Interplay between financial assets and social relations on decline in physical function and mortality among older people

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Abstract It is well established that socioeconomic position (SEP) and social relations impact physical function and mortality in old age. Due to differential vulnerability, few social relations may lead to greater decline in physical function and mortality among older people with low compared to high SEP. The aim was to investigate whether older people with few social relations experience greater decline in physical function and mortality when also subject to low financial assets? The study population included 4060 older people aged 75 or 80 years at baseline in 1998–1999. Social relations at baseline and physical function at baseline and after 1.5, 3.0 and 4.5 years were obtained from questionnaires. Financial assets at baseline and mortality during 10 years of follow-up were obtained

from registers. Analyses of the associations between financial assets combined with social relations and decline in physical function and mortality, respectively, were conducted. Among males, but not females, low financial assets and few social relations were associated with the greatest decline in physical function. Yet, interaction only reached significance between financial assets and visits. Among males and females, low financial assets and few social relations were associated with the highest mortality. Interactions only reached significance between financial assets and visits for females and social activity for males. In conclusion, few social relations implied greater decline in physical function among older males and higher mortality among older males and females with low financial assets; however, the study only supports the presence of differential vulnerability for visits and social activity.

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Introduction

Physical function in old age is essential to independent living, quality of life and longevity (Cesari et al. 2008; Fusco et al. 2012; Pongiglione et al. 2016). The course of decline in physical function with advancing age varies in speed and rapidity and is influenced by a range of individual and social factors (Verbrugge and Jette 1994). It is well established that both indicators of socioeconomic position (SEP) and social relations have an impact on functioning and mortality in old age (Escobar-Bravo et al. 2011; Huisman et al. 2013; Kingston et al. 2015; Litwin and Shiovitz-Ezra 2006). The pathways linking indicators of SEP and social relations to health may partially operate

through access to resources and material goods, social support and influence, and health-related behavior (Berkman et al. 2000; Goldman 2001). In addition, the impact of few social relations on health may depend on levels of SEP, in other words differential vulnerability. Kessler (1979) was the first to describe how the impact of social stressors may differ depending on social status (Kessler 1979). In a conceptual framework of social inequality in health, Diderichsen et al. (2001) further describe the three mechanisms *differential exposure*, *differential vulnerability* and *differential consequence* that potentially facilitate inequality in health, thus also physical function and mortality in old age. Differential exposure concerns how individuals with low SEP are often exposed to more risk factors. Differential vulnerability addresses how the influence of a risk factor for disease or disability is reinforced by the presence of low SEP. Finally, differential consequence states that the negative consequences of a health outcome are reinforced by the presence of low SEP (Diderichsen et al. 2001).

Only few previous studies have investigated whether indicators of SEP modify the impact of social relations on physical function and we did not find studies on mortality in old-age populations. Previous studies have implied differential vulnerability with regard to physical function; however, the studies are not conclusive and have a range of limitations. First, most previous studies have used income and education as indicators of SEP (Buchman et al. 2009; Krause and Shaw 2002; Shaw and Janevic 2004; Unger et al. 1999); however, these indicators of SEP are not optimal measures in old-age populations. Occupation is imprecise because older people generally have left the workforce. Income is in many cases also imprecise because older people's income usually comes from various sources that may be difficult to identify. Finally, the cohorts that have reached old age today more often left school without academic qualifications; thus, the educational levels are very homogenous for these cohorts (Grundy and Holt 2001). Instead in old-age populations, deprivation indicators combined with education or social class have been suggested to be more appropriate predictors for general health status, and financial assets have been found to be the best indicator of SEP to study inequality in physical function (Grundy and Holt 2001; Robert and House 1996). Second, previous studies are also limited by their small study populations or cross-sectional design (Buchman et al. 2009; Krause and Shaw 2002; Shaw and Janevic 2004; Unger et al. 1999). Gender differences have only been investigated in one previous study (Nilsson et al. 2011), but may be of great importance as studies have shown that being subject to few social relations has a greater impact on decline in physical function and mortality among males than females in old age (Avlund et al. 2004; Shye et al. 1995). Overall, this emphasizes the need for a gender-stratified

longitudinal study of differential vulnerability of social relations among males and females with low financial assets.

