Eur J Ageing (2016) 13:15–23
DOI 10.1007/s10433-015-0354-z

ORIGINAL INVESTIGATION

Health and function assessments in two adjacent Danish birth cohorts of centenarians: Impact of design and methodology

Sonja Vestergaard[1] · Karen Andersen-Ranberg[1,2] · Axel Skytthe[1] · Kaare Christensen[1,3,4,5] · Jean-Marie Robine[6,7] · Bernard Jeune[1]

Published online: 8 September 2015

Abstract Using the results from measures of functional ability, cognitive and physical performance from two adjacent birth cohorts of 100-year-old adults, we aimed to elucidate the possible impact of difference in participation rates, design, and interviewer mode. Participants were birth cohort members born in 1910 (DK-1910) and 1911-12 (DK-1911). Both surveys used the same assessment instruments, but the design was different, and data collection was carried out by trained survey agency interviewers in DK-1910 and trained nurses in DK-1911. Participation rate in DK-1911 (49.8 % (251/504)) was lower than in DK-1910 (66.9 % (273/408)) ($p < 0.001$). The proportion of interviews with the participant answering alone or mainly alone was significantly higher in DK-1911 (77 %) than in DK-1910 (56 %), and the proportion living in nursing home was significantly lower (44 vs. 54 %, respectively). Higher proportions of DK-1911 independently performed all activities of daily living (ADL) compared to DK-1910, but only significantly for toileting, bathing, and feeding (all $p < 0.01$). Mini-mental state examination (MMSE) score was higher in DK-1911 than in DK-1910 (23.5 vs. 21.0; $p < 0.001$). Handgrip strength, gait speed, and chair stand were almost similar. DK-1911 participants had significantly better one-year survival than DK-1911 non-participants and DK-1910 participants and non-participants ($p = 0.001$). These results suggest that lower participation rate entails selection towards healthier participants in terms of ADL and cognitive functioning. Caution is warranted when comparing studies of centenarians with different participation rates, design, and interviewer mode, and further studies of these methodological issues are required.

Keywords Cognition · Functional ability · Physical performance · Centenarians · Participation rate

Responsible editor: D. J. H. Deeg.

✉ Sonja Vestergaard
svestergaard@health.sdu.dk

[1] Danish Aging Research Center, Institute of Public Health, University of Southern Denmark, J.B. Winsløws Vej 9.B., 5000 Odense C, Denmark

[2] Geriatric Medicine, Odense University Hospital, Odense, Denmark

[3] Max-Planck Odense Center on the Biodemography of Aging, University of Southern Denmark, Odense, Denmark

[4] Department of Clinical Genetics, Odense University Hospital, Odense, Denmark

[5] Department of Clinical Biochemistry and Pharmacology, Odense University Hospital, Odense, Denmark

[6] French National Institute of Health and Medical Research (Inserm), Montpellier, France

[7] Ecole pratique des hautes études (EPHE), Paris, France

Introduction

The increase in the proportion of the oldest-old will continue in the years to come (Christensen et al. 2009). Surveys yielding estimates of population health status among oldest-old may provide relevant knowledge to public decision makers. However, until recent decades, little was known about the health of oldest-old. With the decline in the mortality of older adults resulting in a substantial increase in the number of the oldest-old, a greater interest in the health and functioning of these age groups has emerged, resulting in several studies (Bootsma-van der Wiel et al. 2002; Collerton et al. 2009; Nosraty et al. 2012; Nybo et al. 2001). However, recruiting oldest-old

participants is still a methodological challenge (Sachdev et al. 2012). Previous studies of centenarians have shown different results in health indicators as well as participation rates (Allard and Robine 2000; Andersen-Ranberg et al. 1999; Beregi and Klinger 1989; Capurso et al. 1997; Louhija 1994; Parker et al. 2014; Poon et al. 2007; Samuelsson et al. 1997; Silver et al. 2001) which are likely due to differences in methods. The participation rates in these centenarian studies vary from about one-third to more than three quarters.

Participation rates are reported in epidemiological studies in order to inform the reader of the possible risk of selection bias (Galea and Tracy 2007). Unfortunately, participation rates in epidemiological surveys have declined in recent decades (Bakke 2010; Galea and Tracy 2007), and factors such as age, gender, health, cognitive impairment, socio-economic status, and survey mode are affecting the willingness to participate (Christensen et al. 2014; Demarest et al. 2013; Strotmeyer et al. 2010).

