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Dog ownership and cardiovascular risk factors: a nationwide prospective register-based cohort study

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ABSTRACT

Objective To study the association between dog ownership and cardiovascular risk factors.

Design A nationwide register–based cohort study and a cross-sectional study in a subset.

Setting A cohort of 2 026 865 participants was identified from the Register of the Total Population and linked to national registers for information on dog ownership, prescribed medication, hospital admissions, education level, income and country of birth. Participants were followed from 1 October, 2006, to the end of the study on 31 December, 2012, assessing medication for a cardiovascular risk factor, emigration and death. Cross-sectional associations were further assessed in 10 110 individuals from the TwinGene study with additional adjustment for professional level, employment status, Charlson comorbidity index, disability and tobacco use.

Participants All Swedish residents aged 45–80 years on 1 October, 2006.

Main outcome measures Initiation of medication for hypertension, dyslipidaemia and diabetes mellitus.

Results After adjustment for confounders, the results indicated slightly higher likelihood of initiating antihypertensive (HR, 1.02; 95% CI, 1.01 to 1.03) and lipid-lowering treatment (HR, 1.02; 95% CI, 1.01 to 1.04) in dog owners than in non-owners, particularly among those aged 45–60 years and in those owning mixed breed or companion/toy breed dogs. No association of dog ownership with initiation of treatment for diabetes was found in the overall analysis (HR, 0.98; 95% CI, 0.95 to 1.01). Sensitivity analyses in the TwinGene cohort indicated confounding of the association between dog ownership and prevalent treatment for hypertension, dyslipidaemia and diabetes mellitus, respectively, from factors not available in the national cohort, such as employment status and non cardiovascularchronic disease status.

Conclusions In this large cohort study, dog ownership was associated with a minimally higher risk of initiation of treatment for hypertension and dyslipidaemia implying that the previously reported lower risk of cardiovascular mortality among dog owners in this cohort is not explained by reduced hypertension and dyslipidaemia. These observations may suffer from residual confounding despite access to multiple important covariates, and future studies may add valuable information.

Strengths and limitations of this study

- This is the largest study to date to examine the impact of dog ownership on cardiovascular risk factors.
- The nationwide register-based cohort study with a cross-sectional investigation in a twin registry with a vast array of lifestyle and clinical variables strengthens the results.
- The main outcome measures were extracted from nationwide registers thus decreasing the risk of recall and selection bias.
- Misclassification of dog ownership, particularly in the twin register, may have led to some loss of power.
- Some important confounding factors were not available in the national data.

INTRODUCTION

There is a growing interest in pet ownership as a possible intervention to enhance cardiovascular health and well-being.[1 2] We recently observed that being registered as a dog owner was associated with a lower risk of cardiovascular and all-cause mortality in the general Swedish population (n=3 432 153).[3] Any causal association of dog ownership with lower cardiovascular mortality could potentially be mediated through increased physical activity[4 5] or through the psychological benefits of companionship,[6] which could in turn reduce other important cardiovascular risk factors such as blood pressure, adiposity, dyslipidaemia and insulin resistance.[7 8] An alternative explanation could be confounding by socioeconomic,[9] cultural,[10] demographic[9] or psychosocial factors.[11 12] A large number of cross-sectional and longitudinal studies across different countries support the association of dog ownership with physical activity,[1] however, reports regarding the association of dog ownership with other cardiovascular risk factors are less consistent.[13–20] These inconsistencies may be due to low statistical power in small studies, use of restricted or

homogenous populations, inability to control for differences across breeds of dogs, or simply an absence of effect. As dogs are reported to be more common in rural areas compared with urban areas,[21–23] as well as in households with children,[24 25] it is also important to account for these differences. The aim of this study was to assess the association of dog ownership with three major clinical risk factors for cardiovascular disease (CVD),[26] specifically initiation of treatment of hypertension, dyslipidaemia and diabetes mellitus. We hypothesised that the cardiovascular risk profile of dog owners is better than that of non-dog owners. To overcome limitations of previous studies concerning study size, generalisability and differences between dog breeds, we investigated this hypothesis using data on all Swedish residents aged 45–80 years of age in 2006 from national registers on dog ownership and drug prescriptions. We further sought to explore the association with other cardiovascular risk factors using cross-sectional data from a subcohort extracted from the Swedish Twin Registry containing detailed information from questionnaire data, physical examinations and laboratory measurements.

METHODS

Design

The main analysis was based on a nationwide cohort study of Swedish residents aged 45–80 followed from 1 October 2006 to 31 December, 2012. We additionally used cross-sectional data of participants (aged 47–80 years) in the TwinGene study, which is a substudy of the Swedish Twin Registry (see online supplementary figure 1).

