

**Associations among age-related changes in physical capabilities: A coordinated analysis**

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Multivariate dynamics of aging-related declines in physical functioning: An IALSA Coordinated  
Analysis of Nine Longitudinal Studies of Aging

For Review Only

## Abstract

Background: Poor physical function in late life predicts mobility limitations, cognitive decline, dementia, falls and death. Cross-sectional associations across different domains of physical functioning are found to be relatively strong and interpreted as indexing multi-domain functional aging or causal links among functions. This study estimated and contrasted baseline associations in grip strength, pulmonary function and gait speed with associations among corresponding rates of change in multiple longitudinal studies.

Methods: Bivariate linear mixed models were applied to nine independent studies in the Integrative Analysis of Longitudinal Studies of Aging (IALSA) Network. Results were combined using fixed- and random-effects meta-analysis.

Results: While physical capabilities were associated at baseline, changes in the physical capability variables considered here, adjusted for baseline age, education, height, smoking history, diabetes and cardiovascular disease, were not significantly correlated. The most consistent correlations, in two of nine studies, were between change in walking speed and change in peak expiratory flow.

Conclusions: Based on nine longitudinal studies, no consistent evidence for associations among simultaneous rates of change was found across these commonly used measures of physical capability.

Keywords: Aging, Longitudinal, Walking Speed, Grip Strength, Pulmonary Function, Meta-analysis

*Word count: 2703*

*Key Messages:*

- Physical function measures are associated across domains in late adulthood.
- Declines in these physical functions are not generally associated over time.
- Occasion-related fluctuations are not associated.

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3 Declines in physical capability are a well-documented feature of later life, with studies showing changes  
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5 in grip strength, walking speed, and pulmonary function (1-5). These declines in physical capability  
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7 measures are associated with mobility limitations, cognitive decline, dementia, falls and death (6-13).  
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9 However, limited evidence exists for how these functions are associated, with most studies emphasizing  
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11 change in one physical function variable at a time.  
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15 Extant cross-sectional evidence suggests that grip strength, walking speed, and pulmonary function are  
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17 associated (6, 14-16). Respiratory muscle strength has been found to account for the relationship  
18  
19 between extremity muscle (including hand grip) strength and mortality (6), and grip strength cut-points  
20  
21 have been suggested to help identify older adults with walking and stair climbing difficulties (17).  
22  
23 However, in another study (16), forced inspiratory volume (FIV) but not forced expiratory volume (FEV)  
24  
25 was related with lower extremity muscle strength, and FIV and FEV were not associated with grip  
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27 strength.  
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31 Several interpretations can arise from such findings. For example, different functional domains may all  
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33 be indices of general aging-related decline (18). Or, it may be that on a given day, respondents who  
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35 were fatigued or depressed underperform across a variety of domains of functioning. However, similar  
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37 associations may also arise from a cascade of multi-morbid declines in which reduced functioning in one  
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39 domain results in declines in others (3, 6), and these influences may be reciprocal. For example, it is  
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41 likely that changes in walking speed are more strongly associated with changes in pulmonary functioning  
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43 than with changes in grip strength, as walking requires pulmonary fitness.  
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49 There are limitations to relying on cross-sectional data and analysis for understanding aging-related  
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51 changes. Between-person differences in age-heterogeneous samples are comprised of many sources of  
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53 variance, including birth cohort (19), early life differences, maturation and aging-related change, and  
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55 sample selectivity over time, particularly in samples of older individuals (20). Analyses of age-  
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3 heterogeneous samples are also sensitive to mean between-person age trends (19) and further  
4 encourage evaluation of pattern and strength of associations among rates of change in longitudinal  
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6 data.  
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### 9 10 *Objectives*

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13 This study uses data from nine international longitudinal studies of aging to examine three overarching  
14 questions. First, it examines whether lower functioning in one domain is associated with worse  
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16 functioning in another. Second, it considers whether individuals experiencing declines in one domain of  
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18 physical function are more likely to experience concurrent declines in other domains of physical  
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20 functioning. Finally, it evaluates whether occasion-specific residuals are correlated. Given expected sex  
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22 differences (1), all analyses are conducted separately in men and women within each study.  
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### 28 *Methods*

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31 Data from nine longitudinal studies of aging, affiliated with the Integrative Analysis of Longitudinal  
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33 Studies on Aging program ([www.maelstrom-research.org/mica/network/ialsa](http://www.maelstrom-research.org/mica/network/ialsa)) were included in this  
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35 research. Studies were chosen because they included at least three observations of physical functioning.  
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37 However, as some studies only fielded such measures in subsamples, only participants with physical  
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39 function data were included in the analysis, resulting in some cases in much smaller samples than may  
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41 be available for other types of analysis.  
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### 45 *Samples.*