When investigating differential vulnerability of few social relations, it is also important to distinguish between different types of social relations. The term *social relations* is in this study used as a main concept covering functional and structural aspects (Due et al. 1999). Previous studies have shown that low social engagement and participation as well as low emotional support and attachment have a great impact on decline in physical function and mortality among older people (Escobar-Bravo et al. 2011; Litwin and Shiovitz-Ezra 2006; Manzoli et al. 2007; McLaughlin et al. 2012; Mendes de Leon et al. 2001). It could be speculated that social engagement and participation, through impact on psychological well-being and better health-related behavior, also most strongly compensate for the impact of few resources related to low financial assets on health outcomes in old age. On the contrary and according to the concept of differential vulnerability, the negative impact of being subject to few of these types of social relations may be even greater among older people with low financial assets.

To achieve a deeper understanding of the mechanisms that contribute to socioeconomic inequality in physical function and longevity among older people, it is important to investigate whether the impact of predictors of physical function and longevity differs by levels of financial assets. If there is a synergistic interaction, a larger beneficial effect would be expected as a result of preventive interventions targeting older people with both socioeconomic insecurity and poor social relations.

The aim of this study is to investigate whether older males and females concomitantly exposed to few social relations and low financial assets experience greater decline in physical function and increased mortality than the additive impact of the two separate exposures. Based on differential vulnerability mechanisms, we hypothesize that low financial assets and few social relations or no social activity interact synergistically in such a way that older people exposed to both factors experience a greater decline in physical function and increased mortality than the additive impact of the two exposures separately. Furthermore, we hypothesize that this is more pronounced among males than females.

Methods

Data source

This study was based on questionnaire data from the Danish Intervention Study on Preventive Home Visits (Vass et al. 2002 for full description). The population

included 4060 non-institutionalized citizens aged 75 or 80 years at baseline (participation rate: 70.8%). Baseline data were collected in 1998–1999 with follow-up in 2000 (T_1), 2001–2002 (T_2) and 2003 (T_3). (Vass et al. 2002) and linked with register data.

Variables

- The main exposure variables were financial assets combined with five structural measures of social relations. We included combined variables in order to estimate the excess risk associated with either low financial assets and/or few social relations and identify and provide estimates for the most vulnerable group. Financial assets in 1999 were based on bonds, stocks and mortgage deposited in financial institutions; funds on deposit in financial institutions; debt for financial institutions; and mortgages credit debt obtained from the Income Statistics Registry (Baadsgaard and Quitzau 2011). *Financial assets* were dichotomized by the 80% with the highest financial assets (>2000€) and the 20% with the lowest financial assets (≤2000€) based on the whole population ($n = 4060$).

Measures of social relations at baseline in 1998–1999 were obtained from the questionnaire data

- *Cohabitation status* was measured by cohabitating and living alone.
- *Visits* were measured by visiting people outside of home and receiving visitors at home within the last month. Each type of visit was scored with one point, and *visits* were categorized as high (2) and low (0–1).
- *Social activity* was measured by participating in social activities outside home (e.g., lectures, movie theater, museum and church) within the last month and categorized as yes (1) and no (0).
- *Family contact* was measured by contact with children, grandchildren, siblings and relatives within the last month. Each type of contact was scored with one point, and *family contact* was categorized as high (2–4) and low (0–1).
- *Friends contact* was measured by contact with friends within the last month and categorized as yes (1) and no (0).

As an example of the combined variables, the variable *financial assets* combined with *cohabitation status* was categorized in the following four categories: (1) high financial assets and cohabitating, (2) high financial assets and living alone, (3) low financial assets and cohabitating and (4) low financial assets and living alone. High on both measures was the reference throughout as this combination

was expected to be associated with the lowest risk of the outcomes.

