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Cognitive and Behavioural Outcomes

Comparison of cognitive and physical functioning of Europeans in 2004-05 and 2013

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Abstract

Background: Adult mortality has been postponed over time to increasingly high ages. However, evidence on past and current health trends has been mixed, and little is known about European disability trends.

Methods: In a cross-sectional setting, we compared cognitive and physical functioning in same-aged Europeans aged 50+ between 2004–05 (wave 1; $n = 18\ 757$) and 2013 (wave 5 refresher respondents; $n = 16\ 696$), sourced from the Survey of Health, Ageing and Retirement in Europe (SHARE).

Results: People in 2013 had better cognitive function compared with same-aged persons in 2004–05, with an average difference of approximately one-third standard deviation. The same level of cognitive function in 2004–05 at age 50 was found in 2013 for people who were 8 years older. There was an improvement in cognitive function in all European regions. Mean grip strength showed an improvement in Northern Europe of 1.00 kg [95% confidence interval (CI) 0.65; 1.35] and in Southern Europe of 1.68 kg (95% CI 1.14; 2.22), whereas a decrease was found in Central Europe (-0.80 kg; 95% CI −1.16; −0.44). We found no overall differences in activities of daily living (ADL), but small improvements in instrumental activities of daily living (IADL) in Northern and Southern Europe, with an improvement in both ADL and IADL from age 70 in Northern Europe.

Conclusions: Our results indicate that later-born Europeans have substantially better cognitive functioning than earlier-born cohorts. For physical functioning, improvements were less clear, but for Northern Europe there was an improvement in ADL and IADL in the oldest age groups.

Key words: Cohort differences, cognitive function, activities of daily living, grip strength, Europe

Key Messages

- Adult mortality has been postponed over time to increasingly high ages, but evidence on health trends has been mixed.
- This study compared cognitive and physical functioning in same-aged Europeans aged 50+ between 2004–05 (wave 1; $n = 18,757$) and 2013 (wave 5; $n = 16,696$ refresher respondents), sourced from the Survey of Health, Ageing and Retirement in Europe (SHARE).
- In all European regions, people in 2013 had better cognitive function than same-aged individuals in 2004–05. The same level of cognitive function in 2004–05 at age 50 was found for people who were 8 years older in 2013.
- For physical functioning (grip strength, ADL and IADL) improvements were small and less clear, but for Northern Europe there was a substantial improvement in ADL and IADL for people in the oldest age groups.

Introduction

Adult mortality has been postponed to increasingly high ages.[1] For more than a century, there has been an average rise in life expectancy of about 3 months per year in low-mortality countries.[2,3] The rise in life expectancy since 1950 has mostly been caused by declining mortality rates at older ages.[4] The consequences of longer lives are profoundly different, depending on whether poor health is also postponed to higher ages. The fundamental question is whether longer life results in extra years spent in good versus bad health.[5] Contrasting scenarios of health trends have been proposed for ageing populations. One hypothesis, the 'failure of success', argues that mortality declines arise from higher survival rates of individuals with health problems, resulting in worse overall health of the elderly population.[6] In contrast, 'the success-of-success' hypothesis states that the same forces that resulted in decreased mortality would postpone the onset of disability among the elderly, resulting in more people living longer with better health than previously.[7]

In the population as a whole, cognition is generally improving in later-born cohorts (the Flynn effect).[8,9] These positive trends seem to persist into late adulthood,[10–15] but perhaps not into the final years of life.[16] Evidence from international data on past and current trends in disability and functional mobility has been mixed,[5] with a somewhat different tendency depending on whether it relates to severe activities of daily living (ADL) disabilities (the prevalence of which have decreased over time in most studies) or light ADL disabilities (the prevalence of which have increased in most studies).[17] The Global Burden of Diseases, Injuries, and Risk Factors Study 2016, which includes data from 195 countries, found that the age-standardized rates of years lived with disability (YLD) for all causes decreased by 2.7% from 1990 to 2016 and concludes that the decrease in death rates in the study period has not been matched by a similar decline in age-standardized YLD rates.[18] In addition, the Global Burden of Disease Study 2016 concluded that populations could expect to spend more time with functional health loss than previously, due to absolute morbidity expansion.[19] Trends from five national surveys in the USA suggest that crude ADL disability prevalence declined among people aged 65 and above until the 1990s; but from 2000-08, there has been a stagnation in the proportion of people aged 65-84 with one or more activity limitations, whereas continuing declines were found in both ADL and instrumental activities of daily living (IADL) limitations for people aged 85 and older.[20]

Little is known about European disability trends.[5,21] One study indicated expansion of disability rates at age 65 between 1995 and 2001 in nine out of 13 European countries, with evidence of compression of disability in only two countries (Austria and Italy) and stable rates in two countries (Belgium and Spain).[22] In contrast, a 10-year longitudinal study of 3496 men and women participating in a baseline survey in 1988-91 found that disability among Europeans declined over time, with a more favourable time trend in Southern than in Northern Europe.[23]

In this study, we investigate differences in physical and cognitive functioning, across three European regions, of people aged 50+ participating in the Survey of Health, Ageing and Retirement in Europe (SHARE), for two waves, conducted 8-9 years apart.

Methods

Study population

SHARE was launched to improve the understanding of ageing in European populations, and is designed as a cross-national and longitudinal survey, collecting individual data about economic, health and social factors of 50+ year-old Europeans.[24] The data collection is done according to strict quality standards and with ex-ante harmonized interviews across the participating countries.[24] Most surveys took place in the participants' homes, and were performed by a well-trained team of interviewers.[24] SHARE also included nursing home interviews, although they were not officially included in the wave 1 sampling frame. A proxy respondent was allowed for the interview if the respondent had physical or mental health limitations; however, no proxy was allowed in the cognitive function section.[24] The samples in SHARE were drawn at household level. The household response rate (the proportion of selected households including at least one person who obtained an interview) differed by country, varying between 51.1% in Spain and 67.1% in Denmark in wave 1 and between 36.7% in Belgium and 62.2% in Spain for refresher respondents in wave 5.[25] To increase sample size and compensate for attrition, refresher samples were consistently added.[24] Calibrated weights have been applied by SHARE to reduce the impact of non-response and sample attrition on estimates.[26]

This study included respondents aged 50+ from waves 1 and 5 of SHARE.[24] To avoid bias due to initial test experience among participants who were part of previous waves,[27] we included only refresher respondents from wave 5. Wave 1 included individuals who were born between 1901 and 1955 and interviewed in 2004–05. Wave 5 respondents from the refresher sample included individuals born between 1911 and 1963, who were interviewed in 2013 (Table 1). Seven European countries included people in wave 1 and refresher respondents in wave 5. The Human Mortality Database (HMD)[28] was used to obtain life expectancy for the countries under study for calendar years 2004 and 2013.

