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Stroke survival and the impact of geographic proximity to family members: A population-based cohort study

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A R T I C L E I N F O

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A B S T R A C T

Introduction: Familial support may be important for post-stroke survival.

Objective: To determine if geographical proximity between stroke survivors and their family members, i.e having a spouse/partner or distance to a nearest first-degree relative (parents, siblings, and offspring), as a proxy for familial support, is related to survivor mortality.

Methods: This study included all stroke survivors (n=128,227) hospitalised in Norway from 1994 to 2009, who were 30 years or older at the time of the stroke (born before 1965). National registries and censuses were used to calculate the distance to the nearest first-degree relative in the hospitalisation year. Cox proportional hazards models estimated hazard ratios (HRs) of all-cause mortality from 1994 to 2014 (mean 6.4 years follow-up), adjusting for sociodemographic and clinical covariates.

Results: Living up to 30 km from the nearest first-degree relative was associated with a higher mortality (HR 1.04, 95% CI: 1.03 to 1.06) than those living in the same household or neighbourhood as their nearest first-degree relatives. The association was more pronounced (1.13, 1.08 to 1.19 for ≤30 km; 1.25, 1.16 to 1.35 for >30 km) in survivors hospitalised at age ≤65 years, compared to older survivors. Among familial care predictors, having a spouse/partner was the most prominent predictor of reduced mortality (0.80, 0.78 to 0.82) in stroke survivors.

Conclusion: Living close to first-degree relatives was weakly associated with better survival in stroke patients while having a spouse/partner exhibited a stronger association. Both associations were larger for survivors hospitalised at age ≤65 years. Our findings thus suggest that the impact of familial support on survival after stroke may differ by familial support condition and patient's age at a stroke hospitalisation.

1. Introduction

Stroke mortality rates have decreased in developed countries over several decades (Feigin et al., 2014; OECD, 2019), and the absolute number of stroke survivors is expected to grow due to an ageing population (Feigin et al., 2014; Norwegian Institute of Public Health, 2018). Post-stroke survivors experience a high level of physical disability and require support for their rehabilitation, often for the rest of their lives (Low et al., 2003; Palmer and Glass, 2003).

Social support and relationships have been attracting considerable interest in the association with health outcomes across different academic disciplines since the 1970s (Berkman and Krishna, 2014; House et al., 1988). However, a relatively small number of studies have examined the impact of social support on the health outcomes of patients with a specific disease, like stroke (Smith et al., 2021; Uchino et al., 2018). These studies have shown that, compared to patients with

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lower levels of perceived support, stroke patients with a high level of social support generally have better health outcomes after their first stroke incidence: faster and greater functional recovery (Glass and Maddox, 1992; Glass et al., 1993; Tsouna-Hadjis et al., 2000), lower levels of post-stroke depression (Palmer and Glass, 2003; Villain et al., 2017), and higher participation in physical activity (Espernberger et al., 2021). Similarly, social isolation has been associated with adverse stroke outcomes, for instance, higher all-cause and cardiovascular mortality (Boden-Albala et al., 2005; Hakulinen et al., 2018; Vogt et al., 1992).

Further research has investigated the potential underlying link between social support and better health outcomes in the general population and CVD patients through behavioural, psychological, and physiological pathways (Berkman and Krishna, 2014; Uchino, 2004). Social support may directly affect patients' behaviour by promoting adherence to medical treatment (DiMatteo, 2004) or more activities in stroke survivors (Espernberger et al., 2021; Villain et al., 2017). Low levels or lack of social support has been related to adverse psychological conditions and depression that lead to low quality of life in patients with chronic diseases (Uchino et al., 2018) and an increased CVD risk among depressed individuals (Barth et al., 2010). Epidemiological and animal experiment studies have examined the direct impact of social support on physical health outcomes and found detrimental levels of biomarkers (higher levels of ambulatory blood pressure, cortisol, and IL-6, low level of oxytocin, and reduced myelination) to cardiovascular reactivity, immune system, inflammation, brain plasticity among those with lack of or low support (Craft et al., 2005; Uchino et al., 2018; Venna and McCullough, 2015; Wang et al., 2005).

However, research on the impact of familial support, separated from overall social support, on post-stroke survival is limited, despite the substantial role of family care for stroke patients. A family member becomes an informal caregiver to a stroke patient (Low et al., 1999; Palmer and Glass, 2003), and the social networks of stroke patients tend to be more family-oriented after stroke (Dhand et al., 2018). Nevertheless, most social support measures in previous studies assessed the overall amount of perceived social support/isolation of the recipients without distinguishing family from other support sources (Glass and Maddox, 1992; Glass et al., 1993; Hakulinen et al., 2018; Shor et al., 2013; Villain et al., 2017; Vogt et al., 1992). Marital status is often to be analysed as a standard measure of structural social support, and having a spouse/partner is protective against mortality in stroke patients (Dupre and Lopes, 2016; Schultz et al., 2017). Yet, it is not known the impact of comprehensive support from other family members than a spouse/partner.

Familial support based on in-person contacts is often limited by the geographical distance between family caregivers and recipients. A spouse/partner who lives with a stroke survivor becomes a caregiver in most cases (Mirkowski et al., 2018), and adult children living closer to their elderly parents are likely to have more frequent contact with their parents and provide care for them (Checkovich and Stern, 2002; Joseph and Hallman, 1998; Pillemer and Suitor, 2014). Thus, the geographical distance between a frail family member and a family member indicates the availability of familial support and, accordingly, having a spouse/partner and the geographical distance between the stroke patient and the nearest first-degree relative (parents, siblings, offspring) may be a useful proxy for familial support.

