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ORIGINAL ARTICLE

Trends in Disability-Free Life Expectancy (DFLE) from 1995 to 2017 in the older Norwegian population by sex and education: The HUNT Study

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Abstract

Aim: Understanding whether increasing Life Expectancy (LE) translates to improved health and function among older adults is essential, but results are inconclusive. We aimed to estimate trends in Disability-Free Life Expectancy (DFLE) in the older Norwegian population by sex and education from 1995 to 2017. *Method:* National life table data were combined with cross-sectional data on functional ability for 70+ year-olds from the population-based Trøndelag Health Surveys 2-4 (1995–1997, 2006–2008 and 2017–2019) (n=24,733). Self-reported functional ability was assessed on a graded scale by a combination of Instrumental Activities of Daily Living (IADL) such as paying bills, going out or shopping (mild disability) and Personal Activities of Daily Living (PADL) such as washing, dressing or eating (severe disability). LE, DFLE, Mild-Disability LE and Severe-Disability LE at age 70 were estimated by the Sullivan method. *Results:* From 1995 to 2017 DFLE at age 70 increased from 8.4 to 13.0 years in women, and from 8.0 to 12.1 years in men. DFLE increased in the basic and high educational groups, but more so in the high educational group among men. Educational inequalities in years spent with disability however, remained low. ***Conclusions:*** **From the mid-1990s and over the past three decades both LE and DFLE at 70 years increased in the older Norwegian population, for both men and women, and across basic and high educational levels. Educational inequalities in DFLE increased, especially in men, but years spent with disability were similar across the three decades.**

Keywords: *Disability-Free Life Expectancy, Activities of Daily Living, Life Expectancy, aged, Norway, HUNT*

Background

Life Expectancy (LE) and the number of older adults is increasing worldwide [1]. LE is higher in the Nordic countries compared to global estimates, and for long periods after World War 2 Iceland, Sweden and Norway had the highest LE worldwide [2]. In Norway, LE at birth (LE_0) increased from 75 to 81 years in men and 81 to 84 in women from 1995 to 2019 [3]. During the same period, LE at 70 years (LE_{70}) increased by 4 years

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in men and 3 years in women [3]. When LE increases, the number of years spent with disability may be compressed, expanded or stable [1]. However, at present there is limited evidence on recent trends in disability among older Norwegians, and we cannot conclude which of these three scenarios has occurred. This would be relevant knowledge for planning of future health care services, resource allocation and age at retirement.

The World Health Organization (WHO) has stressed the need to study functional ability, rather than just focus on the prevalence of diseases or comorbidities [4]. Functional ability is the interaction between an individual's intrinsic capacity and the environmental demands [4]. Disability may be used as a measure of functional ability, and defined as 'difficulty doing activities in any domain of life [. . .] due to a health or physical problem' [5]. Women and lower educated groups have been found to have higher risk of developing disability compared with men and higher educated groups [1]. Increasing inequalities in LE between socioeconomic status (SES) groups have been found in Norway [6], and it is of interest whether this also applies to disability-free life expectancy (DFLE).

Health expectancy calculations combine mortality and morbidity data to provide a composite measure of the health status in a population. One such measure, DFLE, is an estimate of years expected to be lived without disability. DFLE is commonly assessed by using the Global Activity Limitation Index (GALI) or Activities of Daily Living (ADL) [7]. GALI consists of a question about activity limitations in the past 6 months due to a health problem. ADL consists of Personal ADL (PADL) including abilities necessary for basic functioning such as bathing, dressing or eating [8], and Instrumental ADL (IADL) assessing somewhat higher levels of performance, such as the ability to pay bills, go out or do shopping [9]. Overall, ADL disability increases steadily with age, and IADL disability is more common but less severe than PADL disability [1]. There is limited data on DFLE in Norway, and this is the first study including data from the last decade.

Aim

The aim of this study was to estimate time trends in DFLE and years lived with disability (based on ADL) from 1995 to 2017 in older Norwegians by sex and education.

Methods

Study population

The study population was a combination of aggregated data from two data sources for Norwegian adults aged 70 years or older: (1) national life table registry data on mortality and population size by sex, education and year; and (2) self-reported disability data from the Trøndelag Health Study surveys (HUNT) 2, 3 and 4 by sex, education and year. In view of the lack of current national disability data, the HUNT Study data were used as proxy for nationally representative data on community-dwelling older adults.

