# Declining physical abilities with age: a cross-sectional study of older twins and centenarians in Denmark

Karen Andersen-Ranberg[1], Kaare Christensen[1], Bernard Jeune[1], Axel Skytthe[1], Lone Vasegaard[1], James W. Vaupel[1,2]

[1]Ageing Research Centre and Epidemiology, Institute of Public Health and [2]The Danish Centre for Demographic Research, Odense University, Winslowparken 17, DK-5000 Odense C, Denmark

Address correspondence to: K. Andersen-Ranberg. Fax: (+45) 6590 6938. Email: K-Ranberg@win-chs.sdu.dk

## Abstract

**Objective:** to evaluate whether physical disability reaches a plateau in the oldest age groups.
**Design:** cross-sectional survey.
**Participants:** a total of 3351 individuals, which included all those living in Denmark who celebrated their 100th anniversary during the period from 1 April 1995 to 31 May 1996 (276 subjects) and all Danish twins aged 75–94 registered in the Danish Twin Register (3075 subjects).
**Main outcome measures:** the ability to perform selected items of basic activities of daily living independently.
**Results:** the prevalence of independence in each of six selected activities of daily living was significantly lower in both men and women centenarians compared with octo- and septuagenarians. The sex difference in independence in all six selected activities of daily living was larger for each advancing age group, with women being most disabled ($P < 0.001$). In centenarians 20% of women and 44% of men were able to perform all selected activities of daily living independently.
**Conclusion:** compared with individuals aged 75–79 years, physical abilities of men and women gradually diminished in age groups 80–84, 85–90 and 90–94, with the lowest levels among 100-year-olds. Although women have lower mortality, they are more disabled than men, and this difference is more marked with advancing age.

**Keywords:** *activities of daily living, aged, centenarians, oldest-old, twins*

## Introduction

Mortality is levelling off in very old people [1]. In 12 countries with reliable demographic data, the number of octogenarians has grown fourfold, nonagenarians eightfold and centenarians more than 20-fold from 1950 to 1990 [2]. The dramatic increase in the number of centenarians is largely the result of a decrease in mortality among 80- and 90-year-olds [3]. At all ages, mortality rates are lower in women than men, resulting in a sex ratio (M : F) of about 1 : 3 at the oldest ages [2].

Physical ability is important for health and well being in old age. It is influenced by the ageing process and multiple diseases [4, 5]. With advancing age, disability increases with a marked sex difference: women over 75 generally have higher rates of disability than men [6]. As disability can result in the need for additional care, the increasing numbers of the oldest-old could become a huge social and economic challenge—if increased longevity is accompanied by an equal increase of life with disability [7]. However, it is argued that increased longevity is accompanied by an equal increase in years free from disability [8].

We have investigated whether physical ability declines with age or reaches a plateau in the oldest-old. We have also studied the sex differences in age-associated disability.

## Materials and methods

The study is based on two nation-wide studies launched by the Ageing Research Centre at Odense University: the Longitudinal Study of Ageing in Danish Twins (LSADT) and the Longitudinal Danish Centenarian Study (DLCS).

LSADT, based on the Danish Twin Registry [9, 10], was restricted to all registered Danish twins aged 75+

before 1 January 1995 who had not emigrated permanently [11]. In this study, 2383 of 3075 subjects aged 75–94 were interviewed at home by 100 interviewers from February to April 1995 (a participation rate of 77.5%). A proxy respondent was sought when the twin was unable to answer because of mental incapacity or severe deafness. In this study we excluded those aged 95 years and older as the sample size was small (24 people).

The DLCS is a clinical epidemiological survey of all persons living in Denmark who celebrated their 100th birthday during the period 1 April 1995–31 May 1996 (276 people). The addresses of all centenarians in the study population were obtained from the central person registry using the personal identification number of each centenarian. About two weeks after their 100th birthday, all centenarians received a letter explaining the study and asking permission for a geriatrician and a geriatric nurse to visit them for an interview and physical examination. A proxy respondent was sought when the centenarian was unable to answer. A total of 207 (75%) centenarians (162 women and 45 men) participated.

### Non-participants

In both studies all non-participants, including those who died before the interview, were registered by age, sex and type of housing.

### Assessment of activities of daily living (ADLs)

Both the LSADT and the DLCS assess ADL with an instrument which has previously been used and validated in Denmark [12–16]. All the items refer to what the participant was able to do on the day of the interview.