Age and gender were included at baseline from the questionnaire data. Number of comorbidities was identified up to 4 years prior to baseline by hospital diagnoses based on International Classification of Disease version 10 (ICD-10) codes from the National Patient Registry and purchase of medicine based on Anatomic Therapeutic Chemical (ATC) codes from the Danish National Prescription Registry (Hvidberg et al. 2016; Kildemoes et al. 2011; Lynge et al. 2011) (Appendix Table S1). Comorbidities were categorized as none and one or more based on a selection of common chronic conditions among older people: acute myocardial infarction, chronic ischemic heart disease, pulmonary heart disease and diseases of pulmonary circulation, cerebrovascular diseases, heart failure, stroke, dementia, rheumatoid arthritis, osteoporosis, diabetes mellitus, depression, Parkinson, chronic obstructive pulmonary disorder and cancer.

Outcomes

Physical function was self-reported, measured by the validated Mobility-Help scale (Avlund et al. 1995, 1996) and included as a continuous variable ranging from 0 to 6. Management of each of the following activities without help was scored with one point; thus, 6 points was the maximum score: manage transferring, walking indoors, going outdoors, walking outdoors in nice/poor weather and climbing stairs. The information was obtained from questionnaires at baseline in 1998–1999 and at T_1 , T_2 and T_3 . Information of all-cause mortality was included by registering the date of death or emigration from the Danish Civil Registration System. Individuals were followed from January 1, 1999, and until emigration, death or end of follow-up (5 and 10 years).

Statistical analyses

All participants with full information on exposure variables at baseline were included in the analyses of mortality ($n = 3679$). For the analyses of decline in physical function, an additional eligibility criterion was no disablement at baseline measured by the Mobility-Help scale ($n = 2865$).

Decline in physical function was analyzed in linear regression models. The available data at each of the follow-up time points were weighted with the inverse probability of not being missing to adjust for possible differential dropout between the various categories of financial assets and social relations. These probabilities were estimated in a logistic regression model with financial assets, gender, age,

cohabitation status, contact with friends, contact with family, social participation, visits and Mobility-Help scale as explanatory variables. Inference on the model parameters was performed using generalized estimation equations (GEE) models, also to adjust for repeated assessment of decline in physical function on the Mobility-Help scale (0–6) at T_1 , T_2 and T_3 for the same person. For the mortality outcome, additive hazard models (Rod et al. 2012) were used to estimate additional cases of deaths per 1000 person-years associated with each of the five combined exposure variables. Cox regression analyses were conducted to provide relative risk estimates (hazards ratios) in order to enable comparisons with other studies. Time from baseline was used as the underlying timescale. The main analyses were based on combined variables of financial assets and social relations to ease the interpretation of the combined effect estimates (de Mutsert et al. 2009). Interactions between financial assets and the measures of social relations were tested in additional models by including interaction terms.

Potential confounders to adjust for in the analyses were identified by literature review and directed acyclic graphs (Appendix Figures S1 and S2). For the analyses of decline in physical function and mortality, the analyses with financial assets combined with cohabitation status as the main exposure were adjusted for age and gender. Analyses of decline in physical function with financial assets combined with visits, social activity, family contact and friend contact, respectively, as the main exposures were adjusted for age, gender, cohabitation status and comorbidities. Equivalently, mortality analyses were furthermore adjusted for physical function at baseline. Contrary to the other analyses, the analyses of financial assets combined with cohabitation status were not adjusted for comorbidities, physical function and other measures of social relations because these variables were identified as intermediate variables between cohabitation status and the two outcomes.

Results

Males and females with low number of visits, no social activity and no friend contact had significantly more often low financial assets at baseline (Table 1). Also, males with low family contact and females with one or more comorbidities and living alone had significantly more often low financial assets. This illustrates differential exposure in the sense that males and females with low financial assets were more likely to have had few social relations and no social activity. Differential exposure was more pronounced among males than females.