In this study, we aimed to estimate the impact of having a spouse and geographical proximity to first-degree relatives (parent, sibling, offspring) on post-stroke survival. By using large-scale national registries and databases, we included all Norwegian stroke patients hospitalised between 1994 and 2009, who were 30 years or older at the time of the stroke (born before 1965). We calculated the distance between them and their nearest first-degree relatives, which was used as our objective proxy measure of familial support.

2. Methods

2.1. Data sources

We obtained information on birth, migration and marital status from the Norwegian National Population Registry. Information on stroke hospitalisation was obtained from nationwide hospitalisation data of the CVDNOR project, which retrospectively collected information on all hospital stays with CVD as either a primary or secondary diagnosis in 1994–2009 from the electronic Patient Administrative Systems (PAS) of all Norwegian somatic hospitals (Sulo et al., 2013; Sulo et al., 2020). The multigenerational database contains the familial relationships of the entire Norwegian population who participated in the national censuses from 1960 to 2001 (Næss and Hoff, 2013). The censuses, conducted by Statistics Norway every ten years, provided detailed information on families and the residential conditions. As the identification percentage of parental linkage reached over 85% for people born from 1940 onwards (Næss and Hoff, 2013), we assigned all parents of those born before 1940 as missing to reduce a possible selection bias.

This project obtained ethical approval (REK, 2012/827) from the Regional Committees for Medical and Health Research Ethics, Norway.

2.2. Study cohort

We identified 149,703 Norwegians born before 1965 who survived their first stroke hospitalisation from January 1, 1994 to December 31, 2009 when they were 30 years or older, and these were born between 1893 and 1964. The first stroke event was defined as the first stroke record in data from the CVDNOR project since 1994 when PAS began to collect CVD hospitalisation information. Stroke events were identified by International Classification of Diseases (ICD) codes for stroke (ICD 9: 430–434, 436 or ICD 10: I60–I61, I63–I64 except for I63.6) as primary diagnosis in the CVDNOR database (Sulo et al., 2013; Sulo et al., 2020). These patients were linked to other national registries and censuses. Those who died during the initial hospitalisation (n=20,296), with inconsistent information between registries (n=900), and without marital status information (n=280) were excluded. A cohort of 128,227 stroke survivors was established (Fig. 1).

2.3. Outcome

The outcome was all-cause mortality of the 128,227 stroke survivors, who were followed from the discharge date of the first hospitalisation to their death, emigration, or end of the study period (December 31, 2014), whichever occurred first. Information about the date of death or emigration was attained from the Cause of Death Registry and the National Population Registry, respectively.

2.4. Exposure

We utilised the distance between stroke survivors and their families as a proxy for familial support. A Geographic Information System (GIS) was employed to calculate the Euclidean distance by QGIS Desktop 3.10.10, and further details are given in Appendix 1. We used 14,054 basic statistical units of residential information from the 1990 and 2001 censuses. The basic statistical unit (basic unit, hereafter) is the smallest regional segmentation constituting census tracts and city districts. If family members live in the same household or an immediate neighbourhood, they have an identical basic unit code. We used the residential information of the 1990 census for those hospitalised in 1990–2000 and that of the 2001 census for those in 2001–2009, assuming that the information was constant through the follow-up period.

Based on the calculation outlined in Appendix 1, four categorical distance groups were generated. A cut-off value of 30 km was chosen based on a previous study showing that around 50% of elderly