Study population—national cohort

All Swedish residents (n=3 412 946) aged 45–80 years on 1 October, 2006, were identified through the Register of the Total Population. To ensure complete linkage to medical information and sufficient information regarding dog ownership in Sweden, we excluded 11 298 individuals with unverified, reused identification numbers or missing education information, and 137 306 additional individuals that had resided in Sweden for <15 years. We also excluded 531 658 individuals with a history of any CVD (International Classification of Disease [ICD]–9 codes 390–459 and ICD-10 I00-I99) before 1 October, 2006 or with a history of coronary artery bypass grafts or percutaneous coronary artery intervention medical procedure (Nordic surgical procedure codes FNA (anastomosis of internal thoracic artery with coronary arteries), FNC (aorto-coronary bypass using vein graft) and FNG (dilatation and recanalization of coronary arteries) from inpatient and outpatient data. Inpatient data were available from 1987 and outpatient data from 2001. Further, using data from the Swedish Prescribed Drug Register, which covers all Swedish dispensed pharmacy prescriptions since it was established on 1 July, 2005, individuals (n=705 819) were excluded if they had any recorded dispensed prescription of antihypertensive drugs, lipid-lowering drugs or glucose-lowering drugs from 15 months prior to baseline (which was when this register was initiated). Antihypertensive drugs were defined based on the Anatomical Therapeutic Chemical Classification System (ATC) as codes: C02 (antihypertensive drugs), C03A, C03EA01 (thiazide diuretics), C07 (beta-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 ATC-code A10A (insulin and analogues) and A10B (glucose-lowering drugs excluding insulin).

Study population—TwinGene

The TwinGene study originally included 12 614 (of 22 391 invited) twins from the 'Screening Across the Lifespan Twin study' (SALT). It was conducted between April 2004 and December 2008 and included a visit to the participants' local health centre and blood sampling (see online supplementary figure 2).[27] The study-base 'SALT' was a substudy of the Swedish Twin Register in twins born before 1959 and who participated in a telephone-based questionnaire substudy from March 1998 to March 2002[27] (see online supplementary table 1).

We performed a cross-sectional analysis of the association of dog ownership with cardiovascular risk factors in the TwinGene cohort (n=12 105). We excluded 1373 individuals for having a previous history of CVD recorded in the National Patient Register.[28] We also excluded 622 individuals for having missing or incomplete data (see online supplementary figure 1).

Exposure

Dogs in Sweden are required to have a unique identifier (ear tattoo or implanted identity chip) and this is registered alongside their owner's unique personal identity number at the Swedish Board of Agriculture. All dogs sold as purebred are registered by the Swedish Kennel Club. In Sweden, there are virtually no stray dogs,[29] and compliance to regulations is thought to be high due to a general high level of social and institutional trust.[30]

We defined the variable 'dog ownership' in the national cohort as registered dog ownership or having a partner registered as a dog owner in either the Swedish Board of Agriculture and/or the Swedish Kennel Club registers. Exposure to dog ownership was time updated to include only those periods where each dog was alive and registered to the study participant or their registered partner. The identification of partners was possible through annual extracts from the Register of the Total Population that keeps track of couples that are married, registered in same-sex partnership or are cohabiting with common children. It is presently not possible to identify cohabiting non-married partners who have no children in common in the population registers.

Table 1 Baseline characteristics of Swedish adults aged 45–80 years without cardiovascular disease according to dog ownership status (national cohort, n=2 026 865) and (TwinGene, n=10 110, responses derived from Screening Across the Lifespan Twin study (1998–2002))