Decline in physical function

After 1.5 years, 111 (8.9%) males and 207 (14.3%) females had a decline in physical function by going from 6 to 0–5 on the Mobility-Help scale. After 3.0 and 4.5 years, 166 (14.1%) and 175 (16.5%) males and 317 (22.3%) and 373 (27.8%) females, respectively, had a decline in physical function. Only after 3 years for males and 1.5 years for females, significantly more with low financial assets had a decline in physical function compared to those with high financial assets.

Table 2 shows the adjusted associations between financial assets combined with the five measures of social relations and decline in physical function 4.5 years after baseline for males and females from five separate linear regression analyses in GEE models. Among males, but not females, simultaneous exposure to low financial assets and few social relations or no social activity was associated with the greatest significant decline in physical function compared to the reference (high financial assets and high on measures of social relations). As an example, compared to the category high financial assets and high number of visits, the categories high financial assets and low number of visits (β : -0.12 , 95% CI: -0.33 ; 0.08) and low financial assets and high number of visits (β : 0.03 , 95% CI: -0.16 ; 0.22) were not associated with decline in physical function. The category low financial assets and low number of visits was associated with an average of -1.21 (95% CI: -1.92 ; -0.50) more disabilities on the Mobility-Help scale. Tests of interactions to investigate whether the estimates of the combinations of being low on both measures were greater than the additive value of the separate measures of financial assets and each social relation reached significance between low financial assets and low number of visits for males ($p < 0.01$). Overall, similar results were showed after 1.5 and 3.0 years (Table S3). The main effect estimates of financial assets and the five measures of social relations are presented in Table S2 in Appendix.

Mortality

A total of 503 (30.6%) males and 389 (19.1%) females had died after 5 years and 984 (59.8%) males and 909 (44.7%) females had died after 10 years. Both after 5 and 10 years, a larger proportion ($p < 0.01$) of males and females with low financial assets had died compared to older males and females with high financial assets. Figure 1 shows the adjusted additional deaths per 1000 person-years associated with financial assets combined with the five measures of social relations during 5- and 10-year follow-up periods for males and females from additive hazards models. For both males and females, low financial assets combined with few social relations and no social activity were associated with

Table 1 Baseline characteristics for 1800 males and 2260 females

	Males, <i>N</i> (%)				Females, <i>N</i> (%)			
	Financial assets				Financial assets			
	High	Low	All	Missing	High	Low	All	Missing
All	1503 (84.1)	285 (15.9)	1788 (100)	12	1729 (76.8)	523 (23.2)	2252 (100.0)	8
Age								
75 years	1097 (84.3)	204 (15.7)	1301 (100.0)	9	1183 (75.7)	379 (24.3)	1562 (100.0)	4
80 years	406 (83.4)	81 (16.6)	487 (100.0)	3	546 (79.1)	114 (16.5)	690 (100.0)	4
Missing	0	0	0	0	0	1	1	0
Number of comorbidities								
0	1017 (85.2)	176 (14.8)	1193 (100.0)	2	1146 (78.3)	317 (21.7)	1463 (100.0)	2
1+	486 (81.7)	109 (18.3)	595 (100.0)	10	583 (73.9)	206 (26.1)*	789 (100.0)	6
Missing	0	0	0	0	0	0	0	0
Cohabitation status								
Cohabiting	1119 (83.9)	214 (16.1)	1333 (100.0)	9	622 (68.0)	293 (32.0)	915 (100.0)	4
Living alone	381 (84.5)	70 (15.5)	451 (100.0)	3	1107 (82.9)	229 (17.1)***	1335 (100.0)	4
Missing	3	1	4	0	0	1	0	1
Visits								
High	1226 (85.6)	206 (14.4)	1432 (100.0)	8	1479 (78.7)	401 (21.3)	1880 (100.0)	5
Low	254 (77.2)	75 (22.8)***	329 (100.0)	4	235 (67.1)	115 (32.9)***	350 (100.0)	3
Missing	23	4	37	0	15	7	0	22
Social activity								
Yes	733 (87.5)	105 (12.5)	838 (100.0)	6	1025 (80.5)	248 (19.5)	1273 (100.0)	4
No	758 (81.2)	176 (18.8)***	934 (100.0)	6	690 (72.0)	268 (28.0)***	958 (100.0)	4
Missing	12	4	16	0	14	7	0	21
Family contact								
High	1212 (84.7)	219 (15.3)	1431 (100.0)	7	1399 (77.2)	414 (22.8)	1813 (100.0)	7
Low	199 (79.6)	51 (20.4)*	250 (100.0)	4	188 (73.2)	69 (26.8)	257 (100.0)	1
Missing	92	15	107	1	142	40	0	182
Friends contact								
Yes	1379 (84.8)	248 (15.2)	1627 (100.0)	12	1600 (78.2)	445 (21.8)	2045 (100.0)	7
No	117 (76.5)	36 (23.5)*	153* (100.0)	0	126 (63.6)	72 (36.4)***	198 (100.0)	1
Missing	7	1	8	0	3	6	0	9