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48 The Einstein Aging Study (EAS) systematically recruited community-dwelling, English-speaking, Bronx,  
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50 New York residents from Health Care Financing Administration/ Centers for Medicaid and Medicare  
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52 Services rosters for Medicare-eligible persons (1993-2004), then from New York City Board of Elections  
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54 (2004 onwards). Visual and/or auditory impairments or psychiatric symptomatology that interfere with  
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3 neuropsychological testing, and nonambulatory status were excluded (20). Data from up to seven waves  
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5 per person were included to avoid small sex-stratified samples in the later waves.  
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9 The English Longitudinal Study of Ageing (ELSA) is composed primarily of respondents aged 50 and over,  
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11 living in England, who participated in the Health Survey for England (HSE) in 1998, 1999, and 2001. The  
12  
13 first wave of ELSA data collection occurred in 2002/03 (21). Physical capability measures were not  
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15 available at all data collection waves. Data from waves two, four, and six were available for this study.  
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17 Respondents with dementia were excluded from the analysis.  
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21 Health and Retirement Study (HRS) physical function measurements were made in a random subsample  
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23 of ~3,300 randomly selected respondents in 2004. In 2006, measurement was expanded to half of all  
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25 participants (randomly selected), who also had follow-up physical measurements in 2010. Only  
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27 participants assessed in both 2006 and 2004 were included here (22).  
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31 The Interdisciplinary Longitudinal Study of Adult Development (ILSE) includes persons from East (Leipzig  
32  
33 and Rostock) and West Germany (Heidelberg, Bonn and Erlangen-Nuremberg), stratified by sex and  
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35 cohort membership (born 1930-32 and 1950-52; Schmitt, 2006). Data from the Heidelberg and Leipzig  
36  
37 1930-32 cohorts, which have a longer follow-up, were analyzed here.  
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41 The Longitudinal Aging Study Amsterdam (LASA) (23) objective was to examine predictors and  
42  
43 consequences of increasing age on autonomy and well-being. Respondents were recruited in 1992 from  
44  
45 the 3805 respondents of the Living Arrangements and Social Network of Older Adults (LSN) study.  
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48 Bivariate models including grip strength, data from the second wave of data (1995/1996) onward were  
49  
50 included, as grip strength was not available at the first wave. For models including pulmonary function,  
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52 respondents from the fifth wave of data (2005/2006) were excluded given that peak expiratory flow was  
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54 not available for that wave. Respondents with dementia throughout the study were excluded from the  
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56 analysis.  
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3 The Memory and Aging Project (MAP) began in 1997 with ongoing recruitment (24), primarily through  
4 continuous care retirement communities in northeastern Illinois as well as through subsidized  
5 retirement homes, local churches, and social service agencies. Individuals were required to be free from  
6 dementia at study enrollment, participate in annual clinical evaluations, and agree to donation of their  
7 spinal cord and brain at the time of death. There were no other exclusion criteria and all clinical  
8 evaluations were conducted as home visits. Individuals who remained free of dementia throughout the  
9 study period were included in the current analysis. Data from up to five waves per person were included  
10 to avoid small sex-stratified samples in the later waves.  
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22 The Nutrition as a determinant of successful Aging study (NuAge), is a five-year observational study of  
23 1,793 community-dwelling individuals in good general health at recruitment in 2003, drawn from a  
24 random sample stratified by age and sex obtained from the Québec Medicare database (RAMQ) for the  
25 regions of Montreal, Laval, and Sherbrooke in Québec, Canada (25, 26). Participants had to be either  
26 French or English speaking, willing to commit for the 5 years of the study, free of disabilities in activities  
27 of daily living, without cognitive impairment, able to walk without assistance (cane acceptable), to walk  
28 300 meters, and to climb 10 stairs without rest. Exclusionary criteria were Class II heart failure, chronic  
29 obstructive pulmonary disease requiring oxygen therapy or oral steroids, inflammatory digestive  
30 diseases, or cancer treated either by radiation therapy, chemotherapy or surgery in the 5 years prior to  
31 enrolment.  
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46 Origins of Variance in the Oldest-Old (OCTO-Twin). The OCTO-Twin study includes dizygotic (DZ) and  
47 monozygotic (MZ) twin pairs aged 80 years of age and older (28, 29) selected from older adults  
48 participating in the population-based Swedish Twin Registry (30). The initial sample consisted of 702  
49 individuals (351 same-sex pairs). Five cycles of longitudinal data were then collected at two year  
50 intervals. Only participants not diagnosed with dementia were included in the current analysis.  
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3 The Swedish Adoption Twin Study of Aging (SATSA) is a subset of twins from the population-based  
4 Swedish Twin Registry. In 1984, twins were mailed the baseline questionnaires (Q1) and a sample of  
5 those pairs age 50 years or older in which both twins responded was invited to participate in an  
6 additional in-person examination of health and cognitive abilities. In-person testing (IPT1) took place in a  
7 location convenient to the twins during a single 4-hour visit. Up to IPT5, new participants were added at  
8 each wave as they reached age 50. Up to 7 IPT waves were included in the present analyses, for a total  
9 potential follow-up of 19 years (31).

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23 Measures.

