Dog Ownership and Survival After a Major Cardiovascular Event
A Register-Based Prospective Study

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BACKGROUND: Dog ownership is associated with increased physical activity levels and increased social support, both of which could improve the outcome after a major cardiovascular event. Dog ownership may be particularly important in single-occupancy households where ownership provides substitutive companionship and motivation for physical activity.

METHODS AND RESULTS: We used the Swedish National Patient Register to identify all patients aged 40 to 85 presenting with an acute myocardial infarction (n=181,696; 5.7% dog ownership) or ischemic stroke (n=154,617; 4.8% dog ownership) between January 1, 2001 and December 31, 2012. Individual information was linked across registers for cause of death, sociodemographic, and dog ownership data. We evaluated all-cause mortality and risk of recurrent hospitalization for the same cause until December 31, 2012. Models were adjusted for socioeconomic, health, and demographic factors at study inclusion such as age, marital status, the presence of children in the home, area of residence, and income, as well as all registered comorbidities and hospitalization for cardiovascular disease in the past 5 years. Dog owners had a lower risk of death after hospitalization for acute myocardial infarction during the full follow-up period of 804,137 person-years, with an adjusted hazard ratio (HR) of 0.67 (95% CI, 0.61 to 0.75) for those who lived alone, and HR of 0.85 (95% CI, 0.80 to 0.90) for those living with a partner or a child. Similarly, after an ischemic stroke, dog owners were at lower risk of death during the full follow-up of 638,219 person-years adjusted HR of 0.73 (95% CI, 0.66 to 0.80) for those who lived alone and HR of 0.88 (95% CI, 0.83 to 0.93) for those living with a partner or a child. We further found an association of dog ownership with reduced risk of hospitalization for recurrent myocardial infarction (HR, 0.93; 95% CI, 0.87 to 0.99).

CONCLUSIONS: We found evidence of an association of dog ownership with a better outcome after a major cardiovascular event. Although our models are adjusted for many potential confounders, there are also unmeasured confounders such as smoking that prevent us from drawing conclusions regarding a possible causal effect.

Key Words: cardiovascular diseases • dog ownership • motivation • myocardial infarction
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**WHAT IS KNOWN**

- Physical activity and psychosocial support have been shown to be important for optimal recovery after a major cardiovascular event.
- Dog ownership has been shown to be associated with increased physical activity levels and increased social support.
- Some smaller studies have pointed to a lower risk of death after a cardiovascular event in dog owners, but other studies have not replicated this finding.

**WHAT THE STUDY ADDS**

- In this large register-based cohort study, we found evidence of an association of dog ownership with better outcomes after a major cardiovascular event independent of measured socioeconomic variables and comorbidities at admission.

Although with limited evidence, short-term pet therapy has become popular in the acute setting. The aim of this study was thus to assess the association of dog ownership with survival and recurrent events after a major cardiovascular event in a large prospective, nationwide register-based cohort study.

**METHODS**

**Study Participants**

Participants were identified from the Swedish National Patient Register, which includes information on all inpatient care in Sweden with the International Classification of Disease system (ICD-10) for diagnoses since 1997. In the present study, we included all individuals aged 40 to 85 years with acute myocardial infarction (n=186421) or ischemic stroke (n=157851) occurring between January 1, 2001 and December 31, 2012 and no event between 1997 and 2001 in the register. Acute myocardial infarction was defined as an inpatient discharge diagnosis according to the ICD-10 code I21, and ischemic stroke as I63. We used the first occurring event as the index event. Participants were excluded (4725 for myocardial infarction and 3234 for ischemic stroke, respectively) if they had not lived in Sweden for a minimum of 15 years before baseline to ensure complete records and knowledge about the dog register. An individual fulfilling criteria for both outcomes would be included in both analyses. A flow chart depicting the study population is provided as Figure 1.