Background variables

The European countries were classified into three regions: Northern Europe (Denmark and Sweden), Central Europe (Germany, The Netherlands, and Belgium) and Southern Europe (Italy and Spain). Educational attainment was assessed as self-reported highest educational achievement classified into low (ISCED groups 0-2), medium (ISCED groups 3-4) and high (ISCED groups 5-6), following the International Standard Classification of Education (ISCED 1997).[29] Age was grouped into 5-year categories from age 50 to age 89, with an open-ended category from age 90 and above.

Cognitive function

Cognitive function was evaluated by three cognitive tests. Fluency is the number of animals that the respondent could name in 1 min. Immediate recall measures how many of 10 words the respondent could recall immediately after the interviewer read the words. Delayed memory measures the ability to recall the same words after other interview questions. The three cognitive measures were used to compute a cognitive composite score (CCS),[30] calculated by standardizing each single test to the mean and standard deviation (SD) of the values of the 50-54 year olds in the total study population (wave 1 and refresher respondents from wave 5) before summing them into the CCS (low score is poor performance). To facilitate easy interpretation of mean differences, the CCS was made into a T-score.[31] In short, a Z-score was calculated by using the mean and SD of the CCS for the 50-54 year olds, and subsequently this was standardized to a mean of 50 and an SD of 10. If information for an individual was missing for one of the three cognitive tests, the CCS was coded as being missing and hence was excluded from the analysis.

Physical functioning

Grip strength measured in kilograms (kg) was assessed as the maximum score out of four trials (two measurements per hand), recorded with a hand-held dynamometer.[32] ADL and IADL were self-reported scores of current functional limitations of more than 3 months' duration. The ADL scale, adapted from Katz *et al.*,[33] was assessed by six tasks: dressing, bathing/showering, eating, cutting up food, walking across a room and using the toilet. The IADL scale, adapted from Lawton and Brody,[34] was assessed by seven tasks: using a map, preparing a hot meal, shopping for groceries, making telephone calls, taking medications, doing work around the house or garden and handling finances. If all items in the respective ADL and IADL scales were performed independently, ADL and IADL were coded as no limitation and, if not, they were coded as having one or more limitations.

Statistical analysis

Using regression models, we compared cognitive and physical functioning between people in 2004-05 and refresher respondents in 2013, for both sexes combined and for men and women separately. Linear regressions estimated mean differences and 95% confidence intervals (CIs) for the CCS and for grip strength, whereas ADL and IADL were compared by binominal regression models estimating absolute differences in prevalence of having no disabilities. Moreover, age-by-wave, sex-by-wave and region-by-wave interaction analyses and adjustments for region, gender and age at interview were done with regression models. We repeated the analyses for cognitive function,

Table 1. Demographic characteristics of people in SHARE participating in 2004–05 (wave 1) and in 2013 (refresher respondent wave 5)

	All countries		Northern Europe[a]		Central Europe[b]		Southern Europe[c]	
	2004-05 (Wave 1) $n = 18\,757$	2013 (Wave 5) $n = 16\,696$	2004-05 (Wave 1) $n = 4\,579$	2013 (Wave 5) $n = 4442$	2004-05 (Wave 1) $n = 9421$	2013 (Wave 5) $n = 7399$	2004-05 (Wave 1) $n = 4757$	2013 (Wave 5) $n = 4875$
Age bands, *n* (birth years)								
50-54	3354 (1949-55)	3433 (1958-63)	810 (1949-54)	696 (1958-63)	1850 (1949-55)	1881 (1958-63)	694 (1949-54)	856 (1958-63)
55-59	3602 (1944-50)	2796 (1953-58)	914 (1944-49)	708 (1953-58)	1834 (1944-50)	1267 (1953-58)	854 (1944-49)	821 (1953-58)
60-64	3246 (1939-45)	2696 (1948-53)	793 (1939-44)	737 (1948-53)	1580 (1939-45)	1216 (1948-53)	873 (1939-44)	743 (1948-53)
65-69	2839 (1934-40)	2574 (1943-48)	635 (1934-39)	878 (1943-48)	1456 (1934-40)	1001 (1943-48)	748 (1934-39)	695 (1943-48)
70-74	2310 (1929-35)	1972 (1938-43)	521 (1929-34)	582 (1938-43)	1110 (1929-35)	838 (1938-43)	679 (1929-34)	552 (1938-43)
75-79	1738 (1924-30)	1511 (1933-38)	439 (1924-29)	412 (1933-38)	838 (1924-30)	605 (1933-38)	461 (1924-29)	494 (1933-38)
80-84	1039 (1919-25)	1000 (1928-33)	255 (1919-24)	261 (1928-33)	510 (1919-25)	345 (1928-33)	274 (1919-24)	394 (1928-33)
85-89	438 (1914-20)	518 (1923-28)	155 (1914-19)	107 (1923-28)	168 (1914-20)	184 (1923-28)	115 (1914-19)	227 (1923-28)
90+	191 (1901-15)	196 (1911-23)	57 (1902-14)	41 (1912-23)	75 (1904-15)	62 (1912-23)	59 (1901-14)	93 (1911-23)
Men	8632 (46.0)	7940 (47.6)	2146 (46.9)	2108 (47.7)	4407 (46.8)	3519 (47.6)	2079 (43.7)	2313 (47.5)
Particpation by proxy[d]								
Respondent only	17 397 (93.1)	15 855 (95.2)	4417 (96.6)	4321 (97.9)	8629 (91.9)	7114 (96.4)	4351 (91.9)	4420 (90.8)
Proxy and respondent	959 (5.1)	457 (2.7)	108 (2.4)	66 (1.5)	576 (6.1)	186 (2.5)	275 (5.8)	205 (4.2)
Proxy only	340 (1.8)	349 (2.1)	46 (1.0)	28 (0.6)	187 (2.0)	79 (1.1)	107 (2.3)	242 (5.0)
Missing	61 (0.3)	35 (0.2)	8 (0.2)	7 (0.2)	29 (0.3)	20 (0.3)	24 (0.5)	8 (0.2)
Education by both sexes[d]								
Low (primary and lower secondary)	9826 (52.8)	6747 (40.5)	1970 (43.6)	1205 (27.4)	3986 (42.7)	1845 (25.0)	3870 (81.6)	3697 (76.0)
Medium (upper secondary education)	5230 (28.1)	5541 (33.3)	1445 (32.0)	1614 (36.6)	3203 (34.3)	3304 (44.8)	582 (12.3)	623 (12.8)
High (tertiary education)	3539 (19.0)	4359 (26.2)	1107 (24.5)	1586 (36.0)	2143 (23.0)	2231 (30.2)	289 (6.1)	542 (11.2)
Missing	162 (0.9)	49 (0.3)	57 (1.2)	17 (0.4)	89 (0.9)	19 (0.3)	16 (0.3)	13 (0.3)

