



Income in midlife and dementia related mortality over three decades: A Norwegian prospective study



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ABSTRACT

Studies on midlife income and dementia are scarce, and our main aim was to investigate midlife with later risk of dementia related mortality, adjusting for education and dementia related risk factors. The study population consisted of Norwegian men, aged 40–59 years in 1980 at income assessment, which participated in Norwegian health examination studies in the period 1980–2002 where risk factors such as cholesterol level, hypertension, smoking, cardiovascular disease, and diabetes were assessed. Dementia related mortality was defined as a dementia diagnosis on the death certificate until 2012. Cox regression was used. The study included 45,944 participants and 1062 dementia related deaths. There was no association between midlife income and dementia mortality risk (HR = 1.04, 95% confidence interval (CI) 0.85, 1.28 for the lowest fifth of income compared to those in the highest fifth). For total mortality, there was a strong inverse association with income (HR = 1.61, 95% CI 1.53, 1.69), which was attenuated when adjusting for education and risk factors, but still significant (HR = 1.27, 95% CI 1.20, 1.34). Lower educational attainment was significantly associated with increased dementia mortality risk, also after adjustment for income and other known risk factors (HR = 1.30, 95% CI 1.03, 1.64 comparing low versus high education). Midlife income was not associated with dementia related mortality, but low education was independently linked to increased risk of dementia related mortality. Our results support the cognitive reserve hypothesis suggesting that mental activity and not material resources are related to dementia related mortality.

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1. Introduction

An increased risk of dementia related to lower educational attainment is well established [1–5], but there is still an ongoing debate if

other measures of socioeconomic position, such as income, are involved in the etiology of dementia, or if the observed association is due to confounding by education. Regarding education, plausible explanations for the relationship with dementia have been proposed, which include brain [1] and cognitive reserves [6]. It is not likely that the education-dementia link is solely due to different lifestyle profiles between educational groups [7], as suggested in the brain battering hypothesis [8], or that education merely serves as a marker (proxy) for other factors related to dementia [3]. Education in itself might be a protective factor for dementia [3]. Studies on income and dementia are scarce; especially studies with income assessed early in life or in midlife, and the results are mixed [9–16]. Some studies find no association [12,14], while in other studies the initial inverse association between income and dementia disappears when education is accounted for, suggesting the association is spurious and confounded by education [13,17]. Again, in other studies it is reported that income is robust to such adjustment, and independently inversely related to dementia [9–11,18]. One of the few studies with midlife income, a Finnish study found no association between midlife income and dementia but only for late life income,

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where an inverse association was found [19]. Also, the income-dementia relationship seems to be more culture specific [16], than the education-dementia relationship, which is found universally.

Low income level has been found to be associated with shorter life and a range of adverse health outcomes [20], including poor cognitive functioning [21]. Norway, as one of the Scandinavian countries, has a generous welfare state with publicly funded health care services [22], so it is questionable if income poses barriers for health care in Norway, which next affects dementia risk. It has been suggested that factors acting across the lifespan might connect early life socioeconomic status and dementia risk [23]. Another possible mechanism linking income and dementia may be related to increased psychological distress in the lower income groups, which in turn might negatively affect the cardiovascular system and thereby increase dementia risk [24]. A third mechanism could be that the dementia disease, possibly in its early stage, affects income level downwardly [19]. This mechanism would mostly affect income in late life and not so much in midlife. Nevertheless, despite this list of possible explanations, the mechanisms linking income and dementia are largely unknown, if it exists.

With knowledge from our previous studies [25], our main aim was to investigate the association between midlife income (assessed at 40–59 years) and risk of dementia related mortality in a large cohort of Norwegian men, controlling for education and a range of lifestyle-related risk factors. We hypothesized that midlife income would not be associated with dementia related mortality, while higher educational attainment would be associated with reduced risk, independently of income level and risk factor profile.

