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

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)

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>
</tr>
<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) vs Age (years)

Proportional distribution

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 >17/31 possible deficits, and only 7 (of 5586) had >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

Clinical and institutional samples, n=2,573

Community samples n=33,559

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.

![Graph showing the relationship between age and log of the Frailty Index.](image-url)
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 model

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

Goodness of fit

\[ r = 0.99 \]

Legend:

Empty circles: CSHA-1 → CSHA-2
Solid circles: CSHA-2 → CSHA-3

Number of deficits

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
A frailty index based on a Comprehensive Geriatric Assessment
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

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• 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’*

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

Pre-frail

Frail

B. ‘Robust’

Fl<0.25

Fl>0.25

C. ‘Pre-frail’

Fl<0.25

Fl>0.25

D. ‘Frail’

Fl<0.25

Fl>0.25

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?

Disability & Co-morbidity in relation to the Frailty Index

Theou et al. (in preparation)
Prevalence of Disability and Comorbidity in frail older adults

Frailty Index (Frail >0.25FI)
- Only Comorbidity: 24.8%
- Only Disability: 18.5%
- Disability & Comorbidity: 48.1%
- None: 8.6%

Frailty Phenotype (Frail = 3 Phenotypic Frailty Criteria)
- Only Comorbidity: 17.5%
- Only Disability: 17.5%
- Disability & Comorbidity: 59.7%
- None: 5.2%

Theou et al. (in preparation)
Mobility impairment in relation to frailty

Davis et al., Arch Gerontol Geriatr. 2011;53(1):79-83