Data are *n* (%) unless otherwise stated.
[a]Denmark and Sweden.
[b]Germany, The Netherlands and Belgium.
[c]Spain and Italy.
[d]Missing data excluded from percentage calculations.

controlling for education categorized into three categories, in accordance with ISCED 1997.[29] In addition, analyses were repeated in which people living in nursing homes were excluded. Furthermore, we performed a sensitivity analysis including the total sample in wave 5, which included three additional countries: Austria, France and Switzerland.

To investigate the age-shift in cognitive function from 2004-05 to 2013, we performed a linear trajectory of the CCS over age for each wave using simple linear regression. Uncertainty measures were given by parametric bootstrap CIs (Figure 1, bottom left panel). By using this linear trajectory, we computed the difference in cognitive function at each age from 2004-05 to 2013 (Figure 1, bottom right panel). Similarly, to measure the amount of increase in life expectancy at age 50+, we first performed simple linear regression of remaining life expectancy over age in 2004 and 2013 (Figure 1, top left panel) and then computed the increase in years in remaining life expectancy by age (Figure 1, top right panel). In all analyses, we included the calibrated

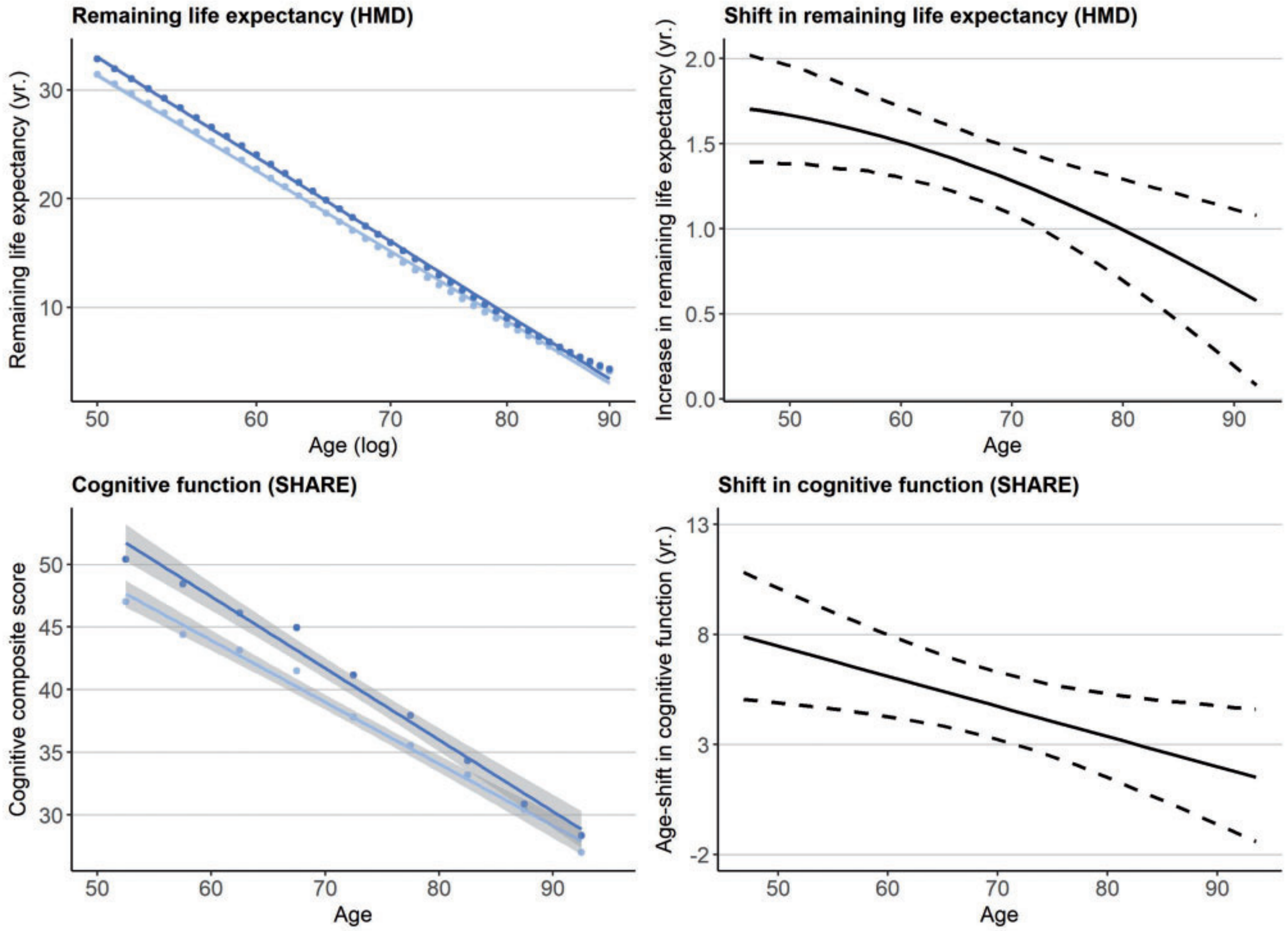

Figure 1. Top left panel: Remaining life expectancy by age in 2004 (light dots) and 2013 (dark dots) (HMD) with linear regression fit (light and dark lines with CI bands). Top right panel: Increase in remaining life expectancy by age between 2004 and 2013 (HMD) with bootstrap CIs. Bottom left panel: CCS by age in 2004–05 (wave 1, light dots) and 2013 (wave 5, dark dots) with linear regression fit (light and dark lines with CIs bands). Bottom right panel: Age-shift in the CCS from 2004-05 (wave 1) to 2013 (wave 5) with bootstrap CIs.

cross-sectional individual weights applied by SHARE.[26] Stata version 14.2 and R version 3.2.2 were used for the analyses.

