Measuring Frailty in Older Canadians:
An Analysis of the Canadian Longitudinal Study on Aging (CLSA)

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Aging and Health

- People in Canada are living longer and the population is aging.
    - Nearly 1 in 6 Canadians over 65
    - More people last year over 65 than under 15
    - High healthcare needs for this population
- There is variation in health status among people of the same age
    - Vulnerability to declining health
   - Risk for institutionalization and mortality

Frailty

- Complex, involving multiple systems
- Dynamic, changing over time

Operationalizing Frailty

- Measuring frailty is useful
  - Interventions
  - Healthcare resource needs
- No consensus on etiology or measurement
- Several measurement tools developed
- Two main theories
  - Phenotype of frailty (Fried 2001)
  - Cumulative deficit model (Mitnitski and Rockwood 2001)
- No gold standard
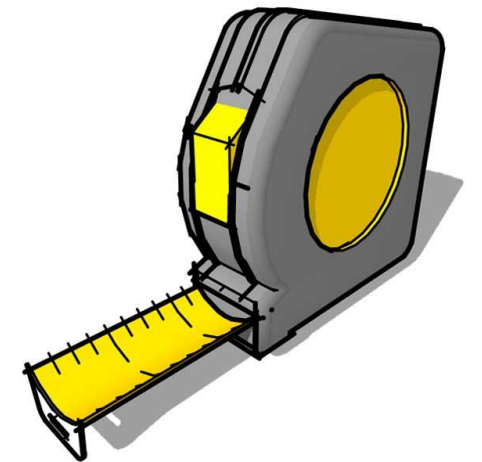
Key theories of Frailty

- Phenotype of Frailty (Fried 2001)
  - Slow mobility
  - Weakness
  - Weight Loss
  - Decreased activities
  - Exhaustion
- Frail if 3 or more

- Cumulative Deficit (Mitnitski 2001)
  - List of health deficits
    - Associated with age
    - Flexible selection of deficits
    - 30-70 items
  - Frailty Index score=
    $$\frac{\text{Number of deficits present}}{\text{Number of items reported}}$$
- Proportion indicates frailty

Objectives

Primary:

- Evaluate frailty of participants in the CLSA

Secondary:

- Study underlying construct of frailty, identify key factors
- Use SEM to compare theoretical measurement models
- Assess validity of frailty measurement

Data Source

- Canadian Longitudinal Study on Aging (CLSA)
  - Large-scale, population-based study
  - Community-dwelling, Canadian adults aged 45-85
  - Wide range of physical, psychological, and social health indicators collected
- CLSA Tracking Cohort
  - 21,241 participants across all 10 provinces
  - Cross-sectional dataset
  - First data release available
    - More data available since Spring 2016 on more than 51,000 participants

Data Collection

- Recruitment
  - Canadian Community Health Survey participants (primary)
  - Provincial healthcare registration databases
  - Random digit dialing
- 60-minute telephone interview
- All data were self-reported
- Data recorded by trained research staff using CATI software

Accessing the Data

- Develop research question and determine data needed

- Explore available variables in CLSA through DataPreview Portal

- Obtain Research Ethics Board approval

- Submit application to Data and Sample Access Committee (DSAC)

- Receive de-identified individual participant dataset

Variables Included

- Health indicators that contribute to frailty

- Chosen based on:
  - Previous primary research studies measuring frailty using original tools
  - Consultation with experts

- Variables organized based on ICF framework (WHO)

- All ICF domains represented

Variables Included

Level of the ICF	Measurement in CLSA
Health conditions	Chronic conditions
	Self-rated health
	Self-rated mental health
Impairments to body structure and function	BMI
	Continence
	Sensory impairment
	Depression (CES-D 10)
	Satisfaction with life (SWLS)
	Anxiety
	Mood disorders
	Cognition (MAT, RAVLT, AFT)
Activity limitations	Functional status (Framingham, EPESE, Nagi, Rosow-Breslow)
	ADL IADL (OARS scale)
Participation restrictions	Social participation
Environmental or contextual factors	Social support availability (MOS Social Support Survey)

Frailty Index

- Variables associated with age and health status
- All variables transformed to a value
  from 1 (maximum deficit) to 0 (no deficit)
  - Self-rated Health: Poor (1) Fair (0.75) Good (0.5) Very Good (0.25) Excellent (0)
  - Chronic Conditions: Present (1) Absent (0)
  - Cognitive Test: 1-[(score)/(maximum achievable score)]
- 90 health deficits included
- Participants with <5% missing data included

Methods

- Exploratory Factor Analysis (EFA)
  - Estimate latent factors from correlations between health indicators
  - Polychoric/tetrachoric correlations – several ordinal/dichotomous variables
  - Observe factor pattern that accounts for the maximum variance
  - No *a priori* predictions for relationships

Methods

- Structural Equation Modelling
  - Specify hypothesized measurement model
    - Hypothesize relationships between observed variables and latent constructs
    - More than one item measuring each latent construct
  - Evaluate fit of predicted model with observed data
  - Step-wise modification of model to achieve best fit