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26 Three types of physical functioning were examined: grip strength, peak flow, and walking speed. Table 2  
27 provides brief descriptions of the measures used in each study. Walking was measured as time to walk a  
28 distance or course in some studies and as velocity in others, so results for those recorded as time were  
29 reversed so that higher scores indicate better performance.

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36 (Table 2 here)

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39 Covariates. Baseline covariates include age (centered at 70 years (75 in HRS; 80 in OCTO-Twin)),  
40 education (in years, centered at 7 years, except ELSA, dichotomized as no educational qualification (0)  
41 versus qualification (1), ILSE, dichotomized as basic (0) and further (1) education, and SATSA, with  
42 elementary school as reference point on four point scale), height (centered at 1.72m for men and 1.60m  
43 for women), smoking history (non-smoker reference), cardiovascular disease (no symptoms as  
44 reference) and diabetes (not diabetic as reference; except ILSE, for which this information was not  
45 available).



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3 Statistical approach.  
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6 Integrative analysis seeks to harmonize both analyses and methodological approaches using data  
7 analyzed for this explicit purpose, and is thus less susceptible to publication bias (33). It is particularly  
8 useful when trying to study consistent, but small, effects across studies and can highlight consistently  
9 null results (34). Bivariate linear mixed models were used to examine the relationship between  
10 trajectories for grip strength, pulmonary function, and gait speed. These models extend the basic  
11 univariate linear mixed models. They estimate the associations between: 1) individual differences at  
12 baseline (intercept-intercept associations), 2) rates of change (slope-slope association), and 3) occasion-  
13 specific residuals (35). Models were specified using time since first measurement, with individual-  
14 varying times of observation to account for variation in time of measurement across individuals. Men  
15 and women differ fundamentally in physical performance and rates of change (36), therefore models  
16 were sex-stratified. Mplus (version 7) was used to fit models (37) with full information maximum  
17 likelihood (FIML) estimation to address missing data on the dependent variables under the missing at  
18 random (MAR) assumption. Parameter estimates were estimated using MLR (38, 39). Results from the  
19 studies analyzed here have been robustly combined to obtain a variance-weighted average effect using  
20 meta-analytic techniques (32).  $I^2$  was used to examine within-sample heterogeneity. Random effects  
21 meta-analysis was used to examine the sensitivity of results to study-level heterogeneity. Syntax and  
22 output for all models are available online at [github/IALSA/IALSA-2015-Portland](https://github.com/IALSA/IALSA-2015-Portland).  
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## 46 47 48 Results

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50 *Sex differences.* Adjusting for covariates, grip strength and pulmonary functioning was, on average,  
51 higher among men than women, and showed greater inter-individual variability, except in ILSE, where  
52 grip strength variance was smaller for men. In contrast, gait speed was largely similar for men and  
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3 women, though men exhibited smaller variance in gait speed, except in ELSA and HRS, where variances  
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5 were virtually identical for men and women.  
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9 *Age differences.* Age at baseline was associated with level of physical function (results not shown), with  
10  
11 some exceptions: EAS female grip and male gait and peak flow, ELSA female pulmonary functioning, HRS  
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13 male pulmonary functioning, and SATSA male grip. Physical capability variables did not vary significantly  
14  
15 by age in ILSE because participants only varied in age by two years.  
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18 *Aging-related declines.* There was limited evidence of decline in gait speed over time. Specifically,  
19  
20 declines were statistically significant in only four of the studies: ELSA, HRS, LASA, and SATSA. Declines in  
21  
22 grip strength and pulmonary functioning were more consistent, with men declining consistently more  
23  
24 rapidly for pulmonary functioning in all but two studies (ELSA and OCTO), though there were fewer  
25  
26 consistent sex differences in changes in grip strength. *Cross-sectional associations.* Correlations among  
27  
28 baseline performance on the physical capability measures were weak, ranging from -0.29 to 0.36 among  
29  
30 men, and -0.06 to 0.36 among women, though they were often statistically significant (Table 3).  
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32 Supportive of this interpretation, meta-analytic averages indicated weak correlations (ranging from  
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34 0.21-0.32), which were significant ( $p < 0.001$  in all cases) and were highly homogeneous (in all cases,  
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36  $I^2 = 0.0\%$ ). They were significant for all variable pairs and both sexes in the ELSA, MAP, and NuAge studies.  
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38 All baseline performance measures were associated in OCTO-Twin, except between pulmonary  
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40 functioning and grip strength in men. About half of the intercept correlations were significant in HRS and  
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42 LASA. Correlations were not significant for EAS, or ILSE (grip-TUG only), and only male grip-peak flow  
43  
44 was significant in SATSA.  
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47 (Table 3 here)  
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51 *Longitudinal associations.* In women, no bivariate slope correlations were identified among the domains  
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53 of physical functioning (Table 4). For men, pulmonary function was correlated with walking speed only in  
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55 LASA and OCTO: for these individuals, those who showed decreased pulmonary functioning over time  
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3 also had slower gait speed. Pulmonary functioning was positively correlated with grip strength in OCTO-  
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5 Twin, but negatively in LASA.  
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9 (Table 4 here)