χ^2 test: * <0.05; ** <0.01; *** <0.001

the highest significant additional number of deaths per 1000 person-years compared to the reference (high financial assets and high on measures of social relations). For example, during 5-year follow-up, the category high financial assets and no social activity was associated with 14.03 (95% CI: 1.51; 26.56) additional deaths and the category low financial assets and social activity was not associated with additional deaths among males (-3.53 (95% CI: -29.30; 22.24)). Low financial assets and no social activity were associated with 72.99 (95% CI: 41.01; 104.98) additional deaths. Comparable results were detected in Cox regression analyses (Table S8). Tests of interactions reached significance between low financial assets and no social activity for 5- and 10-year mortality among males and low financial assets and low number of visits for

5-year mortality among females ($p < 0.01$). The main effect estimates for financial assets and the five measures of social relations are presented in Table S7 in Appendix.

Supplementary and sensitivity analyses

Supplementary analyses stratified by age (75 and 80 years), intervention municipality (control and intervention) and comorbidities (none and one or more) were performed for decline in physical function and mortality (Appendix Table S4–6 and S9–11). The analyses showed overall similar results, however, may have been influenced by lower statistical power. Mortality analyses including the variables (comorbidities, Mobility-Help scale, social relations and financial assets) as time-dependent variables

Table 2 Beta (β and 95% CI) for the associations between financial assets combined with social relations and decline in physical function in 1353 males and 1512 females after 4.5 years

