

ORIGINAL ARTICLE

# Dog Ownership and Survival

## A Systematic Review and Meta-Analysis

See Editorial by Kazi

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**BACKGROUND:** Dog ownership has been associated with decreased cardiovascular risk. Recent reports have suggested an association of dog companionship with lower blood pressure levels, improved lipid profile, and diminished sympathetic responses to stress. However, it is unclear if dog ownership is associated with improved survival as previous studies have yielded inconsistent results. Thus, we performed a systematic review and meta-analysis to evaluate the association of dog ownership with all-cause mortality, with and without prior cardiovascular disease, and cardiovascular mortality.

**METHODS AND RESULTS:** Studies published between 1950 and May 24, 2019 were identified by searching Embase and PubMed. Observational studies that evaluated baseline dog ownership and subsequent all-cause mortality or cardiovascular mortality. Two independent reviewers extracted the data. We assessed pooled data using random-effects model. A possible limitation was that the analyses were not adjusted for confounders. Ten studies were included yielding data from 3 837 005 participants (530 515 events; mean follow-up 10.1 years). Dog ownership was associated with a 24% risk reduction for all-cause mortality as compared to nonownership (relative risk, 0.76; 95% CI, 0.67–0.86) with 6 studies demonstrating significant reduction in the risk of death. Notably, in individuals with prior coronary events, living in a home with a dog was associated with an even more pronounced risk reduction for all-cause mortality (relative risk, 0.35; 95% CI, 0.17–0.69;  $P$ , 0%). Moreover, when we restricted the analyses to studies evaluating cardiovascular mortality, dog ownership conferred a 31% risk reduction for cardiovascular death (relative risk, 0.69; 95% CI, 0.67–0.71;  $P$ , 5.1%).

**CONCLUSIONS:** Dog ownership is associated with lower risk of death over the long term, which is possibly driven by a reduction in cardiovascular mortality.

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## WHAT IS KNOWN

- Dog ownership has been associated with decreased cardiovascular risk. A series of studies has suggested associations of dog ownership with lower blood pressure levels, improved lipid profile, and diminished sympathetic responses to stress.
- The evidence regarding dog ownership and mortality has yielded conflicting results. Whereas the association between dog ownership and mortality has been explored since the 1980s, living in a home with a dog has been associated with improved survival in some studies with others arguing a neutral effect.

## WHAT THE STUDY ADDS

- Pooling the data of 3837005 participants, dog ownership was associated with a 24% risk reduction for all-cause mortality as compared to non-ownership (relative risk, 0.76; 95% CI, 0.67–0.86).
- In analyses of studies evaluating cardiovascular mortality, dog ownership conferred a 31% risk reduction for cardiovascular death (relative risk, 0.69; 95% CI, 0.67–0.71;  $I^2$ , 5.1%).
- Dog ownership is associated with lower risk of death over the long term, which is possibly driven by a reduction in cardiovascular mortality. These results hold implications for future studies on lifestyle interventions.

**A**nimal companionship, in particular canine, has become increasingly common. Half of the households in the United Kingdom own pets,<sup>1</sup> and the most recent National Pet Owners Survey<sup>2</sup> demonstrated that 68% of US households own a pet, with 48% owning  $\geq 1$  dogs. The recognized health benefits of dog ownership include reduced risk of asthma and allergic rhinitis in children exposed to pets during early ages,<sup>3</sup> improvement in wellbeing and alleviation of social isolation in elderly individuals,<sup>4</sup> and increased physical activity.<sup>5,6</sup> Notably the main positive impact of dog ownership seems to be in relation to cardiovascular risk as a series of studies in recent years have suggested an association of dog ownership with lower blood pressure levels,<sup>7</sup> improved lipid profile,<sup>8</sup> and diminished sympathetic responses to stress.<sup>9</sup> The recognition of potential benefits of the animal-human interaction in cardiovascular disease has been reflected in a scientific statement by the American Heart Association in 2013 which concluded that “dog ownership is probably associated with decreased cardiovascular risk.”<sup>10</sup>

Conversely, the evidence for impact of dog ownership on mortality has been conflicting. Whereas the association between dog ownership and mortality has been explored since the 1980s, living in a home with a dog has been associated with longer survival in some

studies,<sup>11–13</sup> whereas others have reported a neutral effect.<sup>14,15</sup> Because there is a lack of randomized clinical trials evaluating the impact of dog ownership for cardiovascular disease prevention, a robust evaluation of observational data is necessary. Thus, we performed a systematic review and meta-analysis to evaluate the association of dog ownership with all-cause mortality and cardiovascular mortality.