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11 Meta-analysis supports the conclusions that 1) level of performance for these three types of physical  
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13 capability are associated; 2) rate of change in performance is not consistently correlated; and 3)  
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15 occasion-related fluctuations in performance are not correlated. Forest plots in Figure 1 display the  
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17 intercept, slope and residual correlations for each variable pair by study and sex.  $I^2$  was rather high due  
18  
19 to the inconsistency of some of the estimates. Sensitivity to model assumptions was considered by  
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21 replicating this analysis using random effects estimates, which did not change our conclusions.  
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26 (Figure 1 here)

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29 (Table 5 here)

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32 *Occasion-specific residuals.* Virtually no statistically significant correlations were found between  
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34 occasion-specific residuals (Table 5), and those identified were very weak: walking speed with peak flow  
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36 for HRS women and grip strength for ELSA women, and, for men, grip with timed-up-and-go for ILSE.  
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38 Meta-analytic averages support this conclusion, with non-significant associations that ranged from 0.02  
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40 to 0.03.  
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## 46 47 Discussion

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50 To date, analyses have largely examined domains of physical functioning separately from one another  
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52 and, when looking at associations between domains, relied on cross-sectional data. The goal of this  
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54 study was to examine the interdependence of physical performance, aging-related change, and  
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56 variability in three domains of physical functioning. Further, analyses were replicated across nine  
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3 longitudinal studies of aging and results were generally consistent. Overall, results are suggestive of  
4 consistently weak associations between different domains of physical functioning.  
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8 Four patterns emerged from these analyses. First, while age-related differences in the three physical  
9 capabilities were relatively consistent in all studies, age-related changes reflecting within-person  
10 declines were less consistent, particularly for walking speed. Second, the baseline (intercept-intercept)  
11 associations were mainly statistically significant. Third, the longitudinal (slope-slope) associations –  
12 between changes in the three main capabilities – were generally not statistically significant. The fourth  
13 consistent pattern to note is the lack of association between occasion-to-occasion fluctuations in  
14 performance within an individual.  
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25 A consistent association between age and baseline performance but not aging-related change  
26 accounting for confounding may imply that while individuals who are older perform less well, declines in  
27 different functional domains may not be associated within an individual. This is supported by a finding  
28 that the magnitude of someone's decline in any one capability, generally does not predict the  
29 magnitude of decline in other capabilities. Furthermore, the consistent lack of association between  
30 occasion-specific residuals highlights this lack of overall association, suggesting that fluctuations from  
31 occasion to occasion may be either random or due to unrelated processes.  
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#### 42 *Limitations*

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45 Several details are relevant to consider in evaluating the findings presented. While this is the first study  
46 to consistently examine these associations across a number of studies, these findings only address  
47 medium-term changes (mainly over 4-12 years), and do not necessarily refer to shorter (e.g., day to day)  
48 or longer-term change (e.g., over decades).  
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55 It is important to note the low slope variances identified for many of the variables and studies, as this  
56 could be a factor in the lack of correlation between the slopes. This is not likely to be due to  
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3 methodology, since significant and moderate associations have been found in domains of  
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5 psychopathology (40), and cognitive functioning (41). This is not likely an issue of statistical power (43),  
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7 as correlations were not seen in ELSA, which had the largest sample, though were in LASA, with the  
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9 second largest, and OCTO, with the oldest. Furthermore, results are consistent with other work  
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11 examining associations between physical functioning and cognition (44).  
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15 This analysis featured data from some of the best and most appropriate studies available globally to  
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17 examine these questions. This study used an integrative multi-study coordinated analysis to  
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19 comprehensively address questions about aging-related dynamics of physical functioning. Using  
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21 harmonized analyses of commonly used measures of physical functioning, this study generated novel  
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23 evidence indicative of consistently weak or null associations in their ageing-related dynamics.  
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53 **Conflict of Interest:** The authors declare that they have no conflict of interest.  
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3 **Ethical approval:** All procedures performed in studies involving human participants were in accordance  
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5 with the ethical standards of the institutional and/or national research committee and with the 1964  
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7 Helsinki declaration and its later amendments or comparable ethical standards.  
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Table 1. Descriptive Baseline Statistics and Characteristics for the Participating Studies

	EAS	ELSA	HRS	ILSE	LASA	MAP	NuAge	OCTO-Twin	SATSA
	(n = 222)	(n =6602)	(n =524)	(n=476)	(n = 1582)	(n =1240)	(n =1781)	(n=402)	(n=633)
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Age, years	78.3 (5.4)	64.98 (10.0)	5.32 (6.49)	62.96 (0.92)	70.8 (2.2)	78.79 (7.73)	74.42 (4.20)	83.58 (3.2)	65.60 (8.47)
Education, years	13.0 (3.7)	0.59	12.56 (3.21)	0.38	8.76 (3.32)	14.57 (3.21)	11.62 (4.51)	7.14 (2.29)	1.60 (0.88)
Height, cm	163.9 (9.9)	165.27 (9.6)	170.08 (11)	168.36 (8.87)	171.10 (8.7)	164 (10)	161 (9)	161.68 (8.65)	165.93 (9.78)
Peak Expiratory Flow:	319.3 (120.7)	2.30 (0.9)	322.95 (114.12)	---	403.07 (130.1)	1.69 (0.58)	---	319.69 (108.4)	2.24 (0.72)
Grip Strength:	20.6 (8.0)	27.8 (11.1)	0.85 (0.25)	77.76 (27.84)	--	48.37 (18.95)	64.82 (18.15)	8.96 (9.0)	28.99 (12.08)
Walking Speed*:	96.1 (22.3)	0.83 (0.3)	29.13 (9.83)	5.80 (1.28)	8.62 (5.93)	0.65 (0.21)	4.24 (0.92)	11.33 (3.75)	10.11 (3.17)