We have chosen to focus on five most basic self-care ADLs: (i) transferring from bed and chair, (ii) walking indoors, (iii) dressing the upper half of the body, (iv) dressing the lower half and (v) using the toilet. To compare these five basic self-care activities with a more demanding activity, we have included 'walking outdoors in fine weather'.

### Statistical methods

Differences in type of housing between participants and non-participants were tested with a $\chi^2$-test. For each of six ADL items, a prevalence proportion ratio (PPR) of remaining independent was calculated for each age group using the 75–79-year-olds as a reference group. Confidence intervals around PPRs were calculated using the standard error of $\log_e(PPR)$, and assuming normal distribution of $\log_e(PPR)$. The centenarians were also compared separately with octo- and nonagenarians. The gender difference between age groups in the ability of performing all the six selected ADL items independently was tested with the Mantel–Haenszel test.

### Results

There were only minor differences in the response rates in the different age groups. More men than women participated (women: 75.6%, men: 80.8%,

Table 1. Ability of women to perform each of six selected activities of daily living (ADLs) independently

| ADL | Age group (years) | | | | |
| --- | --- | --- | --- | --- | --- |
| | 75–79 (n = 615) | 80–84 (n = 493) | 85–89 (n = 326) | 90–94 (n = 99) | 100 (n = 162) |
| Transferring from bed/chair | | | | | |
| PPR (and 95% CI) | 1 | 0.96 (0.93, 0.99) | 0.89 (0.85, 0.94) | 0.78 (0.70, 0.88) | 0.68 (0.61, 0.76) |
| n | 595 | 457 | 282 | 75 | 107 |
| Walking indoors | | | | | |
| PPR (and 95% CI) | 1 | 0.97 (0.94, 0.99) | 0.90 (0.86, 0.94) | 0.78 (0.70, 0.87) | 0.63 (0.56, 0.71) |
| n | 598 | 463 | 284 | 75 | 99 |
| Using the toilet | | | | | |
| PPR (and 95% CI) | 1 | 0.96 (0.93, 0.99) | 0.87 (0.83, 0.91) | 0.70 (0.61, 0.81) | 0.58 (0.50, 0.66) |
| n | 591 | 453 | 272 | 67 | 90 |
| Dressing upper half | | | | | |
| PPR (and 95% CI) | 1 | 0.93 (0.90, 0.97) | 0.87 (0.83, 0.92) | 0.72 (0.63, 0.82) | 0.44 (0.36, 0.52) |
| n | 590 | 442 | 272 | 68 | 68 |
| Dressing lower half | | | | | |
| PPR (and 95% CI) | 1 | 0.93 (0.90, 0.96) | 0.86 (0.81, 0.90) | 0.69 (0.60, 0.80) | 0.33 (0.26, 0.41) |
| n | 586 | 437 | 266 | 65 | 51 |
| Walking outdoors in fine weather | | | | | |
| PPR (and 95% CI) | 1 | 0.82 (0.77, 0.88) | 0.60 (0.54, 0.68) | 0.50 (0.39, 0.63) | 0.33 (0.26, 0.43) |
| n | 524 | 344 | 168 | 42 | 46 |

PPR, prevalence proportion ratio (youngest age group as reference); 95% CI, 95% confidence interval.

Table 2. Ability of men to perform each of six selected activities of daily living (ADLs) independently

| ADL | Age group (years) | | | | |
| --- | --- | --- | --- | --- | --- |
| | 75–79 (n = 358) | 80–84 (n = 291) | 85–89 (n = 168) | 90–94 (n = 30) | 100 (n = 45) |
| Transferring from bed/chair | | | | | |
| PPR (and 95% CI) | 1 | 0.96 (0.92, 1.00) | 0.97 (0.93, 1.02) | 0.91 (0.79, 1.05) | 0.84 (0.72, 0.97) |
| n | 342 | 267 | 156 | 26 | 36 |
| Walking indoors | | | | | |
| PPR (and 95% CI) | 1 | 0.96 (0.92, 1.00) | 0.98 (0.94, 1.03) | 0.94 (0.83, 1.06) | 0.83 (0.72, 0.97) |
| n | 343 | 268 | 158 | 27 | 36 |
| Using the toilet | | | | | |
| PPR (and 95% CI) | 1 | 0.97 (0.93, 1.02) | 0.95 (0.90, 1.01) | 0.89 (0.75, 1.04) | 0.78 (0.65, 0.93) |
| n | 336 | 266 | 150 | 25 | 33 |
| Dressing upper half | | | | | |
| PPR (and 95% CI) | 1 | 0.96 (0.92, 1.01) | 0.95 (0.89, 1.01) | 0.90 (0.77, 1.06) | 0.62 (0.49, 0.80) |
| n | 331 | 259 | 147 | 25 | 26 |
| Dressing lower half | | | | | |
| PPR (and 95% CI) | 1 | 0.94 (0.89, 1.00) | 0.93 (0.86, 0.99) | 0.83 (0.68, 1.02) | 0.60 (0.46, 0.79) |
| n | 329 | 252 | 143 | 23 | 25 |
| Walking outdoors in fine weather | | | | | |
| PPR (and 95% CI) | 1 | 0.88 (0.82, 0.96) | 0.81 (0.73, 0.90) | 0.63 (0.45, 0.88) | 0.63 (0.47, 0.83) |
| n | 305 | 219 | 116 | 16 | 24 |