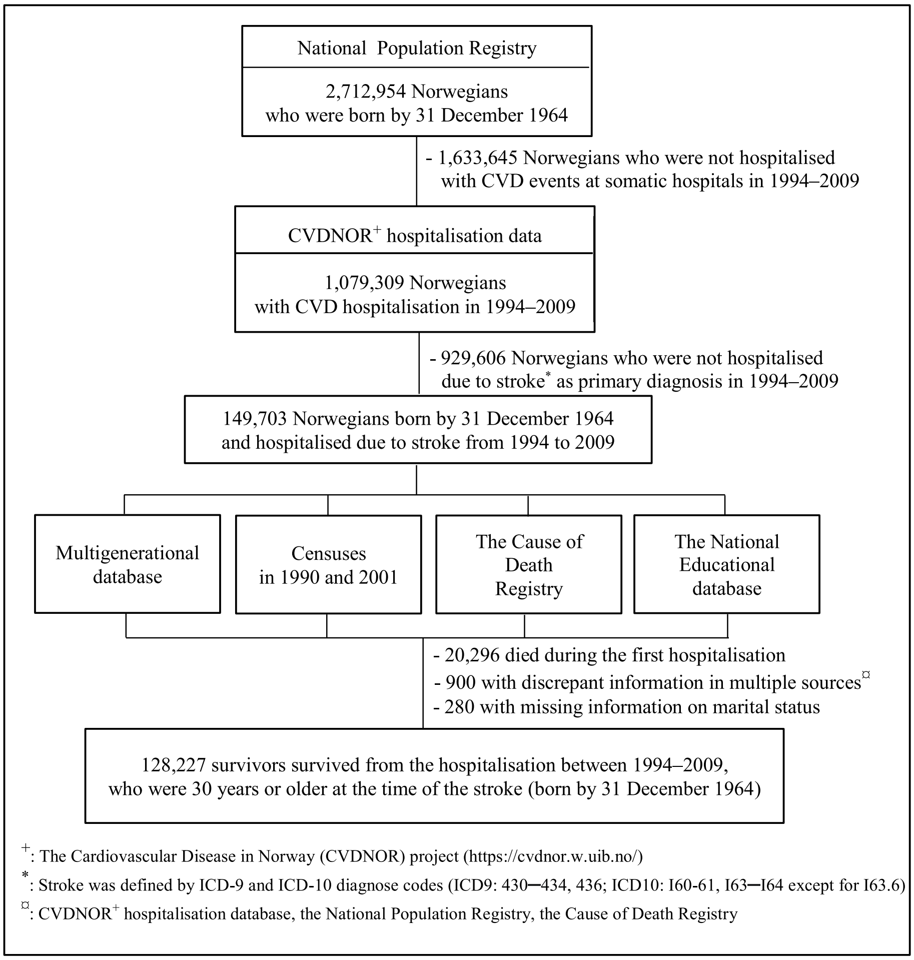

Fig. 1. Flow chart of the study population: All stroke survivors in Norway hospitalised in 1994–2009, who were 30 years or older at the time of the stroke (born before 1965).

Norwegian parents lived within 30 km of their adult children (Lappegård, 2009): the nearest first-degree relative living in (1) the same basic unit indicating 0 km, (2) $0 <$ distance ≤ 30 km, (3) distance >30 km at the year of the first stroke hospitalisation, and (4) missing records for those who lacked information on residential place or family.

Without including the number of alive first-degree relatives, the estimated HRs for distance groups would capture the combined impacts of having relatives and living close to them. Therefore, we calculated the number of alive first-degree relatives (none, 1–3, 4+) living in Norway in the hospitalisation year from the multigenerational database.

Marital status (unmarried, having a spouse/partner, widowed/separated/divorced) at the hospitalisation year was obtained from the National Population Registry.

2.5. *Covariates*

Sociodemographic covariates of stroke survivors included sex, birth year, type of residential municipality (rural, central) (Hustoft et al., 1999) and level of education (primary, intermediate, tertiary, and unspecific/missing) from the National Registry, the 1990 and 2001 censuses and the National Educational Database, respectively. Clinical covariates from the CVDNOR data were patient's age at the first stroke hospitalisation, length of stay for the hospitalisation and stroke type: ischemic stroke (ICD9 433–434; ICD10 I63 except for I63.6), haemorrhagic stroke (ICD9 430–432; ICD10 I60–I61) and undefined stroke (ICD-9436; ICD-10 I64).

2.6. *Statistical analyses*

We hypothesised that having a spouse/partner and a shorter distance to a nearest first-degree relative at the first stroke hospitalisation would be associated with a lower all-cause mortality. To test this hypothesis, we used Cox proportional hazards models to estimate the hazard ratios (HRs) with 95% confidence intervals (CIs) of all-cause mortality in stroke survivors.

Model 1 was adjusted for distance, the number of alive first-degree relatives at the first hospitalisation, and sociodemographic covariates. Model 2 was adjusted for clinical covariates along with Model 1. Adjustment for marital status plus Model 2 was employed in Model 3. We also ran Model 3 on the study population divided into three groups based on age at the first stroke hospitalisation (≤ 65, 66–85, $86\leq$) since a substantial amount of elderly patients used municipal home-care services or lived in institutions.

An interaction between marital status, the number of first-degree relatives and distance was also estimated. For instance, the number of first-degree relatives could be more important when not having a spouse/partner, or distance could be less important when having a spouse/partner. To investigate this, we created 16 mutually exclusive subgroups in a Model 4, based on all existing combinations among marital status, the number of first-degree relatives, and distance. We chose subgroup 6 (having a spouse/partner, 4 or more first-degree relatives, and living in a basic unit with a first-degree relative) as the reference in Model 4, as survivors in this subgroup were assumed to have the most favourable familial support conditions.

As a sensitivity analysis, we fitted Model 3 with different follow-up periods (0–1, 1–5, 5 years to the end of the study period), conditioning on survival in the follow-up stage, to check whether the association between the distance and the risk of all-cause death changed over time. Different support impacts from various types of first-degree relatives were assessed in a subsample of 110,296 survivors having at least one alive first-degree relative. We added the relationships (parents, siblings, offspring) of primary caregivers who lived closest to the survivors at the time of the hospitalisation in an extended Model 3.

The proportional hazard assumption was tested for all models using Schoenfeld residuals plots, and no significant deviations were found. Stata/MP 16.1 to perform the statistical analyses.

3. Results

3.1. Descriptive statistics

Of 128,227 stroke survivors contributing 822,049 person-years, 91,008 died during the follow-up period. In the study population, 51,463 (40%) stroke survivors lived in the same basic unit as one of the first-degree relatives at the year of the first stroke hospitalisation (distance group 1). Survivors missing distance information were generally older, female, unmarried, and had fewer family members compared to other distance groups (distance group 4); see (Table 1).

3.2. Distance and all-cause mortality

Higher risks of death for longer distance categories to the nearest family member were observed compared to living in the same basic unit in all models (Table 2). The HR of all-cause mortality of living within 30 km and further than 30 km from family members, compared to living in the same basic unit, were 1.09 (95%CI: 1.07 to 1.11) and 1.07 (1.05–1.10), respectively, in Model 1. However, they were attenuated to 1.04 (1.03–1.06) and 1.03 (1.00–1.06) in Model 2 adjusted for clinical covariates but remained unchanged in a fully adjusted Model 3 adding marital status. The difference between HRs of living within 30 km and further than 30 km was not observed in Model 3.