## METHODS

This systematic review and meta-analysis is reported in accordance with the Meta-analysis of Observational Studies in Epidemiology<sup>16</sup> guidelines and was registered at International Prospective Register of Systematic Reviews. The data that support the findings of this study are available from the corresponding author on reasonable request.

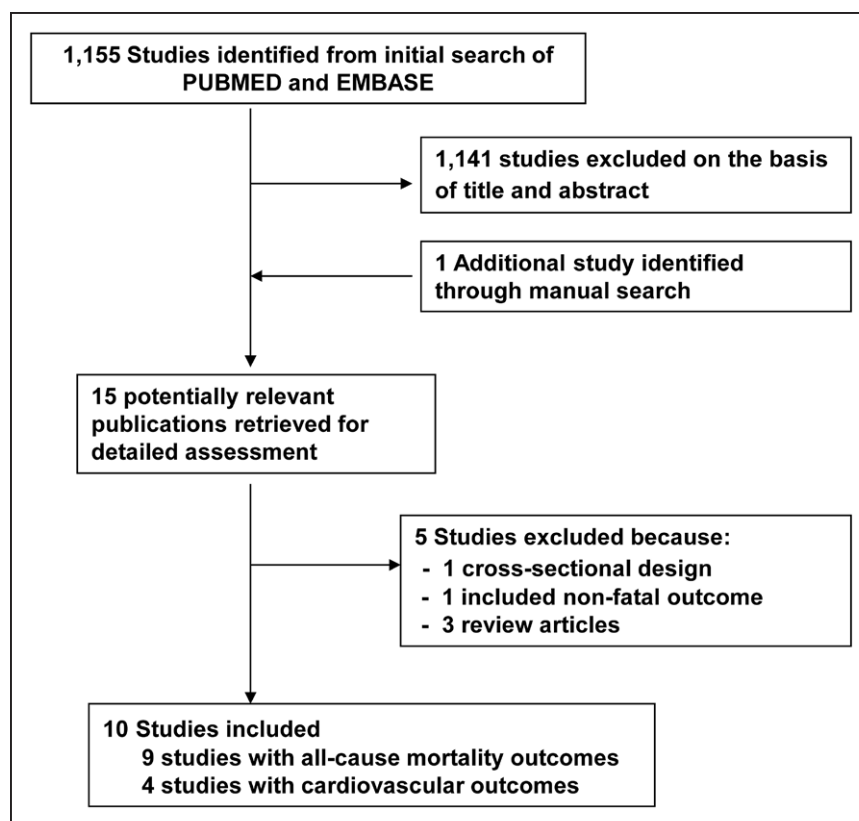
## Search Strategy and Selection Criteria

To perform a systematic review of the published literature, we selected relevant studies published between 1950 and May 24, 2019, by searching Embase and PubMed. We used the combined terms “Dog ownership” or “Pet ownership.” The complete search used for PubMed was (“Dog ownership” OR “Pet ownership” [text]). All potentially eligible studies were considered for review, regardless of the primary outcome or language. A manual search was also performed, using references of key articles published in English (Figure 1).

For this meta-analysis of observational studies evaluating the impact of dog ownership on incident deaths from all-cause or deaths from cardiovascular disease, studies were considered eligible for inclusion if they (1) were conducted in adults aged  $\geq 18$  years; (2) presented original data of prospective observational studies; (3) evaluated dog ownership at baseline; and (4) reported all-cause mortality or cardiovascular mortality. We compared the number of deaths in dog owners (exposed group) to the number of deaths in individuals who do not own dogs (control group). When studies presented data on pet ownership, individuals who do not own pets were considered the control group. Studies reporting data for pet ownership without presenting data for exclusive dog ownership were included if the majority of pet owners consisted of dog owners. Exclusion criteria were as follows: (1) retrospective studies; (2) studies that did not provide any source of absolute number of events in each group; and (3) studies that only reported composite outcome that included cardiovascular nonfatal events.