	Males		Females	
	Number	β (95% CI)	Number	β (95% CI)
Financial assets and cohabitation status + age and gender				
High FA and cohabitating	887	0.00	445	0.00
High FA and living alone	277	−0.24 (−0.43; −0.06)	764	−0.05 (−0.20; 0.11)
Low FA and cohabitating	152	−0.08 (−0.29; 0.13)	185	0.00 (−0.20; 0.20)
Low FA and living alone	37	−0.93 (−1.64; 0.23)	118	0.04 (−0.18; 0.27)
Financial assets (FA) and visits (V)				
+ age, gender, cohabitation status and comorbidities				
High FA and high V	990	0.00	1099	0.00
High FA and low V	174	−0.12 (−0.33; 0.08)	110	−0.24 (−0.52; 0.05)
Low FA and high V	151	0.03 (−0.16; 0.22)	260	0.06 (−0.09; 0.21)
Low FA and low V	38	−1.21 (−1.92; −0.50)**	43	−0.13 (−0.51; 0.24)
Financial assets (FA) and social activity (SA)				
+ age, gender cohabitation status and comorbidities				
High FA and SA	620	0.00	778	0.00
High FA and no SA	544	−0.12 (−0.26; 0.01)	431	−0.18 (−0.34; −0.03)
Low FA and SA	82	0.00 (−0.24; 0.25)	160	0.09 (−0.09; 0.27)
Low FA and no SA	107	−0.45 (−0.79; −0.10)	143	−0.14 (−0.35; 0.07)
Financial assets and family contact (FC)				
+ age, gender, cohabitation status and comorbidities				
High FA and high FC	1013	0.00	1077	0.00
High FA and low FC	151	−0.14 (−0.36; 0.09)	132	−0.10 (−0.34; 0.14)
Low FA and high FC	154	−0.13 (−0.36; 0.11)	271	0.04 (−0.11; 0.19)
Low FA and low FC	35	−0.60 (−1.19; −0.01)	32	0.07 (−0.36; 0.49)
Financial assets and friends contact (F)				
+ age, gender, cohabitation status and comorbidities				
High FA and high F	1087	0.00	143	0.00
High FA and low F	77	−0.48 (−0.91; −0.06)	66	−0.47 (−0.84; −0.09)
Low FA and high F	171	−0.06 (−0.24; 0.13)	272	0.03 (−0.12; 0.18)
Low FA and low F	18	−1.65 (−2.86; −0.44)	31	0.06 (−0.28; 0.40)

The estimates are from separate linear regression analyses in generalized estimation equations for each combination of social relations and financial assets

+ adjusted for the following variables

Statistical significant interaction: * <0.05; ** <0.01

updated at T₂ showed similar estimates. Yet the estimates were elevated for males and interaction between cohabitation status and financial assets became significant for females (Appendix Table S12).

Two sensitivity analyses addressing decline in physical function were performed and showed results similar to the main analyses. The first analysis was performed to take into account those who died before follow-up and included death in the definition of decline in physical function as death also expresses the ultimate loss of physical function. The second sensitivity analysis was performed to take into account that a beginning decline in physical function not detected on the Mobility-Help scale could impact social relations. The analyses were adjusted for tiredness when

performing physical activities (Mobility-Tiredness scale) as this measure expresses first signs of decline in physical function (Avlund et al. 2003).

Discussion

Differential exposure was detected as males and females with low financial assets were often also exposed to few social relations and no social activity, which is in line with previous studies (Baum et al. 2000; Buchman et al. 2009; Lindstrom et al. 2002). However, this study is among the first to show differential vulnerability toward few social relations among older people with low financial assets for

Fig. 1 Additional deaths per 1000 person-years (pyr) in 1654 males and 2050 females during 5- and 10-year follow-up according to baseline financial assets (FA) combined with social relations (SR). The estimates are from separate additive hazard analyses for each

combination of social relations and financial assets. Statistical significant interaction (interaction terms) between financial assets and social relations: * <0.05 , ** <0.01 , *** <0.001

decline in physical function and mortality. To our knowledge, only a few American studies and one Danish study of older people have investigated this previously. Of those, only two studies included repeated measures of decline in physical function (Buchman et al. 2009; Krause and Shaw 2002), one study had included gender-stratified analyses (Nilsson et al. 2011) and two studies were restricted to older people with high physical function at baseline to ensure causality (Nilsson et al. 2011; Unger et al. 1999). Only one previous study on mortality was detected (Veenstra and Patterson 2012); however, it was not restricted to an old-age population. Except from the study by Nilsson et al. (2011), all previous studies used income or education as single indicators of SEP, which have been argued to be insufficient measures for these cohorts in old age (Grundy and Holt 2001; Robert and House 1996). The results from previous studies are not conclusive. In a previous study based on our study population, low financial assets combined with low social participation (social activity and visits) and living alone, respectively, were associated with increased odds of decline in physical function for males and females; however, interactions were not tested for significance. The associations were greatest