2. Methods

2.1. Sample

Our study sample were men participating in either The Norwegian Counties Study (NCS) [26] during 1980–88 or The Cohort of Norway (CONOR) during 1994–2002 [27], in the age range of 40–59 years in 1980 (born 1920–39) at income and education assessment. Women were left out of analyses because of the large percentage with no personal pensionable income in this female birth cohort. Men in households with more than 10 household members were left out of the study sample ($n = 63$ dropped). NCS is a health examination study, with three waves, conducted in Oppland, Sogn og Fjordane and Finnmark counties during 1974–1988 [26], and CONOR is a joint health examination study of several regional studies performed during 1994–2002 [27]. For those participating in several waves of the NCS, results from their first wave, counting from year 1980, was included in our study. Study members were followed from 01.01.1980, and those participating in the health examination surveys after this date entered the study at the date of the health examination. Participants were followed until death, emigration or until 01.01.2012, whichever occurred first. The final study population included 43,887 men and 809,759 person years (Table 1). Mean age at entry into the study was 58.7 years (SD 11.3, range: 40–78 years), mean age in 1980 was 48.8 (SD 4.8, range: 40–59 years). The study population was followed for an average of 18.5 years (SD 9.4, range: 0–32 years), and age at exit was mean 77.1 years (SD 7.2, range: 42–92 years).

2.2. Dementia related mortality

Dementia related mortality was defined as a dementia diagnosis (ICD-9: 331.0, 294.1, 290.0–290.4; ICD-10: F00–F03 and G30) recorded on the death certificate in The Norwegian Cause of Death Registry, either as the underlying cause of death or as a contributory cause. During follow-up, 18,846 of the participants died (43%), and of these 1038 were dementia related deaths (Table 1).

2.3. Income and household size

Men's personal pensionable income in 1980 was linked to the participants using the Norwegian Tax Registry, and defined as the sum of labor income and income from self-employment, and transfers replacing such incomes, before tax is deducted. Income was grouped in five equally sized groups separately for two age groups (40–49 and 50–59 years), and collapsed in the analyses. There was 0.3% missing on the income variable (Table 1). Information about the household size in 1980 was registry based and grouped in four: single households, 2 in household, 3 in household and 4 or more in household. Four birth cohort groups were created: 1920–24, 1925–29, 1930–34 and 1935–39, and included in the analyses as a covariate.

2.4. Educational level, vascular conditions and life-style related risk factors

Highest attained educational level in 1980 was linked to the participants using the National Education Data Base, and classified into three groups: university degree and equivalents (high), advanced secondary qualifications (middle), and basic (public school/elementary school) (low) (Table 1). Participants who reported current or previous diabetes were categorized as having diabetes. Participants reporting cardiovascular disease (CVD), heart attack, angina, stroke, medical treatment of CVD, or symptoms of such a disease, were categorized as having a history of CVD. Smoking was dichotomized as daily smoker or not daily smoker. Leisure time physical activity was dichotomized as physically inactive (watching television mostly) or physically active (light walking, intermediate exercise activities, or intensive exercise). For the CONOR participants, two extra questions about physical activity in leisure time were used; one on hard activity (sweating or out of breath) and one on light activity (not sweating or out of breath). Those performing none or less than one activity per week were classified as physically inactive, while those having more than one activity per week were classified as physically active. Body mass index (BMI) was calculated based on measurements of height and weight as kg/m^2 and grouped as: $<20 \text{ kg}/\text{m}^2$, $20\text{--}25 \text{ kg}/\text{m}^2$, $25\text{--}30 \text{ kg}/\text{m}^2$ and $\geq 30 \text{ kg}/\text{m}^2$. Based on a non-fasting blood sample, total cholesterol level was analyzed and grouped in four categories: $5.20 \text{ mmol}/\text{l}$, $5.20\text{--}6.49 \text{ mmol}/\text{l}$, $6.50\text{--}7.79 \text{ mmol}/\text{l}$ and $\geq 7.80 \text{ mmol}/\text{l}$ [28]. In the Counties Study, the second measurements of resting diastolic and systolic blood pressures were used in the analyses, while in CONOR mean values of the second and third measurements were used. The respondents were categorized as hypertensive if they had systolic pressure $\geq 160 \text{ mm Hg}$ or diastolic pressure $\geq 100 \text{ mm Hg}$ [29].