**Covariates**

Covariates at baseline were derived from linkage of the Register of the Total Population to the longitudinal integrated database for health insurance and labor market studies register which included age at index event, sex, region of birth (Swedish, other Nordic, or other nationality), and education level (3 categories based on the Swedish educational system: compulsory education ≤9 years, secondary school education [10–12 years], and tertiary/university education [≥12 years]). Covariates identified from the year before the event included birth year- and calendar year-standardized disposable income (1, most disadvantaged; to 5, most advantaged), area of residence (Norrland, Svealand, and Götaland), population density, and a correction for latitude of residence. Latitude was included as there are spatially clustered patterns in the distribution of CVD in Sweden. Marital status was defined as single, married (which also included those registered as cohabiting with children in common and same-sex partnerships), divorced, or widowed. We further adjusted for a modified weighted Charlson comorbidity index based on the secondary diagnoses reported at the baseline event (Methods and Table I in the Data Supplement). In sensitivity analyses, we defined use of medication for hypertension, dyslipidemia, and type 2 diabetes mellitus 1 day to 18 months before index event. Medication use was based on extracts from the Swedish Prescribed Drug Register, which covers all Swedish dispensed pharmacy prescriptions since it was established on July 1, 2005. Antihypertensive drugs were defined based on the Anatomic Therapeutic Chemical Classification System as codes C02 (antihypertensive drugs),
C03A, C03EA01 (thiazide diuretics), C07 (β-receptor blockers, excluding sotalol [C07AA07]), C08C (selective calcium antagonists with mainly vascular effects), and C09 (agents acting on the renin-angiotensin system). Lipid-lowering drugs were defined as C10AA (statins), C10AB (fibrates), C10AC (bile acid sequestrants), C10AX (other lipid-modifying agents), and C10B (lipid-lowering drug combinations). Glucose-lowering drugs were defined as Anatomic Therapeutic Chemical Classification System-code A10A (insulin and analogues) and A10B (glucose-lowering drugs excluding insulin).

Exposure
Dog ownership was defined at the index event based on information from linkage of the Register of the Total Population to the Swedish Kennel Club or the Swedish Board of Agriculture dog registers. This was enabled by the mandatory dog registration that has been legislated in Sweden since 2001. The Swedish Kennel Club has registered all pedigree dogs in Sweden since 1889,22 while the Swedish Board of Agriculture has registered dog ownership since 2001. Each registered dog receives a unique identity tattoo or chip ID that can be linked to the unique person number of its owner. We also ascribed ownership to those whose partners were registered dog owners. Based on the Swedish Kennel Club classification of breed groups, we categorized the 247 breeds into 10 groups; further classifying all mixed-breed dogs and those of unknown breed as a mixed pedigree group.

Outcome
Death during follow-up was identified in excerpts from the Cause of Death Register23 as a main outcome. The follow-up included any deaths between January 1, 2001 and December 31, 2012. Death from a cardiovascular cause was defined as having a main cause of death within the ICD-10 codes I00-I99. As a secondary outcome, we investigated recurrent events defined as re-hospitalization for the same event as the index event after day 30 using the same definitions and sources as for the index event.

Statistical Analysis
Crude Kaplan–Meier curves of the survival after the index event were plotted. Cox proportional hazards models were used to evaluate the association of dog ownership with time-to-death using time from index event as the underlying timescale. Individuals were considered censored at emigration or at study end on December 31, 2012. Models were adjusted for age, sex, marital status, presence of children in the home, region of birth, area of residence, population density, income, a weighted Charlson comorbidity index, and previous CVD during the last 5 years. Age was adjusted for using restricted cubic splines with 3 knots, placing the knots at the 10th, 50th, and 90th percentile. The proportional hazards assumption of each model was visually confirmed using log-log plots. We further assessed the association of dog ownership and cardiovascular-specific death, including additional censoring for deaths from other causes while excluding those who died on the date of acute myocardial infarction or ischemic stroke. We also assessed the association of dog ownership and time-to-recurrent event with Cox regression including additional censoring for any-cause death and starting follow-up at day 31. We delayed the follow-up to reduce risk of including re-hospitalizations for the index event. Logistic regression models were used to assess the association of dog ownership with 1-year survival after acute myocardial infarction or ischemic stroke independently, using the same set of covariates. We estimated the absolute risk reduction for death within the first year using the marginal effects from the logistic models stratified on sex and setting all continuous variables to the mean and all other categorical variables to the most common category.

To investigate differences risk for owners of different dog breeds, we ran models defining ownership to eleven different dog breed groups and comparing to nonowners. Given that multiple comparisons were performed, we applied a Bonferroni correction for the 11 tests to the P values.

Subgroup analyses were performed to analyze possible differences in effect according to some characteristics of the study population, including sex (male, female), age category (<65, ≥65 to <75, and ≥75) and whether or not a person was registered as living alone in the home (defined as not...
registered as living with a partner or child in the home (yes, no). We estimated the relative excess risk because of interaction (RERI)\(^2\) of dog ownership with living conditions as subgroup analysis indicated effect measure modification. Using a common reference with the lowest risk of death (dog owner and not living alone), adjusted hazard ratios were calculated for: non dog-owner and not living alone (HR\(_{\text{00}}\)); dog owner and not living alone (HR\(_{\text{10}}\)); and non dog-owner and living alone (HR\(_{\text{01}}\)). The RERI\(^2\) was calculated as HR\(_{\text{11}}\)−HR\(_{\text{00}}\)−HR\(_{\text{01}}\)+1. RERI>0 indicates effect modification greater than the expected additive effect. CIs were calculated using the delta method.\(^2\)

All data management and analyses was performed using Stata version 15 (StataCorp, TX).

