Frailty as deficit accumulation

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Disclosures

With colleagues, I am applying to various Canadian government university-industry schemes for funding to commercialize a version of the Frailty Index, based on a Comprehensive Geriatric assessment.

My colleagues and I are always on the look out for clever young doctors who have undergraduate degrees in engineering, physics, mathematics ...
Frailty is complex and dynamic

- Health
  - Attitudes toward Health and health practices
  - Resources
  - Caregiver

- Illness
  - Disability
  - Dependence on Others
  - Burden on the caregiver

Operationalizing frailty

Variables are *highly specified*: prototype is the frailty phenotype
- Slow mobility
- Weakness
- Weight loss
- Decreased activities
- Exhaustion

Variables are *hardly specified*: prototype is the Frailty Index
- Count health deficits (30-100)
  - age associated but does not saturate;
  - associated with adverse outcome
  - <5% missing data
- Divide by the number of deficits considered.
The building blocks of life do not age

Radioactive Decay Curve

http://www.cerritos.edu/earth-science/images/radioa1.gif
Frailty as deficit accumulation: with age, most problems become more common

(Canadian National Population Health Survey, n= 66,580)

The frailty index is calculated as:

The number of deficits that an individual has
The total number of deficits considered

10 deficits present in an individual = Frailty index score of $10/40 = 0.25$
40 deficits considered in total
Table 1. List of deficits used in the frailty index.

<table>
<thead>
<tr>
<th>Deficits</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Eyesight</td>
<td>5</td>
</tr>
<tr>
<td>2 Hearing</td>
<td>5</td>
</tr>
<tr>
<td>3 Help to eat</td>
<td>3</td>
</tr>
<tr>
<td>4 Help to dress</td>
<td>3</td>
</tr>
<tr>
<td>5 Ability to take care of appearance</td>
<td>3</td>
</tr>
<tr>
<td>6 Help to walk</td>
<td>3</td>
</tr>
<tr>
<td>7 Help to get in and out of bed</td>
<td>3</td>
</tr>
<tr>
<td>8 Help to go to the bathroom</td>
<td>3</td>
</tr>
<tr>
<td>9 Help to take a bath or shower</td>
<td>3</td>
</tr>
<tr>
<td>10 Help to use the telephone</td>
<td>3</td>
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<tr>
<td>11 Help to travel beyond walking distance</td>
<td>3</td>
</tr>
<tr>
<td>12 Help with shopping</td>
<td>3</td>
</tr>
<tr>
<td>13 Help to prepare own meals</td>
<td>3</td>
</tr>
<tr>
<td>14 Help to do housework</td>
<td>3</td>
</tr>
<tr>
<td>15 Ability to take medications</td>
<td>3</td>
</tr>
<tr>
<td>16 Ability to handle own money</td>
<td>3</td>
</tr>
<tr>
<td>17 Self-rated health</td>
<td>5</td>
</tr>
<tr>
<td>18 Troubles prevent normal activities</td>
<td>3</td>
</tr>
<tr>
<td>19 Lives alone</td>
<td>2</td>
</tr>
<tr>
<td>20 Having a cough</td>
<td>2</td>
</tr>
<tr>
<td>21 Feeling tired</td>
<td>2</td>
</tr>
<tr>
<td>22 Nose stuffed up or sneezing</td>
<td>2</td>
</tr>
<tr>
<td>23 High blood pressure</td>
<td>2</td>
</tr>
<tr>
<td>24 Heart and circulation problems</td>
<td>2</td>
</tr>
<tr>
<td>25 Stroke or effects of stroke</td>
<td>2</td>
</tr>
<tr>
<td>26 Arthritis or rheumatism</td>
<td>2</td>
</tr>
<tr>
<td>27 Parkinson’s disease</td>
<td>2</td>
</tr>
<tr>
<td>28 Eye trouble</td>
<td>2</td>
</tr>
<tr>
<td>29 Ear trouble</td>
<td>2</td>
</tr>
<tr>
<td>30 Dental problems</td>
<td>2</td>
</tr>
<tr>
<td>31 Chest problems</td>
<td>2</td>
</tr>
<tr>
<td>32 Trouble with stomach</td>
<td>2</td>
</tr>
<tr>
<td>33 Kidney trouble</td>
<td>2</td>
</tr>
<tr>
<td>34 Losing control of bladder</td>
<td>2</td>
</tr>
<tr>
<td>35 Losing control of bowels</td>
<td>2</td>
</tr>
<tr>
<td>36 Diabetes</td>
<td>2</td>
</tr>
<tr>
<td>37 Trouble with feet or ankles</td>
<td>2</td>
</tr>
<tr>
<td>38 Skin problems</td>
<td>2</td>
</tr>
<tr>
<td>39 Fractures</td>
<td>2</td>
</tr>
<tr>
<td>40 Trouble with nerves</td>
<td>2</td>
</tr>
</tbody>
</table>

Measuring frailty as an index of (40) deficits

Frailty index distribution

- Range = 0 to 0.66, mean 0.16
- The higher the Frailty Index, the more frail the individual
National Population Health Survey - Mean Frailty Index at each cycle in relation to age

Frailty Index (or proportion of health deficits)

Proportional distribution

Age (years)

0.05 0.1 0.15 0.2 0.25 0.3 0.35 0.4 0.45 0.5

A

Rockwood et al., CMAJ 2011; E-pub April 28
5. Why the deficit count matters: transitions from \( n \) deficits to death during 5 years; Canadian Study of Health & Aging, \( N=8,547 \)

Of 8,547 people at baseline, only 18 had \( >\frac{17}{31} \) possible deficits, and only 7 (of 5586) had \( >\frac{17}{31} \) at follow-up.