	National Cohort					TwinGene				
	All n=2026865 (100%)	Non-dog owners n=1 731 183 (85.4%)	Dog owners** n=295682 (14.6%)	Mixed pedigree† n=32003 (1.6%)	'Active dog breeds'†,*** n=65686 (3.2%)	All n=10 110 (100%)	Non-dog owners n=9626 (95%)	Dog owners** n=484 (5%)	Mixed pedigree† n=141 (1.3%)	'Active dog breeds'†,*** n=143 (1.4%)
Age: mean±SD*	52.8 (8.7)	53.3 (8.9)	49.9 (7.3)	49.2 (7.1)	50.0 (7.3)	63.6 (7.1)	63.7 (7.1)	62.0 (6.7)	61.9 (6.3)	62.7 (6.7)
Male	981 094 (48.4)	839 321 (48.5)	141 773 (47.9)	11 841 (37.0)	27 961 (42.6)	4189 (41.4)	3986 (41.4)	203 (41.9)	60 (42.6)	64 (44.8)
Marital status										
Married/cohabiting	1 276 074 (63.0)	1 044 915 (60.4)	231 159 (78.2)	18 991 (59.3)	46 638 (71.0)	8039 (79.5)	7648 (79.5)	391 (80.8)	110 (78.0)	112 (78.3)
Never married	287 589 (14.2)	265 895 (15.4)	21 694 (7.3)	4265 (13.3)	6377 (9.7)	771 (7.6)	734 (7.6)	37 (7.6)	13 (9.2)	14 (9.8)
Divorced	352 209 (17.4)	316 728 (18.3)	35 481 (12.0)	7522 (23.5)	10 325 (15.7)	855 (8.5)	824 (8.6)	31 (6.4)	11 (7.8)	8 (5.6)
Widowed	110 993 (5.5)	103 645 (6.0)	7348 (2.5)	1225 (3.8)	2346 (3.6)	445 (4.4)	420 (4.4)	25 (5.2)	7 (5.0)	9 (6.3)
Type of family										
Children at home	658 355 (32.4)	521 224 (30.0)	137 131 (46.3)	14 079 (44.0)	28 785 (43.8)	1500 (14.8)	1397 (14.5)	103 (21.3)	31 (22.0)	27 (18.9)
No children at home	1 369 617 (67.6)	1 210 920 (69.9)	158 697 (53.7)	17 924 (56.0)	36 901 (56.2)	8610 (85.2)	8229 (85.5)	381 (78.7)	110 (78.0)	116 (81.1)
Education										
Compulsory	541 662 (26.7)	473 952 (27.4)	67 710 (22.9)	8596 (26.9)	13 207 (20.1)	4069 (40.2)	3880 (40.3)	189 (39.0)	56 (39.7)	52 (36.4)
Secondary	891 458 (44.0)	751 156 (43.4)	140 302 (47.5)	16 729 (52.3)	29 352 (44.7)	3107 (30.7)	2958 (30.7)	149 (30.8)	46 (32.6)	36 (25.2)
University	593 745 (29.3)	506 075 (29.2)	87 670 (29.7)	6678 (20.9)	23 127 (35.2)	2934 (29.0)	2788 (29.0)	146 (30.2)	39 (27.7)	55 (38.5)
Income quintile‡										
1 (lowest quintile)	405 929 (20.0)	342 412 (19.8)	63 517 (21.5)	8222 (25.7)	12 695 (19.3)	–	–	–	–	–
2	405 486 (20.0)	348 254 (20.1)	57 232 (19.4)	7472 (23.3)	12 461 (19.0)	–	–	–	–	–
3	405 173 (20.0)	347 691 (20.1)	57 482 (19.4)	6801 (21.3)	12 586 (19.2)	–	–	–	–	–
4	405 175 (20.0)	346 350 (20.0)	58 825 (19.9)	5620 (17.6)	13 364 (20.3)	–	–	–	–	–
5 (highest quintile)	405 102 (20.0)	346 476 (20.0)	58 626 (19.8)	3888 (12.1)	14 580 (22.2)	–	–	–	–	–
Country of birth										
Sweden	1 805 438 (89.1)	1 529 664 (88.4)	275 774 (93.3)	29 168 (91.1)	62 160 (94.6)	10 110 (100)	9626 (100)	484 (100)	141 (100)	143 (100)
Other Nordic countries§	92 043 (4.5)	80 740 (4.7)	11 303 (3.8)	1650 (5.2)	2083 (3.2)	0	0	0	0	0
Non-Nordic countries	129 384 (6.4)	120 779 (7.0)	8605 (2.9)	1185 (3.7)	1443 (2.2)	0	0	0	0	0
Population density: median (interquartile range) inhabitant per square kilometre	72.6 (228.8)	76.7 (315.3)	49.2 (92.8)	45.0 (87.7)	56.8 (106.2)	60.7 (111.1)	60.7 (114.7)	41.8 (72.9)	40.1 (70.3)	45.9 (68.5)
Region of residence										
Norrland	269 897 (13.3)	222 443 (12.8)	47 454 (16.0)	4791 (15.0)	9476 (14.4)	1621 (16.0)	1518 (15.8)	103 (21.3)	32 (22.7)	22 (15.4)
Svealand	771 742 (38.1)	669 673 (38.7)	102 069 (34.5)	10 278 (32.1)	23 451 (35.7)	3391 (33.5)	3240 (33.7)	151 (31.2)	41 (29.1)	42 (29.4)
Götaland	985 226 (48.6)	839 067 (48.5)	146 159 (49.4)	16 934 (52.9)	32 759 (49.9)	5098 (50.4)	4868 (50.6)	230 (47.5)	68 (48.2)	79 (55.2)
Exercise¶										
Little or none	–		–	–	–	2139 (21.2)	2064 (21.5)	75 (15.5)	29 (20.7)	16 (11.2)

Continued

Table 1 Continued

	National Cohort					TwinGene					
	All n=2026865 (100%)	Non-dog owners n=1731183 (85.4%)	Dog owners** n=295682 (14.6%)	Mixed pedigree† n=32003 (1.6%)	'Active dog breeds'†,*** n=65686 (3.2%)	All n=10110 (100%)	Non-dog owners n=9626 (95%)	Dog owners** n=484 (5%)	Mixed pedigree† n=141 (1.3%)	'Active dog breeds'†,*** n=143 (1.4%)
Average	–	–	–	–	–	2611 (25.9)	2508 (26.2)	103 (21.3)	29 (20.7)	27 (18.9)
Above average	–	–	–	–	–	5319 (52.8)	5014 (52.3)	305 (63.1)	82 (58.6)	100 (69.9)
Tobacco use¶										
No history of tobacco	–	–	–	–	–	4314 (42.7)	4155 (43.2)	159 (32.9)	42 (29.8)	46 (32.2)
Previous tobacco user	–	–	–	–	–	4061 (40.2)	3833 (39.8)	228 (47.1)	69 (48.9)	68 (47.6)
Current tobacco user	–	–	–	–	–	1735 (17.2)	1638 (17.0)	97 (20.0)	30 (21.3)	29 (20.3)

*Age is given at baseline. Numbers and % of the respective cohort are reported unless stated otherwise.
**For descriptive purposes, dog owners here are individuals who had a registered dog at any time point during the study period, and for TwinGene taken as ownership at the clinical test date.
†Proportion of this breed group of all participants.
‡Information on income not available for the TwinGene substudy in the Swedish Twin Register.
§Other Nordic countries include Norway, Denmark, Iceland, Finland, the territories of the Åland Islands and the Faroe Islands.
¶Information on exercise levels and tobacco use was not available from the Register of the Total Population.
***Active dog breeds' which comprises all terriers, scent hounds, pointing dog and retriever dog breed groups.