PPR, prevalence proportion ratio (youngest age group as reference); 95% CI, 95% confidence interval.

$P < 0.05$). There were only small and statistically insignificant differences in the proportion of people in nursing homes among participants and non-participants.

The proportions and PPRs of independence in each of six selected ADLs are given for both women (Table 1) and men (Table 2) within each age group. With advancing age a progressively lower proportion of women and men do each selected ADL item independently. The proportion was significantly
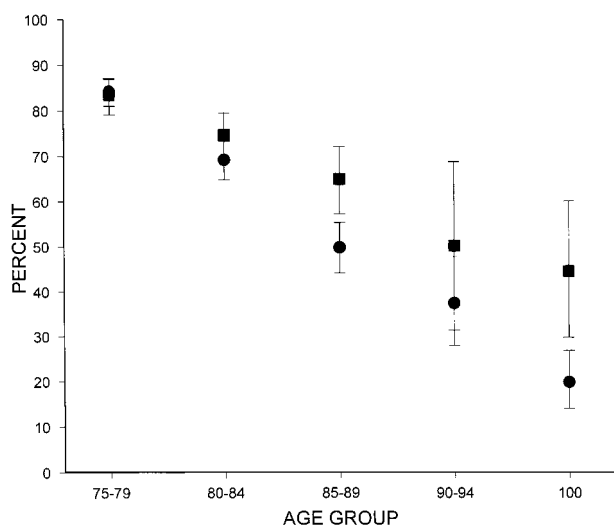


Figure 1. The proportions of men (■) and women (●), who are able to carry out all selected activities of daily living independently, within each age group.

lower ($P < 0.05$) among centenarians compared to septua-, octo- and nonagenarians, except for centenarian men compared to nonagenarians: here the same pattern was observed, but the sample size was small. For each independently-performed ADL, women constituted a lower proportion than did men, and this proportional difference became more pronounced in advancing age groups.

The sex difference was even more marked in the ability to carry out all six selected ADLs independently, as shown in Figure 1. At ages 75–79 there was no difference in abilities between men and women, while there was a progressive and significant difference between sex in advancing age groups (Mantel–Haenszel test: $P < 0.001$). At age 75–79, 84% of all women and 83% of all men were able to perform all six selected basic ADLs, while the corresponding numbers in centenarians were 20% and 44%.

## Discussion

In this cross-sectional study we found no evidence of a levelling-off in physical disability at the most extreme ages. On the contrary, we found a higher level of disability with increasing age, including centenarians. Furthermore, we found that the sex difference was most pronounced in centenarians.

Non-medical trained interviewers carried out the LSADT, while the DLCS used medically trained interviewers. However, this is unlikely to affect the result, because the measurement of basic ADL is robust [17]. The study benefited from a large sample size which

included individuals at the most extreme ages. Furthermore, information on institutionalization suggests that the participants were representative of disability in the total population.

It has been suggested that twins have an increased incidence of certain conditions, such as cardiovascular and Alzheimer's disease, which could pose a potential threat to the validity of epidemiological research based on twins [18, 19]. However, most twin–singleton studies show that disease frequencies and mortality are similar in twins and singletons [20–22]. The Danish twin population is therefore likely to be representative of the general Danish population of elderly people in terms of health status and mortality.

The optimal way to evaluate changes in ADL capabilities with advancing age is by longitudinal study. But as only one in a hundred 80-year olds reaches the age of 100 [23, 24], a study of the oldest-old must include about 20 000 80-year-olds followed for 20 years to have a centenarian sample size comparable to ours.