Registry data. National data on mortality for the years close to the initial years for the HUNT surveys (1995, 2006 and 2016 – latest year available) were provided by *microdata.no*. Microdata is a collaboration service by the Norwegian Centre for Research Data (NSD) and Statistics Norway (SSB). The population aged 70 years and older and alive on 1st of January was followed up for 1 year by sex and education, and mortality was registered. This included 34,057 deaths among 497,679 individuals (mid-year population) in 1995, 31,703 deaths among 491,878 individuals in 2006 and 30,822 deaths among 576,537 individuals in 2016. Education from the national education database (NUDB) was assessed on 1st of January and grouped as basic (9 years or less, ISCED 2011 level 1–2) or higher (10+ years, ISCED 2011 level 3–8). Only two levels were used due to low numbers in the higher educational levels.

HUNT survey data. In total, 24,733 participants aged 70 years and older who completed the ADL questions in HUNT2 in 1995–1997 (n=8895), HUNT3 in 2006–2008 (n=6652) and HUNT4 in 2017–2019 (n=9186) were included (Appendix Table 1). The HUNT Study is a mix of cross-sectional and longitudinal study as all are invited. Our purpose was to cross-sectionally compare different birth cohorts at the same age at different time points; however, some participants are included more than once (84% participated once, 15% twice and 1% three times). The HUNT Study was conducted in the former Nord-Trøndelag County which includes both rural and urban populations, and has been found to be fairly representative of the Norwegian population [10].

Activities of Daily Living (ADL). ADL are self-reported questions concerning practical everyday tasks [11]. ADL can be characterized as Personal ADL (PADL) covering basic tasks, and Instrumental ADL (IADL) covering slightly higher levels of performance. ADL items included in the HUNT Study are shown in Appendix Table 2. Men have been found to be less likely to do the IADL activities housekeeping and laundering, for reasons unrelated to health limitations – reflecting gendered expectations

regarding household activities [12]. To avoid gender bias, the three IADL items *prepare warm meals, do light housework* and *do laundry* were removed from the analyses [12]. There were three response categories (1=yes; 2=with some help; 3=no) in HUNT2, and two (1=yes; 2=no) in HUNT3 and HUNT4. In line with previous reports [13], the latter two categories were combined in HUNT2. Responses were dichotomized into *PADL disability* if they answered yes on at least one of the PADL items, and *no PADL disability* if they answered no for all items (see Appendix Table 2). To be included in the study the respondent had to answer at least one of the items in the PADL battery. In a sensitivity analysis, a stricter inclusion criterium were applied, including only those with non-missing for at least five out of seven PADL items. The two disability prevalences were similar in the two settings, and therefore the former was applied to increase sample size. A similar procedure was applied for IADL.

A graded disability construct based on PADL and IADL. A graded disability construct with three categories based on a combination of PADL and IADL was made: (1) No IADL or PADL disability (*no disability*), (2) IADL disability only (*mild* disability) and (3) PADL disability only or in combination with IADL disability (*severe* disability) [14]. This graded disability variable was used in the $LE_{(70)}$ calculations, which was broken down into three groups: DFLE, Mild-Disability LE and Severe-Disability LE, with accompanying 95% confidence intervals.

Education. Education in HUNT was self-reported. In HUNT3, education was only registered for a small subsample (6%), and therefore education in HUNT3 was imputed from HUNT2 (91%). A small fraction was also imputed from HUNT4 (3%). Overall, missing values for education were 3%, 3% and 1%, for HUNT2, HUNT3 and HUNT4, respectively. Education at all three surveys were dichotomized to match the coding used in the registry data as basic (⩽9 years) or higher (10+ years).

Statistical methods

First, prevalences of each of the three states of the graded disability construct were predicted from a general linear model with Poisson distribution and identity link, including the covariates age (aggregated in 5-year age intervals), sex and a dummy variable indicating the HUNT survey (2, 3 or 4). All interactions (three-way and two-way) were included to ensure full flexibility in the modelling and allowing trends to differ by sex and age. Separate models were run for the educational groups. Secondly, national mortality rates were calculated for 1-year age bands from age 70 to 87+ for 1995 and 2006, and 70 to 88+ years for 2016, and smoothed using Poisson regression and splines. Owing to legal data restrictions in microdata.no, those older than 87 years for HUNT2 and HUNT3, and 88 years for HUNT4 were collapsed into one group and denoted 87+ and 88+ years, respectively. Thirdly, life tables and LEs at age 70 were calculated based on mortality rates and number of persons from national registry data. Lastly, based on prevalences from the HUNT surveys, years spent in each of the three disability categories, with accompanying 95% confidence intervals, were calculated according to the Sullivan method [15].