In the TwinGene data, we did not have access to information on partners' dog ownership and only each person's own dog registrations were used. Dog ownership was defined at the date of inclusion in TwinGene.

If information on a dog's death was missing, we assumed a maximum lifespan of 10 years.[31] We conducted sensitivity analyses examining associations with dog death at a maximum lifespan of 8 years and 12 years. Where birth or registration dates were discrepant between the two registers, we randomly selected one of the two.

To define breed groups, we used the Federation Cynologique International standard with some local adaption from Swedish Kennel Club's definition to categorise the 331 breeds into 10 breed groups based on character and behaviour attributes (see online supplementary table 2). All non-purebred dogs and those of unknown breed were included in an additional mixed-breed group. Where owners had dogs of different breeds, we defined the breed based on the dog registered first and where owners had several dogs, we restricted ownership to three dogs.

Based on previous findings[3] that ownership to four different breed groups was associated with a lower risk of cardiovascular events, we defined a group of these dog breeds (terriers, pointing, scent hounds and retrievers) for additional exploratory analysis. This group is hereafter referred to as 'active dog breeds' as these breeds also generally demand high levels of physical activity.

Outcome

In the national cohort, time to first dispensed prescription of antihypertensive drugs, lipid-lowering drugs or glucose-lowering drugs after baseline was defined from data extracted from the drug register. Each outcome was considered separately as we chose to estimate the total effect of dog ownership and not only the direct effects. Participants were censored at emigration, death or at the end of the study on 31 December, 2012. In the analysis of time to antihypertensive medication, individuals were additionally censored at a diagnosis of heart failure, unstable angina or acute myocardial infarction in the National Patient Register as the same drugs could be administered for their treatment.

Prevalent use of antihypertensive, lipid-lowering or glucose-lowering drugs was defined from the clinical questionnaire data collected during the TwinGene study. Cardiovascular risk factors measured and also used as outcomes in TwinGene included blood glucose, glycosylated haemoglobin A1c, high sensitive C reactive protein (hsCRP), triglycerides, high-density lipoprotein-cholesterol, low-density lipoprotein-cholesterol, waist-hip ratio, body mass index (BMI), systolic and diastolic blood pressure and mean arterial pressure (see online supplementary methods). Only fasting measurements of glucose and triglycerides were used (9873 [97%] of all participants were fasting).

Table 2 Association of dog ownership with initiation of medication for hypertension, dyslipidaemia and diabetes

Cohort	Medication	N treated	Time at risk	Model 1*	Model 2†	Model 3‡
National	Hypertension	503 305	10 659 258	**1.02 (1.01 to 1.03)**	**1.02 (1.01 to 1.03)**	NA
	Dyslipidaemia	276 691	11 508 349	**1.03 (1.02 to 1.04)**	**1.02 (1.01 to 1.04)**	NA
	Diabetes	60 038	12 207 964	**0.91 (0.89 to 0.94)**	0.98 (0.95 to 1.01)	NA
TwinGene	Hypertension	2223	NA	0.96 (0.75 to 1.21)	0.94 (0.74 to 1.20)	0.90 (0.70 to 1.15)
	Dyslipidaemia	963	NA	0.92 (0.65 to 1.29)	0.92 (0.65 to 1.29)	0.87 (0.62 to 1.22)
	Diabetes	318	NA	0.89 (0.49 to 1.61)	0.90 (0.50 to 1.63)	0.78 (0.43 to 1.43)

For national cohort (n=202 6865), Cox regression models with HRs and 95% CI for incident medication are applied, while logistic models for prevalent use is used in TwinGene (n=10 110) and ORs presented.
Estimates in bold represents associations with p<0.05.
*Model 1. Age and sex adjusted.
†Model 2. National cohort: Adjusted for sex, age, type of family, area of residence, population density, marital status, region of birth (Sweden, Nordic, non-Nordic), income, education level, latitude of residence. TwinGene: adjusted for sex, age, type of family, area of residence, population density, marital status, education level and latitude of residence.
‡Model 3. Adjusted for sex, age, number of children in the home, area of residence, population density, marital status, tobacco use, occupational level, employment status, disability and Charlson comorbidity index.
NA, not applicable.

Statistical analyses

All statistical analyses were conducted using Stata V. MP14.1 (StataCorp).

