Medical Science

http://www.aimspress.com/journal/medicalScience

Review

Dog ownership: is it beneficial for physical activity, cardiovascular disease, and diabetes?

Hidetaka Hamasaki*

Hamasaki Clinic, Kagoshima, Japan

* **Correspondence:** Email: h-hamasaki@umin.ac.jp; Tel: +81992503535; Fax: +81992501470.

Abstract: Dog ownership has been shown to have significant health benefits for humans, being associated with an improvement in hypertension, hyperlipidemia, cardiovascular disease, and psychosocial function. Recent systematic reviews have shown that dog ownership is also associated with increased physical activity and reduced mortality. However, the association between dog ownership and diabetes remains unclear. This review summarizes current evidence regarding the associations between dog ownership and physical activity, cardiovascular disease, and diabetes and evaluates the role of dogs in managing diabetes by considering the efficacy and reliability of hypoglycemia alert dogs for identifying hypoglycemia. Previous studies have suggested that hypoglycemia alert dogs are not as reliable as advanced glucose monitoring devices. Furthermore, the benefits of dog ownership in terms of glycemic control in patients with diabetes remains controversial, with little published literature pertaining to this topic. However, it appears that the association between dog ownership and glycemic control may differ among age groups and the form of diabetes (i.e., type 1 vs. type 2). Therefore, further longitudinal studies are required to clarify the effect of dog ownership on the management of this disease.

Keywords: dog ownership; dog walking; physical activity; diabetes; cardiovascular disease; hypoglycemia alert dogs

---

1. Introduction

The relationship between humans and dogs is special. Genetic research suggests that dogs originated more than 100,000 years ago and domestic dogs have a long history [1]. 38.4% of households in the United States owned dogs in 2018 [2].

The American College of Sports Medicine and the American Diabetes Association have recommended that patients with type 2 diabetes (T2D) have at least 150 min of moderate- to vigorous-intensity physical activity (MVPA) per week [3]. Dog ownership is considered to increase daily physical activity [4], and according to the Compendium of Physical Activities by the American College of Sports Medicine [5], the physical activity intensity of walking a dog is 3.0 metabolic equivalents (METs), which comprises an important part of non-exercise activity thermogenesis (NEAT) in dog owners (Figure 1), which is essential for managing obesity and T2D [6].
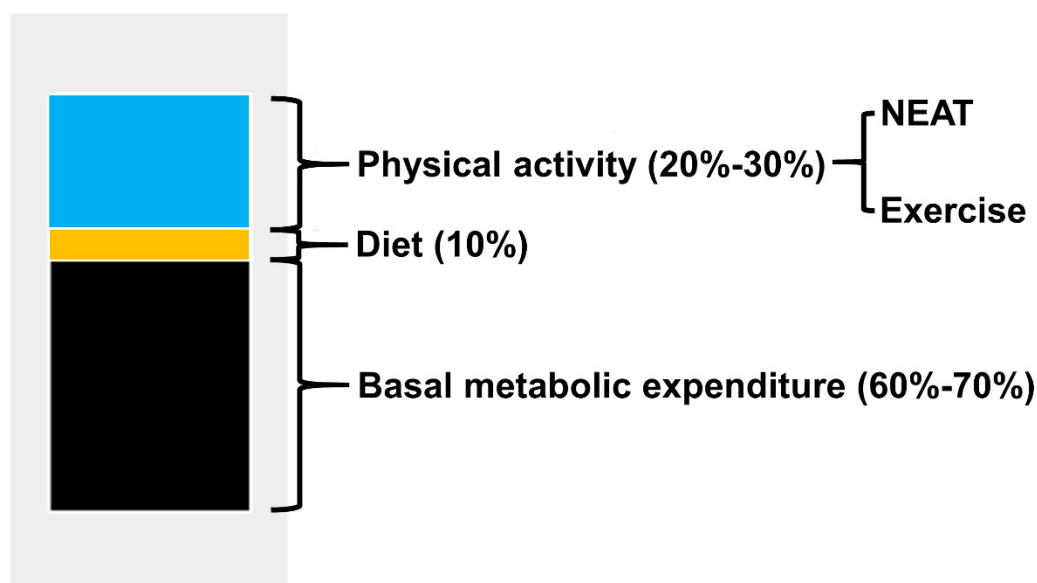

Figure 1. Components of daily energy expenditure in humans. NEAT: Non-exercise activity thermogenesis.