among males, yet, also present among females (Nilsson et al. 2011). The different findings for females in the present study may be explained by the analyses by Nilsson et al. (2011) not being adjusted for comorbidities. Second, not weighting missing values in the study by Nilsson et al. (2011) may also contribute to the different results, which could indicate greater selection bias for females than males when not weighting those who died, emigrated or did not attend follow-up. Two of the American studies that investigated functional measures of social relations detected significant interactions with educational level. First, a longitudinal study of 905 older people aged 65 years and older reported synergistic interactions between negative relations and shorter education for decline in physical function (Krause and Shaw 2002). Second, a cross-sectional study of 1103 older adults aged 60–95 years reported synergistic interaction between low anticipated support and short education for lower physical function (Shaw and Janevic 2004). Two other American studies did not detect significant interactions. First, in a longitudinal study of 850 older adults aged 70–79 years, tests of interactions between income and four measures of social support (instrumental, emotional, marital status and social ties) for

decline in physical function did not reach significance (Unger et al. 1999). Second, another longitudinal study of 906 individuals aged 54–100 years found that educational level did not modify the relation between social activity and decline in physical function (Buchman et al. 2009). None of the two studies provided estimates to determine whether there was a tendency for a greater impact of few social relations among those with low education and income, despite statistically insignificant interactions. Finally, an American longitudinal study of 6157 individuals aged 21 or older was the only previous study identified on mortality. The study found that regular church attendance and participation in a community betterment group only decreased mortality among non-wealthy and poor individuals. Yet, interactions were only marginally significant ($p < 0.10$) (Veenstra and Patterson 2012). Thus, some but not all previous studies support the hypotheses of differential vulnerability toward few social relations among older adults with low SEP.

The different measures of social relations and social activity in the present study were included to capture more of the mechanisms through which Berkman et al. (2000) suggest social networks influence health; social support, social influence, social engagement and participation, person-to-person contact, and resources and material goods (Berkman et al. 2000). It could be speculated that among older people, cohabitation status and contact with family and friends influence health through *social support* covering emotional, instrumental, appraisal and informal support. Visits and social activity could influence health through *social engagement and participation* by ties in real-life activity. The results from the present study could potentially indicate that financial assets only modify the health effects of the more societal-oriented parts of social engagement with more sources (social activity and visits) and not the family- and friend-oriented parts of social engagement based solely on close contact (contact with family and friends and cohabitation status). However, more studies are needed as previous studies have reported diverging findings; thus, whether certain aspects of social relations interact more strongly with low SEP for decline in physical function and mortality is still not clear. However, the two American studies that focused on negative aspects of social relations found interactions with education for decline in physical function (Krause and Shaw 2002; Shaw and Janevic 2004).

We found that males in old age are more likely than females to be subject to both differential exposure and differential vulnerability. Similar to our study, an American cross-sectional study of middle-aged and older males ($n = 330$) and females ($n = 468$) found that low educational level was associated with poorer health (chronic disease and self-rated health) among males, but not

females, with smaller network and no perceived support from their children (Antonucci et al. 2003). More general, social relations have also been found to be more important for health and mortality for older males than females (Avlund et al. 2004; Shye et al. 1995; Unger et al. 1999). Unger et al. (1999) suggest that gender differences in the impact of social relations on health may be explained by differences in seeking contact and help. Females may be more accustomed to social support networks and asking for help than males and therefore are better at utilizing social relations when needed. Thus, males with few social relations may be especially isolated leading to greater health consequences (Unger et al. 1999). Males more often suffer from involuntary social isolation which may contribute to having more pronounced differential vulnerability toward few social relations and no social activity compared to females with low financial assets. This in combination with lack of resources related to low financial assets to compensate may lead to even greater vulnerability.