Using age as a timescale, separate multivariable Cox proportional hazards models were applied to assess the associations between dog ownership and time to initiation of antihypertensive, lipid-lowering and glucose-lowering drugs, respectively. Directed acyclic graphs were used to guide the choice of covariates (see online supplementary figure 3). A first crude model included age and sex, and a second model additionally included the region of birth, area of residence, latitude of residence, population density, level of education, marital status, presence of children in the home and income. A description of the covariates is provided in the online supplementary methods. The proportional hazards assumption was verified by plotting Schoenfield residuals and log-log graphs. Results were reported as HRs and 95% CIs. We repeated the calculations using the breed group as exposure to examine possible breed group effects and we applied Bonferroni correction (for 11 breed groups) to control for multiple testing. Further analyses were stratified by age group, sex, and whether participants lived alone or not. Individuals considered as 'living alone' did not have any spouse, partner with common children, or children living in the same household.

We conducted a sensitivity analysis where we excluded β-blockers as first line antihypertensive treatment to estimate the effect of changing treatment guidelines over the study period. In additional sensitivity analysis, in the lipid-lowering medication analysis, we assessed the effect of censoring participants at a diagnosis of heart failure, unstable angina or acute myocardial infarction in the National Patient Register.

Logistic regression was applied in TwinGene for the association of dog ownership with prevalent antihypertensive, lipid-lowering and blood-glucose-lowering medication and linear regression for the association of dog ownership with continuous variables. hsCRP and triglycerides were transformed to the natural log scale before analysis to approach normality.

In addition to adjusting for age, sex, presence of children in the household, area of residence, population density, marital status, latitude of residence and level of education, we added further covariates, one at a time to investigate their individual importance: tobacco use, occupational level, employment status, Charlson comorbidity index and disability. In all twin analyses, SEs were adjusted with the robust sandwich estimator for dependent observations. For blood pressure and lipid levels, associations were further stratified by current medication.

Patient involvement

No patients were involved in the development, design or analysis of this study.

RESULTS

National cohort

The baseline characteristics of 2 026 865 Swedish residents are shown in table 1. Dog ownership was directly registered in 189 355 (9.3%) at any time during the follow-up period, and this increased to 295 682 (14.6%) individuals when partners' registration were included. At baseline, the average age of dog owners was 50 years versus 53 years in non-owners. Dog owners were more likely to be married than non-owners (78% vs 60%) and more likely to live in low-density areas than non-owners (median: 49 vs 77 inhabitants per square kilometre). Compared to non-owners, mixed pedigree dog owners (n=32,003) were less likely to be married (59 %), were less likely to have a tertiary education (21%) and had fewer people in the top quintile for income (12.2%). Owners of 'active dog

breeds' showed similar characteristics to the overall dog owners.

Medication for cardiovascular risk factors

During 10 692 258 person-years of follow-up, dog ownership was associated with a 2% higher risk of initiation of antihypertensive drug medication in both crude and multivariable-adjusted analyses (HR, 1.02; 95% CI, 1.01 to 1.03). During 11 508 349 person-years of follow-up, there was a 2% higher risk of initiating lipid-lowering medication in the multivariable-adjusted models (HR, 1.02; 95% CI, 1.01 to 1.04). During 12 207 964 person-years of follow-up, there was a lower risk of initiating glucose-lowering drugs in dog owners in minimally adjusted models (HR, 0.91; 95% CI, 0.89 to 0.94), but on multivariable adjustment, the association was attenuated and non-significant (HR, 0.98; 95% CI, 0.95 to 1.01) (table 2).

Owners of 'companion/toy' breeds and of dogs of mixed pedigree were at higher risk of antihypertensive and lipid-lowering drug initiation compared with non-dog owners (table 3). Owners of the Spitz/primitive breed types and the combined group of 'active dog breeds' breed types had lower risks of initiating glucose-lowering medication (HR, 0.83; 95% CI, 0.74 to 0.93 and HR, 0.92; 95% CI, 0.86 to 0.97, respectively), while owners of mixed pedigree dogs had higher risk of getting glucose-lowering medication (HR, 1.17; 95% CI, 1.09 to 1.26) (see online supplementary figure 4).

There was no difference in strength of association when we excluded β-blockers as first-line treatment for antihypertension (see online supplementary table 3) or when censoring was done in those being investigated for lipid-lowering treatment initiation was made for angina, myocardial infarction or heart failure was conducted (see online supplementary table 4).

In age-stratified analysis, there were some evidence of effect modification by age for both antihypertensive and lipid-lowering drugs where an increased risk was observed in those aged below 50 years (HR, 1.04; 95% CI, 1.01 to 1.08 and HR, 1.10; 95% CI, 1.04 to 1.15, respectively), with estimates gradually approaching one with increasing age (figure 1). Inverse associations of dog ownership with glucose-lowering drugs was observed in the lower age groups, in males and those not living alone (HR, 0.89; 95% CI, 0.79 to 0.99, HR, 0.95; 95% CI, 0.92 to 0.99 and HR, 0.91; 95% CI, 0.86 to 0.97, respectively).