In two of our previous studies of 100-year-old persons born 10 years apart, participation rates of 75 % (Andersen-Ranberg et al. 1999) and 62 % (Engberg et al. 2008a) were achieved. Indications of similar health status measured by, e.g., number and/or length of hospitalizations and type of housing in participants compared with non-participants were found (Andersen-Ranberg et al. 1999; Nybo et al. 2001). However, in the latter study, this was contrasted by a significantly lower mortality among participants compared with non-participants (Nybo et al. 2001).

Recently, we have carried out two new surveys of 100-year-old persons from two adjacent Danish birth cohorts, 1910 and 1911. Both were sampled from public registers, and approximately, the same questionnaire and same instruments were used to assess cognitive function and physical performance in the two surveys, but different design and interviewer mode were applied. Centenarians born in adjacent years in the same country are expected to have similar level of functioning and health at age 100. We therefore used the results from measures of functional ability, cognitive and physical performance from the two adjacent birth cohorts of 100-year-old adults to elucidate the possible impact of difference in participation rates, design, and interviewer mode.

Materials and methods

Design and study population

Individuals for both surveys were identified through the Danish Civil Registration System (Pedersen et al. 2006). The first survey (DK-1910) included all birth cohort members born in 1910. Eligible individuals ($n = 408$) were identified in August 2010 and included if they were alive at the time of contact in the period September 7–November 30, 2010. The second survey (DK-1911) was part of the 5-Country Oldest Old Project (5-COOP) (Robine et al. 2010). To minimize the cost, the most remote areas of Denmark were not included, corresponding to less than 10 % of the inhabitants of Denmark (the proportion of 100-year-old persons in these areas did not differ from the average in Denmark in the last quarter of year 2011: 0.85 versus 0.72 persons/10,000 inhabitants according to Statistics Denmark [http://www.dst.dk/en]). Eligible individuals ($n = 504$) were identified and interviewed consecutively when they attained the age of 100 in the period of May 5, 2011–July 5, 2012.

Both surveys were approved by the Danish Data Protection Agency (journal numbers DK-1910: #2010-41-4635; DK-1911: #2010-41-5649) and approved by the ethical committee system in Denmark (trial numbers DK-1910: S-20100011; DK-1911: S-20110011). The project information was mailed out to all eligible participants at their registered address. However, the oral project information was given by personal contact at eligible participants' home in DK-1910, but by telephone in DK-1911. In both surveys, after oral information and consent, interviewers arranged a later interview appointment, and written informed consent was obtained before the interview was started. Both surveys used approximately the same questions and similar assessments of cognitive and physical performance, but while data collection was carried out by trained survey agency interviewers in DK-1910, trained nurses were used in DK-1911. The reason for using trained nurses in DK-1911 was that the optional blood sample collection was performed by venipuncture as opposed to the finger prick method used in DK-1910. Both surveys permitted the presence of proxies (i.e., a family member, a companion, or a lay representative) during the interview. Survey agency interviewers received training organized and lead by the same project manager who also trained the nurse interviewers.

Participant characteristics

Information on type of housing was categorized into two groups: respondents living in nursing homes and respondents living in all other types of housing (farm, house, apartment, supported housing facility, other). As interviews through a proxy were allowed, the following was registered: (1) participant answered all the questions alone, (2) participant answered mainly alone, (3) proxy assisted for about half of the questions, or (4) the proxy answered all questions. These four categories were merged into two groups [(1) and (2) versus (3) and (4)].

Cognitive functioning

The mini-mental state examination (MMSE) (Folstein et al. 1975) was used to collect information on cognitive functioning. This widely used instrument ranges from 0 to 30 (best).

Functional ability

Functional ability was measured by activities of daily living (ADL) (Katz et al. 1970). For analytic purposes, we categorized those needing assistive devices together with those able to carry out the item in question, while those needing personal help were categorized together with those being unable to carry out the item in question. As difference in independency in ADLs could be a result of a different use of assistive devices, we collected information about use of five types of assistive device: walking aids, wheelchair, handle/handgrip, bathing chair, and lifting pole.