Because our data are cross-sectional, we are not able to distinguish cohort from age effects. A cohort effect could explain part of the age differences in physical ability. However, in the Danish Glostrup Population Study [25], no significant difference in ADL capability was found between two 70-year-old cohorts, born 1894 and 1914, while there was a significant difference in cardiovascular risk factors, the younger cohort being healthier. In contrast, the National Long Term Care Survey, 1982–1994 [17] found a reduction in the age-standardized rates of disability among 5-year categories of 65–95+ year olds over 12 years [26].

Period effects may influence the ADL pattern observed, since there is evidence [2] that the decline in oldest-old mortality is primarily caused by period factors with immediate effects. If period effects, and maybe even cohort effects, are present perhaps centenarians of the future will be less disabled than today, when 51% are in nursing homes and 67% are not able to perform all basic ADLs.

Other studies have shown a marked sex difference in functional capability in favour of men. In the EPESE studies, there was a steeply increasing prevalence of ADL disability with increasing age, and women generally showed higher rates of disability than men beginning around age 75 [27]. However, this study was restricted to community dwellers, and the oldest were pooled together in one group of 85+ year olds. The Longitudinal Study of Physical Ability in the Oldest-Old [5], derived from The United States National Health Interview Survey, is also based on non-institutionalized subjects aged 80 or older. In this study Harris *et al.* found that a high level of physical ability was associated with good health and a low risk of morbidity and mortality, and men were more likely to remain at a high level of physical ability in a 2-year follow-up. They also found that women consistently reported more difficulty with each physical activity.

Our data show that the sex difference in the ability of performing basic ADL independently becomes progressively larger as we move upwards in the age groups and is in sharp contrast with the better survival of women. This paradox has not yet been fully explained. A differential mortality leading to a surviving group of highly selected men could partly explain the better physical ability of the very old men. Another explanation of the increasing sex difference in the ability of performing basic ADLs could be the differences in muscle mass between men and women. Given that women are weaker and have smaller muscles than men [28], and that people with advancing age become less mobile and more inactive leading to accelerated muscle atrophy [29, 30], a threshold level for a minimum muscle mass requirement is reached earlier in women. This in turn further increases disability and a vicious cycle perpetuates [31], starting earlier in women. Perhaps if measures are taken to maintain basic physical abilities, the need for care could be reduced: even in very elderly people exercise training is a feasible and effective means of counteracting muscle weakness and physical frailty [32].

## Key points

- Cross-sectional data on 3351 Danes aged 75 or older (including 276 centenarians) reveal that physical ability was significantly lower in centenarians than in octo- and septuagenarians.
- In the 75–79-year age group, 84% of all women and 83% of all men were able to perform all six selected basic activities of daily living independently, while the corresponding numbers among centenarians were 20% and 44%.
- Intervention against physical inactivity in elderly people may improve physical ability in extreme old age.

## Acknowledgement

## References

**1.** Vaupel JW, Carey JR, Christensen K *et al.* Biodemographic trajectories of longevity. Science 1998; 280: 855–60.

**2.** Kannisto V. Development of Oldest-Old Mortality, 1950–1990: evidence from 28 developed countries. Odense Monographs on Population Aging 1. Odense: Odense University Press, 1994.

**3.** Vaupel JW, Jeune B. The emergence and proliferation of

centenarians. In: Jeune B, Vaupel JW eds. Exceptional Longevity: from the prehistory to the present. Odense Monographs on Population Aging 2. Odense: Odense University Press, 1995.

4. Guralnik JM, La Croix A, Abbott RD *et al.* Maintaining mobility in late life. Demographic characteristics and chronic conditions. Am J Epidemiol 1993; 137: 845–57.

5. Harris T, Kovar MG, Suzman R, Kleinman JC, Feldman JJ. Longitudinal study of physical ability in the oldest-old. Am J Public Health 1989; 79: 698–702.

6. Guralnik JM, Simonsick EM. Physical disability in older Americans. J Gerontol 1993; 48 (special issue): 3–10.

7. Kramer M. The rising pandemic of mental disorders and associated chronic diseases and disabilities. Acta Psychiatr Scand 1980; 62 (suppl. 285): 382–97.