Results

In total, we included 18 757 participants interviewed in 2004-05 and 16 696 refresher respondents interviewed in 2013. There were slightly fewer men in 2004-05 than in 2013 (46.0% vs 47.6%) (Table 1). Educational attainment was highest in 2013, but large regional differences were found. Northern Europe had the highest proportion of people with high education, whereas Southern Europe had the lowest (Table 1). For all outcome measures, there were regional differences in baseline levels ($P<0.001$). Southern Europe had the lowest mean for the CCS and for grip strength in 2004-05, and the lowest average proportion of people with no ADL and IADL limitations (Table 2). The difference in life expectancy between 2004 and 2013 for the seven countries combined was approximately 1.7 years at age 50 and 0.7 years at age 90 (Figure 1, top panel).

Participants in 2013 had better cognitive function than those in 2004-05, corresponding to one-third SD (Figure 2A; Supplementary Table 1, available as Supplementary data at *IJE* online). In investigating the age-shift of cognitive function, the same level of cognitive function in 2004-05 at age 50 was found for people who were 8 years older in 2013. The improvement diminished with increasing age to about 2 years for people aged 90 (Figure 1, bottom panel). However, the difference in cognitive function between 2004-05 and 2013 differed by region ($P < 0.001$) (Figure 2B). Southern Europe had the highest average improvement in the youngest age group, but the improvement became smaller with increasing age. Northern Europe, which on average had the highest CCS, had the smallest improvement among the three regions. The improvement was similar for men and women (Figure 3) with no sex-by-wave interaction ($P = 0.090$). After adjustment for education, the improvements in

Table 2. Cognitive function, grip strength, activities of daily living (ADL) scores and instrumental activities of daily living (IADL) scores for participants in 2004-05 (wave 1) and refresher respondents in 2013 (wave 5) participating in SHARE

	All countries		Northern Europe[a]		Central Europe[b]		Southern Europe[c]	
	2004-05 (Wave 1) $n = 18\ 757$	2013 (Wave 5) $n = 16\ 696$	2004-05 (Wave 1) $n = 4579$	2013 (Wave 5) $n = 4442$	2004-05 (Wave 1) $n = 9421$	2013 (Wave 5) $n = 7399$	2004-05 (Wave 1) $n = 4757$	2013 (Wave 5) $n = 4875$
Cognitive composite score[d]								
Mean (SD)	43.2 (10.8)	46.5 (11.1)	47.6 (10.4)	49.5 (9.9)	44.7 (10.0)	48.4 (10.6)	36.0 (9.2)	40.6 (10.7)
Median (IQR)	43.5(35.7-50.9)	47.1(39.5-54.2)	48.3(41.4-54.6)	49.8(43.3-56.1)	45.0(38.2-51.6)	48.8(41.7-55.6)	35.7(29.5-42.0)	41.2(33.3-47.9)
Missing	517 (2.8)	683 (4.1)	105 (2.3)	88 (2.0)	258 (2.7)	170 (2.3)	154 (3.2)	425 (8.7)
Grip strength[d]								
Mean (SD)	34.5 (12.5)	34.9 (12.2)	35.7 (12.7)	36.7 (12.1)	36.0 (12.4)	36.1 (12.1)	30.0 (11.6)	31.0 (11.4)
Median (IQR)	33 (25-43)	33 (26-44)	34 (26-45)	35 (28-46)	34 (27-45)	35 (27-45)	28 (22-37)	30 (23-39)
Missing	1257 (6.7)	1321 (7.9)	254 (5.6)	142 (3.2)	581 (6.2)	455 (6.2)	422 (8.9)	724 (14.9)
ADL[d]								
No limitations	16 790 (89.8)	15 068 (90.5)	4142 (90.6)	4105 (93.0)	8500 (90.5)	6612 (89.7)	4148 (87.6)	4351 (89.4)
1+ limitation	1901 (10.2)	1583 (9.5)	428 (9.4)	307 (7.0)	888 (9.5)	761 (10.3)	585 (12.4)	515 (10.6)
Missing	66 (0.4)	45 (0.3)	9 (0.2)	10 (0.2)	33 (0.4)	26 (0.4)	24 (0.5)	9 (0.2)
IADL[d]								
No limitations	15 603 (83.5)	14 338 (86.1)	3 853 (84.3)	3 910 (88.6)	7 943 (84.6)	6 316 (85.7)	3 807 (80.4)	4 112 (84.5)
1+ limitation	3 088 (6.5)	2 313 (13.9)	717 (15.7)	502 (11.4)	1 445 (15.4)	1 057 (14.3)	926 (19.6)	754 (15.5)
Missing	66 (0.4)	45 (0.3)	9 (0.2)	10 (0.2)	33 (0.4)	26 (0.4)	24 (0.5)	9 (0.2)

Data are *n* (%) unless otherwise stated.
IQR, interquartile range.
[a]Denmark and Sweden.
[b]Germany, The Netherlands and Belgium.
[c]Spain and Italy.
[d]Missing data excluded from percentage calculations.