Hypothesized Base Model

- Predicted associations between included variables
- Predicted latent domains based on ICF
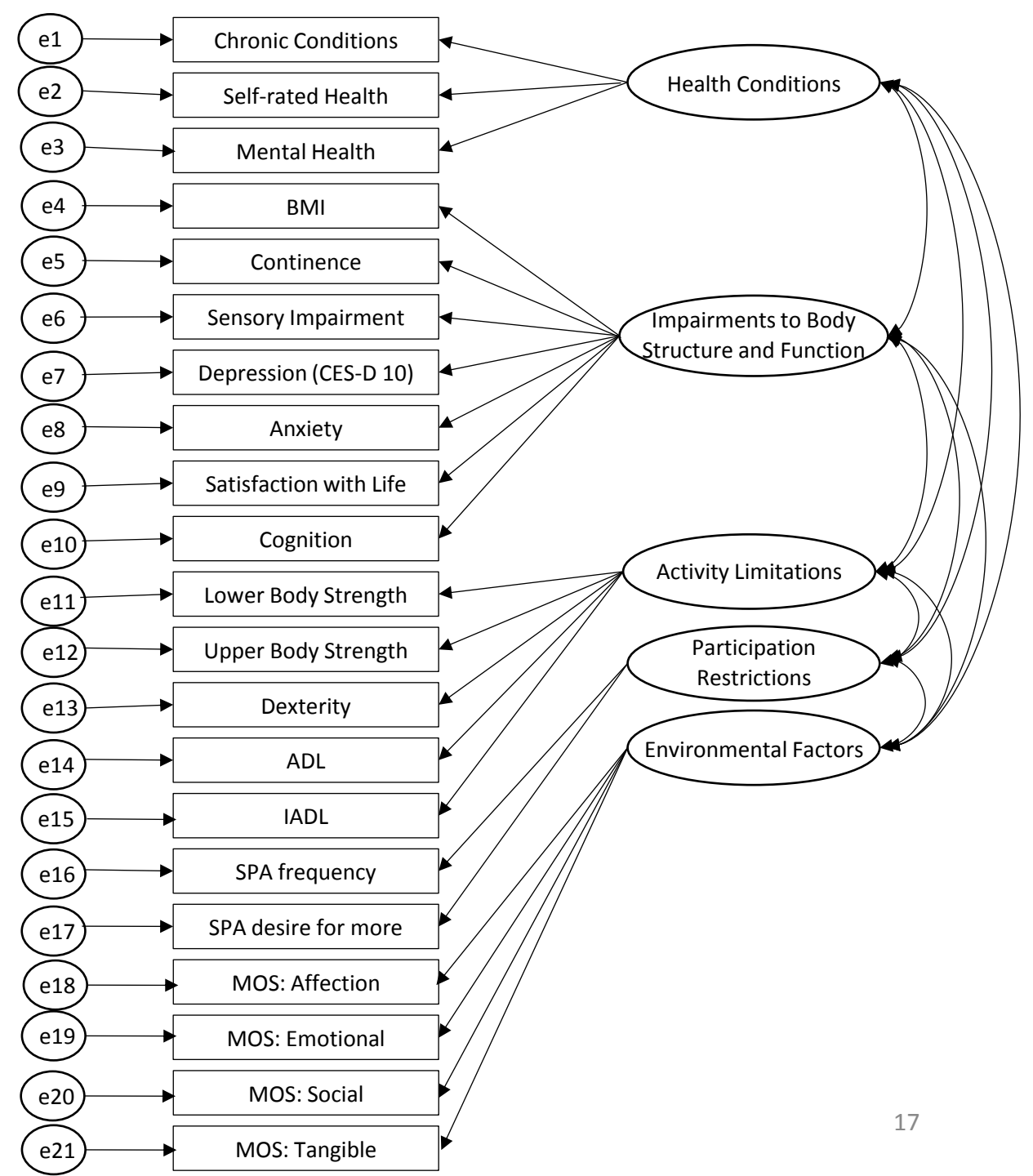
Methods

- Test measurement model fit using split-half reliability
  - Data separated into two sets at random
  - Enables model evaluation in an independent sample

- Evaluate construct validity of the model
  - Test predicted associations with sociodemographic variables

Hypotheses for Construct Validation

What associations would we expect for a measurement of frailty?

- Positive association with:
  - Female gender
  - Age
  - Formal and informal home care
  - Assistive device use

- Negative association with:
  - Education
  - Household income

Descriptive Summary

| Variable	Total Sample		Calibration Sample		Validation Sample	
	N	%	N	%	N	%
Age						
45-54	**5832**	**27.45**	2870	27.02	2962	27.89
55-64	**6563**	**30.90**	3336	31.41	3227	30.39
65-74	**4634**	**21.82**	2326	21.90	2308	21.73
≥75	**4212**	**19.83**	2089	19.67	2123	19.99
Sex - Male	**10405**	**48.99**	5181	48.78	5224	49.19
Total Household Income*						
Less than $20 000	1347	6.78	686	6.92	661	6.64
$20 000-$50 000	5851	29.44	2875	28.99	2976	29.90
$50 000-$100 000	7218	36.32	3553	35.82	3665	36.82
$100 000-$150 000	3215	16.18	1699	17.13	1516	15.23
$150 000 or more	2240	11.27	1105	11.14	1135	11.40
Education*						
Less than secondary school graduation	1986	9.35	997	9.39	989	9.31
Secondary school graduation no post-secondary education	2882	13.57	1453	13.68	1429	13.46
Some post-secondary education	1623	7.64	790	7.44	833	7.84
Post-secondary degree/diploma	**14667**	**69.05**	7348	69.18	7319	68.92
Formal Home Care Services	**1201**	**5.66**	582	5.49	619	5.83
Informal Home Care Services*	**2782**	**13.11**	1444	13.62	1338	12.61
Assistive Devices	**2729**	**12.86**	1353	12.76	1376	12.96
Falls						
No falls reported	**20184**	**95.03**	10095	95.05	10089	95.02
No serious injury due to a fall	367	1.73	185	1.74	182	1.71
Injury receiving medical attention	541	2.55	263	2.48	278	2.62
Injury receiving medical attention and hospitalization	147	0.69	78	0.73	69	0.65