Survival limit close to the frailty Index of about 0.7

A limit to of the number of deficits suggests exhaustion of reserve capacity – is it operationalizable clinically?

For men & women, deficit accumulation is highly related with mortality ($r>0.95$); men have a higher death rate than women

Shi et al., *BMC Geriatr.* 2011 Apr 20;11:17
Deficits accumulate characteristically, both between groups (community vs. institution/clinical) and within groups*.

The slope is ~0.03.

Slope <0.01.

Failure kinetics of systems with different levels of redundancy

From Gavrilov & Gavrilova Sci Aging Knowledge Env, 2003; 28:1-10
The rate of deficit accumulation slows as the value of the Frailty Index (here based on Comprehensive Geriatric Assessment) increases.

Distribution of the Frailty Index

in 4 successive waves of the Chinese Longitudinal Health and Longevity Study;

Subjects aged 80-99 years; n= 6664

Bennett et al., submitted
5-year transitions between different states of health (empty circles), replicated 5 years later (solid circles)*

The transition probabilities

\[ P_{nk} = \frac{\rho(n)^k}{k!} e^{\rho(n)} (1 - P_{nd}) \]

Goodness of fit
\[ r = 0.99 \]

Legend:
Empty circles: CSHA-1 \(\rightarrow\) CSHA-2
Solid circles: CSHA-2 \(\rightarrow\) CSHA-3

Four parameters of the model and their Interpretation

\[
\bar{k}_0
\]

Average number of deficits given zero deficits at baseline

\[
\beta_1 = \bar{k}_{n+1} - \bar{k}_n
\]
The difference between the average number of deficits at the two incremental deficit numbers at baseline

\[
\ln P_{nd} = \ln P_{0d} + \beta_2 n
\]
The intercept and the slope in the probability of death as a function of the number of deficits at baseline
How can we assess frailty in older adults who are ill?
Defining frailty by counting deficits: data from a medical history & examination
What is added by a Comprehensive Geriatric Assessment
Learning from other complex systems applications
Which patient is the more frail?
Which patient is the more acutely ill?
A Frailty Index based on a Comprehensive Geriatric Assessment identifies a group at the highest risk of dying (some of whom live 18 months).

Studies of frailty as deficit accumulation.

There is remarkable consistency in:
• how deficits accumulate with age.
• the limit to how many things can be wrong.
• how deficit counts change over time.

Some clinical lessons:
• How can we count what people have wrong with them?
• Does our clinical intuition about the “stability” of deficit accumulation mislead?
Acknowledgments

Funding sources:
• Fountain Innovation Fund of the QEII Health Sciences Foundation
• Canadian Institutes of Health Research
• Mathematics of Information Technology and Computer Science program, National Research Council
• Alzheimer Society of Canada
• National Natural Science Foundation of China
• Dalhousie Medical Research Foundation

Colleagues & students:
• Arnold Mitnitski
• Nadar Fallah
• Xiaowei Song
• Ruth Hubbard
• Melissa Andrew
• Michael Rockwood
• Samuel Searle
• Paige Moorhouse, Laurie Mallery
Fig. 1. Cumulative distributions of frailty index scores for people defined as ‘robust’, ‘pre-frail’, and ‘frail’*

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Fig. 2. Cumulative distributions of frailty index scores by number of phenotypic items present.

Survival curves by CHS definition (Panel A) and for each CHS level (Panels B-D) by FI value cut-point*)

A. *Robust*  
B. *‘Robust’*  
C. *‘Pre-frail’*  
D. *‘Frail’*  

Additional comparisons of the CHS definition and the FI: FI stratified by CHS (Panel E); Institutionalization of the Robust stratified by FI (Panel F)

How crucial are the exact components of the CHS definition of frailty?

Prevalence of Disability and Comorbidity in frail older adults

Frailty Index (Frail >0.25FI)

- None: 8.6%
- Only Disability: 18.5%
- Only Comorbidity: 24.8%
- Disability & Comorbidity: 48.1%

Frailty Phenotype (Frail ≥ 3 Phenotypic Frailty Criteria)

- None: 5.2%
- Only Disability: 17.5%
- Only Comorbidity: 17.5%
- Disability & Comorbidity: 59.7%

Theou et al. (in preparation)