Physical performance

Maximal handgrip strength was measured using a Smedley handgrip dynamometer (Nybo et al. 2001). The better of two measurements was used. Gait speed was measured applying the 3 m walking test at usual pace after standing start (Guralnik et al. 2000). Time to complete the test in seconds was recorded. The better of two trials was chosen. Lastly, the ability to complete a single chair stand with arms across the chest was assessed. Ability was recorded as (1) able without support, (2) able with use of arms or supportive device, (3) unable.

One-year survival analysis

One-year survival among participants and non-participants in the two cohorts was analyzed to address the healthy selection issue. This information was updated on January 1, 2014.

Statistical analysis

Means with standard error of mean or proportions with 95 % confidence intervals were calculated as appropriate. For continuous variables, significant differences in means were tested using two-sided t-tests. For dichotomized variables, significant differences in proportions by age groups were tested using Chi-square tests. Kaplan–Meier survival estimates illustrated the survivor function for participants and non-participants in DK-1910 and DK-1911, and the log-rank test analyzed the equality of survivor functions. Analyses were performed in STATA 13.1 (StataCorp, College Station, TX, USA). $P < 0.05$ determined statistical significance.

Results

The participation rate was significantly lower in DK-1911 (49.8 %) than in DK-1910 (66.9 %) without gender differences (Table 1). The proportion in percent among non-participants of the reasons for non-participation due to refusals and illness, no contact established, death after invitation, or other reasons was 85.1, 5.2, 6.7, and 3.0, respectively, in DK-1910, whereas it was 87.0, 7.5, 2.4, or 3.2, respectively, in DK-1911. The proportion of proxy signatures for the written informed consent was higher in DK-1910 than in DK-1911 (24.5 vs. 8.8 %).

The DK-1910 participants were about one and a half month older than the DK-1911 participants, while the proportion of women and the proportion of widowers were the same (Table 1). The proportion of interviews during which the participant responded alone or mainly alone was significantly higher in DK-1911 than in DK-1910. Furthermore, the proportion living in a nursing home was significantly lower in DK-1911 than DK-1910.

Higher proportions of participants from DK-1911 than from DK-1910 were able to perform the ADLs independently (Fig. 1), and this was statistically significant for toileting, bathing, and feeding (Fig. 1, pane a, all $p < 0.01$). When analyzing only those participants who provided answers to the interview alone or mainly alone, the proportions of participants performing ADL tasks independently increased in both cohorts (Fig. 1, pane b). Furthermore, differences between the cohorts attenuated and only toileting was now statistically significantly higher in DK-1911 compared with DK-1910. The use of assistive devices was in general lower among those in DK-1911 in comparison with those in DK-1910 (Fig. 2, all $p < 0.01$). Only the use of handle and handgrips as well as bathing chair was similar in both cohorts.

A significantly higher MMSE score was observed in DK-1911 compared with that in DK-1910 (Table 2). However, maximal handgrip strength, gait speed, and the proportion of those able to perform the single chair stand test were not significantly different despite a tendency to an overall poorer physical functioning in DK-1911. In contrast, the proportion performing each individual test was significantly higher among those in DK-1911 compared with those in DK-1910 (Table 2, all $p < 0.001$). Restricting the analyses to those who were interviewed alone or mainly alone (Table 3) increased the level of cognitive function and physical performance in both cohorts, but the MMSE score difference remained significant.

Table 1 Descriptives of the Danish population-based cohorts from DK-1910 and DK-1911

	DK-1910 ($n = 273$)	DK-1911 ($n = 251$)	p value[a]
Participation rate (%)	66.9	49.8	<0.001
Age [years, mean (SD)]	100.24 (0.31)	100.15 (0.06)	<0.001
Sex (%)			
Women	78.4	77.7	0.847
Men	21.6	22.3	
Interview type (%)			
Interviewed alone or mainly alone	56.0	76.9	0.001
Housing (%)			
Nursing home	54.0	44.2	0.025
Marital status (%)			
Married/cohabiting	3.3	4.4	0.499
Widower	85.0	87.3	
Divorced/previously cohabiting	4.4	2.4	
Never married/cohabiting	7.3	6.0	

SD standard deviation

[a] Two-sided t test or Chi-square test for cohort difference

One-year survival of participants in DK-1911 was better than that in DK-1911 non-participants, DK-1910 participants, and DK-1910 non-participants ($p = 0.001$) (Fig. 3). In separate analyses, the participants in DK-1911 had significantly better one-year survival than DK-1911 non-participants ($p < 0.001$), while no difference between participants and non-participants was found in DK-1910 ($p = 0.72$).

