Associations among age-related rates of change in physical function:

A coordinated analysis

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Abstract

Declines in physical function are a well-documented feature of later life that can lead to or predict mobility limitations, falls and death (Laukkanen, Heikkinen, Kauppinen, 1995). On average, estimates from longitudinal studies suggest grip strength loss of from 0.71 kg/year over 9 years (in women initially aged 70-79; Xue et al., 2010) to 1.49 kg/year over 27 years (men initially 65-68; Rantanen et al., 1998). In a sample with similar average initial age, but including a wider cross-section of ages, yearly estimated declines reached 2.2 kg/year (over 6 years; MacDonald et al., 2011). Peak expiratory flow loss of 7.4 l/minute were reported in the latter. Cross-sectional evidence, while confounded with generational differences, suggests differences of 0.5 to 0.8 kg/year in men aged 70-80 (Cooper et al., 2011; Ribom, 2010).

Associations among the changes in different physical functions may exist, and may stem from common indexing of general functional decline or from a causal and possibly reciprocal cascade of decline in which one leads to another. For example, general XXX (atrophy and disuse) associated with biopsychosocial aspects of the aging process may result in general loss of physical function. Alternatively, or concurrently, loss in one function may lead to loss in another, such as declining pulmonary function may limit walking speed, which may in turn contribute to loss of pulmonary and cardiac fitness.

Based on the cross-sectional evidence, it seems that upper body strength (e.g., grip strength), lower body strength (e.g., walking speed), and pulmonary function are associated (Cook et al., 1995; Hirsch et al., 1997; Pegorari, Ruas & Patrizzi, 2013). In particular, walking speed and pulmonary function may have a functional association (need to identify and summarize what is out there; [there is a 2013 paper on Nigerian amateur boxers…!]), although grip strength cut points have also been developed to predict risk of mobility limitation (Sallinen et al, 2010). Timed-up-and-go, which involves both upper and lower body strength, would be expected to correlate more highly with grip strength than would walking speed alone, due to the construct overlap.

Cross-sectional data and analysis, however, represent associations between expected differences among individuals of different ages at a particular point in time, rather than association between changes occurring within individuals over time. Given the risk that these cross-sectional findings may be driven by generational changes (Schaie…) or mean trends (Hofer, Berg & Era, 2003), it is important to validate them, where possible, in longitudinal data. This will address the question of whether it is likely that particular individuals who experience decline in a particular physical function are likely to more or less concurrently experience decline in other physical functions.

The current research simultaneously evaluates cross-sectional, longitudinal, and patterning of associations in the same individuals, and repeats these evaluations in eight-nine longitudinal datasets.

…

Methods

Samples.

(couple of sentences and a reference for each study, then point to table for characteristics to compare)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Baseline age range | Number of occasions | Inter-occasion intervals (year) | Sampling | ? |
| Einstein Aging Study |  | 7 | 1 |  |  |
| English Longitudinal Study of Aging |  | 3 |  |  |  |
| Health and Retirement Study |  | 3 (2004,06,10) | 2,4 |  |  |
| ILSE |  | 3 |  |  |  |
| Longitudinal Aging Study Amsterdam |  | 4-5 |  |  |  |
| Memory and Aging Project |  | 5 | 1 |  |  |
| Nutrition and Aging |  |  |  |  |  |
| Octogenarian Twins | 80-9x | 5 | 2 |  |  |
| Swedish Adoption Twin Study of Aging |  | 4-5 |  |  |  |