Comparability across HUNT surveys. The population size in the former county of Nord-Trøndelag has been stable since the first HUNT survey in 1984 with little in and out migration [16]. The response rate for those aged 70 years and older with valid data on ADL and education was 61% in HUNT2, 49% in HUNT3 and 47% in HUNT4 (Appendix Table 1). Data in the HUNT surveys were collected in a similar manner at field stations, including older adults living in institutions. In HUNT4 an additional data collection from home visits and nursing homes was prioritized to increase participation in these groups and to get a more representative sample of older adults. To ensure comparability across study waves this sample was not included in the main analyses, but an additional analysis was performed for HUNT4 to investigate how the inclusion of these groups impacted the results (Appendix Figure 1).

Ethics. The Regional Committee for Medical and Health Research Ethics (REC) approved HUNT2 and HUNT3, and participants signed a written informed consent to participate. HUNT4 was licensed by the Norwegian Data Protection Authority. This study was approved by REC (REC 2019/149 South East).

Results

Prevalence of disability

In general, self-reported disability decreased during 1995–2017, except for a slight increase in severe disability among men in the oldest age group and women in the highest educated group during 2006–2017 (Table I). During 1995–2017, the percentage reporting no disability increased from 70% to 84% in men and 61% to 83% in women. Thus, disability was slightly more prevalent in women. Both mild and severe disability increased by age, and was higher

Table I. Prevalence of disability[1] from 1995 to 2017 by education[2], sex and age group, the HUNT Study, Norway.

Age, years	No disability								Mild disability								Severe disability							
	1995		2006		2017		2017*		1995		2006		2017		2017*		1995		2006		2017		2017*	
	n	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)	*n*	(%)
Men																								
Basic education																								
70-74	822	(78)	496	(86)	542	(87)	543	(86)	192	(18)	65	(11)	65	(10)	66	(10)	36	(3)	18	(3)	17	(3)	24	(4)
75-79	654	(69)	424	(79)	417	(80)	419	(79)	213	(24)	93	(17)	79	(15)	81	(15)	64	(7)	17	(3)	23	(4)	32	(6)
80-84	279	(58)	231	(69)	214	(73)	215	(69)	161	(33)	84	(25)	69	(23)	73	(24)	41	(9)	20	(6)	11	(4)	22	(7)
85+	84	(36)	90	(60)	98	(56)	101	(43)	105	(45)	50	(34)	57	(32)	75	(32)	43	(19)	9	(6)	21	(12)	57	(24)
Total	1839	(68)	1241	(78)	1271	(79)	1278	(75)	689	(25)	292	(18)	270	(17)	295	(17)	184	(7)	64	(4)	72	(4)	135	(8)
High education																								
70–74	466	(84)	536	(92)	1197	(92)	1198	(91)	78	(14)	38	(7)	80	(6)	81	(6)	12	(2)	11	(2)	30	(2)	34	(3)
75–79	261	(75)	360	(84)	729	(90)	733	(89)	78	(22)	60	(14)	62	(8)	66	(8)	11	(3)	9	(2)	15	(2)	28	(3)
80–84	78	(55)	197	(69)	313	(77)	314	(74)	54	(38)	71	(25)	80	(20)	82	(19)	9	(6)	17	(6)	14	(3)	30	(7)
85+	27	(38)	53	(60)	119	(60)	121	(50)	29	(41)	30	(34)	65	(33)	77	(32)	15	(21)	5	(6)	16	(8)	42	(18)
Total	832	(74)	1146	(83)	2358	(87)	2366	(84)	239	(21)	199	(14)	287	(11)	306	(11)	47	(4)	42	(3)	75	(3)	134	(5)
Women																								
Basic education																								
70–74	1140	(73)	724	(86)	719	(89)	722	(88)	308	(20)	103	(12)	74	(9)	75	(9)	105	(7)	14	(2)	15	(2)	24	(3)
75–79	954	(64)	682	(79)	592	(84)	595	(81)	397	(27)	157	(18)	93	(13)	105	(14)	147	(10)	20	(2)	16	(2)	32	(4)
80–84	398	(45)	404	(65)	343	(72)	346	(67)	347	(39)	183	(30)	117	(24)	129	(25)	141	(16)	31	(5)	19	(4)	40	(8)
85+	110	(29)	149	(47)	153	(49)	159	(31)	157	(41)	132	(41)	130	(41)	189	(37)	115	(30)	39	(12)	32	(10)	159	(31)
Total	2602	(60)	1959	(74)	1807	(78)	1822	(71)	1209	(28)	575	(22)	414	(18)	498	(19)	508	(12)	104	(4)	82	(4)	255	(10)
High education																								
70–74	257	(76)	405	(93)	1180	(92)	1180	(92)	73	(22)	31	(7)	87	(7)	89	(7)	8	(2)	1	(0)	13	(1)	18	(1)
75–79	163	(69)	277	(83)	658	(85)	658	(83)	58	(25)	54	(16)	101	(13)	104	(13)	14	(6)	4	(1)	14	(2)	27	(3)
80–84	61	(57)	134	(77)	274	(81)	278	(78)	31	(29)	35	(20)	51	(15)	60	(17)	15	(14)	5	(3)	12	(4)	20	(6)
85+	22	(33)	38	(45)	91	(57)	95	(41)	29	(44)	40	(48)	55	(34)	74	(32)	15	(23)	6	(7)	14	(9)	60	(26)
Total	503	(67)	854	(83)	2203	(86)	2211	(83)	191	(26)	160	(16)	294	(12)	327	(12)	52	(7)	16	(2)	53	(2)	125	(5)