Frailty Index

Measure	Frailty Index
N	20874
Mean (SD)	0.14 (0.07)
Skewness	1.55
Kurtosis	3.81
Range	0.67
Minimum	0.003
Maximum	**0.677**
% Minimum score	**0**
% Maximum score	**0**
N Missing (%)	**367 (1.73%)**
Frailty prevalence at ≥0.25 cut-off (%)	1440 (6.9%)
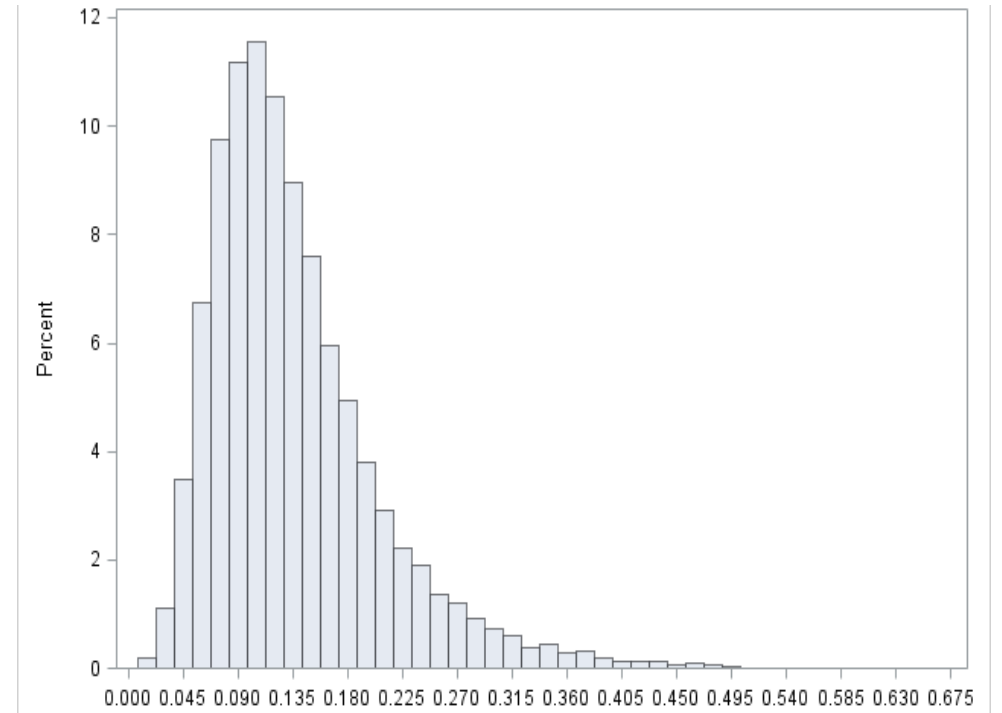
# Exploratory Factor Analysis

- Simple Factor Analysis
- Varimax rotation
- Minimum eigenvalue criterion suggests 16 factors
- 3 factors retained based on Scree test
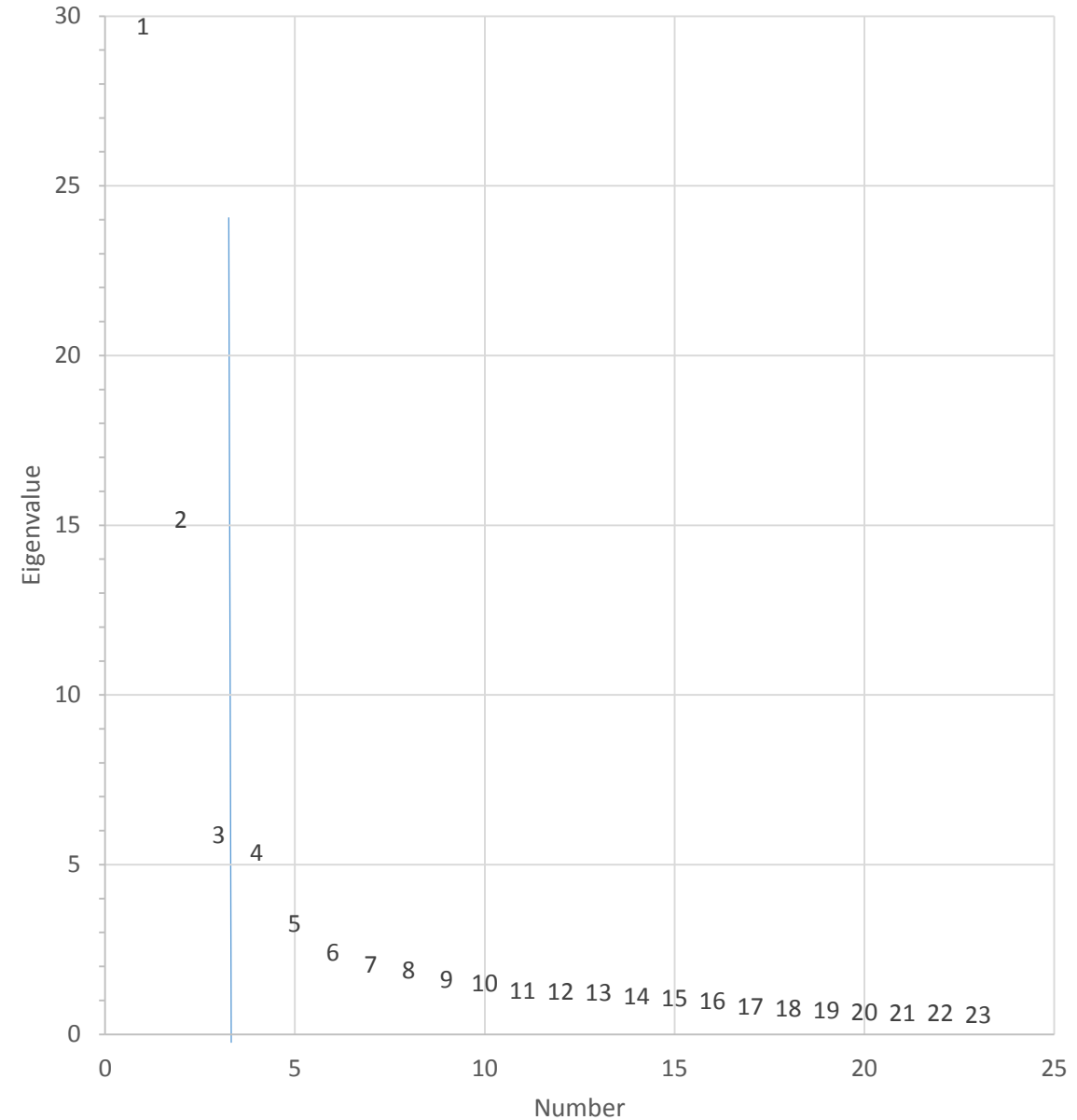
Exploratory Factor Analysis

