td>This study</td>
</tr>
<tr>
<td>ACCuni-Caltrac</td>
<td>−2.75*</td>
<td>6.30</td>
<td>32 M</td>
<td>66 ± 11</td>
<td>Starling et al. (1999)</td>
</tr>
<tr>
<td>−2.07*</td>
<td></td>
<td></td>
<td>35 F</td>
<td>67 ± 9</td>
<td>Starling et al. (1999)</td>
</tr>
<tr>
<td>MLPA</td>
<td>−3.15*</td>
<td>8.14</td>
<td>32 M</td>
<td>66 ± 11</td>
<td>Starling et al. (1999)</td>
</tr>
<tr>
<td>−2.04*</td>
<td></td>
<td></td>
<td>35 F</td>
<td>67 ± 9</td>
<td>Starling et al. (1999)</td>
</tr>
<tr>
<td>−1.31*</td>
<td></td>
<td></td>
<td>19 M</td>
<td>73.4 ± 4.1</td>
<td>Bonnefoy et al. (2001)</td>
</tr>
<tr>
<td>YPAS</td>
<td>−0.44</td>
<td>11.84</td>
<td>32 M</td>
<td>66 ± 11</td>
<td>Starling et al. (1999)</td>
</tr>
<tr>
<td>−0.04</td>
<td></td>
<td></td>
<td>35 F</td>
<td>67 ± 9</td>
<td>Starling et al. (1999)</td>
</tr>
<tr>
<td>0.38</td>
<td></td>
<td></td>
<td>19 M</td>
<td>73.4 ± 4.1</td>
<td>Bonnefoy et al. (2001)</td>
</tr>
<tr>
<td>College Alumni</td>
<td>−1.00*</td>
<td>7.00</td>
<td>19 M</td>
<td>73.4 ± 4.1</td>
<td>Bonnefoy et al. (2001)</td>
</tr>
<tr>
<td><strong>TEE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACCtri</td>
<td>0.03</td>
<td>3.36</td>
<td>14 M, 18 F</td>
<td>75 ± 6</td>
<td>This study</td>
</tr>
<tr>
<td>ACCuni-Lifeorder</td>
<td>−1.06*</td>
<td>4.27</td>
<td>14 M, 18 F</td>
<td>75 ± 6</td>
<td>This study</td>
</tr>
<tr>
<td>−2.37*</td>
<td></td>
<td></td>
<td>24 M</td>
<td>48 ± 10</td>
<td>Rafamantantsoa et al. (2002)</td>
</tr>
<tr>
<td>Armband accelerometer</td>
<td>−0.49*</td>
<td>3.73</td>
<td>13 M, 32 F</td>
<td>35.1 ± 14</td>
<td>St-Onge et al. (2007)</td>
</tr>
<tr>
<td>Flex HR</td>
<td>0.70</td>
<td>7.23</td>
<td>6 M</td>
<td>68.8 ± 2.5</td>
<td>Morio et al. (1997)</td>
</tr>
<tr>
<td>0.60</td>
<td></td>
<td></td>
<td>6 F</td>
<td>71.3 ± 2.4</td>
<td>Morio et al. (1997)</td>
</tr>
<tr>
<td>−0.96*</td>
<td></td>
<td></td>
<td>9 F, 3 M</td>
<td>73 ± 0</td>
<td>Rothenberg et al. (1998)</td>
</tr>
<tr>
<td>0.24</td>
<td></td>
<td></td>
<td>24 M</td>
<td>48 ± 10</td>
<td>Rafamantantsoa et al. (2002)</td>
</tr>
<tr>
<td>Factorial method</td>
<td>−0.10</td>
<td>5.92</td>
<td>6 M</td>
<td>68.8 ± 2.5</td>
<td>Morio et al. (1997)</td>
</tr>
<tr>
<td>−0.80</td>
<td></td>
<td></td>
<td>6 F</td>
<td>71.3 ± 2.4</td>
<td>Morio et al. (1997)</td>
</tr>
<tr>
<td>Activity record</td>
<td>−0.66</td>
<td>7.37</td>
<td>9 F, 3 M</td>
<td>70 ± 0</td>
<td>Rothenberg et al. (1998)</td>
</tr>
<tr>
<td>−1.40*</td>
<td></td>
<td></td>
<td>24 M</td>
<td>48 ± 10</td>
<td>Rafamantantsoa et al. (2002)</td>
</tr>
<tr>
<td>7-d activity recall</td>
<td>1.16*</td>
<td>11.30</td>
<td>19 M</td>
<td>73.4 ± 4.1</td>
<td>Bonnefoy et al. (2001)</td>
</tr>
<tr>
<td>1.26</td>
<td></td>
<td></td>
<td>14 M</td>
<td>74.1 ± 4.1</td>
<td>Seale et al. (2002)</td>
</tr>
<tr>
<td>0.07</td>
<td></td>
<td></td>
<td>13 F</td>
<td>73.5 ± 4.2</td>
<td>Seale et al. (2002)</td>
</tr>
<tr>
<td>QAPSE</td>
<td>−1.50*</td>
<td>9.31</td>
<td>19 M</td>
<td>73.4 ± 4.1</td>
<td>Bonnefoy et al. (2001)</td>
</tr>
<tr>
<td>College Alumni</td>
<td>6.65*</td>
<td>18.74</td>
<td>65 F</td>
<td>59.9 ± 7.5</td>
<td>Mahabir et al. (2006)</td>
</tr>
<tr>
<td>Five City Project</td>
<td>1.72*</td>
<td>7.03</td>
<td>65 F</td>
<td>59.9 ± 7.5</td>
<td>Mahabir et al. (2006)</td>
</tr>
<tr>
<td>CAPS Typical Week</td>
<td>−3.35*</td>
<td>75.14</td>
<td>65 F</td>
<td>59.9 ± 7.5</td>
<td>Mahabir et al. (2006)</td>
</tr>
<tr>
<td>CAPS Four Week</td>
<td>1.22*</td>
<td>24.77</td>
<td>65 F</td>
<td>59.9 ± 7.5</td>
<td>Mahabir et al. (2006)</td>
</tr>
</tbody>
</table>