*Including data from participants from home visits and nursing homes (*n*=570) in the overall sample from HUNT4.
[1]No disability = no IADL or PADL disability, Mild disability = IADL disability only, and severe disability = PADL disability only or in combination with IADL disability.
[2]Education was split into basic (9 years or less, ISCED 2011 level 1–2) and higher education (10+ years, ISCED 2011 level 3–8).

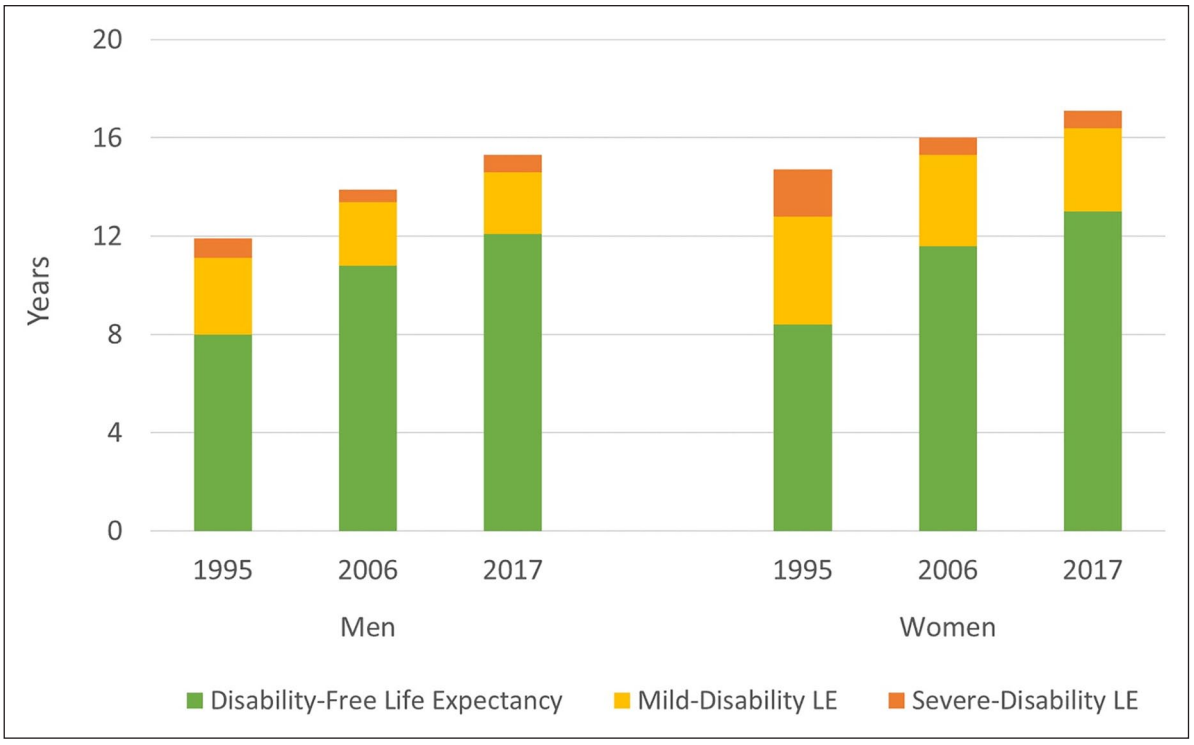

Figure 1. Disability-Free LE (DFLE), Mild-Disability LE, Severe-Disability LE for men and women at age 70 years from 1995 to 2017, the HUNT Study, Norway.

among those with basic educational level compared with those with higher education. In general, mild disability was more prevalent than severe disability; 13% versus 3% in men and 15% versus 3% in women over 70 years in 2017.

Time trends

Between 1995 and 2017 LE increased by 3.4 years for men (from 11.9 to 15.3 years) and 2.4 years for women (from 14.7 to 17.1 years) (Table II). LE increased more for those with high education compared to basic education; in men with high education LE increased by 3.4 years from 12.7 to 16.1 years, while for basic education LE increased by 2.6 years from 11.1 to 13.7 years. Correspondingly, in high educated women LE increased by 2.3 years from 16.2 to 18.5 years, while for basic education the increase was 1.5 years from 14.0 to 15.5.