**Sensitivity Analysis**

In the part of the study population experiencing their index event January 1, 2007 or later, we applied the same models as in the main analysis for time-to-death with further adjustment for medication within 18 months for hypertension, dyslipidemia, or type 2 diabetes mellitus as well as an additional adjustment for education level. Information on education level was missing in individuals born before 1926.

**Ethics Approval**

The regional ethics review board in Stockholm, Sweden, approved the study (approval number 2012/1114-31/2 with amendment 2013-1687-32) and waived the requirement for written consent.

**Data Sharing Statement**

The register data that support the findings of this study were made available by record-linkage with data from Statistics Sweden, the National Board of Health and Welfare, the Swedish Kennel Club and the Swedish Board of Agriculture. Researchers did not have access to the original data bases because of the sensitivity of health data. Restrictions apply to the availability of these data, which were used under license and ethical approval for the current study, and so are not publicly available. Data are however available from the authors on reasonable request and with permission of the Regional Ethical Review Board in Stockholm, Sweden. There are no additional data available.

**RESULTS**

**Survival After Acute Myocardial Infarction**

Among those with an index acute myocardial infarction event (n=181 696), dog ownership was recorded in 10 287 (5.7%). The mean age of study participants was 71 years and they were predominantly male (63.9%). On average, dog owners were younger than non–dog owners (64 versus 71 years, respectively; Table). After age- and sex-standardization, dog owners were more likely to be married (74.4% versus 55.8%). There was no difference in concurrent comorbidities at admission (modified-weighted Charlson comorbidity index ≥2) between dog owners and nonowners at 14.0% versus 15.7%, respectively; but dog owners were more likely to have children living in the home (15.1% versus 11.5%) and be in the highest income tier than non–dog owners (23.0% versus 19.7%). Table II in the Data Supplement provides the baseline characteristics presented as age- and sex-standardized descriptive statistics.

During 804 137 person-years of follow up, 69 232 (38.1%) deaths occurred. After adjustment for sex and age, the risk of death was lower in dog owners than in non–dog owners (HR, 0.74; 95% CI, 0.71–0.78) and this association remained after multivariable adjustment (HR, 0.79; 95% CI, 0.75–0.83; Figure 2). A Kaplan–Meier curve of the survival after acute myocardial infarction is reported as Figure I in the Data Supplement. Within 1 year after acute myocardial infarction, 29 336 (16.1%) deaths were recorded. The odds of having died at 1 year was lower in dog owners than in nonowners (adjusted OR, 0.72; 95% CI, 0.67–0.78; Table III in the Data Supplement) corresponding to an absolute risk reduction of 2.4% (95% CI, 1.8%–2.9%) for death within a year after an acute myocardial infarction for a man and 2.1% (95% CI, 1.7%–2.6%) for a woman, with their respective continuous covariates set to the mean and the categorical variables to the most common category.

The association of dog ownership with death was stronger for those who lived alone, compared with those having a registered partner or child at home (adjusted HR, 0.67; 95% CI, 0.61–0.75 versus HR, 0.85; 95% CI, 0.80–0.90; Figure 2). We found evidence that this effect modification was greater than an additive effect, as indicated by a RERI measure above 0 (RERI, 0.54; 95% CI, 0.40–0.68).

The main cause of death (64.2%) after myocardial infarction was death from cardiovascular causes (Table IV in the Data Supplement). The risk of death from CVD was lower in dog owners than in nonowners (adjusted HR, 0.73; 95% CI, 0.68–0.78; Table V in the Data Supplement).

We found some breed groups (terriers, spitz/primitive dogs, scent hounds, and retrievers) associated with a lower risk of death after myocardial infarction compared with nonowners with HRs ranging from 0.55 to 0.79 (Table VI in the Data Supplement).

**Survival After Ischemic Stroke**

Among those with an index ischemic stroke event (n=154 617), dog ownership was registered in 7344 (4.8%) of the population. The mean age of participants at an ischemic event was 73 years and there were more males than females (55.0%). Dog owners were on average younger than nonowners (67 versus 73 years; Table). On standardization for age and sex, we observed that dog owners were more likely to be married (69.1%
versus 50.9%), respectively and also more likely to have children living in the home (11.8% versus 8.6%) and be in the highest income tier than nonowners (24.8% versus 19.6%), respectively. Table II in the Data Supplement provides the baseline characteristics presented as age- and sex-standardized descriptive statistics.