- Three key factors:
    1. Functional status, ADL, IADL, self-rated health, some chronic conditions
    2. SWLS Scale, positive depressive symptoms from CES-D 10, self-rated mental health
    3. CES-D 10 Scale, reported mood disorder
- Strongest contributors to the variance among observations
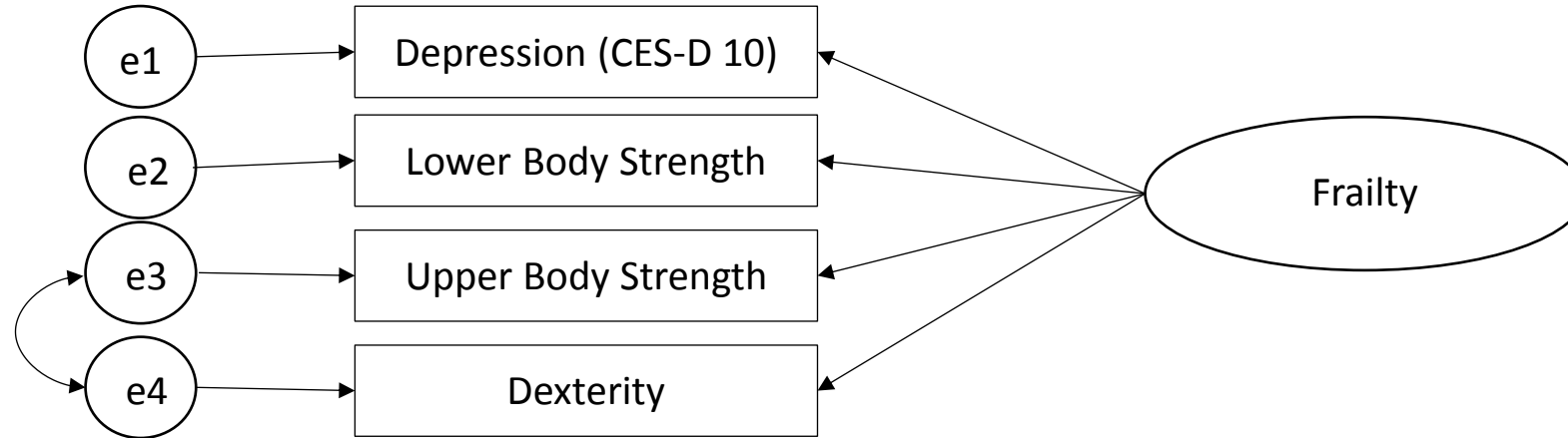- Patterns persist when stratified by sex and age

SEM Base Model
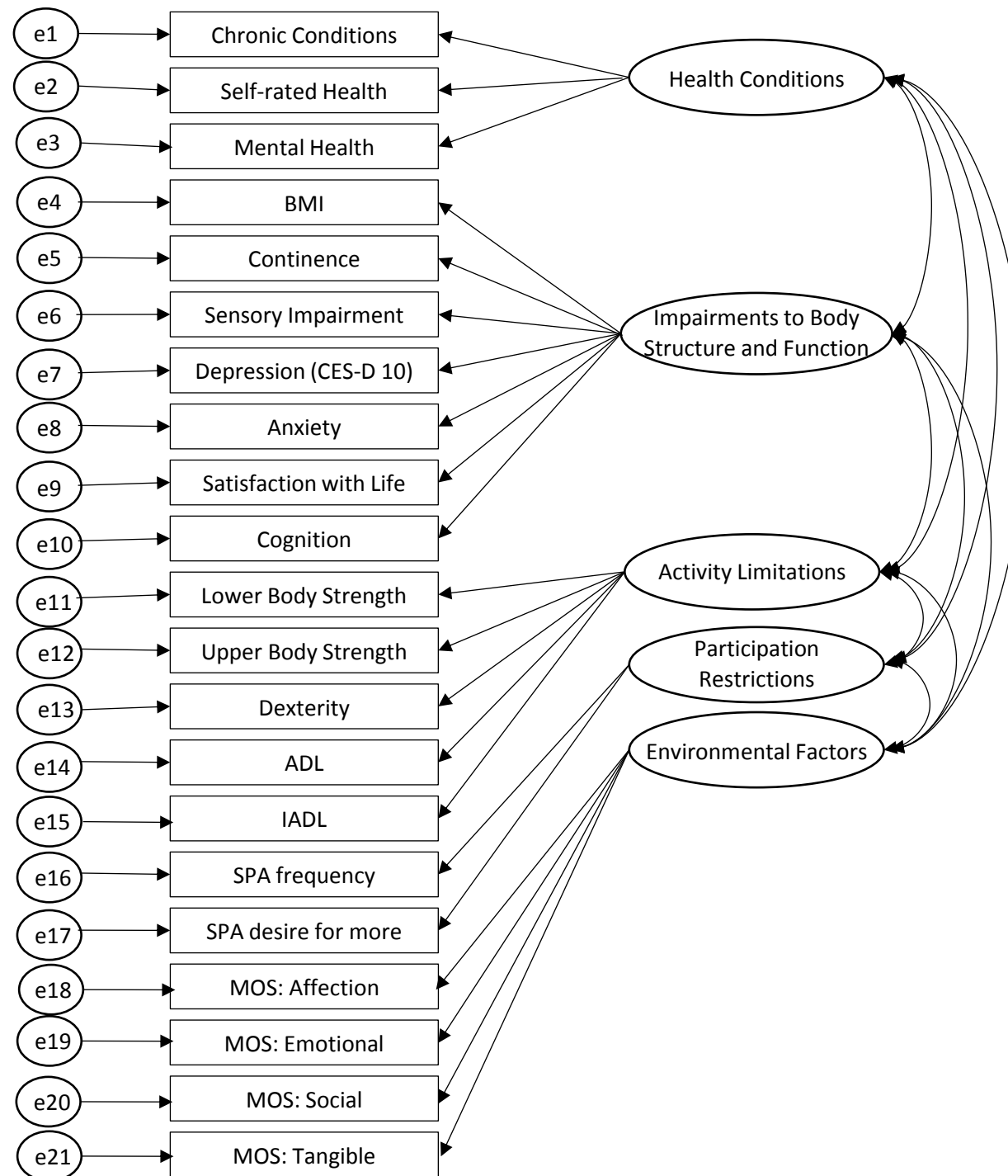
SEM Modified Model
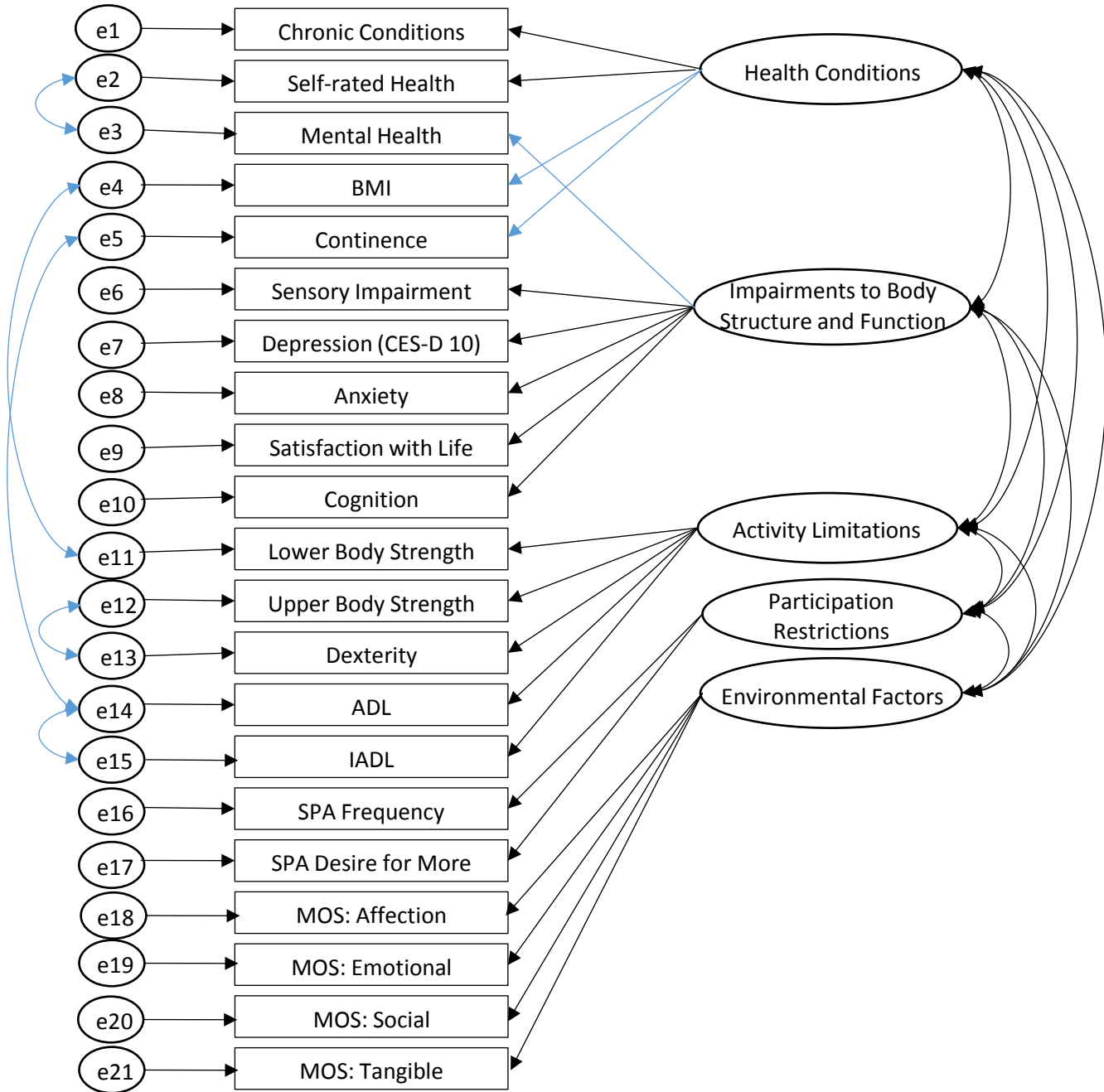
Simplified Frailty Model