2.5. Statistics

To investigate the associations between income and dementia related mortality, a set of Cox regression models were specified, using attained age as the time variable and censoring competing events such as non-dementia related deaths or emigration. By using attained age as the time variable, all analyses are automatically adjusted by age. First, the model was adjusted by household size and birth cohort. Second, education was added to the model, and in the final model all covariates were added. All regression analyses were performed on the participants with non-missing values for all covariates in the final model; $N = 41,035$ (94%) and 937 dementia related deaths (17,290 total deaths). A similar approach was used to investigate the association between education and dementia related mortality, adjusted by income. In addition, analyses similar to those above were run using total mortality as outcome. This was done to investigate if certain trends in the results regarding dementia related mortality also applied to total mortality. Overall p-values in the regression models were estimated using a Wald-test, jointly testing if HRs for all income (or education) categories were equal to 1.00. The proportional hazards assumption was checked both on the basis of analysis of Schoenfeld residuals, and by

Table 1
Study characteristics.

	N (%)	Total mortality (risk = deaths/N, %)	Dementia related mortality (risk)
Income fifths			
Low	8753 (20.0)	4626 (52.9)	189 (2.2)
2	8779 (20.0)	4024 (45.8)	216 (2.5)
3	8740 (19.9)	3764 (43.1)	213 (2.4)
4	8746 (19.9)	3376 (38.6)	183 (2.1)
High	8736 (19.9)	2988 (34.2)	235 (2.7)
Missing	133 (0.3)	68 (51.1)	2 (1.5)
Education			
Low	18,523 (42.2)	9149 (49.4)	453 (2.4)
Middle	19,469 (44.4)	7795 (40.0)	440 (2.3)
High	5761 (13.1)	1823 (31.6)	143 (2.5)
Missing	134 (0.3)	79 (59.0)	2 (1.5)
Household size			
1	2987 (6.8)	1696 (56.8)	81 (2.7)
2	7229 (16.5)	3796 (52.5)	247 (3.4)
3	9088 (20.7)	4227 (46.5)	266 (2.9)
4 or more	24,583 (56.0)	9127 (37.1)	444 (1.8)
Missing	0 (0)	–	–
Diabetic			
No	41,923 (95.5)	17,559 (41.9)	965 (2.3)
Yes	1693 (3.9)	1128 (66.6)	64 (3.8)
Missing	271 (0.6)	159 (58.7)	9 (3.3)
History of CVD			
No	35,563 (81.0)	13,919 (39.1)	791 (2.2)
Yes	8217 (18.7)	4853 (59.1)	241 (2.9)
Missing	107 (0.2)	74 (69.2)	6 (5.6)
Daily smoking			
No	28,127 (64.1)	10,185 (36.2)	701 (2.5)
Yes	15,449 (35.2)	8489 (54.9)	320 (2.1)
Missing	311 (0.7)	172 (55.3)	17 (5.5)
Physical inactive			
No	35,278 (80.4)	14,313 (40.6)	790 (2.2)
Yes	7059 (16.0)	3642 (51.6)	181 (2.6)
Missing	1550 (3.5)	891 (57.5)	67 (4.3)
BMI			
<20	805 (1.8)	528 (65.6)	28 (3.5)
20–25	15,901 (36.2)	6712 (42.2)	429 (2.7)
25–30	21,393 (48.8)	8754 (40.9)	442 (2.1)
> = 30	5114 (11.7)	2489 (48.7)	119 (2.3)
Missing	674 (1.5)	363 (53.9)	20 (3.0)
Cholesterol			
<5.20	7961 (18.1)	3366 (42.3)	192 (2.4)
5.20–6.49	19,159 (43.7)	7934 (41.4)	459 (2.4)
6.50–7.79	12,784 (29.1)	5593 (43.8)	295 (2.3)
> = 7.80	3896 (8.9)	1910 (49.0)	91 (2.3)
Missing	87 (0.2)	43 (49.4)	1 (1.1)
Hypertensive			
No	33,404 (76.1)	13,413 (40.2)	761 (2.3)
Yes	10,405 (23.7)	5380 (51.7)	273 (2.6)
Missing	78 (0.2)	53 (67.9)	4 (5.1)
Total	43,887 (100)	18,846 (42.9)	1038 (2.4)

graphical inspection of the estimated hazard function. No severe violations of proportionality were observed. Correlation between income and education was investigated using Pearson correlation coefficient, and performed separately in five-year age groups and for all ages combined. In addition, mean (and standard deviation, SD) income in NOK was calculated for each of the three educational groups. Stata version 13.0 was used for the analyses.