During 638,219 person-years of follow up, 67,277 deaths occurred representing 43.5% of the study sample. After adjustment for sex and age, the risk of death was lower in dog owners than in nonowners (HR, 0.78; 95% CI, 0.74–0.82) and this association remained after multivariable adjustment (HR, 0.82; 95% CI, 0.78–0.86) (Figure 2). A Kaplan–Meier curve of the survival after ischemic stroke is reported as Figure II in the Data Supplement. Within 1 year after the index event, 24,924 deaths were recorded, representing 16.1% of the study participants. The odds of having died at 1 year was lower in dog owners (adjusted OR, 0.77; 95%
CI, 0.71–0.84; Table III in the Data Supplement) corresponding to an absolute risk reduction of 2.0% (95% CI, 1.4%–2.6%) for death within a year after ischemic stroke for a man and 1.9% (95% CI, 1.3%–2.5%) for a woman, with their respective continuous covariates set to the mean and the categorical variables to the most common category.

We found evidence of an effect modification by whether a person lived alone, compared with a registered partner or child at home (adjusted HR, 0.73; 95% CI, 0.66–0.80; versus HR, 0.88; 95% CI, 0.83–0.93; Figure 2). We found evidence that this effect modification was greater than an additive effect, as indicated by a RERI measure above 0, 0.41; 95% CI, 0.28–0.54.

The main cause of death (63%) after ischemic stroke was from conditions related to the circulatory system (Table IV in the Data Supplement). The risk of death from CVD was lower in dog owners than in nonowners (adjusted HR, 0.77; 95% CI, 0.72–0.83; Table V in the Data Supplement).

We found some breed groups associated with a lower risk of death after ischemic stroke with HRs ranging from 0.69 to 0.83 compared with nonowners including dachshunds, scent hounds, retrievers, and companion and toy dogs (Table VI in the Data Supplement).

Recurrent Events

We found dog ownership to be associated with lower risk of recurrent myocardial infarction 30 days or later after initial myocardial infarction event in models adjusted for age and sex with an HR of 0.91 (95% CI, 0.86–0.97) and in fully adjusted models HR 0.93 (95% CI, 0.87–0.99). The association of dog ownership with recurrent ischemic stroke events after initial ischemic stroke was less clear, with an HR of 0.96 (95% CI, 0.90–1.03) in age- and sex adjusted models and 0.98 (95% CI, 0.92–1.05) in fully adjusted models.

Sensitivity Analyses

Descriptive statistics of the part of the cohort experiencing their index event from January 1, 2007 or later is described in Table VII in the Data Supplement. Further adjustment for medication for hypertension, dyslipidemia, or diabetes mellitus within 18 months before the index event as well as an additional adjustment for education level had little influence on the association of dog ownership with survival after acute myocardial infarction or ischemic stroke (Table VIII in the Data Supplement).

DISCUSSION

In this register-based study of Swedish residents, the main finding was that dog ownership was associated with lower hazard of all-cause and CVD death after an acute myocardial infarction or ischemic stroke. The strongest inverse association was found in single households.

Research in Context

Our results are in line with 2 earlier small studies.\(^1\)\(^2\) The first was a cohort study of 92 patients discharged from a coronary care unit after myocardial infarction or angina pectoris with 58% pet ownership. After a year of follow-up, pet owners were more likely to survive than non–pet owners (94% versus 71%).\(^1\)\(^2\) A replication study conducted on 369 postmyocardial infarction patients showed that dog ownership (in 86 patients [23.3%]) was associated with better survival.
dog owners, a factor regarded important in post-
ction for engagement in consistent physical activity in
roke. One mechanism may be an increased motiva-
survival after acute myocardial infarction or ischemic
material in our study allowed more precise estimates.
The primary strengths of this study are the nation-wide
population-based design, the large sample sizes of both
cohorts, and the long-term complete follow-up. Using
the rich Swedish administrative registers, we were able
to collect information on exposure, the outcome and
various confounders prospectively.