The strongest association between longer distance to the nearest first-degree relative and all-cause mortality was observed in young survivors who had their first hospitalisations between ages 30–65 (Table 3). Young survivors living further than 30 km from the nearest first-degree relative had a HR of 1.25 (1.16–1.35) compared to those living in the same basic unit, whereas increased hazard of longer distance was not found in older survivor groups (HR 1.00, 95%CI 0.97 to 1.03 for those hospitalised between ages 66–85; HR 0.96, 95%CI 0.91 to 1.02 for those hospitalised at age 86 and over).

Taking into account the interactions among the factors of having a spouse/partner, the number of alive first-degree relatives, and distance, similar findings were found for the entire study population and young

Table 1
Descriptive statistics of 128,227 stroke survivors and subgroups by the distance to a nearest first-degree relative on the year of the first hospitalisation.

		Overall	Distance group 1	Distance group 2	Distance group 3	Distance group 4
Number of patients (deaths)		128,227 (91,008)	51,463 (32,117)	43,308 (31,342)	12,264 (8948)	21,192 (18,601)
General characteristics						
Gender (%)	Male	65,022 (50.7)	27,756 (53.9)	22,047 (50.9)	6406 (52.2)	8813 (41.6)
	Female	63,205 (49.3)	23,707 (46.1)	21,261 (49.1)	5858 (47.8)	12,379 (58.4)
The average year of birth (±SD)		1927 (12.8)	1930 (13.6)	1927 (11.2)	1927 (12.1)	1920 (10.7)
Type of municipality (%)	Rural	68,909 (53.7)	28,187 (54.8)	16,422 (37.9)	6095 (49.7)	18,205 (85.9)
	Central	59,318 (46.3)	23,276 (45.2)	26,886 (62.1)	6169 (50.3)	2987 (14.1)
Education level (%)	Primary	62,390 (48.7)	25,132 (48.8)	20,436 (47.2)	5316 (43.4)	11,506 (54.3)
	Intermediate	50,940 (39.7)	20,781 (40.4)	18,022 (41.6)	5001 (40.8)	7136 (33.7)
	Tertiary	13,325 (10.4)	5205 (10.1)	4569 (10.5)	1820 (14.8)	1731 (8.2)
	Unspecific/missing	1572 (1.2)	345 (0.7)	281 (0.7)	127 (1)	819 (3.8)
Clinical characteristics						
Mean age at the first stroke hospitalisation (±SD)		73.8 (12.1)	70.3 (13.1)	74.8 (10.5)	74.7 (11.4)	79.6 (9.9)
Stroke[a] type (%)	Ischemic stroke[b]	89,623 (69.9)	35,698 (69.3)	31,270 (72.2)	8679 (70.8)	13,976 (66)
	Haemorrhagic stroke[c]	17,625 (13.8)	8035 (15.6)	5582 (12.9)	1594 (13)	2414 (11.3)
	Undefined stroke[d]	20,979 (16.3)	7730 (15.0)	6456 (14.9)	1991 (16.2)	4802 (22.7)
Median length of stay(days) for the first stroke hospitalisation between 1994 and 2009 (min, max)		12 (1, 1158)	9 (1, 851)	9 (1, 642)	9 (1, 276)	11 (1, 1002)
Mean of follow-up years (±SD)		6.4 (5.1)	7.4 (5.5)	6.1 (4.7)	6.2 (4.8)	4.6 (4.4)
Family characteristics						
Marital status (%)	Unmarried	11,719 (9.1)	2381 (4.6)	2037 (4.7)	999 (8.2)	6302 (29.7)
	Married/Partner	63,315 (49.4)	30,556 (59.4)	21,653 (50)	5582 (45.5)	5524 (26.1)
	Widowed/Separated/ Divorced	53,193 (41.5)	18,526 (36)	19,618 (45.3)	5683 (46.3)	9366 (44.2)
The median number of alive first-degree relatives (min, max)		2.5 (0, 21)	3 (1, 21)	2 (1, 17)	2 (1, 12)	0 (0, 11)
The number of alive first-degree relatives (%)	None	20,344 (15.9)	0	0	0	20,344 (96)
	1–3	76,326 (59.5)	29,916 (58.1)	34,904 (80.6)	10,754 (87.7)	752 (3.5)
	4 or more	31,557 (24.6)	21,547 (41.9)	8404 (19.4)	1510 (12.3)	96 (0.5)
Distance (%)	Same basic unit (0 km)	51,463 (40.1)				
	Less than or equal to 30 km	43,308 (33.8)				
	Further than 30 km	12,264 (9.6)				
	Missing	21,192 (16.5)				

Distance group 1: survivors had a family member among first-degree relatives who lived in the same basic statistical unit (0 km), indicating living in the same household or an immediate neighbourhood.
Distance group 2: living less than or equal to 30 km.
Distance group 3: living longer distance than 30 km.
Distance group 4: those without distance information resulting from the lack of residential information of either patients or their remaining family members.
[a] ICD-9: 430–434, 436; ICD-10: I60–I61, I63–I64 except for I63.6.
[b] ICD-9: 433–434; ICD-10: I63 except for I63.6.
[c] ICD-9: 430–432; ICD-10: I60–I61.
[d] ICD-9: 436; ICD-10: I64.