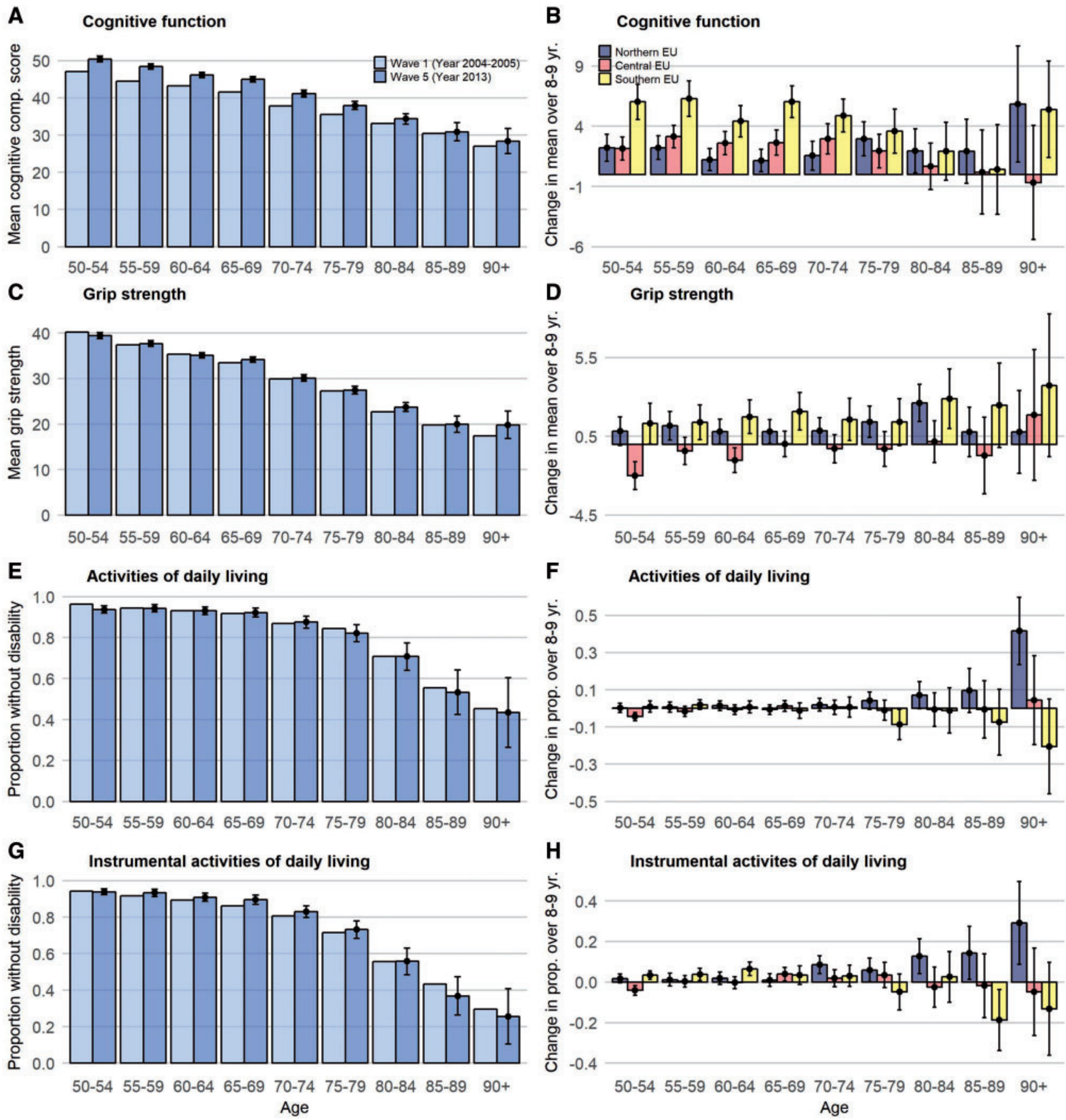

Figure 2. Left panel: Cognitive function, grip strength, ADL and IADL in 2004–05 (wave 1) and in 2013 (refresher respondents wave 5) for seven countries combined in SHARE. Right panel: Difference in cognitive function and grip strength and in the proportion of having no ADL and IADL disabilities between 2004–05 and 2013 for participants in Northern, Central and Southern Europe (EU).

cognitive function persisted; however, the differences were slightly reduced (Supplementary Table 1, available as Supplementary data at *IJE* online).

No difference in grip strength between 2004-05 and 2013 was found for all countries combined (mean difference 0.01 kg; 95% CI −0.27; 0.29), but there was a slight age-by-wave interaction ($P = 0.044$)—i.e. the difference in grip strength between 2004-05 and 2013 differed by age groups. A small impairment in grip strength was present for the youngest age group, whereas an indication of an improvement was found from age 65 and above (Figure 2C; Supplementary Table 2, available as Supplementary data at *IJE* online). The difference in grip strength differed between regions ($P < 0.001$), with an overall improvement in Northern Europe of 1.00 kg (95% CI 0.65; 1.35) and in Southern Europe of 1.68 kg (95% CI