2.6. Ethics

The project has a concession from the Regional Ethics Committee (REK).

3. Results

Income level for 40–49 year olds for quintile groups ranged from an average of NOK 33,000 for the lowest quintile, NOK 74,000 for the

second quintile, NOK 88,000 for the third, NOK 105,000 for the fourth and NOK 150,000 for the fifth quintile. For the age group 50–59, the similar quintile mean income levels (q1–q5) were: 31,000 (q1); 75,000 (q2); 90,000 (q3); 108,000 (q4); and 166,000 (q5).

Income levels in midlife in 1980 differed largely by educational group, with an average income level a year of NOK 74,000 for men in the low education group, NOK 94,000 for those in the middle education group and NOK 142,000 for those with high education (Table 2). The correlation between income and education was 0.40 (Table 2).

Income was not associated with dementia related mortality in a model adjusted only for age, birth cohort and household size ($p = 0.17$) (Table 3, model D1). Further adjustments for education and dementia related risk factors did not change the results substantially – the association still being non-significant. For education, however, the association with dementia related mortality was significant in the minimally adjusted model (age, birth cohort) ($p < 0.001$), in the income and household size adjusted model ($p = 0.003$), and in the fully adjusted

model ($p = 0.018$). The increased dementia mortality risk associated with low compared with high education was $HR = 1.30$ (95% confidence interval 1.03, 1.64) in the fully adjusted model.

For total mortality, there was a strong inverse step-wise association with midlife income level – the higher income the lower overall mortality risk (overall p -value in a model adjusted by age, birth cohort and household size: <0.001) (Table 3, Model T1). Those in the lowest fifth in the income hierarchy had $HR = 1.61$ (95% CI 1.53, 1.69) regarding total mortality (Table 3, Model T1), and adjustment for education attenuated the association somewhat ($HR = 1.37$, 95% CI 1.30, 1.45, Table 3 Model T2), and even more when the risk factors were added to the model ($HR = 1.27$, 95% CI 1.20, 1.34), but the associations were still highly significant ($p < 0.001$). A similar strong association was observed between education and total mortality; the initial association being attenuated in the fully adjusted model but still being significant ($p < 0.001$) (Table 3, Model T1–T3).

4. Discussion

In this large prospective study, following Norwegian men over three decades, there was no association between income level in midlife and later dementia mortality risk. Controlling for education and dementia related risk factors did not change this lack of association. On the other side, lower educational attainment was significantly associated with a 30% increased dementia mortality risk, also after adjustment for income and dementia related risk factors.

In contrast to our finding regarding the lack of an association between midlife income and dementia, results from two US studies suggested that low income was associated with higher dementia risk [9, 13]. In one of these studies, the income-dementia association was attenuated and no longer statistically significant after adjustment for education [13], while in the other study there was still an association, independent of educational level [9]. Furthermore, low income and increased Alzheimer's disease (AD) risk was reported in the German ILSE Study [10]. In two other studies, from Canada [11] and The Netherlands [18], dementia was more prevalent among those with low annual incomes. Similar results were reported in a Brazilian cross sectional study of 65+ year olds, the Sao Paulo Ageing & Health Study (SPAH), where income was inversely associated, in a step-wise fashion, with dementia prevalence [15]. In contrast, no association was found between financial condition and cognitive impairment no-dementia (CIND) in the Italian InCHIANTI Study [14] or between midlife income and dementia in Finland [19]. In this Italian study, however, a strong association

was found between education and CIND. In line with this, results from a Korean study suggested a protective effect of education regarding dementia risk, but they suggested no association between income and dementia [12]. Results from China, contrasts all findings mentioned above, showing a U-shaped association between income and dementia risk [16]. It is suggested that adverse life style habits such as smoking, and lower average educational level in the higher income groups in China might explain the increased dementia risk related to higher income in this group [16].