Table 2
Hazard ratios (95% CI) of all-cause mortality until 31. December 2014 of 128,227 survivors who survived their first stroke hospitalisation in Model 1#, 2¤, and 3*.

		Model 1	Model 2	Model 3
		Hazard ratio (95% CI)		
Distance	0 km (Reference)			
	0 < Distance ≤30 km	1.09 (1.07–1.11)	1.04 (1.03–1.06)	1.04 (1.03–1.06)
	Distance >30 km	1.07 (1.05–1.10)	1.04 (1.01–1.06)	1.03 (1.00–1.06)
	Missing	1.07 (0.97–1.18)	1.13 (1.02–1.25)	1.10 (0.99–1.21)
The number of alive first-degree relatives	None (Reference)			
	1–3	0.91 (0.83–1.01)	0.97 (0.88–1.07)	1.00 (0.91–1.10)
	4 or more	0.83 (0.75–0.92)	0.90 (0.81–0.99)	0.93 (0.84–1.03)
Marital status	Unmarried (Reference)			
	Married/ Partner			0.80 (0.78–0.82)
	Divorced/ Separated/ Widowed			0.92 (0.89–0.94)
Sex	Men (Reference)			
	Women	0.81 (0.80–0.83)	0.77 (0.76–0.78)	0.74 (0.73–0.75)
Born in a later year between 1893 and 1964		0.93 (0.93–0.93)	0.98 (0.98–0.98)	0.98 (0.98–0.98)
Municipality type	Rural municipality (Reference)			
	Central municipality	1.01 (0.99–1.03)	1.01 (0.99–1.02)	1.00 (0.99–1.02)
Education level	Primary (Reference)			
	Intermediate	0.91 (0.90–0.92)	0.90 (0.88–0.90)	0.89 (0.88–0.91)
	Tertiary	0.79 (0.77–0.81)	0.77 (0.75–0.79)	0.78 (0.76–0.80)
	Missing	1.05 (0.99–1.11)	1.03 (0.97–1.10)	1.04 (0.98–1.10)
One year increase at the first stroke hospitalisation			1.07 (1.07–1.07)	1.07 (1.07–1.07)
Stroke type	Ischemic stroke (Reference)			
	Haemorrhagic stroke		1.08 (1.06–1.11)	1.09 (1.06–1.11)
	Undefined stroke		1.08 (1.06–1.10)	1.08 (1.06–1.10)
One day increase in the length of the first stroke hospitalisation in 1994–2009			1.00 (1.00–1.00)	1.00 (1.00–1.00)

Model 1# included distance, the number of alive first-degree relatives at the first hospitalisation, and was adjusted for sociodemographic covariates (sex, birth year, municipality type, and education).
Model 2¤ was adjusted for clinical covariates (age at the first hospitalisation, stroke type, and length of stay for the first stroke hospitalisations between 1994–2009) plus Model 1.
Model 3* included marital status plus Model 2.

survivors, as shown in Tables 2 and 3, respectively (Fig. 2). When the entire study population was considered, mortality only varied with distance for those with four or more first-degree relatives, and the differences were small. However, given the same familial support conditions, the HRs of death were higher for young survivors living away from their family members than those for other young survivors.

3.3. Other predictors of familial support and all-cause mortality

Having a spouse/partner lowered the risk of mortality for stroke survivors by 20% (HR 0.80, 95%CI 0.78 to 0.82), compared to being unmarried in Model 3 (Table 2). For young stroke survivors hospitalised at aged ≤65 years, strong reductions in mortality for having a spouse/partner (0.61, 0.57 to 0.65) and the larger number of first-degree relatives (4+) (0.79, 0.65 to 0.96) were found (Table 3). The protective impact of having a spouse/partner or the larger number of first-degree relatives was attenuated or not found in older survivors (Table 3).

When also considering the model with interactions, the HRs for mortality of the spouse/partner groups (1–8) were lower than those of the non-spouse/partner groups (9–16), in comparison to the reference group 6 with the most favourable support situation. This difference was greater in the groups of young survivors (Fig. 2).

3.4. Sensitivity analyses

When the follow-up period was restricted to 0–1 years and 1–5 years after stroke, the association between distance to the nearest first-degree relative and mortality was very weak and not statistically significant. Yet, the increased mortality for further distance groups appeared in the later follow-up time (from 5 years to the study endpoint) (Table S1). However, having a spouse/partner was consistently associated with a lower risk for death over different follow-up times (Table S1).

As Table S2 shows, stroke survivors with their parents (1.43, 1.23 to 1.67) or siblings (1.04, 1.01 to 1.09) as primary caregivers were at an increased risk of mortality compared to those with offspring, while the distance estimates remained unchanged. We did not find different risks of mortality according to specific familial relationships (father, mother, brother, sister, son, daughter) of primary caregivers, setting daughter as a reference in the same model (results not presented).

4. Discussion

4.1. Principal findings

In this study, we used the distance between stroke survivors and their nearest family members, i.e having a spouse/partner or distance to first-degree relatives, as a proxy for familial care. A weak association between the distance to a nearest first-degree relative and all-cause mortality was observed in 128,227 stroke survivors, but the extent of this association was more prominent for those survivors hospitalised at a young age (≤65). Overall, having a spouse/partner was the most protective predictor for death among familial support predictors in stroke survivors.