There was a significant increase in DFLE from 1995 to 2017 for both men (4.1 years, 95% confidence interval (CI) 3.4–4.5) and women (4.6 years, 95% CI 2.4–5.0) (Table II). In the same period, DFLE increased for all educational groups; the increase was 3.1 years (95% CI 2.6–3.6) for men with basic education and 4.3 years (95% CI 3.4–5.0) for men with high education, while the corresponding numbers in women were 3.8 years (95% CI 1.5–4.3) and 4.7 years (95% CI 2.3–5.8) (Table II, Figure 1). Mild-Disability LE decreased significantly in both men and women during 1995–2017; from 3.1 to 2.5 years in men, and from 4.3 to 3.4 years in women. Furthermore, in women, Mild-Disability LE decreased significantly both among those with basic (−1.0, 95% CI −1.5 to −0.5) and high education (−1.4, 95% CI −2.5 to −0.3), while in men there was no significant change over time. Years with severe disability were stable in men (0.8 years in 1995 and 0.7 years in 2017), while in women there was a significant reduction from 2.0 years in 1995 to 0.7 years in 2017. In men, years with severe disability were stable over time both among basic and high educated. In women, however, there were significant reductions in both basic (−1.3 years, 95% CI −1.6 to −1.0) and high educated (−1.0 years, 95% CI −1.8 to −0.2).

Sex and educational differences

Women had both longer LE and DFLE at age 70 compared to men for all years, but the differences in LE between men and women decreased from 2.8 to 1.8 years, while DFLE remained stable with a female advantage of 0.9 years in 2017 (95% CI 0.5–1.3) (Table III). At the same time, there were increasing educational differences in DFLE for men; the excess

Table II. Life Expectancy (LE), Disability-Free LE (DFLE)[1], Mild-Disability LE, Severe-Disability LE at age 70 years from 1995 to 2017 by sex and education[2].

	Year	LE	Disability-Free LE (DFLE)		Mild-Disability LE		Severe-Disability LE	
		Years	Years	95% CI	Years	95% CI	Years	95% CI
Sex								
Men	1995	11.9	8.0	(7.8–8.2)	3.1	(2.9–3.3)	0.8	(0.7–0.9)
	2006	13.9	10.8	(10.6–11.0)	2.6	(2.4–2.8)	0.5	(0.4–0.6)
	2017	15.3	12.1	(11.9–12.3)	2.5	(2.3–2.7)	0.7	(0.6–0.8)
Change 1995–2017		3.4	4.1	(3.4–4.5)	−0.6	(−1.0–−0.2)	−0.1	(−0.3–0.1)
Women	1995	14.7	8.4	(8.2–8.6)	4.3	(4.1–4.5)	2.0	(1.8–2.2)
	2006	16.0	11.7	(11.5–11.9)	3.6	(3.4–3.8)	0.7	(0.6–0.8)
	2017	17.1	13.0	(12.8–13.2)	3.4	(3.2–3.6)	0.7	(0.6–0.8)
Change 1995–2017		2.4	4.6	(2.4–5.0)	−0.9	(−1.3–−0.5)	−1.3	(−1.6–−1.0)
Education								
Men								
Basic	1995	11.1	7.4	(7.2–7.6)	2.9	(2.7–3.1)	0.8	(0.7–0.9)
	2006	12.8	9.8	(9.5–10.1)	2.5	(2.2–2.8)	0.5	(0.4–0.6)
	2017	13.7	10.5	(10.2–10.8)	2.5	(2.2–2.8)	0.7	(0.5–0.9)
Change 1995–2017		2.6	3.1	(2.6–3.6)	−0.4	(−0.9–0.1)	−0.1	(−0.4–0.2)
High	1995	12.7	8.7	(8.3–9.1)	3.2	(2.8–3.6)	0.8	(0.5–1.1)
	2006	14.6	11.5	(11.1–11.9)	2.6	(2.2–3.0)	0.5	(0.3–0.7)
	2017	16.1	13.0	(12.7–13.3)	2.5	(2.2–2.8)	0.6	(0.4–0.8)
Change 1995–2017		3.4	4.3	(3.4–5.0)	−0.7	(−1.4–0.0)	−0.2	(−0.7–0.3)
Women								
Basic	1995	14.0	8.0	(7.8–8.2)	4.1	(3.9–4.3)	1.9	(1.7–2.1)
	2006	15.1	10.9	(10.6–11.2)	3.5	(3.2–3.8)	0.7	(0.6–0.8)
	2017	15.5	11.8	(11.5–12.1)	3.1	(2.8–3.4)	0.6	(0.5–0.7)
Change 1995–2017		1.5	3.8	(1.5–4.3)	−1.0	(−1.5–−0.5)	−1.3	(−1.6–−1.0)
High	1995	16.2	9.8	(9.2–10.4)	4.7	(4.1–5.3)	1.7	(1.2–2.2)
	2006	17.2	12.8	(12.2–13.4)	3.9	(3.3–4.5)	0.5	(0.2–0.8)
	2017	18.5	14.5	(14.0–15.0)	3.3	(2.8–3.8)	0.7	(0.4–1.0)
Change 1995–2017		2.3	4.7	(2.3–5.8)	−1.4	(−2.5–−0.3)	−1.0	(−1.8–−0.2)