One possible explanation for the mixed findings in the literature regarding the association between income and dementia might be because in some studies income was measured in midlife and in other studies it was assessed in late life. We found two studies investigating midlife income and dementia risk, one Finnish study by Anttila et al. (including 70 cases of dementia), [19] where income levels were assessed at ages 25–64 years and one German study by Sattler et al. (including 26 cases of AD) with income levels assessed at age 61–64 years [10], while studies on old age income and dementia are more numerous [9,11,13–15,18]. Low income, especially when assessed late in life, might be a consequence of the dementia disease process rather than income level being a risk factor for dementia [19]. Following this line of thought, one might hypothesize that only income in late life, and not in midlife, matters regarding dementia risk. This hypothesis is supported by the findings by Anttila et al., which found income to be associated with dementia only when income was assessed in old age, and not when it was assessed in midlife [19]. They also found that decreasing income levels from midlife to old age was associated with increased dementia risk [19]. In line with Anttila et al., we found no association between midlife income and dementia risk. Results from the other study with midlife income, the German study by Sattler et al., are in conflict with the results from Finland and our results, as they report low midlife income to be associated with increased risk of mild cognitive impairment and AD independently of educational level [10]. However, age at income level was somewhat higher in this German study (61–64 years), and age at income assessment might be denoted late midlife rather than midlife (we assessed income at age 40–59 years), and this might explain the diverging findings. Another reason for diverging findings between countries might be related to differences in income inequalities across countries. Norway and Finland are among the countries with the smallest income inequalities, while Germany has larger inequalities [30].

For sensitivity purposes, we added analyses of the association between midlife income and total mortality, to investigate if these reflected the analyses restricted to dementia mortality as end point. Unlike the null finding regarding income and dementia related mortality, income levels strongly predicted total mortality, to some degree through education and life-style related risk factors, suggesting different mechanisms than for dementia related mortality. The inverse association between midlife income level and total mortality has been found in several other studies [31,32], also in Norway [33]. One could speculate if the null finding regarding midlife income and dementia in our study is due to the fact that low income individuals are more prone to die from other causes before they reach the age of dementia onset, or the age of a clinical manifestation of a dementia diagnosis, and thereby washes away a possible association. However, if this was the case, one would expect null finding also for education and dementia.

Income is a measure of material resources, while education is a marker for cognitive abilities. The association with dementia related mortality was stronger for education than for midlife income, which is in accordance with several other reports [10,19], and this could imply that material resources are of less importance regarding dementia risk than those of cognitive abilities. Furthermore, education is an indicator of early life circumstances [34], it is more stable across life, and is easier to measure than income. Education might therefore capture more of the early life exposures than income does. Karp et al. suggest that unknown-education-related factors operate during the two first decades

Table 2
Income level by educational groups in 1980 and age groups.

Education in 1980 by age groups	Mean income in 1980, in 1000 NOK (SD)	Correlation income and education
40–44		
Low	76 (34)	
Middle	90 (41)	
High	127 (58)	0.34
45–49		
Low	75 (35)	
Middle	93 (40)	
High	142 (94)	0.38
50–54		
Low	74 (36)	
Middle	96 (42)	
High	149 (68)	0.46
55–59		
Low	71 (50)	
Middle	98 (50)	
High	158 (83)	0.44
40–59		
Low	74 (37)	
Middle	94 (42)	
High	142 (76)	0.40

Table 3
Income and education at age 40–59 years and risk of dementia related mortality and total mortality over 32 years of follow-up, from 1980 to 2012 for Norwegian men, estimated using Cox regression with attained age as time scale.

Socio-demographics	Dementia related mortality (N = 41,035, #deaths = 937)			Total mortality (N = 41,035, #deaths = 17,290)		
	HR (95% CI) Model D1*	HR (95% CI) Model D2*	HR (95% CI) Model D3*	HR (95% CI) Model T1*	HR (95% CI) Model T2*	HR (95% CI) Model T3*
<i>Income, fifths</i>						
Low	1.04 (0.85, 1.28)	0.90 (0.71, 1.13)	0.83 (0.66, 1.04)	1.61 (1.53, 1.69)	1.37 (1.30, 1.45)	1.27 (1.20, 1.34)
2	1.09 (0.90, 1.33)	0.94 (0.76, 1.17)	0.89 (0.72, 1.11)	1.35 (1.28, 1.42)	1.15 (1.09, 1.21)	1.10 (1.04, 1.16)
3	1.06 (0.87, 1.28)	0.94 (0.76, 1.16)	0.91 (0.74, 1.13)	1.26 (1.20, 1.33)	1.10 (1.05, 1.17)	1.07 (1.01, 1.13)
4	0.88 (0.72, 1.07)	0.82 (0.66, 1.01)	0.80 (0.65, 0.99)	1.14 (1.08, 1.20)	1.05 (1.00, 1.11)	1.02 (0.97, 1.08)
High	1.00	1.00	1.00	1.00	1.00	1.00
Overall p-value**	0.174	0.423	0.268	<0.001	<0.001	<0.001
<i>Education</i>						
Low	1.34 (1.10, 1.63)	1.37 (1.09, 1.73)	1.30 (1.03, 1.64)	1.69 (1.60, 1.78)	1.45 (1.37, 1.54)	1.22 (1.15, 1.30)
Middle	1.06 (0.87, 1.29)	1.10 (0.89, 1.36)	1.07 (0.86, 1.32)	1.31 (1.24, 1.38)	1.20 (1.14, 1.27)	1.09 (1.03, 1.15)
High	1.00	1.00	1.00	1.00	1.00	1.00
Overall p-value**	<0.001	0.003	0.018	<0.001	<0.001	<0.001