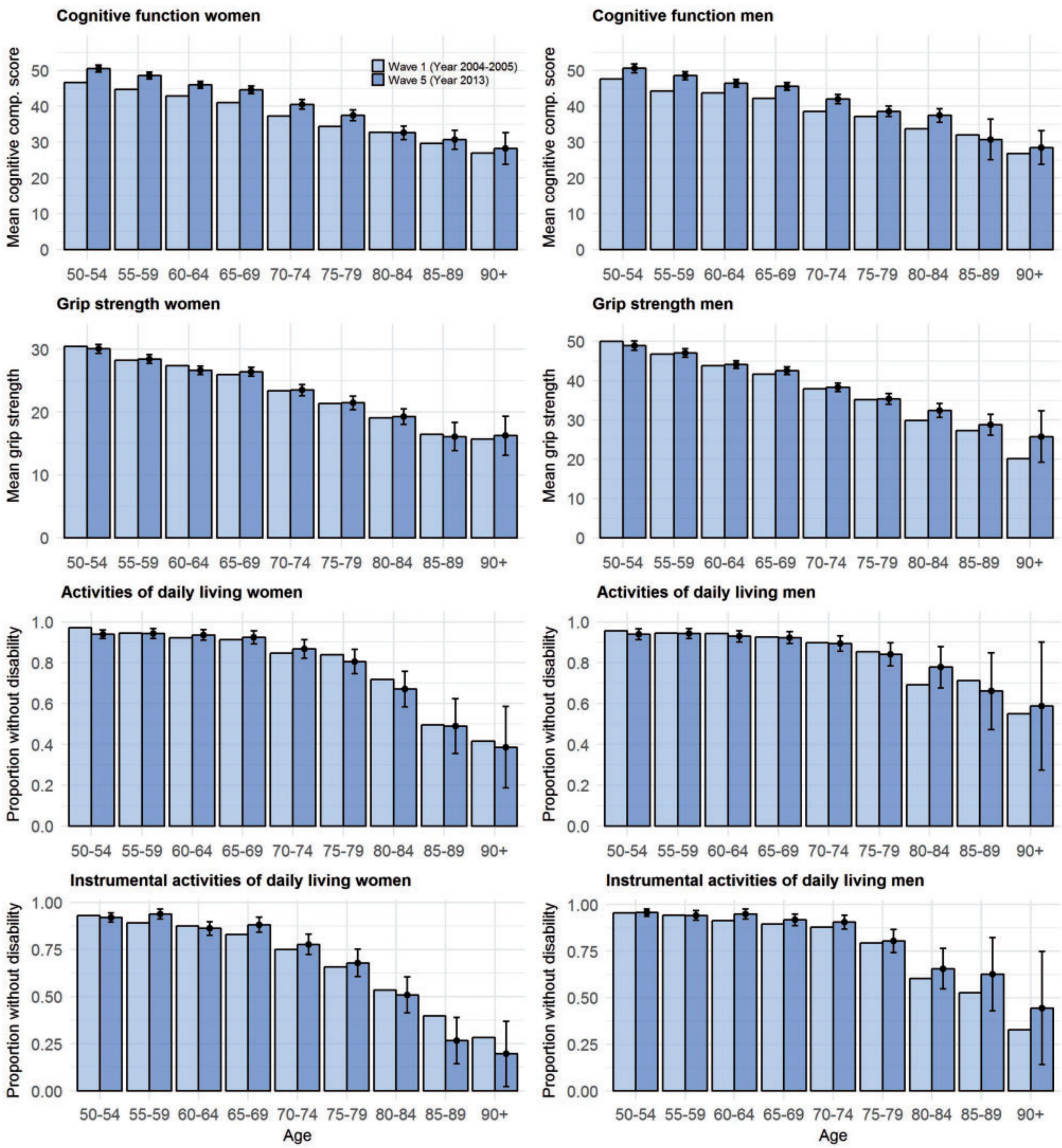

Figure 3. Cognitive function, grip strength, ADL and IADL in 2004–05 (wave 1) and in 2013 (refresher respondents wave 5) for women and men participating in SHARE.

1.14; 2.22), whereas a slight decrease of 0.80 kg (95% CI −1.16; −0.44) was found in Central Europe. There were no age-by-wave interactions in the specific regions (Figure 2D). The mean difference in grip strength differed between genders ($P < 0.001$), with a higher improvement for men than for women (Figure 3).

The proportion of people having no ADL disabilities was approximately similar in 2004-05 and 2013 (absolute improvement −0.01; 95% CI −0.02; −0.00) (Figure 2E; Supplementary Table 3, available as Supplementary data at *IJE* online) with no age-by-wave interaction ($P = 0.227$), but there were regional differences ($P = 0.017$). A small overall impairment between 2004-05 and 2013 was found in Central Europe, with no average differences in Northern or Southern Europe. However, there was an increasing improvement in ADL from age 70 in Northern Europe, with a substantial difference for ages 90+ (absolute difference of 0.42) (Figure 2F). The difference between 2004-05 and 2013 was similar for men and women ($P = 0.620$).

The proportion of people having no IADL disabilities was similar (absolute improvement 0.01; 95% CI −0.00; 0.02) with no age-by-wave ($P = 0.067$) and no sex-by-wave ($P = 0.231$) interactions (Figure 2G; Supplementary Table 4, available as Supplementary data at *IJE* online); however, there were regional differences ($P < 0.001$). For Northern and Southern Europe, there was an overall improvement between 2004-05 and 2013 (absolute difference of 0.03), with an increasing improvement from age 70 in Northern Europe (Figure 2H).

In total, 153 interviews (0.9%) were conducted in nursing homes among refresher respondents in 2013. In excluding them from the analyses, the results were quite similar to the main results (results not shown). Also, when comparing people interviewed in 2004-05 with the total sample interviewed in 2013 ($n = 46\,747$), the results were overall similar to the results found when only refresher respondents were included (Supplementary Figure 1, available as Supplementary data at *IJE* online). However, for cognitive function, the average improvement between 2004-05 and 2013 was slightly higher.

Discussion

Among Europeans, remaining life expectancy increased by 1.7 years at age 50 and 0.7 years at age 90 from 2004 to 2013. In the same period, we found better cognitive function for people interviewed in 2013 compared with people interviewed in 2004-05. The same level of cognitive function in 2004-05 at age 50 was found for people who were 8 years older in 2013. Thus, although population ageing is a major challenge for most countries in the world,[1,35] our study is encouraging in demonstrating large improvements in cognitive functioning over 8–9 years, despite more people living to older ages. One reason for this finding could be a postponement of cognitive decline, i.e. the decline in cognition is starting at higher ages in later-born cohorts or with a slower slope of decline. Another explanation could be the dramatic difference in IQ/cognition among young adults during the 20th century.[8,9,36] Later-born cohorts have a substantially higher starting level in their youth. It is possible that the age at which the decline starts has remained unchanged over cohorts and the decline could have the same slope of decline. This is known as the 'preserved differentiation hypothesis'[37] —simply, a parallel shift vertically upwards over cohorts. In our cross-sectional scenario, it was not possible to differentiate between the possible explanations, because higher starting levels would look like a postponement of cognitive decline. A recent longitudinal study from Amsterdam[38] suggests that it is the starting level and not postponement of cognitive decline that is the reason for better cognition among later-born elderly; however, the evidence is mixed from study to study.[39]

Different factors have been linked to trends favouring later-born cohorts in cognitive function, including improvements in education.[40,41] Even after adjusting for education, people in 2013 still had better cognitive function than same-aged people in 2004–05. These findings are in line with previous studies in which education did not account for—or only partially accounted for—cohort differences in cognitive functioning in late life.[10,15,39,42] Thus although improvement in education may explain some of the improvement in cognitive functioning, differences in other factors such as general living conditions, including nutrition, work environment and intellectual stimulation, may also play an important role.[10] Although the improvement in cognitive function somewhat declined with increasing age, our findings suggest that the positive trend in cognitive function seems to persist into late adulthood, in accordance with previous literature.[10–14]