* Significantly different from zero (P < 0.05)
Comparison of Range of LoA

*From the review by Yamada et al. 2009 Eur J Appl Physiol.*

Physical activity questionnaires or 7-day activity recalls

1679 (best) *(Bonnefoy et al. 2001)* to 4477 (worst) kcal/d

Factorial methods / physical activity records

748 (best) *(Rafamantanantsoa et al. 2002)* to 1761 (worst) kcal/d

Accelerometers or heart rate monitors

779 (best) *(Yamada et al. 2009)* to 1727 (worst) kcal/d

A multisensor device (Armband)

843 kcal/d *(Mackey et al. 2011)*

sPAR on the present study

868 kcal/d for TEE; 781 kcal/d for PAEE

⇒ One of most reliable methods (small LoA)
Duration of “housekeeping with standing,” “gymnastics, tai chi, stretching”, and “swimming, hill climbing, jogging” were positively correlated with PAL.

Duration of “sleeping time and rest periods,” “sedentary activities,” and “slow walking” were negatively correlated with PAL.
Conclusion for measurement of physical activity

The ranges of LoA for triAC and sPAR were sufficiently-small compared with other validation literatures using DLW method.

TriAC and sPAR is useful for assessing TEE and PAEE.

Participation in “housekeeping” and “various sports activities” may be important for maintaining a high activity level in the elderly, in addition to “preventing sedentary behavior”.

Large scale, international collaboration studies are needed in future.
Physical fitness, physical activity and skeletal muscle
Body cell mass and mortality

Istituto di Riposo per Anziani Study. (Padua, Italy) 344名の65歳以上高齢者。
Volpato et al. 2004 J. Am. Geriatric. Soc. 52;886-891
Muscle volume assessment *in vivo*

Sanada et al. 2006 EJAP

The muscle volume (or mass), *per se*, is not strongly associated with mobility disability and mortality.
Muscle mass is not muscle cell mass

- The “muscle mass” estimated by imaging methods (e.g. MRI, CT, DXA, and Ultrasonography) is not “muscle cell mass,”

- Because those “muscle mass” contains also extra-cellular water (ECW), which may not be related to muscle strength.

- We will propose how to eliminate ECW from those “muscle mass,”

- And show it is essential to assess muscle mass-strength relationship in the elderly.
Skeletal muscle tissue holds a large amount of water

From Ohishi 2000

▲ normal muscle tissue of 14-wk-old mouse

▲ after 4wk hindlimb suspension

From Ohishi 2000

Muscle cell

Interstitial space

Intra-cellular water (ICW)

Extra-cellular water (ECW)

Relative expansion of ECW may mask actual muscle atrophy
DXA may not reflect actual muscle atrophy

A creatinine excretion

B DXA

C total body protein

D body water

Proctor et al. AJP 1999

Stimpson, Evans et al. have proposed creatine- (methyl-d3) dilution method.

JAP 2012

-Under development
Segmental bioelectrical impedance spectroscopy (S-BIS)

The regional ICW and ECW can be measured by using segmental multi-frequency bioelectrical impedance analysis (S-MFBIA) or spectroscopy (S-BIS) (Zhu et al. 1998; Bartok and Schoeller 2004; Lee et al. 2008).

Segmental ICW in the limbs derived by S-BIS is proportional to skeletal muscle cell volume (Pietrobelli et al. 2002) and decrease with aging (Yamada et al. 2010).
Relative expansion of ECW during aging


Awarded the 65th Anniversary Celebration Article
My hypothesis

Even in MRI or CT, not to speak DXA, the measured muscle volume contains ECW.

Relative expansion of ECW is observed during aging. “ECW may mask actual muscle atrophy.”

We should measure “creatine mass,” “protein mass,” or “muscle cell mass” for assessing muscle atrophy.

Single frequency BIA measures TBW. Multi-frequency BIA or BIS measures ICW. Thus, BIS have different information compared with BIA.
What’s the difference between BIA and BIS?

Cell membrane composed by phospholipid bilayer acts as capacitor at electric circuit. Thus, low frequency alternating current pass only ECW component, and high frequency current also pass ICW (Giaever and Keese, Nature, 1993).
ROC curve analysis of KES and GS weakness

A) For KES weakness

B) For GS weakness

The AUC was significantly larger in BIS than BIA
Changes of skeletal muscle cell mass during aging

We are conducting international collaborative research in Japan, Finland, and USA.
Acute effect of hospitalization

- ICW in the leg (%baseline)
  - \( y = -1.04x + 100.98 \)
  - \( R^2 = 0.8989 \)
  - Days after hospitalization
  - \( n = 18 \)

- ECW in the leg (%baseline)
  - \( y = 0.2433x + 97.646 \)
  - \( R^2 = 0.5029 \)
  - Days after hospitalization
Easy assessment tools of healthy aging

Skeletal Muscle Cell Mass

Physical Fitness Age

Physical Activity Level

BIS

DLW

sPAR

We’ve measured over 10,000 Japanese.

We are strongly looking for the collaborators in Asia and other countries.