SEM Model Fit

	Model	Chi-square	Degrees of freedom	CFI	NNFI	RMSEA	AIC
Calibration Sample	Base	6865.25	179	0.900	0.882	0.063	6969.25
	Modified	2959.41	174	0.958	0.950	0.041	3073.40
	Simplified	2.99	1	0.999	0.999	0.015	20.00
Validation Sample	Base	6504.19	179	0.902	0.885	0.061	6608.19
	Modified	2764.88	174	0.960	0.952	0.040	2878.88
	Simplified	10.53	1	0.999	0.999	0.032	28.53

Simplified Frailty Scale

- Four domains based on model best fitting the data: Strength, Mobility, Dexterity, Depressive Symptoms

- Scored based on recommendations from Norman & Streiner (2005)

- Items within domains weighted equally

- All 4 domains assigned equal weights to avoid unintentional weighting

- SF score is an average of domain scores:
  - 0 = Minimum Frailty
  - 1 = Maximum Frailty

Frailty Indices

Measure	Frailty Index	Simplified Frailty Scale
N	20874	21105
Mean (SD)	0.14 (0.07)	0.09 (0.10)
Skewness	1.55	2.53
Kurtosis	3.81	8.60
Range	0.67	0.96
Minimum	0.003	0.000
Maximum	0.677	0.956
% Minimum score	0	6.7
% Maximum score	0	0
N Missing (%)	367 (1.73)	136 (0.64)
Frailty prevalence at ≥0.25 cut-off (%)	**1440 (6.9%)**	**1303 (6.3%)**