As described above, a number of differences between DK-1910 and DK-1911 were observed. Table 4 summarizes the main differences in the findings and methods.

Discussion

Against our expectation of approximately the same level of functioning in the two adjacent birth cohorts, we found that 100-year-old persons in the DK-1911 cohort had better cognitive function and better self-reported functional ability than their peers in the DK-1910 cohort. Also a smaller proportion of DK-1911 compared to DK-1910 used assistive devices or lived in nursing home. However, the two cohorts did not differ in any of the measures of physical performance, but the proportion performing the physical performance tests was higher in the DK-1911 study than in the DK-1910 study.

As in the present study, our surveys of 100-year-old persons, born 10 years apart, also achieved different participation rates: 75 % in the oldest cohort who had been interviewed by a geriatrician and a nurse, and 62 % in the younger cohort who had been interviewed by trained survey agency interviewers as in study of the DK-1910 cohort. Similar cognitive status was found, but the lower ADL disability in the youngest cohort was interpreted as a cohort improvement effect (Engberg et al. 2008a, 2008b). However, it was underlined that the differences could partly be due to selection bias.

Participation rates in our recent comparison of two Danish birth cohorts of nonagenarians born in 1905 and 1915, who were interviewed by the same trained survey agency interviewers, were similar (62 and 63 %) (Christensen et al. 2013). Therefore, the findings of better cognitive function and ADLs in the younger cohort were interpreted as a cohort improvement effect. As the cohorts of the present study were only separated by one year, a cohort effect could hardly explain the differences. One of the main explanations might be a selection bias as indicated by the substantial difference in the participation rates between the two surveys. Also the substantial difference in proxy signatures for written informed consent suggests a healthy selection bias. However, also other methodological differences may have contributed to the findings as summarized in Table 4.

Although the major strength of the present study was that the participants from both cohorts had been retrieved from the Danish Civil Registration System, a potential limitation of the present study is the difference in the study design: eligible participants in the DK-1910 survey were retrieved at once in August 2010 and the interviews were carried out during the following 3 months in the autumn, whereas eligible participants in the DK-1911 were consecutively included as they turned 100 years old during more than 1 year, i.e. including all seasons. This difference in design explains that on average the DK-1910