## Data Extraction and Quality Assessment

Two independent investigators (Dr Kramer and S. Mehmood) reviewed study titles and abstracts, and studies that satisfied the inclusion criteria were retrieved for full-text evaluation. Studies selected for detailed analysis were analyzed by 2 investigators with an agreement value ( $\kappa$ ) of 96.5%, and data extraction was also performed in duplicate. Disagreements were resolved by a third investigator (R. Suen). We extracted the following data from each selected study: total number of participants, mean age, study duration as median or mean follow-up duration as described by each study, percentage of



**Figure 1.** Flow diagram of the literature search to identify observational studies evaluating dog ownership and all-cause/ cardiovascular mortality.

dog owners within the pet owners' population (Table 1),<sup>11–15,17–21</sup> and number of deaths from any reason and cardiovascular deaths in dog owners and non-dog owners. Unadjusted estimates were extracted, enabling inclusion of the maximum number of studies.

The Newcastle-Ottawa Scale for assessing quality of observational studies in meta-analysis was applied (Table 2).<sup>22</sup> The Newcastle-Ottawa Scale contains 8 items, categorized into 3 domains including selection, comparability, and exposure. For each item, a series of response options is provided. A star system is used to enable semiquantitative assessment of study quality, such that the highest quality studies are awarded a maximum of 1 star for each item, with the exception of the comparability domain which allows the assignment of 2 stars. As such, the Newcastle-Ottawa Scale ranges between 0 to 9 stars.<sup>23</sup>

## Data Synthesis and Analysis

An overall relative risk (RR) was calculated to assess the impact of dog ownership in all-cause mortality and cardiovascular mortality. We calculated pooled estimates of the relative risk by using a random-effects model (DerSimonian-Laird method) to adequately account for the additional uncertainty associated with study-to-study variability where each study weight are estimated based on individual study sample sizes and between-study variability. The Cochran Q test was used to evaluate heterogeneity between studies, with threshold  $P < 0.1$  indicating statistically significant heterogeneity. We also evaluated the magnitude of the heterogeneity between studies using  $I^2$  testing, with values  $> 50\%$  considered indicative of high heterogeneity.<sup>24</sup> We explored heterogeneity between studies using 2 strategies. First, we reran the meta-analysis

removing each study one at a time to determine whether a particular study accounted for the heterogeneity. Second, we performed sensitivity analyses to assess subgroups of studies most likely to yield valid estimates of the exposure based on clinically relevant study characteristics such as characteristics of study population (Figure 2)<sup>11–15,17,19–21</sup> and duration of follow-up (Figure 3).<sup>13,15,19–21</sup> In addition, recognizing that dog ownership may impact incident death by mainly affecting cardiovascular death, we performed analyses that were restricted to studies reporting data for fatal cardiovascular events (Figure 4).<sup>13,15,18,19</sup>

Publication bias was assessed by funnel plot of effect size against SE for every study. Funnel plot asymmetry was tested using Harbord-Egger test, with significant publication bias defined by  $P < 0.1$  (Figure I in the [Data Supplement](#)). All analyses were performed using Stata 11.0 (Stata Corp, College Station, TX).

## Role of Funding Source

The study was supported by intramural funds, with no commercial entity involved. The funding source had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author (Dr Kramer) had full access to all the data in the study and had final responsibility for the decision to submit for publication.