Measures.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Upper body strength (Grip) | Pulmonary function (FEV, PEF) | Lower body strength (Walking) |
| Einstein Aging Study | Maximum of three dominant hand trials, grip dynamometer | Maximum of three trials? | Walk 12 ft at usual pace on GAITRite walkway; two trials; average cm/s |
| English Longitudinal Study of Aging | Three trials at waves 2,4,6. | Maximum of three trials, Vitalograph Micro Spirometer (l in first s (FEV1); waves 2,4,6 | Walk 8 ft at usual pace; Average of two trials;  Walking aids permitted; Waves 1-6; (m/s) |
| Health and Retirement Study | Two trials for each hand, Smedley spring-type hand dynamometer (kg) | Average Maximum expiration speed of three trials of Mini-Wright peak flow meter, taken 30s apart. | Walk 98.5in (~2.5m), turn and return; Average of up to two trials (s) |
| ILSE | Vigorimeter (largest bulb), 3 trials each hand (+2 practice) | -- | *Timed Up-and-Go*: Stand from chair, walk 3m, return and sit down (s) |
| Longitudinal Aging Study Amsterdam | Average of larger of two trials, each hand, Takei strain-gauged dynamometer adjusted to each hand. | Maximum expiration speed of three trials of Mini-Wright peak flow meter. | Walk 3m, turn and return as quickly as possible (s) |
| Memory and Aging Project | Average of two trials each per hand (lbs) | Average of two spirometer trials (l/s) | Time to walk 8m (m/s) |
| Nutrition and Aging | Average of best of three maximal contractions for each hand, Martin Vigorimeter (KPa) | --- | *Timed Up-and-Go*: Stand from chair, walk 3m, return and sit down (s)  *Gait speed*: faster of two usual pace trials, 4m (s) |
| Octogenarian Twins | Maximum force, three trials per hand, Martin Vigorimeter (lbs/in2) | Maximum of three spirometer trials repeated twice (15 mins apart) (l/s) | Normal gait 3m, turn and return (s) |
| Swedish Adoption Twin Study of Aging | Maximum force, three trials per hand, dynamometer (kg) | \_\_\_\_trial of portable 10-1 dry bellows Vicatest spirometers (Mijnhardt, Bunnik, The Netherlands) with subjects in seated position and nasal passages blocked with nose clips. Forced expiratory volume during the first second (FEV1) was collected. At IPT3, pulmonary function for 30% of the subjects was measured using the Vicatest, with the remaining assessed using portable ML 330 spirometer (Micor Medical, Kent, United Kingdom). FEV1 values for both spirometers were expressed in BTPS (body temperature and pressure saturated with water vapor). | Normal gait 3m, turn and return (s) |

Statistical analysis.

We fit Bivariate Latent Growth models separately for men and women, specifying linear growth and time since first measurement as the chronological metric, allowing time to vary by individual. Covariates include Baseline Age (centered at xxx), education (in years, centered at xxx, except for ELSA and ILSE for which education is dichotomized as XXX and XXX, with XXX as reference) height (centered at 1.72m for men and 1.60m for women), smoking history (non-smoker reference), cardiovascular disease (no symptoms as reference) and diabetes (not diabetic as reference). Mplus version(s) xxx-xxx were used (Muthén & Muthén, xxxx). Syntax and output for all models are available at GitHub/IALSA/IALSA-2015-Portland. In the interest of space, here we focus on correlations among the slopes, though summarize other relevant aspects of the models to provide context. Values for walking speed measured in seconds are reversed so that for all measures in all studies higher scores indicate better performance.

Results

*Sex differences.* On average, men had higher scores than women on all physical functions. (compare variability – in EAS men more variable except for gait)

*Age differences.* On average, all of the physical functions showed significant differences across baseline age (LASA; check the rest!!).

*Age changes.* On average, all of the physical functions showed significant declines over time (check, and describe magnitude relative to the cross-sectional differences – and comment). For most of the studies, sexes and variable combinations

*Other Covariates*.

*Cross-sectional associations.* Correlations among baseline performance (intercepts) on the physical measures were statistically significant for all variable pairs and both sexes in the ELSA, MAP, and NuAge studies. None of the correlations were significant for EAS or ILSE (Grip Strength and Timed-up-and-go only). HRS and LASA had significant correlations between PEF and walking for both sexes and between PEF and Grip (women only in HRS). Similarly, PEF and Grip were correlated only for women in OCTO-Twin. (SATSA?)

*Longitudinal associations*. No bivariate slope correlations were identified for women among the physical functions studied. For men, pulmonary function and walking speed were correlated for half of the studies (HRS, LASA, OCTO), such that individuals who showed decreased pulmonary function over time also took progressively longer to complete a walking course. In particular, all studies where this correlation was significant, the task was 3m walk, turn and return. Changes in Grip and Timed-up-and-go were significantly associated over time in NuAge. A longitudinal association between pulmonary function and grip was found for LASA alone.