TwinGene

On cross-sectional analysis of 10 110 individuals, 484 (5%) were registered as dog owners (partners' dogs not included) and their characteristics are described in table 1 and online supplementary table 5. Using similar covariates as in the national cohort, no association of dog ownership was found with prevalent use of antihypertensive drugs (OR, 0.94; 95% CI, 0.74 to 1.20), lipid-lowering drugs (OR, 0.92; 95% CI, 0.65 to 1.29) or glucose-lowering drugs (OR, 0.90; 95% CI, 0.50 to 1.63) (table 2). Upon inclusion of additional covariates, the Charlson comorbidity index and the employment status were found to be the most influential confounders and the fully adjusted model yielded lower but still non-significant estimates: OR, 0.90 (95% CI, 0.70 to 1.15) for use of antihypertensive drugs, OR, 0.87 (95% CI, 0.62 to 1.22) for lipid-lowering drugs and OR, 0.78 (95% CI, 0.43 to 1.43) for glucose-lowering drugs (see online supplementary table 6). We found no association between dog ownership and the other clinical and biochemical cardiovascular risk factors (figure 2).

Sensitivity analyses on changing the maximum lifespan of dogs in the national cohort that had no dates of death to 8 years or 12 years yielded similar results to the maximum of 10 years used in the main analysis (see online supplementary table 7). To provide additional information, the output from the fully adjusted Cox regression models for the association of dog ownership with the initiation of medication for hypertension, dyslipidaemia and diabetes mellitus in the national cohort are included in the supplementary material as online supplementary tables 8–9, respectively.

DISCUSSION

In this nationwide study in a population without previous cardiovascular disease, we observed a minimally higher risk of initiation of treatment for hypertension and dyslipidaemia among persons with a dog in their household compared with those without dogs in the household. Associations were most prominent in younger age groups (45–60 years). Owning a dog of mixed pedigree or a dog belonging to the 'companion/toy' breed group was associated with hypertension and dyslipidaemia, while ownership of a dog from the 'Spitz/primitive' breed and the combined group of' active dog breeds', consisting of breeds identified in our previous study (terriers, pointing, scent hounds and retrievers),[3] was associated with lower risk of treatment for diabetes mellitus. Cross-sectional analyses in 10 110 participants from TwinGene showed no association of dog ownership with BMI, waist-to-hip-ratio, blood pressure or biochemical cardiovascular risk factors, and indicated that the association of dog ownership with medication for hypertension, dyslipidaemia and diabetes was confounded by employment status and non-CVD-chronic conditions. This suggests that the slightly higher associations observed in the national cohort would potentially be attenuated in the presence of the additional confounders.

That owners of mixed breed and 'companion/toy' breeds, as well as dog owners in younger age groups, had mildly increased risks for hypertension and dyslipidaemia are in line with our previous study regarding higher risk of myocardial infarction and stroke in this group.[3] The level of dog walking might be lower in the smaller companion/toy dogs and mixed-breed dogs as compared with the 'active dog breeds' group, which consists of dog breeds originally bred for hunting.[32] This was also supported by data from TwinGene where 69.9% of active

Table 3 Association of dog ownership with initiation of medication for hypertension drugs, dyslipidaemia and diabetes by breed group in the National cohort with non-dog owners as the reference group

	Antihypertensive drugs		Lipid-lowering drugs		Glucose -lowering drugs	
Breed Groups	**Crude* HR**	**Adjusted† HR**	**Crude* HR**	**Adjusted† HR**	**Crude* HR**	**Adjusted† HR**
Sheep and cattle dogs	1.04 (1.01–1.07)	1.03 (1.00–1.06)	1.01 (0.97–1.06)	1.01 (0.97–1.06)	1.03 (0.95–1.13)	1.06 (0.96–1.15)
Pinscher and schnauzer	1.03 (0.99–1.06)	1.03 (1.00–1.07)	1.07 (1.02–1.12)	**1.07 (1.02–1.12)**	0.92 (0.82–1.02)	0.98 (0.88–1.09)
Terriers	0.98 (0.95–1.02)	0.99 (0.96–1.03)	1.01 (0.96–1.05)	1.02 (0.97–1.07)	**0.84 (0.76–0.94)**	0.91 (0.81–1.01)
Dachshunds	1.01 (0.96–1.06)	1.02 (0.97–1.07)	1.06 (0.99–1.13)	1.06 (0.99–1.13)	0.96 (0.84–1.11)	1.03 (0.89–1.18)
Spitz and primitive types	1.05 (1.01–1.09)	1.00 (0.97–1.04)	1.04 (0.99–1.09)	1.01 (0.96–1.06)	**0.82 (0.73–0.91)**	**0.83 (0.74–0.93)**
Scent hounds and related	1.05 (1.00–1.09)	1.03 (0.98–1.07)	1.07 (1.01–1.13)	1.05 (0.99–1.11)	**0.86 (0.76–0.98)**	0.88 (0.77–0.99)
Pointing dogs	0.95 (0.89–1.02)	0.95 (0.88–1.02)	0.96 (0.88–1.06)	0.97 (0.89–1.07)	**0.65 (0.51–0.82)**	0.73 (0.58–0.93)
Retrievers	1.00 (0.98–1.03)	1.02 (0.99–1.05)	1.00 (0.96–1.04)	1.02 (0.98–1.06)	**0.87 (0.80–0.95)**	0.98 (0.90–1.06)
Companion and toy dogs	**1.10 (1.06–1.13)**	**1.09 (1.05–1.12)**	**1.12 (1.08–1.17)**	**1.12 (1.07–1.16)**	1.01 (0.92–1.12)	1.03 (0.93–1.14)
Sight hounds	0.90 (0.79–1.02)	0.90 (0.79–1.02)	0.94 (0.79–1.12)	0.94 (0.79–1.12)	0.84 (0.57–1.26)	0.87 (0.59–1.30)
Mixed pedigree‡	**1.10 (1.07–1.13)**	**1.07 (1.05–1.11)**	**1.09 (1.06–1.12)**	**1.09 (1.05–1.13)**	**1.22 (1.13–1.32)**	**1.18 (1.09–1.27)**