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Table 1. (cont'd) Descriptive Baseline Statistics and Characteristics for the Participating Studies

Smoking history (%)	53	64	52	78	26	46	48	39	46
Cardiovascular disease (%)	17	12	30	29	29	10	22	45	13
Diabetes (%)	17	7	20	.	8	14	11	10	3
Study Characteristics									
N Occasions Modeled	7	3	3	3	4-5	5	4	5	6
Inter-occasion Intervals (yrs)	1	4	2,4	4,8	3	1	1	2	3
Total follow-up (yrs)	6	8	6	12	12	4	3	8	19
Start year	1993	2002	2004	1993	1992	1997	2003	1991	1984

Note: \*Timed-up-and-go for ILSE; Final wave not defined for studies with rolling enrolment (EAS and MAP).

Table 2. Physical Capability Variables

	Upper body strength (Grip strength)	Pulmonary function (FEV, PEF)	Lower body strength (Walking, TUG)*
Einstein Aging Study	Maximum force; 3 dominant hand trials, grip dynamometer(kg)	Maximum expiration of three trials, peak flow meter, taken 30s apart.	Walk 12 ft at usual pace on GAITRite walkway; Average of two trials; (cm/s)
English Longitudinal Study of Aging	Average force; 6 trials (3 trials per hand) (kg)	Maximum of three trials, Vitalograph Micro Spirometer (1/2 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	Average of maximum force in 2 trials with dominant hand, Smedley spring-type hand dynamometer (kg)	Average maximum expiration speed of three trials of Mini-Wright peak flow meter, 30s apart.	Walk 98.5in (~2.5m), turn and return; Average of up to two trials (m/s)
ILSE	AVERAGE OR MAX force; 3 trials per hand (+2 practice); Vigorimeter (largest bulb) (lbs )	--	<i>Timed Up-and-Go</i> : Stand from chair, walk 3m, return and sit down (s)
Longitudinal Aging Study Amsterdam	Average of maximum force from each hand; 2 trials per hand; Takei strain- gaged dynamometer	Maximum expiration speed of three trials of Mini-Wright peak flow meter.	Walk 3m, turn and return as quickly as possible (s)

	adjusted to each hand (?)		
Memory and Aging Project	Average force; 2 trials per hand; Jamar hydraulic hand dynamometer (Lafayette Instrument, Lafayette, Ind., USA) (lbs)	Average of two spirometer trials (MicroPlus Spirometer MS03, MicroMedical Ltd.) (ℓ/s)	Time to walk 2.48m (m/s)
Nutrition and Aging	Average of maximum force, 3 trials per hand; Martin Vigorimeter (KPa)	---	<i>Timed Up-and-Go</i> : Stand from chair, walk 3m, return and sit down (s) <i>Walk</i> : faster of two usual pace trials, 3m (s)
Octogenarian Twins	Maximum force; 3 trials per hand; Martin Vigorimeter (lbs/in <sup>2</sup> )	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; 3 trials per hand; dynamometer (kg)	FEV1: Forced expiratory volume in first second; portable 10-1 dry bellows Vicatest spirometer until IPT3, when 30% used Vicatest and rest used portable ML 330. (ℓ/s).	Normal gait 3m, turn and return (s)

Note. \*Values for walking speed measured in seconds are reversed so that for all measures in all studies higher scores indicate better performance.

Table 3a. Bivariate Intercept Correlations among Physical Functioning Measures for Women

	FEV-GAIT			FEV-GRIP		GAIT-GRIP		TUG-Grip	
	n	r	se	r	se	r	se	r	se
EAS	150	0.05	0.19	0.29	0.15	0.18	0.17		
ELSA	3511	0.22*	0.04	0.25*	0.05	0.36*	0.03		
HRS	285	0.29*	0.11	0.29*	0.09	0.21	0.13		
ILSE	224							-0.06	0.23
LASA	782	0.23	0.13	0.28*	0.10	0.34	0.21		
MAP	931	0.24*	0.05	0.13*	0.04	0.30*	0.05		
NuAge	934					0.18*	0.04	0.27*	0.04
OCTO	270	0.35*	0.08	0.39*	0.07	0.33*	0.07		
SATSA	367	0.38	0.23	0.22	0.15	0.17	0.42		