The Health, Aging and Body Composition (Health ABC) study found that dog owners engaged in non-exercise walking more frequently than non-dog owners but there was no difference in sports-like physical activity between the two groups [7]. Dog walking has the potential to improve metabolic disturbances such as diabetes.

Previous studies have shown that dog ownership is associated with an improvement in hypertension, hyperlipidemia, and cardiovascular disease [8], with dog owners exhibiting higher cardiovascular health scores in terms of physical activity, diet, and blood glucose levels than non-dog owners [9]. Recent studies have also indicated that dog ownership improves feelings of happiness [10], social function [11], and sleep [12,13]. Thus, dog ownership and dog walking appear to be beneficial for both physical and mental health. However, the association between dog ownership and diabetes has yet to be fully clarified. The aim of this review is to summarize the effect of dog ownership on physical activity, cardiovascular disease, and mortality and to review current evidence for the association between dog ownership and diabetes.

2. Methods

This is a narrative review searching the current evidence on the association between dog ownership and physical activity, cardiovascular disease, and diabetes. The author searched the literature on dog ownership using PubMed from its inception to May 2020. The search terms were "dog ownership," "dog walking," "physical activity," "cardiovascular disease," and "diabetes." First, the author conducted a search in the association between dog ownership and physical activity, which yielded 149 published articles. Second, the author searched in the association between dog ownership and cardiovascular disease, and this yielded 40 articles. Finally, the author searched in the association between dog ownership and diabetes, and this yielded 25 articles. The titles and abstracts of the identified articles were reviewed to determine their relevance. A total of 30 articles were included.

3. Dog ownership and daily physical activity

Soares et al. [14] previously reviewed eight cross-sectional studies and one prospective cohort study conducted between 1990 and 2012 to investigate the effect of dog walking on daily physical activity. They found that 60.7% of dog owners who usually walked their dogs achieved the recommended level of physical activity and that the odds ratio (OR) of achieving 150 min per week of physical activity for dog walkers vs. non-dog walkers was 2.74 (95% confidential interval (CI), 2.09–3.60). In another comprehensive review of 24 cross-sectional studies, 3 observational studies, 3 qualitative studies, and 1 randomized controlled trial providing evidence for specific correlates with dog walking, Westgarth et al. [15] suggested that dog walking may be most effectively encouraged by targeting the dog–owner relationship to increase the owner's responsibility and motivation and by providing dog-supportive physical environments. Similarly, a critical realist review showed that the physical activity level of not only dog owners but also non-dog owners could be effectively increased by providing neighborhood social cohesion, a sense of safety, and a social environment [16].

These reviews clearly show that improvement of the physical and social environment as well as a positive relationship between dog owners and their dogs is critical to increasing physical activity (Figure 2).

However, there are some limitations to the studies conducted to date. Firstly, most studies have been cross-sectional or observational, with few intervention studies examining the effect of dog ownership on human health. One randomized controlled trial showed that a dog walking intervention group significantly increased their step count by 1,823 steps compared with a control group 12 weeks after an intervention using messages about increasing canine exercise [17]; however, the sample size was small, study participants were not supervised, and physical activity levels were self-reported, reducing the strength of the evidence. Secondly, in the vast majority of studies, physical activity (intensity, duration, and frequency) has not been objectively measured, which should be achieved through the use of wearable devices such as accelerometers [18]. However, this limitation will be resolved by the development of information technology in the future.

Figure 2. Influential factors for increasing physical activity in dog owners.