Estimates that pass Bonferroni correction for 11 breed groups (p=0.05/11) are marked in bold.
*Adjusted for age and sex.
†Adjusted for age, sex, marital status, presence of children in the home, population density, area of residence, education level, region of birth, income and a correction for latitude of residence.
‡Group comprising all non-pure pedigree dogs.

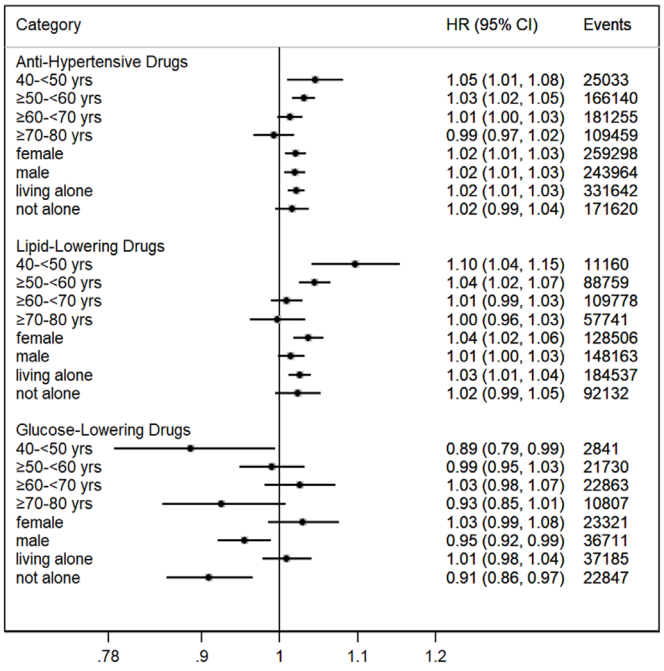

Figure 1 HRs and 95% CIs for the association of dog ownership and time to initiation of medication for hypertension, dyslipidaemia and type 2 diabetes.

dog breeds' breed owners reported a high level of physical activity versus 52.3% in non-dog owners and 58.6% for mixed-breed dog owners.[32] We chose to analyse these four 'active dog breeds' together (terriers, pointing, scent hounds and retrievers) to explore the association with CVD risk factors as they were all associated with lower risk of incident CVD events in our previous study,[3] but should not be viewed as the only active breed groups in the study. We also note that the proportion of highest education level in the mixed-breed group was remarkably lower than the general population (20.9% vs 29.3%). Although we adjusted for educational level, it is likely that there is unmeasured confounding from differences in health-seeking behaviour, smoking habits or stress in dog owners in working age groups. In TwinGene, we noted that additional adjustment for employment status (unemployed, retired, sick leave or unemployed) and a comorbidity index (for diseases other than CVD) were important confounders lowering the estimates. These covariates were not available in the national cohort, implying that the results in the national cohort are likely to have been confounded by these or other factors.

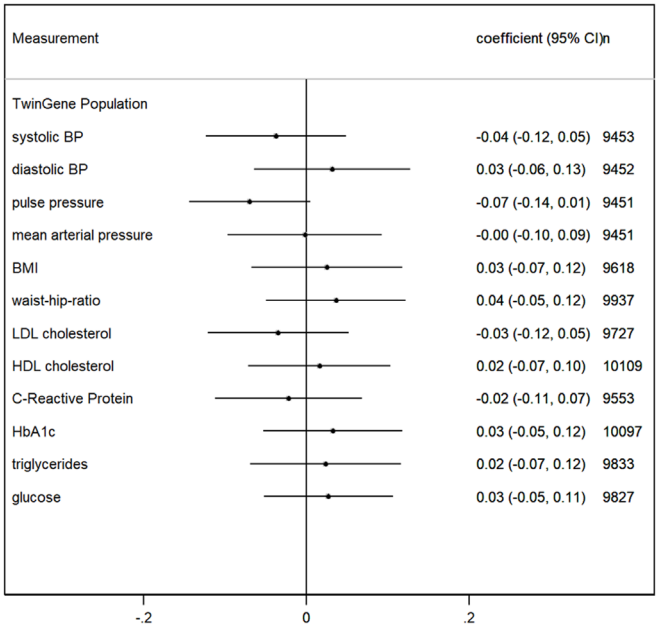

Figure 2 Coefficients and 95% CIs for the exposure to dog ownership compared with non-dog ownership on SD-transformed biochemical and clinical measurements in the TwinGene. BMI, body mass index; BP, blood pressure; HDL, high-density lipoprotein; LDL, low-density lipoprotein.