Our work does however also have some limitations.
Misclassification of dog ownership may have occurred,
particularly in partners not registered as living togeth-
er. We attempted to decrease this loss of information
by registering the partners' dog registration as being
attributed to the index patient provided they were reg-
istered as living together. In addition, date of dog death
and change of ownership are often not reported to the
registers. If the rates of changes in ownership is larger
in owners with higher likelihood of death after an ini-
tial cardiovascular event, our results could be affect-
ed toward the null as we would wrongly classify the
nonowners as owners. Further, we did not adjust for
readmission during follow-up, which may have differed
between the exposed and the unexposed. While this
observational analysis provides an important addition
to the smaller studies conducted previously, it cannot
infer causality. We would recommend further research
to understand these observed associations including
the following topics: (1) to assess the determining fac-
ors for who gets a dog and the type of dog associ-
ated with different owner characteristics, which would
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Strengths and Limitations

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In accordance with our previous research on dog
ownership and the risk of cardiovascular disease
(n=3432153), our present study shows that dog
ownership demonstrated even more pronounced
inverse associations with the outcome among those liv-
ing alone in the home than in homes with a partner
or child. One potential explanation for this could be
that dogs can provide psychosocial support in environ-
ments where human companionship is not available.30
As observed in a cross-sectional study, dog ownership
seems to facilitate consistent walking routines.31 There
could also be residual confounding from concurrent
health issues that acts stronger in single households.

In line with our previous research in the general pop-
ulation, we found mixed breed dogs and companion
and toy to have the least protective point estimates for
survival after acute myocardial infarction.29 This could
be explained by differences in physical activity or resid-
ual confounding from socioeconomical factors. Many
of the companion and toy dogs are miniature breeds.
A recent study showed that owners of different dog
breeds tend to differ in the frequency, duration, and
distance that they exercise their dogs, despite prevail-

In the latter study, adjustment was made
for severity of disease as measured by physiological
variables, such as ejection fraction, runs of ventricular
arrhythmias and diabetes mellitus. In addition, adjust-
ment was made for psychosocial factors such as liv-
ing alone. In the present study, we could not include
the same covariates; however, by using the Charlson
comorbidity index and previous history of CVD, it was
possible to adjust for a measure of frailty which helped
us to account for some other important conditions that
may affect recovery from myocardial infarction or isch-
emic stroke. However, our finding stands in contrast to
those of the largest longitudinal study conducted on
this topic to date, including 412 postacute coronary syn-
drome patients (with 39% pet ownership) followed for
12 months. In that study, pet ownership was associated
with worse outcomes; however, this result was mainly
driven by cat owners, and in dog owners no difference
in cardiac deaths and readmission was identified (OR
1.59; 95% CI, 0.76–3.32).16 In contrast to our study,
their study excluded participants with readmissions or
deaths during the first month and any participant with
serious underlying morbidities such as metastatic can-
cer. In addition, they included a wide age range (28–92
years) and did not investigate all-cause mortality as an
outcome. However, the greatest difference to our study
was the number of participants, as the larger study
material in our study allowed more precise estimates.

The associations found in the present study may
represent a causal relationship of dog ownership with
survival after acute myocardial infarction or ischemic
stroke. One mechanism may be an increased motiva-
tion for engagement in consistent physical activity in
dog owners, a factor regarded important in post-
vent recovery of cognition, arm function, balance, and
gait.25 Another explanation is reduced risk of depres-
sion, an important risk factor for death after myocardial
infarction.26 Dog ownership has previously been asso-
ciated with alleviation of stress factors such as social
isolation, depression, and loneliness.11,27,28 It is also pos-
sible that dog owners seek medical advice at an earlier
stage because of more easily detectable symptoms dur-
ing physical activity. However, we cannot rule out that
chronic disease, propensity to physical activity, and a
social personality influence the choice of getting a dog
and thus may potentially confound these associations.
The effect sizes are large which would support the asso-
ciations might be confounded. However, consistency
across age and sex groups and the effect modification
by household type are in accordance with our hypothe-
sis. The adjustment for comorbidities and previous CVD
did not markedly affect the estimates, but our disease
definitions is not likely to capture all comorbidities.

In evidence of smaller dogs being walked less frequently
than bigger dogs.33

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activity levels and need for social support after myocardial infarction or ischemic stroke differs in dog owners and nonowners, and (3) to investigate whether interventions including dog therapies improves the owner’s motivation to rehabilitate after myocardial infarction or stroke. Interventions including pet therapies after a cardiovascular event has the potential to improve outcomes in this population, but randomized studies are warranted. The external validity of the study is mainly related to cultural differences in dog ownership across countries.

CONCLUSIONS

In this study of 321430 Swedish adults aged 40 to 85, dog ownership was associated with a lower risk of death after an acute myocardial infarction or ischemic stroke.

ARTICLE INFORMATION

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Disclosures

Dr Ingelsson is a scientific advisor for Precision Wellness and Olink Proteomics for work unrelated to the present project. The other authors report no conflicts.

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29. Mubanga et al; Dog Ownership and Mortality After a MACE