[1]Disability-Free = no IADL or PADL disability, Mild disability = IADL disability only, and Severe disability = PADL disability only or in combination with IADL disability.
[2]Education was split into basic (9 years or less, ISCED 2011 level 1–2) and higher education (10+ years, ISCED 2011 level 3–8).

DFLE among high educated increased from 1.3 to 2.5 years during 1995–2017. A similar pattern was seen in women, but the change over time was not significant. This increased inequality in men was driven mainly by increasing educational differences in LE, since there were negligible educational differences in Mild-Disability LE and Severe-Disability LE (Table III, Figure 2). From 1995 to 2017 differences in Severe-Disability LE between men and women disappeared, and remained negligible between educational groups (Table III).

Including institutionalized data in HUNT4

When including data from participants collected at home visits and nursing homes (n=570) in the overall sample from 2017, the percentage reporting low levels of disability remained relatively stable, while the percentage reporting high levels of disability increased (Table I). Consequently, DFLE in 2017 decreased from 12.1 to 11.6 years in men and 13.0 to 12.0 years in women, when including this sample in the calculations (Appendix Figure 1). Mild-disability LE did not change in men (and only from 3.4 to 3.3 years in women), so the change was mostly for Severe-Disability LE, which increased from 0.7 to 1.2 years in men and from 0.7 to 1.8 years in women.

Discussion

Key findings

From 1995 to 2017 DFLE increased while the number of expected years lived with disability was compressed among older Norwegians. Sex differences for the latter metric decreased, resulting in no sex differences in expected years with severe disability in 2017. Educational inequalities in DFLE increased from 1995 to 2017, while inequalities in

Table III. Sex and educational inequalities in Life Expectancy (LE), Disability-Free LE (DFLE)[1], Mild-Disability LE, Severe-Disability LE at age 70 years.

	Year	LE	Disability-Free LE (DFLE)		Mild-Disability LE		Severe-Disability LE	
			Years	(95% CI)	Years	(95% CI)	Years	(95% CI)
Sex								
Women–men								
	1995	2.8	0.4	(0.0–0.8)	1.2	(0.8–1.6)	1.2	(0.9–1.5)
	2006	2.1	0.9	(0.5–1.3)	1.0	(0.6–1.4)	0.2	(0.0–0.4)
	2017	1.8	0.9	(0.5–1.3)	0.9	(0.5–1.3)	0.0	(−0.2–0.2)
Change 1995–2017		−1.0	0.5	(−0.3–1.3)	−0.3	(−1.1–0.5)	−1.2	(−1.7–−0.7)
Education								
Men								
High–basic								
	1995	1.6	1.3	(0.7–1.9)	0.3	(−0.3–0.9)	0.0	(−0.4–0.4)
	2006	1.8	1.7	(1.0–2.4)	0.1	(−0.6–0.8)	0.0	(−0.3–0.3)
	2017	2.4	2.5	(1.9–3.1)	0.0	(−0.6–0.6)	−0.1	(−0.5–0.3)
Change 1995–2017		0.8	1.2	(0.0–2.4)	−0.3	(−1.5–0.9)	−0.1	(−0.9–0.7)
Women								
High–basic								
	1995	2.2	1.8	(1.0–2.6)	0.6	(−0.2–1.4)	−0.2	(−0.9–0.5)
	2006	2.1	1.9	(1.0–2.8)	0.4	(−0.5–1.3)	−0.2	(−0.6–0.2)
	2017	3.0	2.7	(1.9–3.5)	0.2	(−0.6–1.0)	0.1	(−0.3–0.5)
Change 1995–2017		0.8	0.9	(−0.7–2.5)	−0.4	(−2.0–1.2)	0.3	(−0.8–1.4)

[1]Disability-Free = no IADL or PADL disability, Mild disability = IADL disability only, and Severe disability = PADL disability only or in combination with IADL disability.

expected years with mild disability decreased and inequalities in years with severe disability remained negligible.