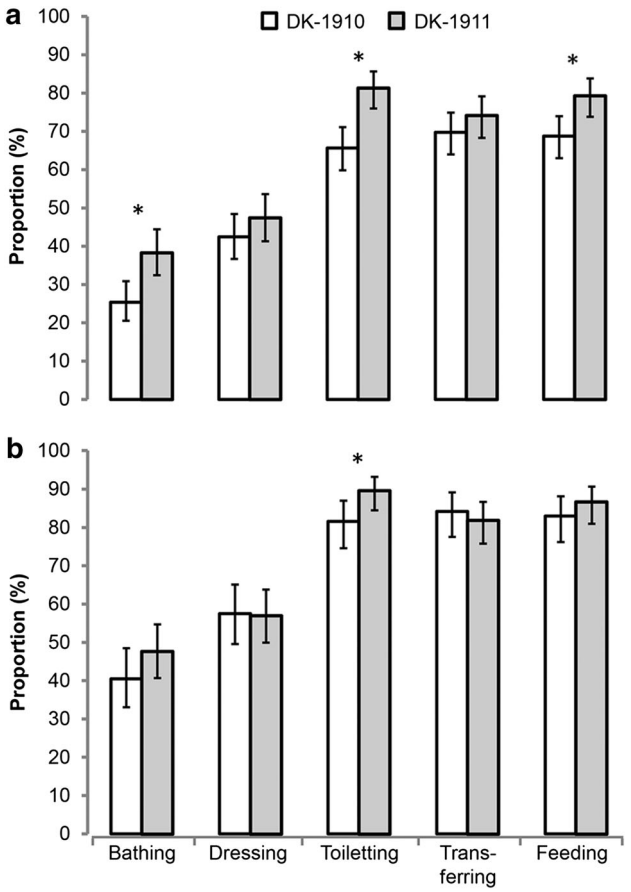

Fig. 1 Independency in ADL activities in the population-based cohorts from DK-1910 and DK-1911 among all participants (**a**) and only among those answering alone or mainly alone (**b**). *Bars* and *error bars* proportion and 95 % confidence intervals. *Represents $p < 0.05$, Chi-square test for cohort difference. *Note* sample size varies in different functions due to few missing. **a** DK-1910, $N = 273$, but $n = 271$ in dressing, toileting, and transfer, $n = 272$ in bathing and feeding. For DK-1911 sample is 251 in all functions. **b** DK-1910, $n = 153$, but $n = 152$ in toileting and transfer, $n = 153$ in remaining functions. For DK-1911 sample is 193 in all functions

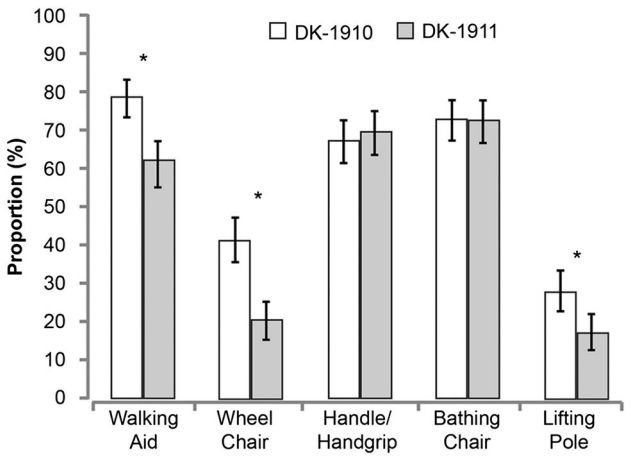

Fig. 2 Use of assistive devices in the population-based cohorts from DK-1910 and DK-1911 among all participants. *Bars* and *error bars* proportion and 95 % confidence intervals. *Represents $p < 0.05$, Chi-square test for cohort difference

participants were a little, but significantly, older than DK-1911 participants. However, it is difficult to imagine that an average age difference of one and a half month could explain most of the substantially poorer functioning in the DK-1910 cohort participants. In the case that this age difference does still pose a small effect, it would be counterbalanced by seasonal effect, as the participants from DK-1910 had all just gone through a summer that might have enhanced their functioning levels. However, we believe that this difference in study design is of minor importance.

The use of different interviewers in the two surveys could have affected the participation rates. Survey agency interviewers are assigned to surveys carried out in their local geographical area. After sending an initial letter of invitation with written information about the project, the interviewers personally contacted eligible participants living in their area, gave oral information about the project, and made an appointment for the interview if the participants consented orally. In contrast, in the DK-1911, a few nurses covered almost the whole country and therefore had to make the appointments by telephone. However, telephone contacts may be more easily refused than in-person contacts. Furthermore, the nurses—with their professional background—could have been more alert than the agency interviewers to potential signs of mild dementia in the participants when obtaining the interview appointments and inclined rather to give up obtaining oral informed consent. Although survey agency interviewers received instructions from the same project manager as the nurses, pre-interview training sessions may have differed based on the differences in the occupational background of the nurses and survey agency interviewers.

The observed differences in the assessment of cognitive functioning and physical performance between the two surveys also merit discussion. The proportion of centenarians who participated in the tests was clearly higher among participants in the DK-1911 survey than in the DK-1910 survey. This could in part be explained by a more active attitude among nurses than among survey agency interviewers towards carrying out assessments. When analyzing only those who participated in the interview alone or mainly alone, the MMSE score increased more than one score point in both survey populations. However, the higher MMSE score in the DK-1911 remained statistically significant, which is unlikely to be due to cohort effects.

The healthier of the two cohorts may be the DK-1911 participants, which is also supported by the lower

Table 2 Cognitive function and physical performance among participants from the cohorts DK-1910 and DK-1911

	All ($N = 524$)	DK-1910 ($N = 273$)	DK-1911 ($N = 251$)	p value[a]
MMSE (score)				
Mean (SE)	21.7 (0.3)	21.0 (0.5)	22.4 (0.4)	0.018
N	402	188	214	
Performing test (% total)	77	69	85	<0.001
Maximal handgrip strength (kg)				
Mean (SE)	13.1 (0.3)	13.7 (0.4)	12.8 (0.4)	0.170
N	364	148	216	
Performing test (% of total)	69	54	86	<0.001
Gait speed, 3 m (m/s)				
Mean (SE)	0.45 (0.01)	0.47 (0.02)	0.44 (0.01)	0.127
N	257	102	155	
Performing test (% of total)	49	37	62	<0.001
Single chair stand (%)				
Able	25.5	28.4	23.2	0.435
Able, using arms/support	57.8	54.7	60.2	
Unable	16.7	16.8	16.6	
N	257	102	155	
Attempting or performing single chair stand test (% of total)	82	70	96	<0.001

Continuous variables are presented as mean and standard error of mean (SE)

MMSE mini-mental state examination

[a] Two-sided *t* test or Chi-square test for cohort difference

Table 3 Cognitive function and physical performance among participants from DK-1910 and DK-1911 answering alone or mainly alone

	All ($N = 524$)	DK-1910 ($N = 273$)	DK-1911 ($N = 251$)	p value[a]
MMSE (score)				
Mean (SE)	23.0 (0.3)	22.4 (0.5)	23.5 (0.4)	<0.001
n	335	152	183	
Maximal handgrip strength (kg)				
Mean (SE)	13.7 (0.4)	14.4 (0.5)	13.3 (0.5)	0.140
n	364	120	177	
Gait speed, 3 m (m/s)				
Mean (SE)	0.46 (0.01)	0.47 (0.02)	0.45 (0.01)	0.413
n	218	86	132	
Single chair stand (%)				
Able	30.4	33.6	27.8	0.189
Able, using arms/support	57.7	52.4	62.0	
Unable	11.9	14.1	10.2	
N	336	149	187	

Continuous variables are presented as mean and standard error of mean

MMSE mini-mental state examination

[a] Two-sided *t* test or Chi-square test for cohort difference

proportion needing assistive devices and the better survival. However, if the DK-1911 participants were healthier than the DK-1910 participants because they were more selected, it would be expected that they also had a better physical performance. But this was not the case; on the contrary, the results of the DK-1911 survey suggested that they were slightly worse off. It may be explained by the higher proportion attempting to carry out the physical

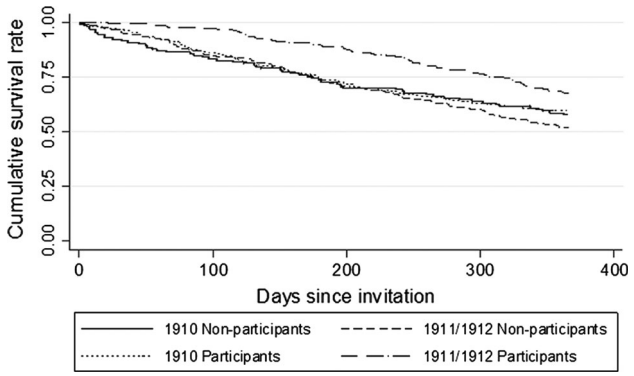

Fig. 3 Kaplan–Meier survival estimates of one-year survival from date of invitation to death in two Danish cohorts of centenarians. Log-rank test for equality of survivor functions, $p = 0.0013$

performance tests in the DK-1911 (62–96 %) compared with DK-1910 (37–70 %). However, it may also be that low physical performance among 100-year-old persons has a less negative impact on the participation rate than impaired cognitive function.

The comparison of the results between these two adjacent Danish centenarian surveys illustrates the problems of comparing studies of the oldest-old. Despite the advantage of using public registers and of using the same assessment instruments in both surveys, it seems that other methodological issues such as modest differences in the procedure used to contact eligible participants and the background and training of the interviewers can have an impact on the selection of participants and on the proportion of participants who can be examined with objective measurement instruments. Compared to studies of younger older persons, the risk that the differences in results are mainly due to differences in methods is higher, especially when comparing centenarians (Andersen-Ranberg et al. 1999; Poon et al. 2007; Sachdev et al. 2012).

This should be taken into account when comparing the results of international centenarian studies as other factors such as mortality level among centenarians and the proportion of nursing home vary between countries (Robine et al. 2010). The extent to which the variation in the participation rates between the centenarian studies depends on sampling from public registers or from local census data is unclear. It may have an effect on the identification of living centenarians and how deaths are excluded from the denominator. Death occurring between the identification and the invitation to participate should be excluded from the denominator but not if death occurs between the invitation date and the planned examination date.

A high participation rate in itself does not necessarily result in an unselected participation. This is excellently illustrated in the Leiden study of 85-year olds (Bootsma-van der Wiel et al. 2002). This study obtained a high participation rate in the city of Leiden in the Netherlands (74 %) by advertising the study in public before inviting the participants and giving them oral information by telephone. However, an even higher participation was obtained (87 %) by approaching non-responders (to telephone contacts) personally again (2nd-stage). Interestingly, the survival of 1st-stage participants and non-participants was similar and in both cases better than the survival of 2nd-stage participants, who had poorer health and were more likely to be institutionalized. This was in accordance with our DK-1910 study that showed the same survival among participants and non-participants, but was in contrast to our more selected DK-1911 participants who had remarkably better survival than the non-participants. If the Danish ethical committee system had allowed us to contact non-participants personally after the telephone contact without having obtained their oral informed consent, we would likely have recruited more participants from the frail proportion of the centenarians as shown in the DK-1910 study. This is also clearly illustrated in a recent Swedish study of

Table 4 Main differences in design and findings in DK-1910 and DK-1911

	DK-1910	DK-1911
Data collection period	3 Months	14 Months
Interviewers	Agency interviewers	Nurses
Oral information given[a]	In person	By telephone
Participation rate	66.9 %	49.8 %
Nursing home residents	54.0 %	44.2 %
Proxy consent rate	24.5 %	8.8 %
Mental functioning	Worse off[b]	Better off[b]
Functional ability	Worse off[b]	Better off[b]
Physical functioning	Similar, tendency to better[b]	Similar, tendency to worse[b]
Survival of participants	Worse off[b]	Better off[b]

[a] After posted project information letter, and before setting up the appointment for interview

[b] In comparison with the other cohort. For specific results, please see tables and figures

100-year olds, which was part of the 5-COOP project (Parker et al. 2014). In their study, the participation rate was very high (85.9 %), and the proportion of only proxy-interviews was, accordingly, also very high (38 %), i.e., even higher than the proxy consent rate of our DK-1910 study (24.5 %).

We will soon face these problems in a comparison between the centenarians from the five countries participating in the 5-COOP project (Robine et al. 2010). Exactly the same questionnaire and the same assessment instruments are used in all the studies, but different sampling procedures as well as different interviewers. The preliminary analysis shows that the participation rate varies from 30.4 % in France, 31.6 % in Japan, 39.3 % in Switzerland, 49.8 % in Denmark to 85.9 % in Sweden (Robine in press).

Conclusion

A lower participation rate in DK-1911 is most likely to explain a selection towards healthier participants in terms of ADL and cognitive functioning. It suggests that harmonization of survey design and methods is very important in order to compare cognitive and physical functions in centenarians. Further in-depth study of differences in interviewer approach should include qualitative interviews with nurses and survey agency interviewers to probe their strategies.

Acknowledgments This work was supported by a Grant from The Danish Council for Independent Research—Medical Sciences (DK-1910: Grant Number 09-070081). DK-1911 was supported by Grants from the AXA Research Fund to the Project The Five Country Oldest Old Project (No Grant Project Number) and The Health Foundation, "Helsefonden" (Grant Number 2011B062). The Danish Aging Research Center is supported by a Grant from the VELUX Foundation. We are grateful for the valuable suggestions received during peer review.

Compliance with ethical standards

Conflict of Interest The authors declare that they have no conflict of interest.

References

Allard M, Robine JM (2000) Les centenaires francais. Etude de la Fondation IPSEN, 1990-2000. Rapport final. Serdi Édition, Paris

Andersen-Ranberg K, Christensen K, Jeune B, Skytthe A, Vasegaard L, Vaupel JW (1999) Declining physical abilities with age: a cross-sectional study of older twins and centenarians in Denmark. Age Ageing 28:373–377

Bakke PS (2010) Non-response in epidemiological studies—how to cope with it? Respir Med 104:323–324

Beregi E, Klinger A (1989) Health and living conditions of centenarians in Hungary. Int Psychogeriatr 1:195–200

Bootsma-van der Wiel A, van Exel E, de Craen AJ, Gussekloo J, Lagaay AM, Knook DL, Westendorp RG (2002) A high response is not essential to prevent selection bias: results from the Leiden 85-plus study. J Clin Epidemiol 55:1119–1125

Capurso A et al (1997) Epidemiological and socioeconomic aspects of Italian centenarians. Arch Gerontol Geriatr 25:149–157

Christensen K, Doblhammer G, Rau R, Vaupel JW (2009) Ageing populations: the challenges ahead. The Lancet 374:1196–1208

Christensen K et al (2013) Physical and cognitive functioning of people older than 90 years: a comparison of two Danish cohorts born 10 years apart. The Lancet 382:1507–1513

Christensen AI, Ekholm O, Glumer C, Juel K (2014) Effect of survey mode on response patterns: comparison of face-to-face and self-administered modes in health surveys. Eur J Public Health 24:327–332

Collerton J et al (2009) Health and disease in 85 year olds: baseline findings from the Newcastle 85+ cohort study. BMJ 339:b4904

Demarest S, Van der Heyden J, Charafeddine R, Tafforeau J, Van Oyen H, Van Hal G (2013) Socio-economic differences in participation of households in a Belgian national health survey. Eur J Public Health 23:981–985

Engberg H, Christensen K, Andersen-Ranberg K, Jeune B (2008a) Cohort changes in cognitive function among Danish centenarians. A comparative study of 2 birth cohorts born in 1895 and 1905. Dement Geriatr Cogn Disord 26:153–160

Engberg H, Christensen K, Andersen-Ranberg K, Vaupel JW, Jeune B (2008b) 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 63:1186–1192

Folstein MF, Folstein SE, McHugh PR (1975) Mini-mental state. A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 12:189–198

Galea S, Tracy M (2007) Participation rates in epidemiologic studies. Ann Epidemiol 17:643–653

Guralnik JM et al (2000) Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. J Gerontol A Biol Sci Med Sci 55:M221–M231

Katz S, Downs TD, Cash HR, Grotz RC (1970) Progress in development of the index of ADL. Gerontologist 10:20–30

Louhija J (1994) FINNISH CENTENARIANS. A clinical epidemiological study. Ph.d. thesis, University of Helsinki

Nosraty L, Sarkeala T, Hervonen A, Jylha M (2012) Is there successful aging for nonagenarians? The vitality 90+ study. J Aging Res 2012:868797

Nybo H, Gaist D, Jeune B, Bathum L, McGue M, Vaupel JW, Christensen K (2001) The Danish 1905 cohort: a genetic-epidemiological nationwide survey. J Aging Health 13:32–46

Parker MG, Meinow B, Berndt H, Sundberg L, Fors S (2014) Swedish 100-year-olds need a lot of care. Swedish centenarian survey–on health and living conditions among 100-year-olds. Lakartidningen 111:1244–1247

Pedersen CB, Gotzsche H, Moller JO, Mortensen PB (2006) The Danish Civil Registration System. A cohort of eight million persons. Dan Med Bull 53:441–449

Poon LW et al (2007) Methodological considerations in studying centenarians: lessons learned from the georgia centenarian studies. Annu Rev Gerontol Geriatr 27:34

Robine JM (in press) The Five Country Oldest Old Project (5-COOP). In: Pachana N (ed) Encylopedia of geropsychology. Springer, Berlin

Robine JM, Cheung SL, Saito Y, Jeune B, Parker MG, Herrmann FR (2010) Centenarians today: new insights on selection from the 5-COOP study. Curr Gerontol Geriatr Res 2010:120354

Sachdev PS, Levitan C, Crawford JD (2012) Methodological issues in centenarian research: pitfalls and challenges. Asian J Gerontol Geriatr 7:44–48

Samuelsson SM et al (1997) The Swedish centenarian study: a multidisciplinary study of five consecutive cohorts at the age of 100. Int J Aging Hum Dev 45:223–253

Silver MH, Jilinskaia E, Perls TT (2001) Cognitive functional status of age-confirmed centenarians in a population-based study. J Gerontol B Psychol Sci Soc Sci 56:P134–P140

Strotmeyer ES et al (2010) Long-term retention of older adults in the Cardiovascular Health Study: implications for studies of the oldest old. J Am Geriatr Soc 58:696–701