## RESULTS

We identified 1155 studies through electronic searches and 1 study by manual search. Of these, 1141 were

**Table 1. Characteristics of the Included Studies**

Author, Year	Country	Sample Size	Population	Age (y)	Duration of Follow-Up (y)	% Dog Owners Among Pet Owners/ Overall	Mortality Outcome (No. of Events)	Male (%)
Friedmann et al, <sup>11</sup> 1980	United States	92	Participants postacute coronary syndrome	NA	1*	100/43.4	All-cause (14)	69.5
Friedmann et al, <sup>12</sup> 1995	United States	396	Participants postmyocardial infarction enrolled in cardiac arrhythmia trials	62.8	1*	100/21.9	All-cause (20)	85.1
Gillum et al, <sup>14</sup> 2010	United States	5903	Participants of the NHANES III study older than 40	>40	8.5†	100/10.9	All-cause (1624)	46
Friedmann et al, <sup>17</sup> 2011	Australia, Canada, New Zealand, and United States	460	Participants postmyocardial infarction enrolled in a trial evaluating the impact of automated external defibrillator	61.0	2.8*	60/34.6	All-cause (17)	85.2
Ogechi et al, <sup>18</sup> 2016	United States	3964	Participants of the NHANES III study without major illness	63.1	12.8†	100/22	Cardiovascular (671)	47.5
Chowdhury et al, <sup>13</sup> 2017	Australia	6083	Elderly hypertensive individuals	71.6	10.9‡	60/21.6	All-cause (958) and cardiovascular (499)	49.5
Mubanga et al, <sup>19</sup> 2017	Sweden	3432 153	Swedish residents	57	12.0*	100/13.1	All-cause (502 896) and cardiovascular (76 106)	47.7
Torske et al, <sup>20</sup> 2017	Norway	53 418	Participants of the HUNT study	50.3	18.5‡	100/20	All-cause (12 698)	53.9
Ding et al, <sup>15</sup> 2018	England	59 352	English National Death Registry	46.5	11.5†	100/28.8	All-cause (8169) and cardiovascular (2451)	45.5
Sorensen et al, <sup>21</sup> 2018	Denmark	275 184	Danish National Registry	76.6	22*	100/8	All-cause (45 864)	49.8

HUNT indicates The Nord-Trøndelag Health Study; NA, not available; and NHANES, National Health and Nutrition Examination Survey.

\*Total.

†Mean.

‡Median duration of follow-up.

excluded on the basis of title and abstract, leaving 15 studies for further assessment (Figure 1). Ten studies met our inclusion criteria<sup>11–15,17–21</sup> and were included in the analysis, providing data on 3837005 participants (530515 deaths; mean duration of follow-up ranging from 1 to 22 years). Table 1 summarizes the included studies, which were published from 1980 to 2018. The mean study-specific duration of follow-up varied from 1.0 to 22.0 years. Table 2 demonstrates study quality. In accordance with the Newcastle-Ottawa Scale quality assessment scale for cohort studies, the majority of studies achieved at least 7 stars, indicative of overall good quality. However, these observational studies received 1 star for comparability as the study population was not controlled for additional confounders.

In the main analyses (n=3833041 participants), dog ownership was associated with a 24% risk reduction for all-cause mortality as compared to non-dog ownership (RR, 0.76; 95% CI, 0.67–0.86; Figure 2).<sup>11–15,17,19–21</sup> This association was significant in the context of population-based studies (RR, 0.78; 95% CI, 0.68–0.88) as well as

in the context of individuals with prior coronary events (RR, 0.35; 95% CI, 0.17–0.69; Figure 2).<sup>11–15,17,19–21</sup> In the overall analyses, 6 studies demonstrated significant decrease in the risk of death associated with dog ownership. However, there was significant heterogeneity in the individual estimates of the magnitude of the association ( $I^2=97.6\%$ ,  $P<0.001$ ). There was no evidence of publication bias on Harbord-Egger test ( $P=0.94$ ; Figure I in the [Data Supplement](#)). In an attempt to explore the heterogeneity between studies, we reran the meta-analysis removing each study one at a time but found that no particular study accounted for the heterogeneity. In addition, subgroup analyses excluding the studies with the shortest duration of follow-up (<10 years) which excluded the 3 studies that evaluated participants with previous cardiovascular events confirmed the results but did not eliminate the heterogeneity (Figure 3).<sup>13,15,19–21</sup> Noteworthy, the high heterogeneity was eliminated in the analyses restricted to studies evaluating individuals with prior cardiovascular disease ( $I^2=0\%$ ,  $P=0.52$ ; Figure 2)<sup>11–15,17,19–21</sup> and in the meta-analyses of cardiovascular events described below.