4.2. Comparison with other studies

In line with previous studies on social support, our findings confirm the positive impact of familial support on the health outcome of patients with stroke. In the general population, marital status is a well-known determinant of mortality and is likely to be observed in patients with CVD as well (Dupre and Lopes , 2016; Molloy et al., 2009; Schultz et al., 2017). Although the mechanism of the marital status, in general, remains unknown and may be influenced by unobserved factors, patients with stroke may benefit from a stable socioeconomic situation and emotional support from their partner (Dupre and Lopes, 2016; Palmer and Glass, 2003). Molloy et al., (2009) found that marital status is also related to maintaining and promoting healthy behaviours (Molloy et al., 2009), which could be related to better adherence to medical treatment and rehabilitation in patients (Molloy et al., 2008).

Living further from those who could provide familial support may be disadvantageous to those who become fragile due to illness or ageing. Older adults with a disability had less average hours of help from their adult children when the distance between them increased (Schoeni et al., 2022). Also, they were likely to have a higher probability of depressive symptoms when in-person contact with their children and others declined (Teo et al., 2015), which is often restricted by distance.

Table 3
Hazard ratios (95% CI) of all-cause mortality until 31. December 2014 of 128,227 stroke survivors for familial support factors (the geographical proximity to a nearest first-degree relatives, the size of family, and marital status) by different age groups at the first hospitalisation in Model 3*.

		Young survivors at 30–65 years old in the first stroke hospitalisation	Old survivors at 66–85 years old in the first stroke hospitalisation	Elderly survivors at 86 years old and over in the first stroke hospitalisation
Number of survivors (deaths)		29,698 (9052)	78,708 (62,988)	19,821 (18,968)
		Hazard ratio (95% CI)		
Distance	0 km (Reference)			
	0 < Distance ≤30 km	1.13 (1.08–1.19)	1.03 (1.01–1.05)	0.99 (0.95–1.03)
	Distance >30 km	1.25 (1.16–1.35)	1.00 (0.97–1.03)	0.96 (0.91–1.02)
	Missing	1.10 (0.92–1.31)	1.15 (1.01–1.32)	0.90 (0.68–1.18)
The number of alive first-degree relatives	None (Reference)			
	1–3	0.86 (0.71–1.04)	1.03 (0.91–1.18)	0.85 (0.65–1.14)
	4 or more	0.79 (0.65–0.96)	0.98 (0.86–1.12)	0.84 (0.63–1.12)
Marital status	Unmarried (Reference)			
	Married/Partner	0.61 (0.57–0.65)	0.84 (0.81–0.86)	0.97 (0.91–1.03)
	Divorced/ Separated/ Widowed	0.87 (0.81–0.94)	0.94 (0.91–0.97)	0.98 (0.93–1.04)

*Model 3 was adjusted for sociodemographic (birth year, sex, municipality type, and education), clinical (age at the first hospitalisation, stroke type, and length of stay for the first stroke hospitalisations between 1994–2009) covariates.

A meta-analysis showed that family cohesion and living with others were related to increased adherence to medical treatment in patients by encouraging psychological well-being and healthy behaviours (DiMatteo, 2004).

A stronger impact of familial support on the mortality of young stroke survivors (≤65 years) may be related to their characteristics. A buffering model emphasising the role of social support in reducing the detrimental effects of stress on recipients could be applied to this finding (Cohen and Wills, 1985). Due to a higher degree of subjective stress, young ischemic stroke survivors showed significantly higher levels of depressive symptoms (McCarthy et al., 2016), and had a stronger association between depression and death than older survivors (Ayerbe et al., 2014). Because of their poor health conditions during their prime years of work and parenting, young patients with stroke are more likely to be stressed, and they may require more assistance to resume their normal routine (McCarthy et al., 2016; Morris, 2011). Thus, living close to a relative and having more relatives may be advantageous in terms of receiving/asking for support from various family members, thereby reducing the negative effects of stroke. Furthermore, younger stroke survivors could benefit more from support because their familial support network also consists of younger people who provide better help. This finding is consistent with a previous study showing excess mortality among Norwegians aged 45–68 years with no or one child compared to those with two children (Grundy and Kravdal, 2010).

Our sensitivity analysis (Table S2) indicated that survivors with parents as primary caregivers living closest to them had 43% higher mortality than those with offspring. Considering the age of the survivors' parents, these survivors were likely to be caregivers taking care of their parents. The burden/pressure of caring for their older parents might negatively influence life after stroke, given that caregivers were more likely to have psychological and physical distress than non-caregivers (Low et al., 1999; Pinquart and Sörensen, 2003). It is also possible that the different features of support according to types of relatives might exist, yet, we could not investigate it further in this study.

The estimated impacts of familial support, measured by the distance to the nearest first-degree relatives in this study, was smaller than in previous studies which showed that those with lower levels or lack of social support were at a 30–40% increased risk of adverse stroke outcomes (Boden-Albala et al., 2005; Hakulinen et al., 2018; Vogt et al., 1992). This could arise from how familial support was operationalised in this study. The distance may not incorporate either the actual care offered by family members or survivors' perception of care, whereas previous studies have directly measured the level of support based on the recipient's perception through interviews or questionnaires (Boden-Albala et al., 2005; Glass and Maddox, 1992; Glass et al., 1993; Hakulinen et al., 2018; McLeroy et al., 1984; Mirkowski et al., 2018; Tsouna-Hadjis et al., 2000). Moreover, social support evaluated by a single measure, for example, distance in this study, tended to yield smaller HRs than those with composite measures (Holt-Lunstad et al., 2010; Shor and Roelfs, 2015). It could also be argued that the impact of familial support might play a minor role in a welfare state like Norway (Hank, 2007), since Norwegian municipalities are responsible for providing home-nursing and institutional care services to their inhabitants regardless of individual's financial situation (Holm et al., 2017).