Several recent studies have been undertaken that have not been included in previous reviews. Salmon et al. [19] investigated cross-sectional associations between dog ownership and physical activity in children aged 5–6 and 10–12 years and their parents. The children's physical activity was measured using a uniaxial accelerometer, while the parents' physical activity was evaluated by a self-reported questionnaire. The authors found that dog ownership was positively associated with MVPA in younger girls, who exhibited an additional 29.3 min of MVPA per day than non-dog owners. Dog ownership was also associated with an increase in frequency of walking in children, with older girls who owned a dog walking more often (1.5 sessions per week) than non-dog owners. In addition, mothers and fathers who owned dogs also spent more time (90–158 min per week) in physical activity, and mothers of older girls who owned a dog had 1.62 higher odds of achieving the physical activity guideline recommendations compared with those who did not own a dog. Christian et al. [20] also undertook a cross-sectional analysis of physical activity in children aged 10–12 years who had a family dog, in which the frequency and duration of MVPA and sports-like activities by the children were self-reported by their parents and the children's step counts were measured by a pedometer. These authors similarly found that children who owned dogs went for a walk (OR = 3.55; 95% CI, 2.56–4.91) and played in the street (OR = 2.02; 95% CI, 1.48–2.76) and outside in the yard (OR =

1.97; 95% CI, 1.23–3.13) more frequently than non-dog owners. Furthermore, children who walked with their dogs showed higher independent mobility than those who did not.

By contrast, the effect of dog ownership on accelerometer-measured MVPA in adolescents (aged 12–17 years) is controversial. Engelberg et al. [21] reported that adolescents who walked their dogs had 4–5 more min of MVPA per day than non-dog owners, and Sirard et al. [22] found that adolescent dog owners spent more time in MVPA than non-dog owners (32.1 vs. 29.5 min per day, respectively). However, the significant association observed in the latter study disappeared once adjustments had been made for potential confounders such as age, gender, and ethnicity.

The effect of dog ownership on daily physical activity may differ among age groups; children, adolescents, adults, and older adults. In postmenopausal women, dog ownership was associated with a 14% higher likelihood of walking ≥150 min per week and a 14% lower likelihood of being sedentary than non-dog ownership [23]. In addition, older dog owners (mean age of 79 years) had a 12% higher level of physical activity measured using a triaxial accelerometer than non-dog owners [24], indicating that dog ownership is also effective for increasing daily physical activity in the elderly. Importantly, Wasenius et al. [25] found that dog ownership after age 40 was significantly associated with leisure-time physical activity (LTPA) in later life. In this study, the authors evaluated participants' NEAT (e.g., housework, working, and gardening) and volitional LTPA (e.g., running, cycling, and swimming) using questionnaires and found that current dog owners had a higher amount of LTPA than non-dog owners (mean difference = 14.7 MET-hours per week) after adjusting for age, sex, body mass index (BMI), chronic disease, and socioeconomic status. Intriguingly, dog ownership after the age of 40 was also associated with a higher NEAT (mean difference = 15.6 MET-hours per week) after adjusting for confounding factors. This increase in daily physical activity corresponds to approximately 300 min of light- to moderate- intensity-physical activity (3 METs), which meets the recommended level of physical activity.

Two longitudinal studies have also been conducted recently to investigate whether owning a dog influences owners' daily physical activity. Dall et al. [26] showed that dog owners walked 2,762 steps further and for 23 min longer and had eight fewer sedentary events per day than non-dog owners. Similarly, Potter et al. [27] showed that fostering a dog for 6 weeks as an alternative to dog ownership increased the number of steps by 119.1 ± 2457.8 steps per day and the time spent in MVPA by 12.7 ± 20.9 min per day and decreased sedentary time by 49.8 ± 41.1 min per day compared with baseline levels. In addition, 73% of the study participants continued to own their dog after the foster period, which reduced their depressive symptoms and perceived stress.

Thus, although there have been no well-designed, large-scale, randomized controlled clinical trials to date investigating the effect of dog ownership on daily physical activity, reliable and high-quality evidence is accumulating. Table 1 summarizes these studies assessing the association between dog ownership and physical activity.

Table 1. Association between dog ownership and physical activity.