To our knowledge, there is no evidence that there has been a similar, dramatic improvement in physical strength throughout the 20th century. In this study, we found less clear improvements in physical functioning, supporting the body of evidence on stable/no clear overall trends in activity limitations.[43–45] However, in agreement with previous studies from Denmark and Sweden,[10,46,47] we found improvements in ADL and IADL at older ages in Northern Europe. This could be due to differences in economic development between the European regions during the study period, particularly as the global economic crisis in 2007 influenced Southern Europe more than other European regions.[48]

One of the major strengths of this study is the large national samples of people from seven European countries interviewed 8-9 years apart, making it possible to investigate health trends across European regions. The included outcomes were harmonized across countries,[24] including performance-based measures on cognitive functioning and grip strength, thus avoiding biases that might arise in self-reports. Although this study includes middle-aged Europeans, it also includes elderly people and people living in nursing homes, for whom data are sparser.[10,49] A potential limitation in this study is that cognitive function is a composite of three measures, and thus it is not likely to reflect all aspects of the cognitive ability. Moreover the sampling procedures might vary from country to country, and there may be differences between respondents in 2004–05 and the refresher sample in 2013, which could lead to potential bias and thus may explain at least part of the differences in cognitive function between waves. In addition, nursing homes were not officially included in the wave 1 sampling frame, which could potentially bias results for the oldest old. However, less than 1% of refreshers in wave 5 were interviewed in nursing homes, and excluding them did not change the results. Another limitation of the SHARE data is the response rate, which was slightly lower in wave 5 (36.7-62.2%) than in wave 1 (51.1-67.1%). However, SHARE provides data with calibrated weights, which are constructed to reduce the impact of these issues.[24] The proportion of missing data differed between items and regions, with a slightly higher proportion of missing values for cognitive function in wave 5 than in wave 1 (4.1% vs 2.8%). In contrast, few ADL and IADL items were exposed to missing responses. Further waves of SHARE are needed to investigate the age trajectories for different birth cohorts at same ages.

In summary, in this large study, Europeans in 2013 had better cognitive function compared with individuals of the same age in 2004–05. The same level of cognitive function in 2004–05 at age 50 was found for people who were 8 years older in 2013. These findings confirm better cognitive functioning among later-born cohorts, which might be due to better starting levels or postponement of cognitive decline. For physical functioning (grip strength, ADL and IADL), improvements were small and less clear, but for Northern Europe there was a substantial improvement in ADL and IADL for people in the oldest age groups.

Supplementary data

Supplementary data are available at *IJE* online.

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References

1. Vaupel JW. The remarkable improvements in survival at older ages. *Philos Trans R Soc Lond B Biol Sci* 1997;**352**:1799–804.
2. Christensen K, Doblhammer G, Rau R, Vaupel JW. Ageing populations: the challenges ahead. *Lancet* 2009;**374**:1196–208.
3. Oeppen J, Vaupel JW. Demography. Broken limits to life expectancy. *Science* 2002;**296**:1029–31.
4. Rau R, Soroko E, Jasilionis D, Vaupel JW. Continued reductions in mortality at advanced ages. *Popul Dev Rev* 2008;**34**:747–68.
5. Beltran-Sanchez H, Soneji S, Crimmins EM. Past, present, and future of healthy life expectancy. *Cold Spring Harb Perspect Med* 2015;**5**:a025957.
6. Gruenberg EM. The failures of success. *Milbank Mem Fund Q Health Soc* 1977;**55**:3–24.
7. Fries JF. Aging, natural death, and the compression of morbidity. 1980. *Bull World Health Organ* 2002;**80**:245–50.
8. Flynn JR. Searching for justice: the discovery of IQ gains over time. *Am Psychol* 1999;**54**:5–20.
9. Trahan LH, Stuebing KK, Fletcher JM, Hiscock M. The Flynn effect: a meta-analysis. *Psychol Bull* 2014;**140**:1332–60.
10. Christensen K, Thinggaard M, Oksuzyan A *et al*. Physical and cognitive functioning of people older than 90 years: a comparison of two Danish cohorts born 10 years apart. *Lancet* 2013;**382**:1507–13.
11. Finkel D, Reynolds CA, McArdle JJ, Pedersen NL. Cohort differences in trajectories of cognitive aging. *J Gerontol B Psychol Sci Soc Sci* 2007;**62**:P286–94.
12. Langa KM, Larson EB, Karlawish JH *et al*. Trends in the prevalence and mortality of cognitive impairment in the United States: is there evidence of a compression of cognitive morbidity? *Alzheimers Dement* 2008;**4**:134–44.
13. Rönnlund M, Nilsson L-G. The magnitude, generality, and determinants of Flynn effects on forms of declarative memory and visuospatial ability: time-sequential analyses of data from a Swedish cohort study. *Intelligence* 2008;**36**:192–209.
14. Schaie KW, Willis SL, Pennak S. An historical framework for cohort differences in intelligence. *Res Hum Dev* 2005;**2**:43–67.
15. Gerstorf D, Hulur G, Drewelies J *et al*. Secular changes in late-life cognition and well-being: towards a long bright future with a short brisk ending? *Psychol Aging* 2015;**30**:301–10.
16. Hulur G, Infurna FJ, Ram N, Gerstorf D. Cohorts based on decade of death: no evidence for secular trends favoring later cohorts in cognitive aging and terminal decline in the AHEAD study. *Psychol Aging* 2013;**28**:115–27.
17. Robine J-M, Romieu I, Michel J-P. *Trends in Health Expectancies. Determining Health Expectancies*. Chichester, UK: Wiley, 2003.
18. GBD 2016 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017;**390**:1211–59.
19. GBD 2016 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national disability-adjusted