Trends in DFLE

Prevalence of disability has decreased both among Norwegian and Swedish older adults from the 1970/1980s to 2000 [17,18]. A large review of the literature in Europe and USA during 1991–2011 suggests compression of ADL limitations in more recent born cohorts of older adults [1]. In line with this, other review studies report a decline in prevalence of disability over time, especially for mild and moderate disability but less so for severe disability [19], with simultaneous increase in chronic disease [1,20,21]. Globally, population ageing has led to a total increase in years lived with disability, even though there has been a slight decrease in age-standardized disability incidence rates [22]. In Sweden, years with activity limitations at age 65 years decreased between 1980 and 2011, and there was a compression of disability [23]. In the USA, increased DFLE among older adults between 1980 and 2010 has been found [24]. The increase for men was higher compared to women, and thus sex differences decreased [25]. Findings from review studies are in line with this study, where women and higher educated groups have been found to have higher LE and DFLE than men and lower educated groups [1,20,21].

Interpretation of findings

The finding that LE increased and years with disability were compressed between 1995 and 2017 may be explained by improved treatment and prevention of diseases. This may in turn have improved health and function. PADL dependency has been found to be associated with higher level of home nursing [26]. Thus, decreasing years with severe disability might indicate a lower demand for home nursing per person, but the total demand will depend on the number of older adults. Further, technological advances may also affect functional abilities, without altering older adults' intrinsic capacity [4].

Compression of disability might also be explained by cohort-specific changes for those born during the 1920s and 1940s. A Norwegian study from 2019, with birth cohorts overlapping with the cohorts in our study, found improved grip strength at older ages for more recent born cohorts [27]. Grip strength is strongly associated with ageing [28]. In the Norwegian study, improvement in height and education, which both have their origins in early life, were important drivers for the cohort changes in grip strength. Thus, cohort differences in disability in old age could also

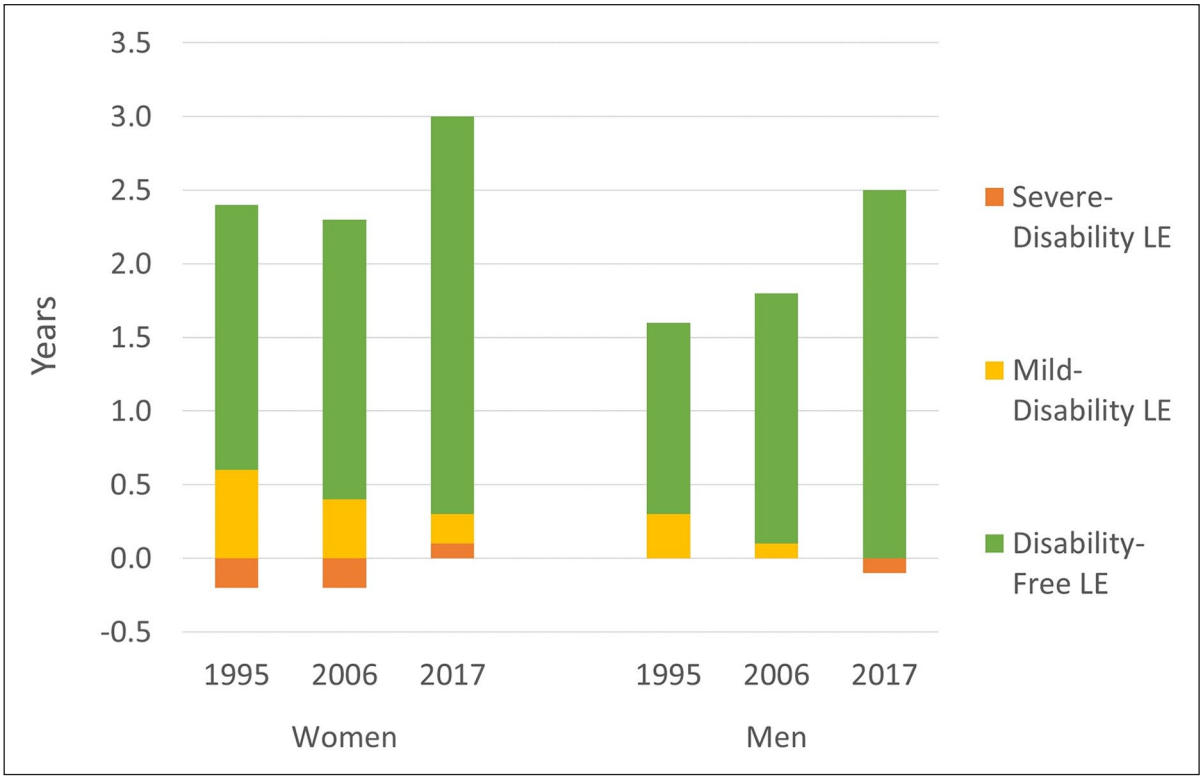

Figure 2. Difference in years between high and basic educational groups in Disability-Free Life Expectancy (DFLE), Mild-Disability LE and Severe-Disability LE for women and men at age 70 from 1995 to 2017, the HUNT Study, Norway. Negative values mean that the group with basic education had fewer years with Severe-Disability LE than the higher educated group.

partly be attributable to differences in exposures accumulating from early life and onwards. Further research is needed to investigate the causes influencing the prevalence of disability.