The protective impact of living close to family members on post-stroke survival may raise the question of whether there is a causal pathway between familial support and mortality in stroke survivors. A positive association has been found between social support and stroke patients' health conditions (Espernberger et al., 2021; Glass and Maddox, 1992; Glass et al., 1993; Tsouna-Hadjis et al., 2000; Villain et al., 2017). However, one randomised controlled trial (RCT) found an improvement in anxiety and depression scores but no difference in mortality between stroke patients with trained versus untrained caregivers in a 1-year follow-up (Kalra et al., 2004). Another RCT found better psychological states in myocardial infarction patients provided with cognitive therapy for improving social isolation but no difference in mortality with a 29-month average follow-up (Berkman et al., 2003). This may imply that better recovery in terms of psychosocial measures might not necessarily lead to reduced mortality in CVD patients (Berkman et al., 2003).

However, it may imply that the favourable effect of support on survival might occur in the long term, which is not reflected in a short follow-up (Uchino et al., 2018). A greater progression of coronary artery disease was observed in an average of 3.2-year follow-up among Swedish female patients with cardiac diseases who lacked perceived emotional support (Wang et al., 2005). Although they did not analyse the participants' mortality, this finding suggests that the mortality rate may differ in the long term. The long-term impact is partly supported by our sensitivity analysis (Table S1) with different follow-up periods, presenting different risks of mortality in the long term.

4.3. Strengths and limitations of this study

This study used data from multiple national registries and censuses that covered the entire Norwegian population. To the best of our knowledge, this is the first study to combine multigenerational and geographical large-scale data to investigate the impact of family support