Frailty Index

Simplified Frailty
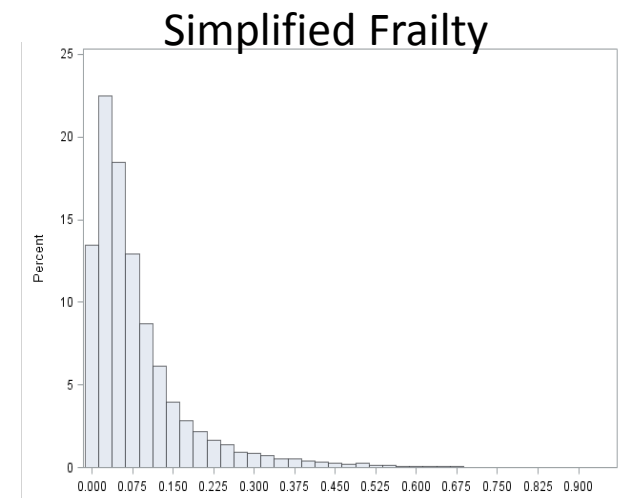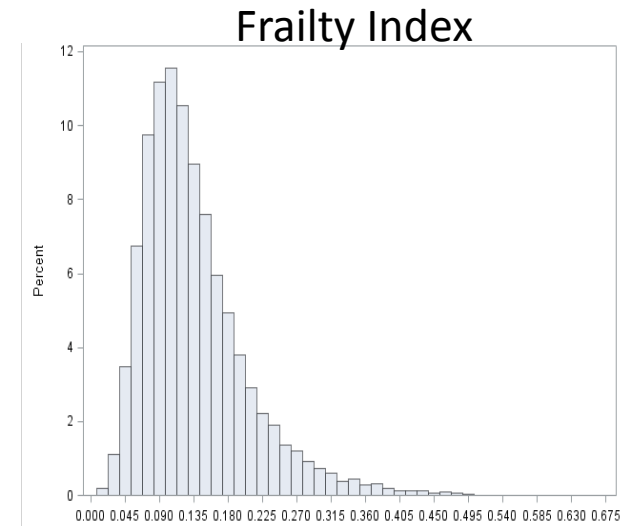
Correlations with Outcomes

	Age	Sex (M)	Income	Education	Injury from Fall	Serious Injuries	Informal Home care	Formal Home Care
Frailty Index	0.170	-0.119	-0.339	-0.174	0.122	0.122	0.324	0.300
Simplified Frailty	0.097	-0.118	-0.259	-0.155	0.107	0.123	0.329	0.315

Frailty Indices by Age Group
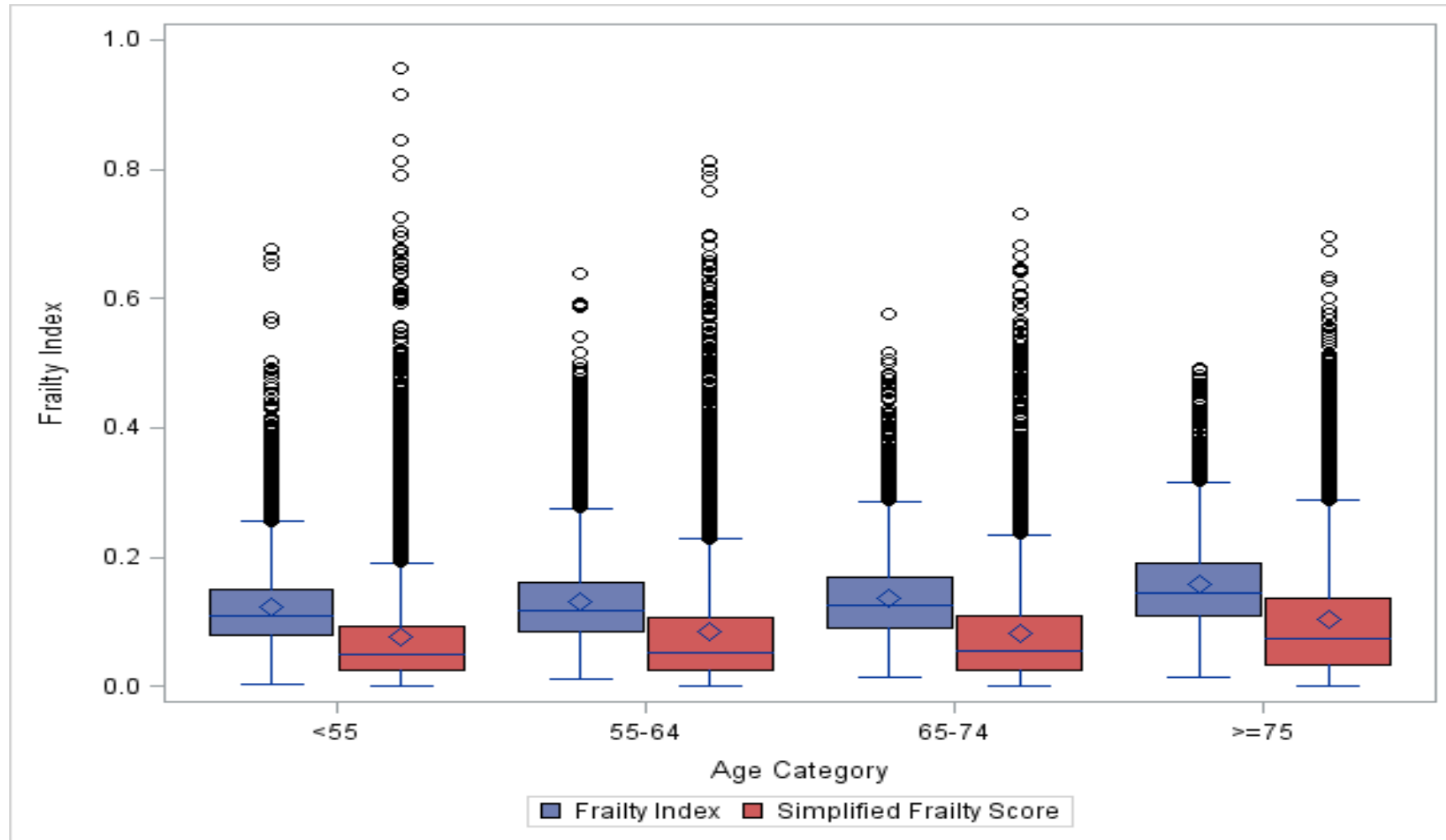
Scale Agreement

FI	SF		Total
	0-0.25	0.25+	Total
0-0.25	19003	357	19360
0.25+	494	946	1440
Total	19497	1303	20800

Frequency Missing = 441

Simple Kappa Coefficient	
Kappa	**0.6679**
ASE	0.0107
95% Lower Conf Limit	0.6470
95% Upper Conf Limit	0.6888

Test of H0: Kappa = 0	
ASE under H0	0.0069
Z	96.4658
One-sided Pr > Z	<.0001
Two-sided Pr > |Z|	<.0001