Table x-A. Correlations among Random Effects for Grip Strength and Walking Speed\*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Female | | | Male | | |
|  | Intercepts | Slopes | Residuals | Intercepts | Slopes | Residuals |
| Einstein |  |  |  |  |  |  |
| English | 0.39\* | 0.74 | 0.01 | 0.28\* | 0.43 | 0.01 |
| HRS | 0.20 | 0.12 | 0.02 | 0.16 | 0.07 | 0.05 |
| ILSE | -0.01 | 0.49 | 0.11 | 0.50 | 0.83 | -0.14 |
| LASA | -0.28 | -0.50 | 0.01 | -0.45 | -0.32 | -0.04 |
| MAP | 0.30\* | -0.47 | -0.01 | 0.27\* | 0.35 | 0.002 |
| NuAge | -0.18\*/-0.27\* | -0.10/-0.26 | -0.04/-0.01 | -0.20\*/-0.25\* | -0.25/-0.24\* | -0.05\*/-0.04 |
| Octo-Twin | -- | -- | -- | -- | -- | -- |
|  |  |  |  |  |  |  |

\* Timed-up-and-go in ILSE and NuAge.

Note: Controlling for Baseline Age, education, height, smoking, cardiovascular illness, and diabetes.

Table x-B. Correlations among Intercepts for physical function variables

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | F |  |  | M |  |
|  | Grip strength-Walking speed | Grip-strength—Pulmonary | Pulmonary- Walking Speed | Grip strength-Walking speed | Grip-strength—Pulmonary | Pulmonary- Walking Speed |
| Einstein |  |  |  |  |  |  |
| English | 0.39\* | 0.21\* | 0.18\* | 0.28\* | 0.18\* | 0.22\* |
| HRS | 0.20 | 0.29\* | 0.28\* | 0.16 | 0.11 | 0.30\* |
| ILSE | /-0.01 | -- | -- | / 0.50 |  |  |
| LASA | 0.28 | 0.30\* | -0.29\* | -0.45 | 0.23\* | -0.29\* |
| MAP | 0.30\* | 0.12\* | 0.24\* | 0.27\* | 0.29\* | 0.22\* |
| NuAge | -0.18\*/-0.27\* | -- | -- | -0.20\*/-0.25\* | -- | -- |
| Octo-Twin | -- | 0.37\* | -- | -- | 0.15 | -- |
|  |  |  |  |  |  |  |

Table x-C. Correlations among Intercepts for physical function variables

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Grip strength-Walking speed | | Grip-strength—Pulmonary | | Pulmonary- Walking Speed | |
|  | F | M | F | M | F | M |
| Einstein |  |  |  |  |  |  |
| ELSA | 0.39\* | 0.28\* | 0.21\* | 0.18\* | 0.18\* | 0.22\* |
| HRS | 0.20 | 0.16 | 0.29\* | 0.11 | 0.28\* | 0.30\* |
| ILSE | -0.01 | 0.50 | -- |  | -- |  |
| LASA | 0.28 | -0.45 | 0.30\* | 0.23\* | -0.29\* | -0.29\* |
| MAP | 0.30\* | 0.27\* | 0.12\* | 0.29\* | 0.24\* | 0.22\* |
| NuAge | -0.18\*/-0.27\* | -0.20\*/-0.25\* | -- | -- | -- | -- |
| Octo-Twin | -- | -- | 0.37\* | 0.15 | -- | -- |
|  |  |  |  |  |  |  |

*Time-patterned fluctuations.* Virtually no statistically significant correlations were found between occasion-specific residuals, and those identified were weak: maximum expiration and walking speed for HRS women, and, for men, grip strength and walking in NuAge and grip with timed-up-and-go for ILSE.

Discussion

Grip strength in particular has been shown to have high test-retest stability (for average of three trials, ICC=0.81; Wolinsky et al., 2005). Although gait speed was found to be less reliable (for average of two trials, ICC=0.56; Wolinsky et al., 2005), this may be an underestimate due to variations in the course length for half of the participants.

Three patterns emerge very clearly from this analysis. First, both age-related differences and age-related changes reflect decline in (almost) all of the three physical functions considered here, in (almost) all of the studies. This means that both cross-sectionally and longitudinally there is evidence for age-related decline in physical function.

Second, the annual longitudinal declines are almost always larger than the annual cross-sectional differences. Based on the probable existence of re-test effects, this is opposite to what might have been expected. However, this pattern is consistent with a situation in which the cross-sectional effect of selection based on physical health and function is greater than the longitudinal effect of attrition.

Third, the longitudinal associations – between changes in the three main functions are (almost always?) smaller than the cross-sectional associations among the functions at baseline. This implies that although all three types of functions are strongly correlated with age (controlling for smoking history, cardiovascular disease and diabetes), meaning that individuals who are older are more likely to perform less well, declines in the different functions do not tend to be associated within an individual. The magnitude of someone’s decline in any once function, after accounting for age, sex, height (SES) and some health characteristics such as smoking history, cardiovascular health and diabetes, does not predict the magnitude of decline in the other functions.