**Table 2.** Newcastle-Ottawa Quality Assessment Scale for Cohort Studies

Study Reference (Author, Year)	Selection (0–4 Stars)	Comparability (0–2 Stars)	Outcome (0–3 Stars)
Friedmann et al, <sup>11</sup> 1980	***	*	***
Friedmann et al, <sup>12</sup> 1995	***	*	***
Gillum et al, <sup>14</sup> 2010	****	*	***
Friedmann et al, <sup>17</sup> 2011	***	*	***
Ogechi et al, <sup>18</sup> 2016	****	*	***
Chowdhury et al, <sup>13</sup> 2017	****	*	***
Mubanga et al, <sup>19</sup> 2017	****	*	***
Torske et al, <sup>20</sup> 2017	****	*	***
Ding et al, <sup>15</sup> 2018	****	*	***
Sorensen et al, <sup>21</sup> 2018	****	*	***

To evaluate the impact of dog ownership on the risk of death in the setting of cardiovascular disease, we performed analyses including only the 4 studies<sup>13,15,18,19</sup> that reported data on fatal cardiovascular events and demonstrated that dog ownership conferred a 31% risk reduction for death due to cardiovascular disease as compared to non-dog ownership (RR, 0.69; 95% CI, 0.67–0.71) with no significant heterogeneity ( $I^2$  5.1%; Figure 4).<sup>13,15,18,19</sup>

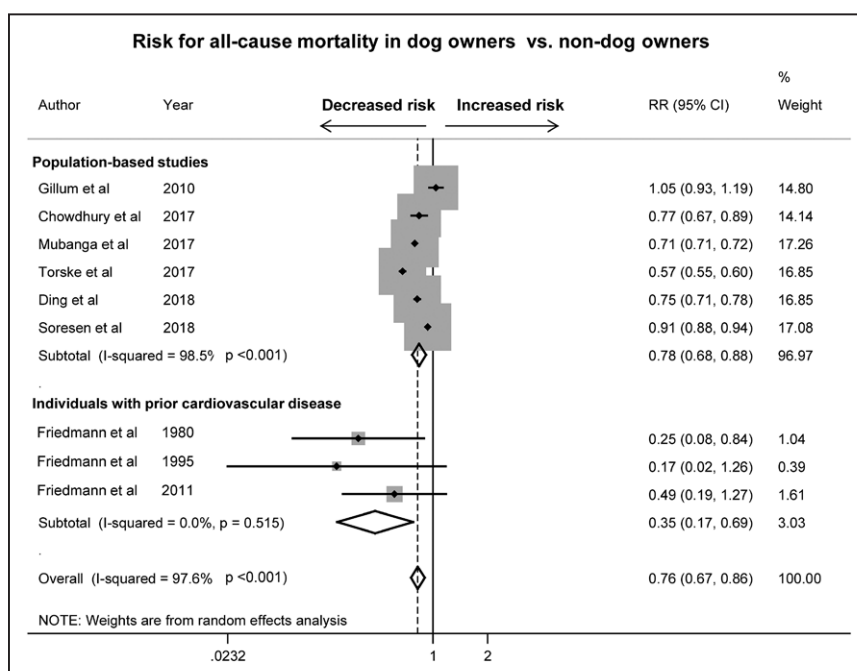
## DISCUSSION

In this meta-analysis involving over 3 million participants, we demonstrate that dog ownership is associated with a 24% risk reduction in overall mortality over long-term follow-up. Importantly, the risk reduction of mortality conferred by dog companionship is pos-

sibly driven by a reduction in cardiovascular death as observed in our results restricted to participants post-acute coronary syndrome (65% risk reduction) and data exclusive to cardiovascular mortality (31% risk reduction).