Table 3b. Bivariate Intercept Correlations among Physical Functioning Measures for Men

	FEV-GAIT			FEV-GRIP		GAIT-GRIP		TUG-Grip	
	n	r	se	r	se	r	se	r	se
EAS	72	-0.01	0.53	0.11	0.38	0.32	0.45		
ELSA	3210	0.19*	0.04	0.19*	0.04	0.28*	0.05		
HRS	236	0.30*	0.10	0.11	0.08	0.16	0.11		
ILSE	252							-0.29	0.44
LASA	800	0.36*	0.06	-0.22*	0.05	0.32*	1.25		
MAP	309	0.25*	0.09	0.25*	0.07	0.31*	0.08		
NuAge	847					0.20*	0.06	0.25*	0.05
OCTO	132	0.36*	0.06	0.15	0.14	0.35*	0.14		
SATSA	266	0.10	0.34	-0.21*	-0.10	0.51	0.49		

Note: \* p &lt; 0.05

Table 4a. Bivariate Slope Correlations among Physical Functioning Measures for Women

	FEV-GAIT			FEV-GRIP		GAIT-GRIP		TUG-Grip	
	n	r	se	r	se	r	se	r	se
EAS	150	-0.55	0.52	0.03	0.80	0.38	0.50		
ELSA	3511	0.40	0.25	0.63	0.95	0.50	0.10		
HRS	285	0.58	1.21	-0.52	1.12	0.13	1.00		
ILSE	224							0.40	1.63
LASA	782	0.25	0.20	0.03	1.57	-0.69	1.64		
MAP	931	-0.03	0.39	0.16	0.37	-0.46	0.31		
NuAge	934					0.10	0.12	0.26	0.17
OCTO	270	0.58	0.91	0.34	0.37	0.04	0.24		
SATSA	367	0.38	0.36	0.89	0.67	0.03	0.59		

Table 4b. Bivariate Slope Correlations among Physical Functioning Measures for Men

	FEV-GAIT			FEV-GRIP		GAIT-GRIP		TUG-Grip	
	n	r	se	r	se	r	se	r	se
EAS	72	-0.53	2.63	0.20	1.84	0.24	2.86		
ELSA	3210	0.42	0.34	0.42	0.34	0.55	0.41		
HRS	236	0.85	0.48	-0.16	1.17	0.10	0.76		
ILSE	252							-0.84	1.24
LASA	800	0.40*	0.09	-0.57*	0.09	0.76	0.60		
MAP	309	-0.46	0.62	-0.04	0.40	0.40	0.34		
NuAge	847					0.25	0.28	0.24	0.12
OCTO	132	0.40*	0.09	0.40*	0.13	0.70	0.51		
SATSA	266	0.55	0.62	-0.75	0.45	0.42	0.46		

Note: \* p &lt; 0.05



Table 5a. Bivariate Residual Correlations among Physical Functioning Measures for Women

	FEV-GAIT			FEV-GRIP		GAIT-GRIP		TUG-Grip	
	n	r	se	r	se	r	se	r	se
EAS	150	0.10	0.12	0.11	0.10	0.03	0.10		
ELSA	3511	0.02	0.03	0.01	0.02	0.06*	0.02		
HRS	286	0.14*	0.06	0.08	0.07	0.02	0.05		
ILSE	224							0.10	0.14
LASA	782	0.02	0.03	0.03	0.04	0.01	0.03		
MAP	931	0.02	0.03	0.02	0.03	-0.01	0.03		
NuAge	934					0.04	0.03	0.01	0.03
OCTO	270	0.02	0.07	0.03	0.06	0.05	0.05		
SATSA	367	0.04	0.06	-0.05	-0.08	0.01	0.05		

Table 5b. Bivariate Residual Correlations among Physical Functioning Measures for Men

	FEV-GAIT			FEV-GRIP		GAIT-GRIP		TUG-Grip	
	n	r	se	r	se	r	se	r	se
EAS	72	0.14	0.20	0.23	0.14	0.22	0.25		
ELSA	3210	0.01	0.03	0.01	0.03	0.02	0.03		
HRS	238	0.05	0.08	0.12	0.07	0.06	0.07		
ILSE	252							0.28*	0.10
LASA	800	0.03	0.03	0.05	0.03	0.04	0.05		
MAP	309	-0.01	0.05	-0.01	0.05	0.01	0.06		
NuAge	847					-0.05	0.03	0.04	0.02
OCTO	132	0.03	0.03	0.14	0.09	0.13	0.09		
SATSA	266	-0.05	0.07	-0.16	-0.04	0.02	0.07		

Note: \*  $p < 0.05$

**Figure 1.** Slope-Slope associations derived from random-effects meta-regression across domains of functioning separated by sex and by paired association.

**Notes:** Labels are shown for all samples, irrespective of availability of result. Analyses are sex-stratified; M refers to male-specific analyses, while F refers to female-specific analyses. Individual studies are represented by squares, diamonds represent averages derived from fixed-effects meta-analysis. The size of the square represents the weight of the estimate. R indicates correlation coefficient. 95% CI references the 95% Confidence Interval around the estimate and is shown visually on the graph using uncapped error bars. -No estimates available for this sample in this category. \*NuAge and ILSE rely on timed up and go (TUG) to estimate walking speed.