These findings apply across the time scale considered here (i.e., long term, over 6-8 years), and do not necessarily refer to much shorter (e.g., moment to moment) or much longer (e.g., decades) periods. A fourth consistent pattern to note, however, is the lack of association between occasion-to-occasion fluctuations in performance within an individual.

References

(possibly see also Buchman et al, 2008, Physical frailty in older persons is associated with Alzheimer disease pathology)

Annie – Could you possibly combine the following tables so that this first one contains, rather than each of the years for EAS, the baseline year for each study (in alphabetical order)? I’ve put EAS in col 1 and LASA in col 4 already.

Table 1. Descriptive Statistics for the Participating Studies

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | |  | | Study | |  | |  | |
| Variable |  | | EAS  (n = 2254) | ELSA  (n =) | HRS  (n =) | ILSE | LASA  (n = 3107) | MAP  (n =) | NuAge  (n =) | OCTO-Twin |
|  |  | | M (SD) | M (SD) | M (SD) |  | M (SD) | M (SD) | M (SD) |  |
| Demographic | | |  |  |  |  |  |  |  |  |
| Age, years | | | 78.3 (5.4) |  |  |  | 70.8 |  |  |  |
| Education, years | | | 13.0 (3.7) |  |  |  | 8.76(3.32) |  |  |  |
| Height, cm | | | 163.9 (9.9) |  |  |  | 171.10(8.7) |  |  |  |
| Smoking history(%) | | | 1125 (53.4) |  |  |  | 25.5% |  |  |  |
| Cardiovascular disease (%) | | | 364 (16.8) |  |  |  | 29% |  |  |  |
| Diabetes (%) | | | 365 (16.8) |  |  |  | 7.9% |  |  |  |
| Physical | |  |  |  |  |  |  |  |  |  |
| Peak Expiratory Flow: | |  | 319.3 (120.7) |  |  |  | 403.07 (130.1) |  |  |  |
| Grip Strength: | |  | 20.6 (8.0) |  |  |  | -- |  |  |  |
| Walking Speed: | |  |  |  |  |  | 8.62 (5.93) |  |  |  |
| Study Characteristics | | |  |  |  |  |  |  |  |  |
| Retention to final wave (%) | | | NA |  |  |  |  |  |  |  |
| Representative sample | | | Yes |  |  |  | Yes |  |  |  |
| Oldest Birth Cohort (year) | | | 1898 |  |  |  | 1908 |  |  |  |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  | Year of Assessment | | | | |
| Variable | |  | Baseline  (n = 2254) | Year 2  (n = 1355) | Year 4  (n = 729) | Year 6  (n = 441) | Year 8  (n = 242) |
|  | |  | M (SD) | M (SD) | M (SD) | M (SD) | M (SD) |
| Demographic | | |  |  |  |  |  |
| Age, years | | | 78.3 (5.4) | 79.5 (5.5) | 81.4 (5.2) | 82.8 (5.1) | 84.0 (4.5) |
| Education, years | | | 13.0 (3.7) | 13.5 (3.6) | 13.8 (3.5) | 14.1 (3.5) | 14.1 (3.6) |
| Height, cm | | | 163.9 (9.9) | 163.1 (10.2) | 163.4 (9.9) | 163.8 (10.3) | 162.4 (9.8) |
| Smoking historya (%) | | | 1125 (53.4) | 684 (53.3) | 371 (54.1) | 216 (50.9) | 98 (46.7) |
| Cardiovascular diseasea,b (%) | | | 364 (16.8) | 229 (17.2) | 130 (17.9) | 95 (22.1) | 51 (24.1) |
| Diabetesa (%) | | | 365 (16.8) | 218 (16.4) | 132 (18.2) | 87 (20.3) | 41 (19.3) |
| Physical |  | |  |  |  |  |  |
| Pulmonary: | Peak flow, L/min | | 319.3 (120.7) | 306.3 (112.3) | 301.2 (122.2) | 285.1 (114.6) | 270.3 (121.5) |
| Muscle: | Grip strength, kg | | 20.6 (8.0) | 19.9 (7.9) | 18.8 (8.9) | 18.2 (8.3) | 16.7 (9.1) |
| Cognitive |  | |  |  |  |  |  |
| Global: | MMSE | | 25.7 (2.4) | 25.9 (2.3) | 26.2 (2.3) | 26.4 (1.9) | 26.5 (1.6) |
| Memory: | Logical Memory | | 18.7 (7.2) | 19.8 (7.6) | 20.7 (7.7) | 21.1 (7.5) | 20.8 (8.2) |
| Working M: | Digit Span (total) | | 13.3 (3.7) | 13.6 (3.7) | 14.5 (3.6) | 14.9 (3.6) | 15.1 (3.3) |
| Knowledge: | Vocabulary | | 44.7 (14.1) | 45.7 (13.1) | 45.2 (13.1) | 44.3 (12.9) | 44.0 (12.8) |
| Reasoning: | Block Design | | 19.6 (9.5) | 20.5 (9.6) | 23.4 (9.9) | 24.5 (9.1) | 25.2 (8.7) |
| Speed: | Digit Symbol Coding | | 37.2 (14.8) | 39.2 (14.6) | 42.7 (14.4) | 43.9 (14.7) | 44.1 (12.9) |
| Visuospatial: | Figure Copy Recall | | 10.5 (3.8) | 10.8 (4.1) | 11.4 (4.1) | 11.1 (4.4) | 10.5 (4.6) |
| Executive: | Trail Making Test B | | 157.0 (77.3) | 148.6 (74.7) | 145.3 (72.7) | 149.1 (76.1) | 148.2 (74.) |
| Fluency: | Category | | 35.0 (9.7) | 35.6 (10.1) | 36.2 (10.3) | 35.8 (10.3) | 36.0 (10.9) |
|  | FAS | | 32.7 (13.3) | 34.1 (13.3) | 36.1 (13.6) | 38.0 (13.6) | 38.2 (13.3) |
|  | Boston Naming Task | | 11.2 (2.9) | 11.3 (2.8) | 11.5 (2.9) | 11.6 (2.8) | 11.9 (2.7) |
| Study Characteristics | | |  |  |  |  |  |
| Retention from previous wave (%) | | | NA | 60.2 | 53.8 | 60.5 | 54.9 |
| Representative sample | | | Yes | Yes | Yes | Yes | Yes |
| Oldest Birth Cohort (year) | | | 1898 | 1899 | 1903 | 1908 | 1911 |