- Using 0.25 cut-off for frailty
- Significant agreement beyond chance
- Under 0.8 threshold for "very good"

Exploring Cases of Scale Disagreement

- Comparable scale associations with health outcomes
- Frailty Index more sensitive to age and chronic conditions

	Frailty Index ≥0.25, Simplified Frailty <0.25 N=494	Frailty Index <0.25, Simplified Frailty ≥0.25 N=357
	N (%)	N (%)
Age (category)		
45-54	102 (21)	73 (20)
55-64	128 (26)	122 (34)
65-74	106 (21)	74 (21)
≥75	158 (32)	88 (25)
Sex - Male	210 (42)	155 (43)
Informal Care	95 (19)	58 (16)
Formal Care	151 (31)	146 (41)
Injuries	107 (22)	63 (18)
Falls	61 (12)	27 (8)
Assistive Devices	173 (35)	160 (45)
	Mean (SD)	Mean SD)
Age (years)	66.3 (11.2)	64.8 (10.6)
Chronic Conditions	8.4 (2.7)	4.5 (2.2)

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Summary

- Explored factor structure of frailty indicators
- SEM model showed all variables contributed significantly
- Modified and Simplified models had good fit
- Model fit results persisted in independent dataset
- Frailty Index and Simplified Frailty showed good construct validity

Limitations

- Secondary data limited variable selection
- Cross-sectional, difficult to discern predictors from outcomes
- Missing data may exclude vulnerable participants
- Simplified Frailty scale may measure disability

Conclusions

- Frailty Index
  - Simple to calculate and interpret
  - Commonly used, generalizable
  - Includes all ICF health domains
  - Recommended for CLSA and similar datasets
- Simplified Frailty
  - Acceptable agreement with Frailty Index
  - Similar domains to Phenotype of Frailty model
  - May identify important components of frailty
  - Fewer variables, potential for use where data collection is limited
  - Should be explored further

Next Steps

- Further validation of Simplified Frailty using longitudinal data (CSHA)
- Examine frailty in relation to prospective outcomes
- Compare sensitivity to change of Frailty Index and Simplified Frailty

Supplementary Slides

Health Deficits Included in Frailty Index with mean FI contribution (deficit)

Variable	N	Mean	Std Dev
OARS scale: Able to travel	21222	0.012	0.111
OARS scale: Able to do housework	21179	0.060	0.238
OARS scale: Able to use telephone	21237	0.004	0.065
OARS scale: Able to handle money	21229	0.004	0.066
OARS scale: Able to go shopping	21213	0.021	0.145
OARS scale: Able to prepare meals	21215	0.009	0.095
OARS scale: Able to take medicine	21221	0.004	0.061
OARS scale: Able to dress	21223	0.010	0.101
OARS scale: Able to get out of bed	21235	0.007	0.085
OARS scale: Able to feed	21234	0.001	0.034
OARS scale: Able to take care of appearance	21236	0.003	0.051
OARS scale: Able to walk	21225	0.018	0.131
OARS scale: Able to take bath	21232	0.014	0.116
OARS scale: Trouble to get in time to bathroom	21199	0.059	0.183
Affection - MOS Subscale	21064	0.137	0.203
Emotional and Informational Support - MOS Subscale	20560	0.185	0.198
Positive Social Interaction - MOS Subscale	20964	0.184	0.204
Tangible Social Support - MOS Subscale	20736	0.184	0.212
Frequency of Community-Related Activity Participation	21029	0.266	0.171
Desire to participate in more activities (Past Year)	21214	0.389	0.488
BMI Classification	21135	0.328	0.311

Variable	N	Mean	Std Dev
Arthritis (any type)	21106	0.389	0.488
Asthma	21215	0.111	0.314
Stroke or CVA (cerebrovascular accident)	21218	0.018	0.134
Memory problem	21230	0.021	0.144
Bowel disorder	21203	0.087	0.281
Glaucoma	21200	0.045	0.208
Allergies	21183	0.371	0.483
Osteoporosis	21190	0.095	0.293
High blood pressure or hypertension	21213	0.382	0.486
Diabetes, borderline diabetes, or high blood sugar	21222	0.167	0.373
Heart attack or myocardial infarction	21211	0.062	0.241
Mini-stroke or TIA (transient ischemic attack)	21177	0.035	0.185
Parkinsonism or Parkinson's Disease	21230	0.004	0.061
Cataracts	21214	0.249	0.432
Back problems excluding fibromyalgia and arthritis	21218	0.245	0.430
Heart disease (including congestive heart failure)	21195	0.103	0.304
Migraine headaches	21213	0.137	0.344
Intestinal or stomach ulcers	21215	0.077	0.267
Over-active thyroid gland	21071	0.022	0.147
Emphysema, chronic bronchitis, COPD (chronic obstructive pulmonary disease)	21224	0.068	0.251
Angina (or chest pain due to heart disease)	21221	0.054	0.226
Peripheral vascular disease or poor circulation	21184	0.072	0.258
Dementia or Alzheimer's disease	21237	0.002	0.045
Epilepsy	21226	0.008	0.088
Urinary incontinence	21219	0.088	0.284
Macular degeneration	21198	0.041	0.199
Under-active thyroid gland	21066	0.116	0.320
Kidney disease or kidney failure	21213	0.028	0.165
Bowel incontinence	21226	0.023	0.150
Cancer	21225	0.154	0.361
Mood disorder	21221	0.146	0.353
Anxiety disorder	21216	0.074	0.261