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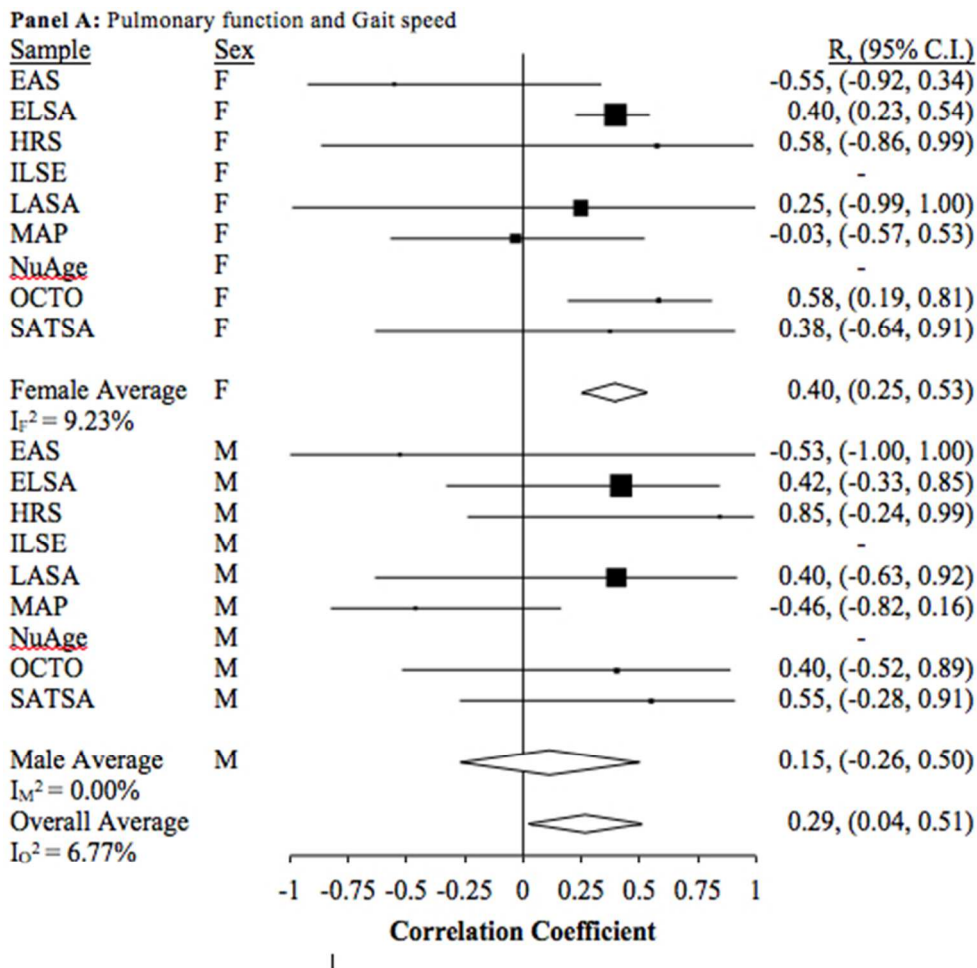


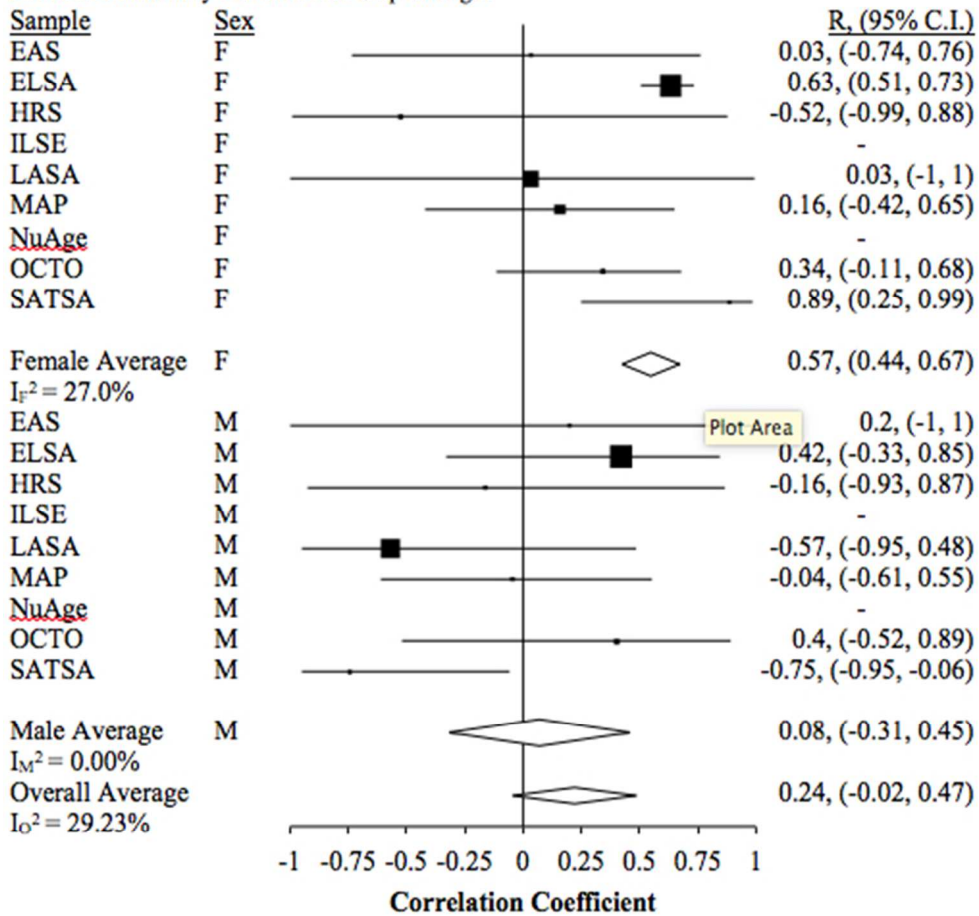
Figure 1. Slope-Slope associations derived from random-effects meta-regression across domains of functioning separated by sex and by paired association.