a.Dichotomous variable (0=no; 1=yes). b = Cardiovascular disease = History of myocardial infarction or angina or ever had heart failure.

**SLOPE-SLOPE Correlations**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  | FEMALE | |  |  |  |  |  |  | MALE |  |  |  |  |
|  | FEV-GAIT | | FEV-GRIP | | GAIT-GRIP | | TUG-Grip | | FEV-GAIT | | FEV-GRIP | | GAIT-GRIP | | GRIP-TUG | |
|  | r | se | r | se | r | se |  |  | r | se | r | se | r | se |  |  |
| EAS | -0.444 | 0.76 | -0.152 | 0.875 | 0.412 | 0.484 |  |  | -0.487 | 1.779 | 0.032 | 2.346 | 0.42 | 2.312 |  |  |
| ELSA | 0.358 | 0.609 | 0.335 | 0.547 | 0.742 | 0.431 |  |  | 0.261 | 0.303 | 0.336 | 0.29 | 0.426 | 0.299 |  |  |
| HRS | 0.578 | 1.189 | -0.523 | 1.109 | 0.12 | 0.987 |  |  | 0.816 | 0.311 | -0.262 | 0.913 | 0.07 | 0.667 |  |  |
| ILSE |  |  |  |  |  |  | 0.488 | 1.13 |  |  |  |  |  |  | 0.828 | 6.663 |
| LASA | -0.316 | 0.197 | 0.096 | 1.283 | -0.532 | 3.202 |  |  | -0.513 | 0.099 | 0.565 | 0.097 | -0.321 | 0.319 |  |  |
| MAP | -0.028 | 0.386 | 0.016 | 0.362 | -0.471 | 0.306 |  |  | -0.475 | 0.59 | -0.027 | 0.393 | 0.345 | 0.327 |  |  |
| NuAge |  |  |  |  | -0.104 | 0.116 | -0.26 | 0.17 |  |  |  |  | -0.245 | 0.283 | -0.238 | 0.119 |
| OCTO | -0.583 | 0.909 | 0.344 | 0.374 | -0.043 | 0.24 |  |  | -0.792 | 0.169 | 0.101 | 0.604 | -0.7 | 0.51 |  |  |
| SATSA |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |