ORIGINAL INVESTIGATION

Disability trends among nonagenarians in 2001–2007: Vitality 90+ Study

Tytti Sarkeala · Tapio Nummi · Merja Vuorisalmi · Antti Hervonen · Marja Jylhä

Abstract Substantial growth of the population aged 90 years or over has focused interest on trends in the functioning and disability of the oldest old, but research findings are scarce and they vary. In the Vitality 90+ Study, we evaluated overall, gender-specific, and age-specific trends in disability among total cohorts of people aged 90 years or older in the city of Tampere, Finland, in the years 2001, 2003, and 2007. The size of the target population ranged from 1113 to 1146 and the participation rate from 79 to 86%. The participants were asked whether they were able to get in and out of bed, dress and undress, move about indoors, walk 400 m, and use stairs. Independence was defined as being able to perform an activity without help. The aggregate outcome measures included independence in all five activities, dependence in one to four activities, dependence in all five activities (severe dependence), and a disability score. In analyses taking into account the within subject associations which resulted due to those who participated in several years, and proxy respondents, no overall or gender-specific trend was found in any of the independence or dependence estimates. In each year, independence decreased clearly by increasing age. Our results imply stable disability levels in nonagenarians in a population with increasing life expectancy and

improving survival until the age of 90. Longer-time series are needed to confirm the trends.

Keywords Oldest old · Nonagenarians · Independence · Functioning · Activities of daily living · Population studies

Introduction

As a result of the rapidly declining old age mortality, the oldest old constitutes the fastest growing population segment in the Western world (Vaupel et al. 1998). During the past 20 years in Finland, life expectancy at the age of 65 has increased by more than 3 years, and at the age of 90 from 3.6 to 4.2 years (Statistics Finland 2010a). In 2008, the proportion of persons aged 90 years or over was 0.6% of the total population and 3% of the population aged 65 years or over. By 2030, these figures are expected to rise 1.3 and 5% (Statistics Finland 2010b, c), bringing them to a slightly higher level than the corresponding projections for the United States (U.S. Census Bureau 2010a, b). Whether the years gained are years with disability or free of disability has long been a focus of debate (Cai and Lubitz 2007), and three scenarios related to population aging—compression of morbidity, expansion of morbidity, and dynamic equilibrium—have been proposed (Fries 1980; Kramer 1980; Olshansky et al. 1991; Manton 1982).

The compression of morbidity scenario suggests that the onset of disability will be postponed toward the end of a person's lifetime which, assuming that the total life expectancy does not increase, would lead to a longer healthy life expectancy (Fries 1980). The expansion of morbidity points to gains in longevity being associated with longer periods of morbidity (Kramer 1980; Olshansky et al. 1991). The dynamic equilibrium approach faults the

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first two for underestimating the links between mortality, morbidity, and disability, and argues that increased prevalence of chronic diseases in old age is counterbalanced by a decrease in the severity and consequences of the same diseases (Manton 1982). The continuing increase in life expectancy, which contrasts with the original compression of morbidity hypothesis, creates a complex dynamic between longevity and disability.

Empirical findings on disability trends in older populations are inconsistent. For people younger than 85 years, studies from the United States have reported declining rates of disability (Cai and Lubitz 2007; Crimmins 2004, 2009; Manton and Gu 2006), but also stable or increasing disability levels (Fuller-Thomson et al. 2009; Seeman et al. 2010). The rates in Europe have varied according to country, period, setting, and methodology (Jeune 2008; Parker et al. 2008; Robine et al. 2009). For the oldest old, data are sparse, and the results have shown both rising and declining trends (Cai and Lubitz 2007; Engberg et al. 2008; Parker et al. 2005; Seeman et al. 2010). Recent publications from the United States indicate a more favorable trend among the oldest old than among those younger than 80 years (Cai and Lubitz 2007; Seeman et al. 2010). In Finland, the few existing studies imply decreasing disability since the 1980s until the age of 80, but not after that; the number of the oldest old in these studies has, however, been very small (Koskinen et al. 2006; Sulander et al. 2007).

Our study examines the trends in disability among people aged 90 years or over from the year 2001 to 2007. We also explore gender-specific levels and development of independence, and assess independence according to age. The data come from three mailed surveys of the Vitality 90+ Study carried out in total cohorts of people aged 90 years or over in the city of Tampere, Finland.

Methods

Design and population

The Vitality 90+ Study was started in 1995 in Tampere, the third largest city of Finland, with over 200,000 inhabitants. The aim of the study is to explore wellbeing and functioning among people aged 90 years or over and to assess predictors of longevity and healthy aging (Goebeler et al. 2003; Jylhä et al. 2007). During the first round of the study, a mailed survey was carried out among community-dwelling nonagenarians in the Tampere area. Due to very few reported experiences with this type of data collection among the oldest old, a major goal of the baseline survey was to examine the feasibility of the survey instrument (Jylhä and Hervonen 1999). A high response rate (81%)

encouraged the continuation of the survey in an extended fashion for the following years.

The first main round of the Vitality 90+ survey was carried out in 1996, and the following rounds in 1998, 2001, 2003, and 2007. In 1996 and 1998, questionnaires were mailed to all individuals 90 years old or older who according to the Tampere City Population Register were living in the community in a private house, an apartment, or in sheltered housing. In 2001, 2003, and 2007 there were no exclusion criteria due to residence, and the questionnaires were sent to all Tampere citizens aged 90 years or over, including those living in institutions (nursing homes or hospitals). The focus of the current study is on the three cross-sectional surveys carried out in 2001, 2003, and 2007, when all Tampere citizens aged 90 years or over were included in the Vitality 90+ Study.

For each of the three rounds carried out between 2001 and 2007, names, addresses, dates of birth, and places of residence of the target population were derived from the Tampere City Population Register. The register includes every individual whose official place of residence is Tampere. The target population was formulated as close to the delivery of the survey as possible. A reminder was sent to those not returning the questionnaire within 1 month. Persons unable to fill out the questionnaire were instructed to ask for help from a family member, a caregiver, or a friend. If a person was unable to answer, a caregiver or a family member was asked to answer the questions as a proxy participant.

Measures

In each survey round, five identical questions were asked. The questions were: [1] "Are you able to get in and out of bed?" [2] "Are you able to dress and undress?" [3] "Are you able to move about indoors?" [4] "Are you able to walk 400 meters?" and [5] "Are you able to use stairs?" For each of these five questions, the participants could choose between four alternative answers: "Yes, without difficulty," "Yes, with difficulty," "Only if someone helps," or "Not at all".

Participants able to perform an activity without help (i.e., without or with difficulty) were classified as independent, and participants able to perform an activity only with help or unable to perform an activity, were classified as dependent in the respective activity. In addition, four other outcome measures were created: independence in all five activities, dependence in one to four activities, dependence in all five activities (severe dependence), and a disability score, designed to indicate the number of activities in which the participants were dependent.

The survey questionnaire also included questions about the type of residence and cohabitation. As the information

provided by this question was more up-to-date than the original register information, the answers on residence and cohabitation were used in the data to determine the living arrangements of the participants. Participants living alone in a private house, an apartment, or in sheltered housing without 24-h assistance were labeled as "living alone in a community;" participants living with a spouse, children, or someone else in a private house, in an apartment, or in sheltered housing without 24-h assistance as "living with others in a community;" and participants living in sheltered housing with 24-h assistance, in a nursing home, or in a hospital were categorized as "institutionalized."

Statistical analyses

We first used logistic regression to analyze the overall and gender-specific proportions of those independent in each activity, those independent in all five activities, those dependent in one to four activities, and those severely dependent who were unable to manage any of the activities. These analyses treated the three rounds of the survey as independent cross-sectional samples, and were carried out by the statistical program package SPSS.

Due to the study protocol, recurrent questionnaires were sent to people aged 90 years or over in 2001, 2003, and 2007. Hence, some individuals participated in the survey in 2 or 3 years. To account for the possible within-subject associations, we incorporated a generalized linear mixed model as our second modeling frame (Fitzmaurice et al. 2004), and analyzed, by logistic mixed regression, (a) overall and gender-specific proportions of those independent in each individual activity in 2001–2007; (b) overall, gender-specific, and age-specific proportions of those independent in all five activities in 2001–2007; (c) overall and gender-specific proportions of those dependent in one to four activities in 2001–2007; (d) overall and gender-specific proportions of those severely dependent in 2001–2007, and, finally, by Poisson mixed regression, (e) an overall and gender-specific disability score, reflecting the number of activities in which the individuals were dependent [dependent in none (i.e., independent in all five), dependent in one, two, three, four, five] in 2001–2007.

The distinctive feature of linear mixed models is that the mean response is modeled as a linear combination of population characteristics shared by all individuals, and subject-specific effects that are unique to a particular individual (Fitzmaurice et al. 2004). The former model terms are referred to as fixed effects, and the latter terms as random effects. Since some study participants were measured repeatedly over the study years, a subject-specific, individual random (person) effect was incorporated into our mixed models. As the type of participation (in person

or via proxy) constituted one possible source of extra variation, it, too, was included as a random effect in the models. To control for changes in living arrangements in the study period, we also carried out analyses with living arrangements (alone in community, with others in community, institutionalized) as a third random effect. Since the results obtained from models with and without living arrangement were not significantly different, in our final models we only include two random variables (person and proxy). All mixed analyses were carried out by the statistical program package R with the package lme4.

Age was used as a fixed continuous variable, and the survey year and gender as fixed categorical variables in all models.

Results

In the three rounds of the study, a total of 3,388 questionnaires were sent to the target population (Table 1). The total number of completed and returned questionnaires was 2,799, and the number of participating individuals 2,060. Between the years, the number of participants varied from 892 to 944, and the participation rate from 79 to 86%. The proportion of proxy participants was somewhat lower in 2007 than in the first two survey years (18 vs. 23–24%).

The number of women in the study population was four times larger than the number of men (Table 1). The participation rates were similar for both genders, but women were found to be living in institutions more often and were on average 1 year older than the participating men.

Among the three survey years 2001, 2003, and 2007, the level of independence varied from 80 to 84% in getting in and out of bed, 70 to 77% in dressing and undressing, 81 to 85% in moving about indoors, 50 to 54% in walking 400 m, and 51 to 52% in using stairs (Table 2). In each activity, men were more often independent than women. In the non-mixed logistic regression analysis, where the three rounds of the survey were treated as independent cross-sectional samples, there was a small but significant overall improvement in getting in and out of bed, dressing and undressing, and moving about indoors between the years 2001 and 2007 in the total sample (analyses not shown). In gender-specific analyses, a borderline significant improvement was observed in women only in getting in and out of bed. In the mixed analysis, where persons and proxy answers were treated as random variables, no overall or gender-specific change in independence was observed in any of the five activities ($p = 0.34$–0.99, $p = 0.55$–0.99, Table 3).

The proportion of those independent in all five activities remained at the level of 41% in 2001, 2003, and 2007 (Fig. 1), and showed a stable pattern both in the non-mixed

Table 1 Demographic characteristics of the study population in 2001, 2003, and 2007

	2001			2003			2007		
	Men	Women	Total	Men	Women	Total	Men	Women	Total
Population (N)	217	912	1129	212	901	1113	228	918	1146
Participants (n)	171	721	892	189	774	963	192	752	944
Participation rate (%)	79	79	79	89	86	86	84	82	82
Among participants									
In person (%)	84	75	77	76	76	76	78	83	82
Via proxy (%)	16	25	23	24	24	24	22	17	18
Community-dwelling, alone (%)	33	40	38	36	43	42	34	44	42
Community-dwelling, with others (%)	46	17	23	40	18	22	44	18	23
Institutionalized (%)	21	43	39	24	39	36	22	38	35
Dwelling unknown (%)	–	–	–	–	–	–	–	<1	–
Median age in years (range)	91	92	92	91	92	92	91	92	92
	(90–102)	(90–106)	(90–106)	(90–102)	(90–106)	(90–106)	(90–99)	(90–105)	(90–105)

Table 2 Ability to get in and out of bed, to dress and undress, to move about indoors, to walk 400 m, and to use stairs among the study participants in 2001, 2003, and 2007 (%)

Ability to get in and out of bed	2001			2003			2007		
	Men n = 171	Women n = 711	Total n = 882	Men n = 187	Women n = 770	Total n = 957	Men n = 192	Women n = 749	Total n = 941
Without difficulty (%)	73	61	63	74	65	67	71	61	63
With difficulty (%)	17	17	17	17	15	16	22	21	21
Only with help (%)	5	7	7	2	8	7	4	8	7
Not able (%)	5	15	13	6	12	11	3	10	9
Ability to dress and undress	n = 171	n = 709	n = 880	n = 187	n = 768	n = 955	n = 192	n = 749	n = 941
Without difficulty (%)	59	49	51	65	53	55	57	48	50
With difficulty (%)	22	21	21	19	20	20	27	28	27
Only with help (%)	10	13	12	9	12	12	11	11	11
Not able (%)	9	17	16	7	15	13	5	13	12
Ability to move about indoors	n = 170	n = 714	n = 884	n = 184	n = 768	n = 952	n = 190	n = 750	n = 940
Without difficulty (%)	55	46	48	65	53	56	65	50	53
With difficulty (%)	34	32	33	25	28	28	27	33	32
Only with help (%)	5	7	6	3	7	5	5	8	7
Not able (%)	6	15	13	7	12	11	3	9	8
Ability to walk 400 m	n = 169	n = 700	n = 869	n = 185	n = 765	n = 950	n = 191	n = 745	n = 936
Without difficulty (%)	40	27	30	48	29	33	45	27	31
With difficulty (%)	27	19	20	21	19	19	25	22	23
Only with help (%)	9	15	14	6	14	13	7	14	12
Not able (%)	24	39	36	25	38	35	23	37	34
Ability to use stairs	n = 169	n = 711	n = 880	n = 186	n = 767	n = 953	n = 191	n = 747	n = 938
Without difficulty (%)	33	20	23	35	22	25	33	18	21
With difficulty (%)	34	27	28	36	24	26	35	30	31
Only with help (%)	16	18	18	10	17	16	11	19	17
Not able (%)	17	35	31	19	36	33	21	34	31

Table 3 Odds ratios (OR), 95% confidence intervals (95% CI), and p values from the likelihood-ratio test (LR) for the gender-specific and overall level of independence in each activity in 2001-2007

	Men			Women			Both genders		
	OR	95% CI	LR p value	OR	95% CI	LR p value	OR	95% CI	LR p value
Ability to get in and out of bed									
2001	1			1			1		
2003	1.12	(0.47–2.67)		1.09	(0.79–1.50)		1.09	(0.81–1.48)	
2007	0.91	(0.38–2.20)		0.98	(0.70–1.37)		0.97	(0.71–1.33)	
Over 2001–2007			0.96			0.96			0.75
Ability to dress and undress									
2001	1			1			1		
2003	1.17	(0.60–2.27)		1.17	(0.87–1.56)		1.17	(0.89–1.52)	
2007	0.95	(0.49–1.83)		1.08	(0.80–1.45)		1.05	(0.80–1.39)	
Over 2001–2007			0.85			0.85			0.55
Ability to move about indoors									
2001	1			1			1		
2003	1.00	(0.44–2.28)		1.26	(0.91–1.73)		1.22	(0.91–1.64)	
2007	0.97	(0.41–2.29)		1.00	(0.72–1.39)		1.00	(0.73–1.35)	
Over 2001–2007			0.55			0.55			0.38
Ability to walk 400 m									
2001	1			1			1		
2003	1.07	(0.63–1.79)		1.06	(0.83–1.34)		1.06	(0.85–1.32)	
2007	0.99	(0.26–1.68)		1.02	(0.80–1.31)		1.02	(0.81–1.27)	
Over 2001–2007			0.99			0.99			0.89
Ability to use stairs									
2001	1	(0.76–2.12)		1			1		
2003	1.22	(0.48–1.42)		0.94	(0.73–1.20)		0.98	(0.78–1.23)	
2007	0.82			0.86	(0.67–1.12)		0.85	(0.67–1.08)	
Over 2001–2007			0.55			0.55			0.38

Adjusted according to age and sex

Person and type of attendance random effects

and mixed logistic regression analyses ($p = 0.73$, $p = 0.95$ for the trend). Among the women, the proportion of independence (37%) was constantly at a lower level than the corresponding proportion among the men (58%) (Odds ratio 0.40, 95% confidence interval 0.31–0.51, mixed analysis), but neither women nor men showed any change in their level of independence from 2001 to 2007 ($p = 0.85$ for the trend, mixed analysis).

The proportion of those dependent in one to four activities increased slightly, from 41 to 46%, in the study period 2001–2007 (Fig. 1), but the increase was non-significant ($p = 0.59$ for the trend, mixed analysis). Similar, stable, pattern was observed also in the gender-specific analyses ($p = 0.86$ for the trend, mixed analysis).

The proportion of those severely dependent decreased from 18 to 13% between the years 2001 and 2007 (Fig. 1). The overall development appeared as significant (OR 0.95, CI 0.91–0.99) in the non-mixed logistic regression analysis,

whereas in the mixed analysis, no decreasing trend was observed ($p = 0.67$). In gender-specific analyses, neither non-mixed ($p = 0.11$) nor mixed ($p = 0.82$) analyses showed any significant change in severe dependence from 2001 to 2007.

There was no overall or gender-specific change between the study years in the disability score ($p = 0.75$, $p = 0.95$, respectively; Fig. 1).

In addition to the time trends, we also analyzed the impact of age on the proportion of those independent in all five activities in the years 2001, 2003, and 2007, using mixed logistic regression. The overall and gender-specific decline with age was similar in 2001, 2003, and 2007 ($p = 0.52$, $p = 0.85$). Per each year of age, there was a significant decrease of 22% (OR 0.78, CI 0.74–0.81) in independence, indicating an overall decline from 50–58% at the age of 90 to 0–17% at the age of 100 (Fig. 2). The decrease among women was 23% (OR 0.77, CI 0.74–0.81), and among men 22% (OR 0.78, CI 0.75–0.82).
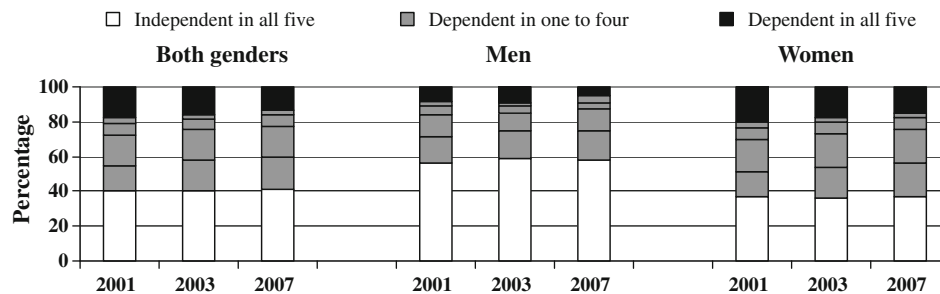
Fig. 1 Disability score in 2001, 2003, and 2007. Sections inside the *gray portion* of the *bars* refer to the number of activities with dependence; the first section from the bottom to those dependent in

one, the second to those dependent in two, the third to those dependent in three, and the fourth section to those dependent in four activities
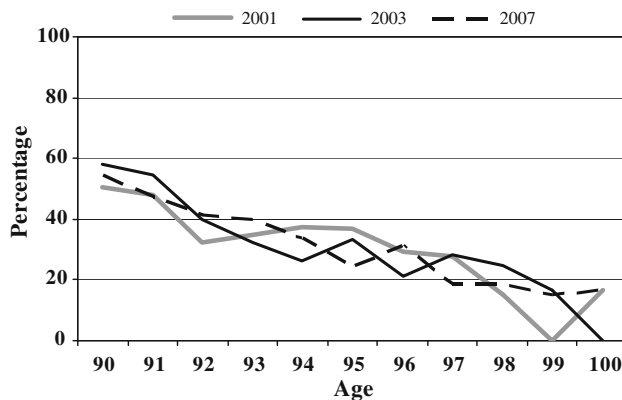

Fig. 2 Proportion of those independent in all five activities by age in 2001, 2003, and 2007

Discussion

In the Vitality 90+ Study, we examined disability in total cohorts aged 90 years or older in the city of Tampere, Finland, in 2001, 2003, and 2007. In analyses taking into account the within-subject associations and proxy respondents, there were no changes between the years 2001 and 2007 in the level of independence in any of the activities measured: getting in and out of bed, dressing and undressing, moving about indoors, walking 400 m, and using stairs. The proportion of those independent in all five activities, those dependent in one to four activities, those dependent in all five activities, and the disability score also remained stable during the study period. Women had more limitations than men in all activities. In every year, independence was strongly dependent on age.

To our knowledge, this study is the first to investigate self-reported functional status among a population aged 90 years or over by identical sampling frames, designs, and questionnaires over several consecutive years. In each year, the whole 90+ population in the city of Tampere was included in the study. The participation rate was high among both genders in each survey round. In many studies,

estimates relating to functional status are biased due to exclusion of institutionalized individuals; in our study, the response rate was also high for this group. The proportion of institutionalized individuals is approximately similar in our data to that which is found in the basic population; therefore, we believe that our data well represents the population aged 90+ in Tampere. The proportion of proxy respondents varied from 18 to 24%, being the lowest in the final study year. Several studies (Magaziner et al. 1988; Todorov and Kirchner 2000) have found that proxy respondents usually overestimate an older person's disability relative to him- or herself. Therefore, even if the differences in the proportions of proxy answers were not large, we included the proxy answers as a random variable in our mixed models.

Among the oldest old, different studies have used different approaches to measure independence, dependence, and disability. Cai and Lubitz (2007) in the United States used seven tasks to measure the activities of daily living (ADL), and defined persons as disabled if they had difficulties with or were not able to do the tasks. Danish researchers categorized participants as physically independent if they were able to perform the activities without or with assistive devices, and as dependent, if they needed help or could not do the activity (Christensen et al. 2008; Engberg et al. 2008). In Sweden, those without any difficulty in accomplishing mobility tasks, ADL, or instrumental ADL were categorized as having "no functional limitations" (Parker et al. 2005). In our study, the disability indicators included both ADL and mobility disability. We categorized the participants as independent if they were able to perform an activity without help, and as dependent if they were able to perform an activity only with help, or not at all. Emphasizing independence, not difficulty, is probably a more reliable approach to measuring disability, and less sensitive to contextual interpretations. On the other hand, "difficulty" necessarily covers a wide range of different situations, and excluding it may lead to underestimating the prevalence of disability.

As expected, women outnumbered men in our study and were less independent than men. These findings are consistent with earlier studies, and reflect a well-known gender paradox (Cai and Lubitz 2007), which has been explained by a higher prevalence of fatal diseases and a higher mortality due to certain chronic conditions among men, and higher prevalence of non-fatal, but disabling diseases among women (Case and Paxson 2005; Ferrucci et al. 2003; Oman et al. 1999; Verbrugge 1989).

In each survey year, the level of independence decreased clearly with age. Our findings from repeated cross-sectional analyses add a new perspective to the results from Denmark, where a longitudinal study of the 1905 cohort discovered only a modest decline (39–32%) in the proportion of independent individuals between ages 92 and 100 (Christensen et al. 2008). The stability, however, was mostly explained by a higher mortality among disabled participants; for individuals who survived from age 92 to age 100, the level of independence declined from 70 to 33% (Christensen et al. 2008). The Danish survey had a lower participation rate (63%) than our study. Independence was classified as a combination of physical and cognitive functioning, while in our study only physical measurements were used. The fact that we did not address cognitive status is a limitation. Regardless of differences between the measures of independence, the results are consistent: higher disability with older age at the population level, and high mortality among disabled individuals, resulting in a rather stable level of disability in a longitudinal follow-up of one birth cohort (Christensen et al. 2008).

Earlier studies among the oldest old have indicated differences in the trends of functional status between countries, and some have also reported dissimilar time trends between the oldest and the younger old. A comparison between two nation-wide studies carried out over the past 20 years in Finland showed improvements in functional abilities among the 65–84-year-old men and women, but not among people aged 85 and older (Martelin et al. 2004; Sulander et al. 2007). In the NHANES study in the United States, rates of disability and functional limitations between the periods 1988–1994 and 1999–2004 increased among those aged 60–69, but declined among people aged 80 years or over (Seeman et al. 2010). Also the Medicare Current Beneficiary Survey from the United States showed declining ADL disability for people aged 85 or older from 1992 to 2002 (Cai and Lubitz 2007). A review of several large studies in the US found declining ADL disability for people aged 70 or over since the mid-1990s, but the oldest old were not analyzed separately (Freedman et al. 2004). During the same period in Sweden, no change in ADL disability was found among people aged 77 or over (Parker et al. 2005). Our results in nonagenarians from 2001 to 2007 differed somewhat according to the analytic method used. When recurrent participation and proxy respondents were taken into account, there was no difference between the study years in any of the individual or aggregate measures. When the surveys were treated as independent cross sections, a slight decrease was observed in severe disability. Additional survey rounds are needed to clarify whether these signs indicate a real pattern of improvement in functional ability among the oldest old, similar to that which was earlier reported in Finland among people younger than 85 years (Koskinen et al. 2006; Sulander et al. 2007).

Robine et al. (2009) recently discovered that healthy life expectancy increased most in countries that lagged behind in terms of life expectancy at age 65. During our study period 2001–2007, life expectancy at age 65 in Finland increased from 18.0 to 19.4 years, and at age 90 from 3.8 to 4.1 years (Statistics Finland 2010a). The proportion of those surviving from birth to age 90 rose from 7.1 to 9.4% (Statistics Finland 2010d). During a period of rapidly improving survivorship and increasing life expectancy among the oldest old, our results, indicating stable or slightly declining disability in nonagenarians, can be interpreted as good news. In this group, improved survival of the disabled does not seem to be the main driver of increased life expectancy (Crimmins et al. 2009), but life is being extended for groups with diverse functional levels. Longer lives apparently do not result in excessive levels of disability (Christensen et al. 2008). They do, however, result in increasing numbers of both well-functioning and disabled individuals, and thus create major challenges for health care, social care, and environmental planning.

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