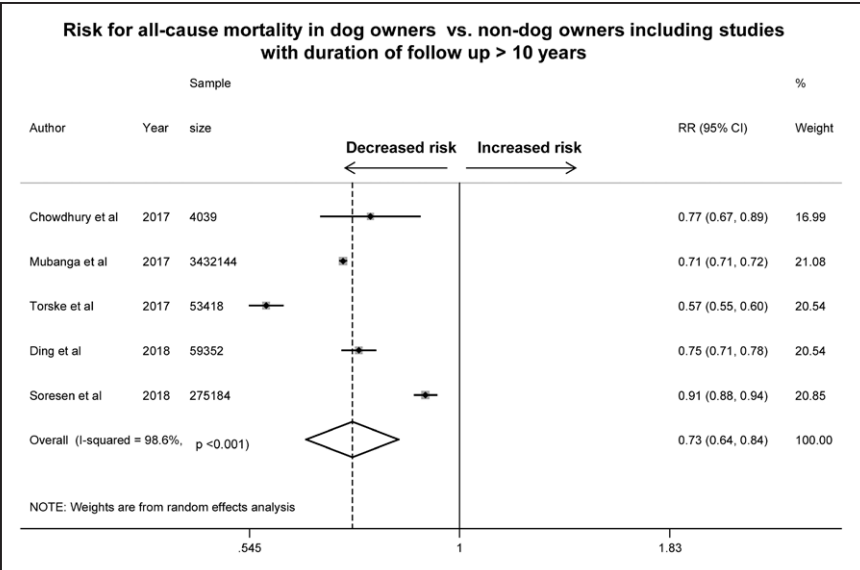
The results of our meta-analyses are consistent with previous reports demonstrating an association between dog ownership and lower cardiovascular risk.<sup>7–9</sup> Specifically, an Australian epidemiological study of 5741 participants found that dog owners had lower systolic blood pressure, reaching 2 mmHg difference, and plasma triglycerides as compared to nondog owners.<sup>8</sup> Notably, this association was independent of smoking status, diet, body mass index, or socioeconomic status.<sup>8</sup> Similar association was demonstrated in the Rancho Bernardo Study, a community-based cohort study, although the significance of this association did not persist after adjustment for age, sex, body mass index, beta-blocker use, exercise, and use of antihypertensives.<sup>7</sup> In another report, a cross-sectional survey of 916 individuals, dog owners who walked their dogs were less likely to report dyslipidemia and diabetes mellitus than non-dog owners.<sup>25</sup> In parallel to these findings, previous reports also demonstrated a beneficial association between pet ownership and autonomic function or cardiovascular reactivity to stress, with lower resting heart rate and blunted blood pressure responses to stress observed in pet owners as compared to non-pet owners.<sup>9,26</sup>

Although there is a lack of randomized clinical trials evaluating the impact of dog companionship on cardiovascular risk factors and cardiovascular reactivity over long term follow-up, short-term interventional studies have yielded positive results. An interventional study of 48 hypertensive individuals randomized to acquire a pet

**Figure 2.** Meta-analysis of the association between dog ownership and the risk of all-cause mortality.<sup>11–15,17–21</sup>

$I^2$  is a measure of heterogeneity between studies, where  $I^2 > 50\%$  indicates significant heterogeneity. RR indicates relative risk.





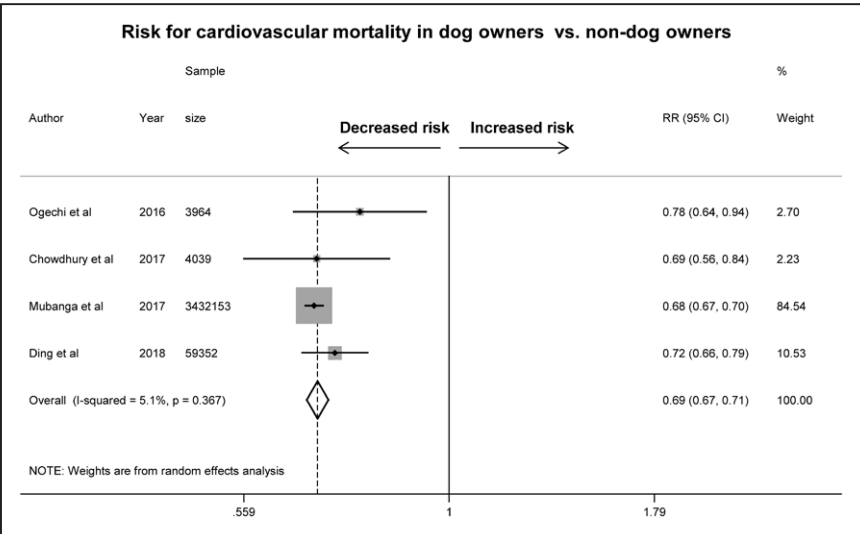
**Figure 3. Meta-analysis of the association between dog ownership and the risk of all-cause mortality.**<sup>13,15,19-21</sup>  
*I*<sup>2</sup> is a measure of heterogeneity between studies, where *I*<sup>2</sup> > 50% indicates significant heterogeneity. RR indicates relative risk.