8. Manton KG. Changing concepts of morbidity and mortality in the elderly population. Milbank Quart 1982; 60: 183–244.

9. Hauge M, Harvald B, Fischer M *et al.* The Danish Twin Register. Acta Genet Med Gemellol 1968; 2: 315–31.

10. Kyvik KO, Christensen K, Skytthe A, Harvald B, Holm NV. The Danish Twin Registry. Danish Med Bull 1996; 43: 467–70.

11. McGue M, Christensen K. Genetic and environmental contributions to depression symptomatology: evidence from Danish twins 75 years and older. J Abnorm Psychol 1997; 106: 439–48.

12. Avlund K, Schultz-Larsen K. What do 70 year-old men and women do? And what are they able to do? From the Glostrup survey in 1984. Aging Clin Exp Res 1991; 3: 39–49.

13. Schultz-Larsen K, Avlund K, Kreiner S. Functional ability of community dwelling elderly. Criterion-related validity of a new measure of functional ability. J Clin Epidemiol 1992; 45: 1315–26.

14. Avlund K, Kreiner S, Schultz-Larsen K. Construct validation and the Rasch model: functional ability of elderly people. Scand J Soc Med 1993; 21: 233–45.

15. Avlund K, Kreiner S, Schultz-Larsen K. Functional ability scale for the elderly. Eur J Publ Health 1996; 6: 35–42.

16. Olsen H, Jeune B, Andersen-Ranberg K. Centenarians in a county of Denmark. Morbidity and functional capacity (in Danish). Ugeskr Laeger 1996; 158: 7397–401.

17. Manton KG, Corder L, Stallard E. Chronic disability trends in elderly United States populations: 1982–1994. Proc Natl Acad Sci USA 1997; 94: 2593–8.

18. Räihä I, Kaprio J, Koskenvuo M, Rajala T, Sourander L. Alzheimer's disease in Finnish twins. Lancet 1996; 347: 573–8.

19. Phillips DIW. Twins studies in medical research: can they tell us whether diseases are genetically determined? Lancet 1993; 341: 1008–9.

20. Duffy DL. Twin studies in medical research. Lancet 1993; 341: 1418–9.

21. Christensen K, Vaupel J, Holm NV, Yashin AI. Mortality among twins after age 6: fetal origins hypothesis *versus* twin method. Br Med J 1995; 310: 432–6.

22. Christensen K, Holm NV, Vaupel J. Alzheimer's disease in twins. Lancet 1996; 347: 976.

23. Kannisto V. The Advancing Frontier of Survival: life tables for old age. Odense Monographs on Population Aging 3. Odense University Press, Odense, Denmark 1996.

24. Jeune B, Kannisto V. Emergence of centenarians and super-centenarians. In: Robine J-M, Vaupel JW, Jeune B, Allard M eds. Longevity: to the limits and beyond. Research and Perspectives in Longevity. Foundation IPSEN. Berlin: Springer-Verlag, 1997.

25. Jürgensen KS, Avlund K, Schroll M. The social situation in two 70-year-old populations. A cohort comparison of persons born in 1897 and 1914 cohorts from the Glostrup Population Studies (in Danish). Ugeskr Laeger 1990; 152: 2993–7.

26. Manton KG, Stallard E, Corder LS. The dynamics of dimensions of age-related disability 1982 to 1994 in the US elderly population. J Gerontol A Biol Sci Med Sci 1998; 53(1): B59–70.

27. Cornoni-Huntley J, Brock DB, Ostfeld A, Taylor JO, Wallace RB, eds. Established Populations for Epidemiologic Studies of the Elderly, Resource Data Book. NIH publication no. 86–2443. Bethesda, MD: National Institutes of Health, 1986.

28. Lexell J. Human aging, muscle mass, and fiber type composition. J Gerontol 1995; 50A (special issue): 11–6.

29. Rodgers MA, Evans WJ. Changes in skeletal muscle with aging: effects of exercise training. Exerc Sports Sci Rev 1993; 21: 65–102.

30. Coggan AR, Spina RJ, King DS *et al.* Histochemical and enzymatic comparison of the gastrocnemius muscle of young and elderly men and women. J Gerontol Biol Sci 1992; 47: B71–6.

31. Tseng BS, Marsh DR, Hamilton MT, Booth FW. Strength and aerobic training attenuate muscle wasting and improve resistance to the development of disability with aging. J Gerontol 1995; 50A (special issue): 113–9.

32. Fiatarone MA, O'Neill EF, Ryan ND *et al.* Exercise training and nutritional supplementation for physical frailty in very elderly people. N Engl J Med 1994; 330: 1769–75.