Health Deficits Included in Frailty Index

Variable	N	Mean	Std Dev
Self-rated general health	21220	0.352	0.250
Self-rated mental health	21223	0.268	0.224
Eyesight rating	21222	0.328	0.236
Hearing rating	21222	0.341	0.254
SWLS scale: Satisfied with life	21194	0.172	0.247
SWLS scale: Life close to ideal	21139	0.237	0.283
SWLS scale: Have important things in life	21147	0.158	0.226
SWLS scale: Would change almost nothing about life	21110	0.322	0.336
SWLS scale: Life conditions excellent	21175	0.241	0.289
CES-D 10 scale: Frequency feel fearful or tearful	21195	0.115	0.231
CES-D 10 scale: Frequency feel happy	21154	0.155	0.249
CES-D 10 scale: Frequency feel could not get going	21200	0.162	0.271
CES-D 10 scale: Frequency trouble concentrating	21169	0.214	0.303
CES-D 10 scale: Frequency feel depressed	21211	0.107	0.231
CES-D 10 scale: Frequency feel everything is an effort	21189	0.176	0.287
CES-D 10 scale: Frequency sleep is restless	21189	0.367	0.361
CES-D 10 scale: Frequency easily bothered	21181	0.185	0.280
CES-D 10 scale: Frequency feel hopeful about the future	20897	0.206	0.309
CES-D 10 scale: Frequency feel lonely	21208	0.124	0.255
Mental alternation test (T score)	18605	0.481	0.241
RAVLT first recall (T score)	19332	0.494	0.243
RAVLT second recall (T score)	19227	0.494	0.243
Animal fluency test (T score)	20188	0.490	0.251
Difficulty walking up and down stairs	21227	0.058	0.178
Difficulty walking 2 to 3 blocks	21202	0.066	0.206
Difficulty taking force or impact in arms, hands	21122	0.071	0.204
Difficulty stooping, crouching or kneeling	21224	0.154	0.266
Difficulty pulling/ pushing large objects	21200	0.061	0.198
Difficulty handling small objects	21236	0.029	0.116
Difficulty making bed	21216	0.026	0.125
Difficulty standing up after sitting	21229	0.081	0.174
Difficulty washing back	21220	0.046	0.164
Difficulty lifting 10 pounds	21226	0.043	0.166
Difficulty standing for a long period	21215	0.078	0.204
Difficulty sitting for a long period	21225	0.047	0.150
Difficulty extending arms above shoulders	21229	0.054	0.165
Difficulty using a knife	21235	0.011	0.076

Functional Status Variables

- Mobility/lower body function
  - Difficulty walking 2 to 3 blocks
  - Difficulty walking up and down stairs
  - Difficulty standing for a long period
  - Difficulty stooping, crouching or kneeling
  - Difficulty standing up after sitting
  - Difficulty sitting for a long period

- Strength/upper body function
  - Difficulty making bed
  - Difficulty pulling/ pushing large objects
  - Difficulty lifting 10 pounds
  - Difficulty taking force or impact in arms, hands
  - Difficulty washing back

- Dexterity
  - Difficulty using a knife
  - Difficulty handling small objects
  - Difficulty extending arms above shoulders

EFA Rotated Factor Pattern

	Factor 1	Factor 2	Factor 3
Difficulty making bed	0.974	0.021	0.079
OARS scale: Able to get out of bed	0.964	0.078	0.046
OARS scale: Able to take bath	0.964	-0.006	-0.002
OARS scale: Able to do housework	0.960	0.007	0.052
OARS scale: Able to go shopping	0.958	0.044	0.049
OARS scale: Able to walk	0.957	0.029	0.030
OARS scale: Able to prepare meals	0.956	-0.005	0.022
Difficulty washing back	0.955	0.032	0.068
OARS scale: Able to dress	0.943	-0.034	-0.002
OARS scale: Able to travel	0.940	0.021	0.008
Difficulty pulling/ pushing large objects	0.933	0.035	0.109
Difficulty using a knife	0.933	0.042	0.049
Difficulty standing for a long period	0.930	0.022	0.076
Difficulty walking 2-3 blocks	0.928	0.015	0.052
Difficulty lifting 10 pounds	0.925	0.054	0.145
Difficulty walking up and down stairs	0.922	0.030	0.075
Difficulty standing up after sitting	0.914	-0.011	0.094
Difficulty taking force or impact in arms or hands	0.911	0.031	0.082
OARS scale: Able to take medicine	0.903	-0.052	-0.045
OARS scale: Able to take care of appearance	0.892	0.088	0.060
Difficulty extending arms above shoulders	0.888	-0.009	0.058
Difficulty handling small objects	0.882	-0.052	0.018
OARS scale: Able to handle money	0.861	0.049	0.096
Difficulty stooping, crouching, or kneeling	0.851	-0.004	0.059
OARS scale: Trouble getting to bathroom in time	0.776	-0.045	0.074
OARS scale: Able to use telephone	0.767	-0.105	-0.067
Parkinson's Disease	0.745	-0.073	-0.042
Self-rated Health	0.718	0.252	0.109
Difficulty sitting for a long period	0.697	0.097	0.268
OARS scale: Able to feed	0.623	0.143	0.116
Peripheral vascular disease	0.600	-0.108	-0.069
Stroke or CVA	0.595	-0.126	-0.112
Epilepsy	0.574	-0.001	0.026
Osteoporosis	0.560	-0.159	-0.024

	Factor 1	Factor 2	Factor 3
SWLS scale: Satisfied with life	0.078	0.905	0.292
SWLS scale: Life close to ideal	0.078	0.898	0.245
SWLS scale: Life conditions excellent	0.235	0.885	0.256
SWLS scale: Have important things	0.039	0.870	0.170
SWLS scale: Would change almost nothing	-0.086	0.859	0.191
CES-D 10 scale: Frequency feel hopeful about the future	-0.060	0.723	0.347
CES-D 10 scale: Frequency feel happy	-0.128	0.706	0.501
Self-rated Mental Health	0.091	0.587	0.469
Frequency of Community-Related Activity Participation	0.280	0.350	-0.067

	Factor 1	Factor 2	Factor 3
CES-D 10 scale: Frequency feel fearful or tearful	0.021	0.315	0.830
CES-D 10 scale: Frequency easily bothered	0.095	0.284	0.819
CES-D 10 scale: Frequency trouble concentrating	0.085	0.213	0.803
CES-D 10 scale: Frequency feel depressed	0.032	0.512	0.775
CES-D 10 scale: Frequency feel everything is an effort	0.428	0.300	0.720
CES-D 10 scale: Frequency feel could not get going	0.326	0.346	0.710
CES-D 10 scale: Frequency sleep is restless	0.252	0.131	0.583
CES-D 10 scale: Frequency feel lonely	0.024	0.547	0.555
Mood disorder	0.033	0.402	0.510
Anxiety disorder	0.089	0.308	0.471