demonstrated a diminished response to mental stress at 6 months in pet owners as compared to non-pet owners.<sup>27</sup> In addition, among dog owners, the act of petting a dog has been observed to lower blood pressure levels as compared to other activities,<sup>28</sup> supporting the positive impact of dog companionship in reducing cardiovascular reactivity. The acute effect of living with a dog on cardiovascular responses to stress may be particularly relevant for individuals post-acute ischemic heart events. In this context, the results of these previous studies are consistent with the 65% risk reduction for mortality conferred by dog ownership following myocardial infarction and 31% risk reduction of cardiovascular mortality observed in our analyses.

A possible mechanism for the longer survival associated with dog ownership is through augmented physical activity provided by dog walking. A meta-analysis of 11 studies demonstrated that dog owners walk significantly more and are more likely to achieve the

recommended level of physical activity than nonowners.<sup>5</sup> Reinforcing these findings, 2 reports noted an increase in self-reported physical activity after adopting a dog.<sup>29,30</sup> In addition, having a dog was shown to support maintenance of physical activity in older English adults during poor weather.<sup>31</sup> The importance of attaining the recommended level of physical activity for overall health is highlighted by a recent worldwide report from 17 countries, including 130843 middle-age participants without preexisting cardiovascular disease.<sup>32</sup> In that study, higher recreational and nonrecreational physical activity was associated with a lower risk of mortality and cardiovascular events, suggesting that increasing physical activity is a simple, widely applicable, low-cost global strategy that could reduce deaths and cardiovascular events.

Our meta-analysis suggests that dog ownership warrants further investigation as a lifestyle intervention given the positive association with longer survival.



**Figure 4. Meta-analysis of the association between dog ownership and the risk of cardiovascular mortality.**<sup>13,15,18,19</sup>  
*I*<sup>2</sup> is a measure of heterogeneity between studies, where *I*<sup>2</sup> > 50% indicates significant heterogeneity. RR indicates relative risk.

Randomized controlled trials evaluating the impact of dog ownership on mortality are needed. In particular, future interventional studies assessing the adoption of a dog by individuals at higher risk for cardiovascular events should be considered. Likewise, additional health benefits of dog companionship, such as positive social-psychological effects, should be taken into consideration as dog ownership can be particularly beneficial for specific populations such as single elderly individuals.<sup>6</sup>

A limitation of our meta-analysis is that it was not possible to perform an analysis adjusted for confounders of the association between dog ownership and the outcomes. Other factors, such as socioeconomic and overall health status, could interfere with the mortality estimates. For instance, individuals with higher socioeconomic status, better physical fitness, and healthier lifestyle (such as not smoking or drinking alcohol) could be more likely to own a dog such that the impact of dog ownership in reducing risk of death may partially be representative of an overall lifestyle profile. Finally, we recognize that publication bias and the quality limitations of individual studies may still be relevant, despite our best efforts to conduct a comprehensive search and the lack of statistical evidence of bias.

In conclusion, our findings demonstrate that dog ownership is associated with reduced all-cause mortality possibly driven by a reduction in cardiovascular mortality. Taken together, our meta-analysis suggests the need for further investigation of the potential for dog ownership as a lifestyle intervention that may offer significant health benefits, particularly in populations at high-risk for cardiovascular death.

## ARTICLE INFORMATION

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## Disclosures

Dr Kramer reports grants from Boehringer Ingelheim, outside the submitted work, and is a proud dog owner. The other authors report no conflicts.

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