We found that DFLE increased more among higher educated compared to the group with basic education. However, this change was mainly due to increasing inequalities in LE since expected years with severe disability was similar for those with basic and high education during the whole study period. One possible interpretation is that severe disability occurs towards the end of life, but occurs later among those with higher education as they live longer. Those with high education could in fact expect to live slightly longer with mild disability. Thus, it could be that increasing LE results in more years spent with mild disability. The general educational level in the population has increased over the same time period, and consequently more people have moved into the high educated group. The group with basic education has become more marginalized, which could have contributed to the increasing educational difference in DFLE.

Expected years spent with severe disability among men decreased, but more so for women and thereby sex differences disappeared. However, women could expect to live more years than men with mild disability. This is in line with studies both from USA and Europe, reporting more health-related IADL limitations among women than among men [12]. In a recent SHARE study, including 16 European countries, women generally reported more activity limitations (GALI), but the magnitude differed between countries and age groups [29].

Strengths and limitations

Strengths of this study are the high-quality data from national registers and the population-based HUNT Study with high participation. Except for a more active recruitment of older participants in HUNT4 including nursing homes and home visits, the same data collection procedure was used in all HUNT surveys. This gives comparable data over time, and the long follow-up time enables the study of trends.

Several limitations should be highlighted. First, as HUNT2 had the highest response rate, this sample might be more representative of the total underlying population, while the latter two study waves might have had a stronger healthy selection bias, biasing the findings towards improved functioning. Nevertheless, it is unlikely that such a bias was driving the positive

DFLE trend between the latter two waves because the response rate in HUNT4 was similar to HUNT3. Secondly, participation in the HUNT Study depended on attendance at a field station, but in HUNT4 additional data were collected from home visits and nursing homes. When including this subsample, the calculations for HUNT4, DFLE and LE decreased, indicating that DFLE for the whole population would be somewhat lower. Third, non-participants in HUNT3 have been found to have lower SES and higher prevalence of several chronic illnesses [30]. Thus, the findings may be generalized to the healthier part of the older Norwegian population. Lastly, data on mortality from microdata were only available until 2016, and this was applied to data from HUNT4, which was carried out in 2017–2019. Mortality data for HUNT2 (1995–1997) and HUNT3 (2006–2008) corresponded to the first year of the survey (1995 and 2006).

Conclusions

Findings from this study suggest increased DFLE and a compression of disability among older Norwegians from the 1990s until recently. The educational gap in DFLE increased in men, but inequalities in years spent with disability remained stable. More research is needed to investigate causes behind this trend and evaluate the impact of population ageing on future need of health care and nursing and home care. To get a better picture of the health care load associated with population ageing, expected life years with utilization of health care services could be calculated.

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Research ethics and patient consent

This study was approved by the Regional Committee for Medical and Health Research Ethics (REC 2019/149 South East). HUNT2 and HUNT3 was approved by the Regional Committee for Medical and Health Research Ethics and all participants signed a written consent to participate. HUNT4 was licensed by the Norwegian Data Protection Authority in 2017.

Data

The Trøndelag Health Study (HUNT) has invited persons aged 13–100 years to four surveys between 1994 and 2019. Comprehensive data from more than 150,000 persons having participated at least once and biological material from 100,000 persons are collected. The data are stored in HUNT databank and biological material in HUNT biobank. HUNT Research Centre has been given concession to store and handle these data by the Norwegian Data Inspectorate. The key identification in the data base is the unique personal identification number given to all Norwegians at birth or immigration, while de-identified data are sent to researchers. Owing to confidentiality HUNT Research Centre wants to limit storage of data outside HUNT databank, and we have restrictions for researchers for handling of HUNT data files. We have precise information on all data exported to different projects, and there are no restrictions regarding data export given approval of applications to HUNT Research Centre (http://www.ntnu.edu/hunt/data).

Microdata is a collaboration by Norwegian Centre for Research Data (NSD) and Statistics Norway (SSB). The service provides access to anonymous register data from SSB. Researchers and students at approved research institutions can be registered to gain access to the data (https://microdata.no/).

Supplemental material

Supplemental material for this article is available online.

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