Strength and limitations

A major strength of this study is the large study population of 4060 older people (participation rate: 70.1%) with three follow-ups for decline in physical function and 10-year follow-up for mortality. The prospective design limits the risk of reverse causality. SEP was measured by financial assets from a register of high validity (Baadsgaard and Quitzau 2011). Financial assets more broadly express financial resources and have been found a better measure of SEP compared to education and income for physical function in old age (Robert and House 1996). Low financial assets were measured by the lowest 20% as the largest contrast when predicting mortality has been found for older people with the lowest financial assets (Robert and House 1996). However, it would have strengthened the study further if more indicators of SEP had been included. Further strengths are the use of validated outcomes. The outcome decline in physical function was measured using the validated Mobility-Help scale that also has been validated as a self-rated measure (Avlund et al. 1995, 1996) and mortality was included from a registry with full coverage (Pedersen 2011). Furthermore, we were able to investigate change in physical function three times over a 4.5-year period with weighting of missing values and almost complete follow-up in registers for mortality (emigration: 4 persons). Finally, it is a great strength of this study that all the interactions and joint effect estimates are investigated on the additive scale. We hereby detect additive rather than multiplicative deviation from the main effects, which is important in a public health perspective in order to focus on the groups with the greatest number of potentially preventable cases (Rod et al. 2012).

Potential limitations must also be acknowledged. The baseline measures are from 1998 to 1999, which could give rise to concern about the relevance of the results in a present context. However, the impact of SEP on health has been shown to date back to the 1800s (Goldman 2001) and persist over time in the Nordic countries (Mackenbach et al. 2016). Research on social relations does not go back as far, but a clear link between social relations and health has been established over the last decades (Umberson and Montez 2010). Thus, the results are most likely also relevant today. Change in social relations over time was not taken into account for the analyses of decline in physical function, which may have diluted the associations. However, supplementary analyses were conducted for mortality including the exposures as time-dependent variables, which showed similar, however, elevated results for males. Furthermore, there is risk of selection bias as older people had to survive until follow-up for decline in physical function to be included in the analyses; however, this is limited by weighting of missing values. Also, sensitivity analyses that included death in the definition of decline in physical function showed results in line with the main analyses. Additionally, the analyses of physical function were restricted to older people with full physical function at baseline in order to limit the risk of reverse causality. However, this restriction limits the generalizability of the findings to older people with high physical function. Also, risk of reverse causality cannot be completely avoided. A study has found that older people with beginning physical limitations turn to their spouse, children and other family members for support before turning to formal help (Stoller and Pugliesi 1988). Thus, decline in physical function may also lead to more social contact, which would probably strengthen the associations with no social activity and weaken the associations with low number of visits and low family contact. It could be speculated that due to limited mobility caused by beginning decline in physical function, those with decline in physical function would limit social activity and increase visits and contact with family. However, we believe that the risk of bias is limited as the Mobility-Help scale is a validated measure of physical function and because a sensitivity analysis adjusting for Mobility-Tiredness, a marker of early functional decline, showed results similar to the results from the main analyses.

Implications and future research

Our findings can be used to target vulnerable older people in order to prevent decline in physical function and premature mortality. The results suggest that apart from limiting financial insecurity among older people, preventive interventions should target older people with both low financial assets and few social relations to strengthen social

relations and activities and limit negative health consequences. A special focus should be on males as they to a greater extent are subject to both differential exposure and differential vulnerability of social relations when having low financial assets. However, it is also important to emphasize that we, in line with other studies, found that more females than males experience decline in physical function in old age (Gill et al. 2013).

Conclusion

Simultaneous exposure to few social relations or no social activity and low financial assets was associated with the greatest decline in physical function among males and mortality among males and females. Interaction analyses indicated that financial assets only significantly modified the health effects of social activity and visits and not cohabitation status and contact with family and friends. Thus, the study only supports the presence of differential vulnerability for visits and social activity. Furthermore, males with low financial assets were exposed to a great burden because they, more than females, also experienced differential exposure by more often being subject to few social relations. Preventive interventions may benefit from focusing on older people, especially males, with both low financial assets and few social relations to ensure independency in old age and longevity.

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Compliance with ethical standards

Conflict of interest None.

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