Notes: Labels are shown for all samples, irrespective of availability of result. Analyses are sex-stratified; M refers to male-specific analyses, while F refers to female-specific analyses. Individual studies are represented by squares, diamonds represent averages derived from fixed-effects meta-analysis. The size of the square represents the weight of the estimate. R indicates correlation coefficient. 95% CI references the 95% Confidence Interval around the estimate and is shown visually on the graph using uncapped error bars. -No estimates available for this sample in this category. \*NuAge and ILSE rely on timed up and go (TUG) to estimate walking speed.

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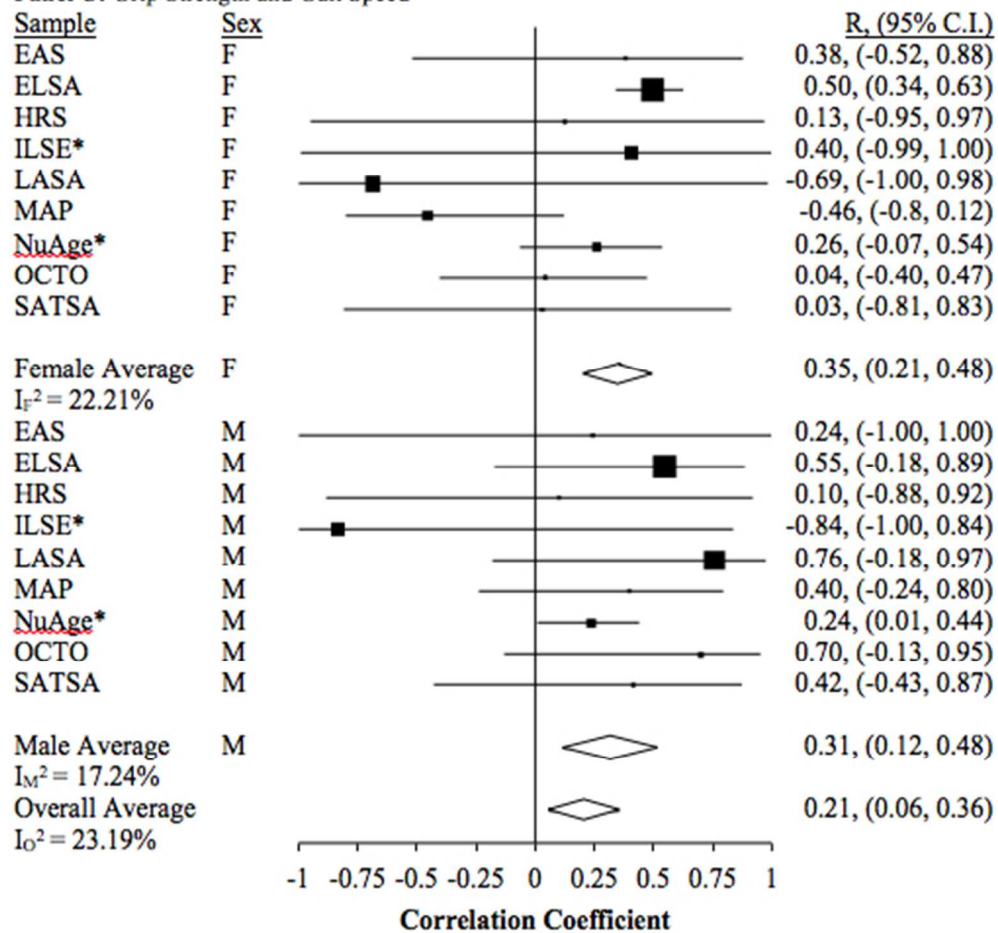
**Panel B: Pulmonary Function and Grip Strength**



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Panel C: Grip Strength and Gait Speed



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