life-years (DALYs) for 333 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017;**390**:1260–344.
20. Freedman VA, Spillman BC, Andreski PM *et al*. Trends in late-life activity limitations in the United States: an update from five national surveys. *Demography* 2013;**50**:661–71.
21. Bowling A. Commentary: trends in activity limitation. *Int J Epidemiol* 2011;**40**:1068–70.
22. Jagger C, Gillies C, Cambois E *et al*. Trends in disability-free life expectancy at age 65 in the European Union 1995-2001: a comparison of 13 EU countries. *Gerontologist* 2011;**51**:250.
23. Aijanseppa S, Notkola IL, Tijhuis M, van Staveren W, Kromhout D, Nissinen A. Physical functioning in elderly Europeans: 10 year changes in the north and south: the HALE project. *J Epidemiol Community Health* 2005;**59**:413–19.
24. Borsch-Supan A, Brandt M, Hunkler C *et al*. Data Resource Profile: The Survey of Health, Ageing and Retirement in Europe (SHARE). *Int J Epidemiol* 2013;**42**:992–1001.
25. Bergmann M, Kneip T, De Luca G, Scherpenzeel A. *Survey Participation in the Survey of Health, Ageing and Retirement in Europe (SHARE), Wave 1-6. Based on Release 6.0.0 (March 2017), SHARE Working Paper Series 31-2017*. Munich, Germany: Munich Center for the Economics of Aging (MEA), 2017.
26. Börsch-Supan A, Jürges H. *The Survey of Health, Aging, and Retirement in Europe—Methodology*. Mannheim, Germany: Mannheim Research Institute for the Economics of Aging (MEA), 2005.
27. Salthouse TA. Aging cognition unconfounded by prior test experience. *J Gerontol B Psychol Sci Soc Sci* 2016;**71**:49–58.
28. Human Mortality Database. Human mortality database. University of California, Berkeley, USA and Max Planck Institute for Demographic Research, Rostock, Germany, 2017. Mismatch]
29. United Nations Educational, Scientific and Cultural Organisation (UNESCO). *International Standard Classification of Education (ISCED)*. Paris: UNESCO, 1997.
30. McGue M, Christensen K. The heritability of cognitive functioning in very old adults: evidence from Danish twins aged 75 years and older. *Psychol Aging* 2001;**16**:272–80.
31. Hale CD, Astolfi D. *Standardized Testing: Introduction. Measuring Learning & Performance: A Primer*. 2nd edn. St Leo, FL: Saint Leo University, 2011.
32. Andersen-Ranberg K, Petersen I, Frederiksen H, Mackenbach JP, Christensen K. Cross-national differences in grip strength among 50+ year-old Europeans: results from the SHARE study. *Eur J Ageing* 2009;**6**:227–36.
33. Katz S, Downs TD, Cash HR, Grotz RC. Progress in development of the index of ADL. *Gerontologist* 1970;**10**:20–30.
34. Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. *Gerontologist* 1969;**9**:179–86.
35. Kannisto V, Lauritsen J, Thatcher AR, Vaupel JW. Reductions in mortality at advanced ages: several decades of evidence from 27 countries. *Popul Dev Rev* 1994;**20**:793–810.
36. Christensen GT, Molbo D, Angquist LH *et al*. Cohort profile: The Danish Conscription Database (DCD): a cohort of 728 160 men born from 1939 through 1959. *Int J Epidemiol* 2015;**44**:432–40.
37. Salthouse TA. Mental exercise and mental aging: evaluating the validity of the “use it or lose it” hypothesis. *Perspect Psychol Sci* 2006;**1**:68–87.
38. Brailean A, Huisman M, Prince M, Prina AM, Deeg DJ, Comijs H. Cohort differences in cognitive aging in the longitudinal aging study Amsterdam. *J Gerontol B Psychol Sci Soc Sci* 2016, Sep 30. pii: gbw129. [Epub ahead of print.].
39. Gerstorf D, Ram N, Hoppmann C, Willis SL, Schaie KW. Cohort differences in cognitive aging and terminal decline in the Seattle Longitudinal Study. *Dev Psychol* 2011;**47**:1026–41.
40. Alwin DF, McCammon RJ. Aging, cohorts, and verbal ability. *J Gerontol B Psychol Sci Soc Sci* 2001;**56**:S151–61.
41. Blair C, Gamson D, Thorne S, Baker D. Rising mean IQ: cognitive demand of mathematics education for young children, population exposure to formal schooling, and the neurobiology of the prefrontal cortex. *Intelligence* 2005;**33**:93–106.
42. Karlsson P, Thorvaldsson V, Skoog I, Gudmundsson P, Johansson B. Birth cohort differences in fluid cognition in old age: comparisons of trends in levels and change trajectories over 30 years in three population-based samples. *Psychol Aging* 2015;**30**:83–94.
43. Parker MG, Ahacic K, Thorslund M. Health changes among Swedish oldest old: prevalence rates from 1992 and 2002 show increasing health problems. *J Gerontol A Biol Sci Med Sci* 2005; **60**:1351–55.
44. van Gool CH, Picavet HS, Deeg DJ *et al*. Trends in activity limitations: the Dutch older population between 1990 and 2007. *Int J Epidemiol* 2011;**40**:1056–67.
45. Lafortune G, Balestat G. *Trends in Severe Disability Among Elderly People: Assessing the Evidence in 12 OECD Countries and the Future Implications. (OECD Health Working Paper, No 26)*. Paris: Organisation for Economic Co-operation and Development, 2007.
46. Engberg H, Christensen K, Andersen-Ranberg K, Vaupel JW, Jeune B. Improving activities of daily living in Danish centenarians - but only in women: a comparative study of two birth cohorts born in 1895 and 1905. *J Gerontol A Biol Sci Med Sci* 2008;**63**:1186–92.
47. Falk H, Johansson L, Ostling S *et al*. Functional disability and ability 75-year-olds: a comparison of two Swedish cohorts born 30 years apart. *Age Ageing* 2014;**43**:636–41.
48. Organisation for Economic Co-operation and Development (OECD). *OECD Factbook 2015-2016: Economic, Environmental and Social Statistics*. Paris: OECD Publishing 2016.
49. Crimmins EM, Beltrán-Sánchez H. Mortality and morbidity trends: is there compression of morbidity?*J Gerontol Ser B Psychol Sci Soc Sci* 2011;**66B**:75–86.