Our findings in TwinGene are different from an Australian cohort study in 5741 individuals with 13.6% pet ownership who found lower levels of plasma cholesterol, triglycerides and systolic blood pressures in pet-owners than non-owners.[20] Dog owners (6.3%) had better self-rated health but no difference in blood pressure than non-pet owners in cross-sectional analysis of the Nord-Trondelag Health Study (HUNT)-3 study (n=12 297).[13]

There are a limited number of studies of the association between dog ownership and the risk of type 2 diabetes. A study by Lentino *et al*,[16] (n=916) showed that regular dog walkers (n=399, 44%) in a primarily well-educated Caucasian population had lower BMI and were at lower risk of both dyslipidaemia and type 2 diabetes than other study participants. These findings were contradicted by Wright *et al*,[19] who showed that dog owners were more likely to be overweight, and have diabetes than non-owners in a study of 1179 community dwellers with 30% pet ownership. Differences in findings across countries could be due to differences in study design, or to inherent differences in dog management and the type of dog breeds in the country.

A previous study in this population showed a lower risk of cardiovascular disease and all-cause mortality in dog owners.[3] The current study suggests that it is unlikely that hypertension and dyslipidaemia mediates these effects. Other potential factors that may explain this reduction in mortality include increased social well-being and decreased psychological stress.[33]

Strengths and weaknesses

The main strengths of our study include its size and the population-based approach increasing generalisability beyond healthy volunteers in a cohort study. To the best of our knowledge, this is the largest register-based study to date to explore the association between dog ownership and cardiovascular risk factors. At the same time, while national registers allow for large and unselected populations with no loss to follow-up, they lack information on individual attributes such as body mass index, blood pressure, lipid levels and physical activity. A strength of this study is that we were able to include

additional clinical health measurements and socioeconomic variables using data from the TwinGene study supporting the presence of additional confounding of the relationship between dog ownership and cardiovascular risk factors from employment status and non-CVD comorbidities. Although our findings show an association between certain dog breeds and cardiovascular risk factors, these observational results do not imply a causal relationship.

The main limitation of the study is the possibility of remaining unmeasured confounding by unmeasured socioeconomic factors or pre-existing personality traits. Further, the register-based nature of our study made it impossible for us to account for pet-associated factors such as primary pet responsibility, physical activity, the level of dog attachment or indeed the reason for acquiring a dog. Physical activity related to dog walking may however be a mediator of the association between dog ownership and health outcomes and separating activity performed in relation to dog walking and other types of activity would be important. However, a large randomised study of dog ownership over several years cannot be done. Further, despite adjustment for several health, socioeconomic and lifestyle indicators, there is still a possibility of residual confounding or reverse causation. For instance, we could not assess health status before pet acquisition in the national cohort. A smaller study population, although not selected in relation to exposure or outcome, and possible misclassification of dog ownership (due to a lack of information on partners' dog ownership) or lifestyle questionnaire data (collected some years earlier) were important limitations in the subcohort analyses. Misclassification of dog ownership was also possible in non-married cohabiting partners without children in common as these would not be registered as cohabiting in the Register of The Total Population. Another important limitation is that we were unable to account for those that did not initiate treatment due to any of the three conditions. The Prescribed Drug Register does not keep a record of adherence to treatment or records of those prescribed lifestyle interventions such as diet or exercise.

CONCLUSION

In this large cohort study, we observed that dog ownership was associated with a minimally higher risk of initiation of treatment for hypertension and dyslipidaemia, and that ownership of dogs of the previously identified 'active dog breeds' was associated with a lower risk of initiating treatment for diabetes. These observations may suffer from residual confounding despite access to multiple important covariates, and future studies may add valuable information. The observed inverse association of dog ownership and cardiovascular disease previously reported in this population are unlikely to be explained by reduced hypertension and dyslipidaemia.

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Contributors TF conceived the study and acquired funding. MM, AE, EI, JS and LB contributed to the design of the study. TF acquired the national data and PKEM is responsible for the Swedish Twin Registry data. MM performed data cleaning. MM and TF ran statistical analyses. MM drafted the manuscript and all authors reviewed the manuscript.

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Competing interests EI is a scientific advisor for Precision Wellness and Olink Proteomics for work unrelated to the present project.

Patient consent for publication Not required.

Ethics approval The regional ethical review board in Stockholm, Sweden, approved the study (national study: 2012/1114-31/2, with amendment 2013-1687-32; TwinGene: 2007/644-31/2 and 2016/1392-31/1).

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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, Swedish Board of Agriculture and the Swedish Twin Register. 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 upon reasonable request and with permission of the Regional Ethical Review Board in Stockholm, Sweden.

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