* Models D1 and T1 are adjusted for birth cohort. Income is unadjusted for education and vice versa. Income is adjusted for household size; Models D2 and T2 are mutually adjusted for income and education in addition to adjustments described in Models D1 and T1; Models D3 and T3 are fully adjusted (Model D2/T2 + history of heart disease, diabetes, BMI, total cholesterol, hypertension, smoking and physical inactivity).

** Overall p-value calculated using a Wald-test, jointly testing if HRs for all categories is equal to 1.00.

of life might be involved in the development of dementia [17]. Our findings fit with the reserve hypotheses [1,6], as we previously reported from analyses of education and dementia related deaths without including income [25]. In the present analyses, we had access to both education and midlife income, while in the former we only could access education.

Dementia related mortality has been used in several observational studies as a proxy for clinical dementia diagnosis [25,35–38], but as we have discussed previously, studying dementia related deaths rather than dementia disease has limitations [25,37]. Dementia was only observed among people who died, which implies that among people with dementia more cases might have been detected among persons with lower education, because this group generally had a higher mortality. However, the results were similar when only underlying cause of death was used as dementia end point, so this is probably not an important source of bias. The reporting of dementia in the Cause of Death Registry has increased during the last decades, but dementia is still underreported on the death certificate [39]. This underreporting will possibly blur any weak true associations between income and dementia related mortality. A validation study of Norwegian death certificates on dementia in residents of nursing homes revealed a quite low sensitivity of 38–39%, but high specificity and positive predictive values (100%) [40]. These results indicate that death certificate data is not feasible in prevalence studies, but the hazard ratios will be unbiased as long as our main exposure (midlife income) does not interfere with the death certificate coding [40]. We do not know if sensitivity differs between educational levels and thereby introduces a diagnostic bias; if higher performing individuals (with high education) are less likely to be clinically diagnosed with dementia despite a decline in cognitive function compared to those with less education, this might partly explain why those with high education has lower dementia related mortality compared to those with low education. Our recent findings from a large case-control study with dementia related mortality as cases (n = 561) matched with alive controls (n = 584), which showed that dementia related mortality risk for the various ApoE genotypes were in line with other reports using clinical dementia diagnoses as end point [41], suggest that dementia related mortality might be a feasible proxy for clinical dementia diagnoses in epidemiological studies. Residual confounding might be an issue regarding the education-dementia related mortality link, which also was evident in the fully adjusted analyses. We did not incorporate dietary factors and measures of exposure were limited to one point in time, and would thereby not capture changes in for example smoking. Another limitation is the lack of late life income.

5. Conclusion

Income levels in midlife were not associated with higher dementia related mortality in this study of Norwegian men, but low education was associated with increased dementia mortality risk independently of income and a range of dementia and life-style related risk factors. Our results are in support of the cognitive reserve hypothesis linking cognitive ability, but not material resources, to dementia related mortality.

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Competing interests

None.

Author contributions

Study concept, planning and design: Strand, Engedal, Rosness, Skirbekk, Bjertness. Acquisition of data: Strand. Analysis and interpretation of the data: Strand. Drafting of the manuscript: Strand. Critical revision of the manuscript for important intellectual content: Strand, Engedal, Rosness, Skirbekk, Bjertness. Statistical analysis: Strand had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors discussed the results and have seen and approved this final version.

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