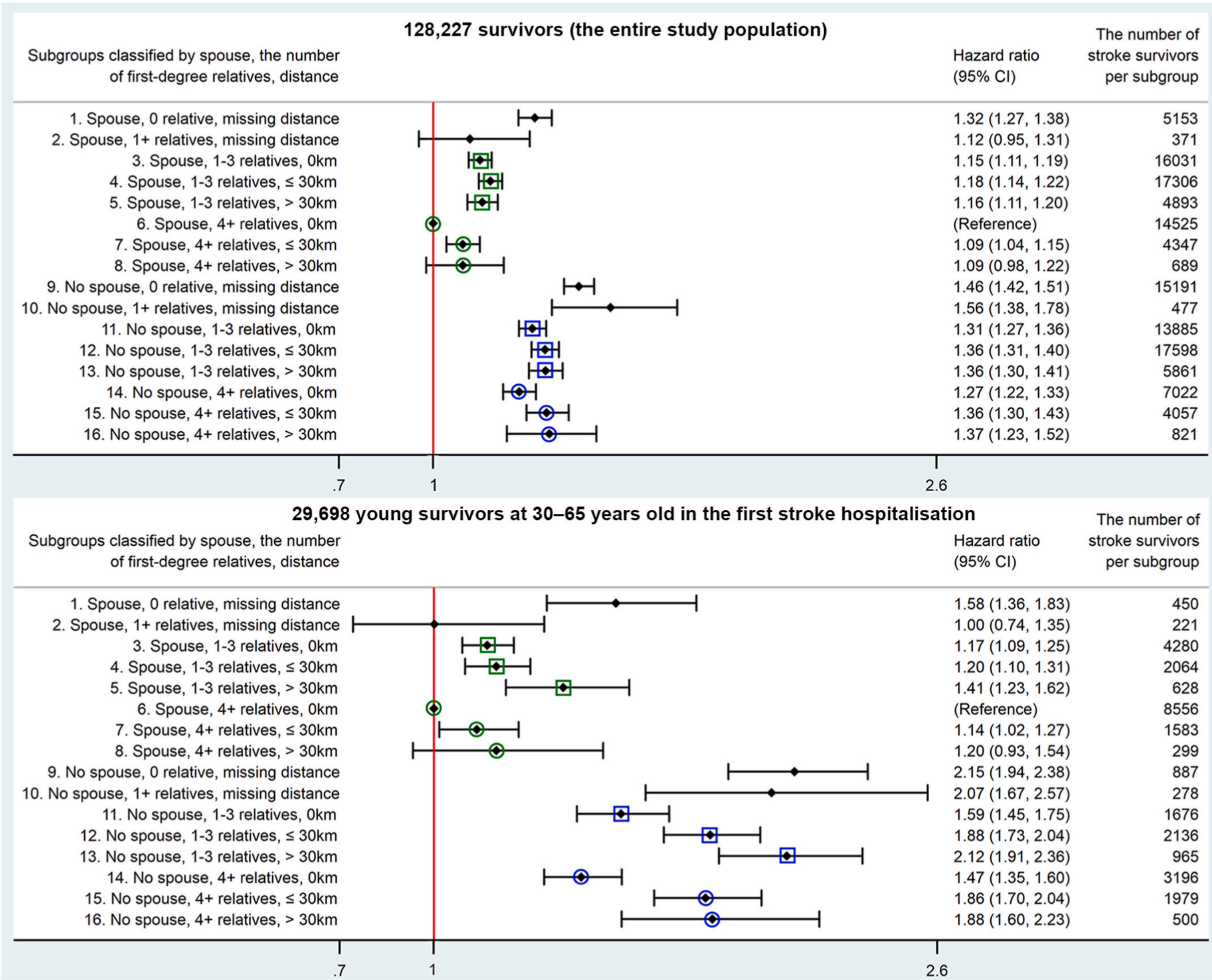

Fig. 2. Coefficient plots of hazard ratios (95% CI) of all-cause mortality until 31. December 2014 for combined familial support factors by the entire study population and subgroup (young stroke survivors), after adjustment for sociodemographic[#] and clinical[¤] covariates.
[#]sociodemographic covariates: birth year, sex, municipality type, and education. ¤clinical covariates: age at the first hospitalisation, stroke type, and length of stay for the first stroke hospitalisations between 1994–2009. Blue for the subgroups with having a spouse/partner, and green for those without a spouse/partner. Square shape (□) for the groups with 1–3 first-degree relatives, while circle (○) for those with 4 or more first-degree relatives. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

on stroke survival as measured by geographical distance.

Distance can be objectively evaluated for a large number of people using data from administrative sources, and this feature is useful in assessing patient health needs in this study. Interviews and questionnaires, which were commonly employed to quantify social support measures, are likely to have a small number of participants (Glass and Maddox, 1992; Glass et al., 1993; Mirkowski et al., 2018; Uchino, 2004) and rely on subjective perceptions (Lett et al., 2007; Palmer and Glass, 2003; Shor et al., 2013). Thus, this method could be used in future research on related chronic medical conditions, where residential and familial information is available.

However, the study population that survived initial stroke hospitalisation could have been selected in a certain manner. In the U. S., social support and isolation have been linked to stroke incidence (Nagayoshi et al., 2014). Further, in the U.K, social isolation has been linked to death from the first stroke event before reaching the hospital (though there was only a weak association between social isolation and hospital admission for the first stroke event) (Smith et al., 2021). Thus, social support may have already altered our population's likelihood of having a stroke and surviving the incidence of the first stroke-related hospitalisation.

Similarly, social selection may have led to the associations observed in this study by affecting the family structures and living arrangements from the outset. For example, marriage might result from the social selection where healthy individuals are married while unhealthy are not able to (Molloy et al., 2009). Those without a spouse/partner may have a lower chance of having their own families and children; hence, this selection mechanism might have influenced the results. Furthermore, family ties may have an impact on the residential locations of family members (Mulder and van der Meer, 2009). Families with strong ties could co-reside or live close to their care recipients before the stroke event, depending on the availability of formal care services and health conditions of the recipients. Because of the lack of detail in the registered data, these factors were beyond the scope of this study. Future research may delve deeper into these issues.

5. Conclusion

We found a weak association between the geographical distance to the nearest first-degree relatives and mortality, whereas having a spouse/partner seems to have more influence on the risk of death in stroke survivors. The impact of familial support was more prominent for those hospitalised at a young age (≤65). Therefore, care and rehabilitation policies may need to consider that stroke survivors need more support from municipal health care, particularly for young stroke survivors without a spouse or family nearby, to compensate for the reduced familial support.

Ethics approval

This project obtained ethical approval (REK, 2012/827) from the Regional Committees for Medical and Health Research Ethics, Norway.

Declaration of interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: M. LeBlanc has served as speaker for MSD outside the submitted work.

Disclaimer

The interpretation and reporting of the data are the sole responsibility of the authors, and no endorsement by the Norwegian Cause of Death Registry is intended, nor should be inferred.

Author statement

Hye Jung Choi: Methodology, Software, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. Marissa LeBlanc: Methodology, Writing – review & editing, Supervision, Tron Anders Moger: Methodology, Writing – review & editing, Supervision, Morten Valberg: Methodology, Writing – review & editing, Geir Aamodt: Methodology, Software, Writing – review & editing, Christian M. Page: Methodology, Writing – review & editing, Grethe S. Tell: Resources, Methodology, Writing – review & editing, Øyvind Næss: Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Project administration, Funding acquisition

Data availability

The authors do not have permission to share data.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.socscimed.2022.115252.

Appendix

We used the 'N50' land-use map and 'the basic statistical units in 2018' provided by the Norwegian Mapping Authority to define residential areas in all 14,054 basic statistical units in Norway (except Svalbard). These residential areas were mainly defined by the following three criteria of: (1) city blocks, (2) developed or predominantly residential areas, and (3) agricultural land in the N50 map. Each mean point was generated by weighting the size of the defined residential areas in each basic statistical unit. The Euclidean distance was measured between the mean points of a basic unit to another point of a different unit, by QGIS Desktop 3.10.10. We also calculated the distance between 422 municipalities and 14,054 basic units with the same method for those patients or family members who had only had municipality information registered in the censuses. Outdated codes of municipalities and basic units were updated according to the 2018 standard.

It is well-known that network analyses in GIS, based on the road maps, are more precise in calculating geographical distance and travel time. Yet, we could not use the analysis due to a lack of road map information between the 1990s and 2000s. There have been criticisms of over-simplified measurements in the Euclidean calculation (Jones et al., 2010). However, the potential errors resulting from this problem could be minimised by using smaller spatial aggregation (Mizen et al., 2015). Therefore, we used the basic statistical unit, which is the smallest spatial aggregation in Norway, constituting the census tracts and city districts.

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