Authors, year	Study design	Subjects	Results
Soares et al., 2016 [14]	Systematic review with meta-analysis	6,980 dog owners aged 18–81 years Age: Mean values are not reported. Sex (male/female): 41%/59%	4,463 dog owners walked their dogs. Total weekly PA: 210 min to 410 min. 2,710 dog owners met the recommended level of PA. OR of achieving 150 min per week of PA: 2.74 (95% CI, 2.09–3.60).
Rhodes et al., 2012 [17]	Randomized controlled trial	58 inactive dog owners (30 individuals were allocated to the intervention group and 28 individuals were allocated to the control group) Age: 48.69 ± 13.18 years Sex (male/female): 6/52	Self-reported PA increased. Dog walking group increased their step count by 1,823 step/day compared with a control group.
Salmon et al., 2010 [19]	Cross-sectional study	1,151 children, 1,152 mothers, and 957 fathers who are dog owners Age: 39.8 ± 5.5 years Sex (male/female): 16%/84%	Dog ownership and dog walking among children increased regular PA among families.
Christian et al., 2014 [20]	Cross-sectional study	403 dog walkers and 324 non-dog walkers Age: 11.0 ± 0.8 years Sex (male/female): 48%/52%	Dog walkers went for a walk (OR = 3.55; 95% CI, 2.56–4.91), played in the street (OR = 2.02; 95% CI, 1.48–2.76) and outside in the yard (OR = 1.97; 95% CI, 1.23–3.13) more frequently than non-dog walkers.

Authors, year	Study design	Subjects	Results
Engelberg et al., [21]	Cross-sectional study	300 dog owners who walk their dog ≥1 day/week, 184 dog owners who do not walk their dog, and 441 non-dog owners Age: 14.09 ± 1.40 years Sex (male/female): 49.6%/50.4%	Dog walkers had 4–5 more min of MVPA per day than non-dog owners.
Sirard et al., 2011 [22]	Cross-sectional study	323 dog owners and 295 non-dog owners Age: 14.6 ± 1.8 years Sex (male/female): 49%/51%	Dog owners spent more time in MVPA than non-dog owners (32.1 vs. 29.5 min per day, respectively).
Garcia et al., 2015 [23]	Cross-sectional study	152,629 postmenopausal women (36,984 dog owners and 115,645 non-dog owners) Age: 61.5 years and 63.9 years, respectively	Dog owners had a higher likelihood of walking ≥150 min/week (OR = 1.14; 95%CI, 1.10–1.17), a lower likelihood of being sedentary ≥8 h/day (OR = 0.86; 95% CI, 0.83–0.89).
Feng et al., 2014 [24]	Cross-sectional study	547 older adults (50 dog owners and 497 non-dog owners) Age: 79 ± 8 years Sex (male/female): 46%/54%	Dog owners had a 12% higher level of PA.
Wasenius et al, 2018 [25]	Cross-sectional study	379 individuals who had a dog during their lifetime and 335 individuals who did not have a dog Age: 70.8 ± 2.6 years Sex (male/female): 42%/58% BMI: 27.0 ± 4.6 kg/m^2	Current dog ownership was associated with a higher LTPA by 15.2 MET-hours/week.

Authors, year	Study design	Subjects	Results
Dall et al., 2017 [26]	Case-controlled study	43 dog owners and 43 non-dog owners Age: 69.9 ± 4.1 years and 70.2 ± 4.1 years, respectively Sex (male/female): 16/27 and 16/27, respectively BMI: 25.4 ± 4.3 kg/m^2 and 25.8 ± 3.7 kg/m^2, respectively	Dog owners walked 2,762 steps further and for 23 min longer and had eight fewer sedentary events per day than non-dog owners.
Potter at al., 2019 [27]	Before-after study	12 female non-dog owners Age: 37.8 ± 16.3 years	Dog ownership increased the number of steps by 119.1 ± 2457.8 steps/day, the time spent in MVPA by 12.7 ± 20.9 min/day, and decreased sedentary time by 49.8 ± 41.1 min/day.

BMI: body mass index; PA: physical activity; MVPA: moderate- to vigorous-intensity physical activity; LTPA: light intensity physical activity; MET: metabolic equivalents; OR: odds ratio; CI: confidential interval. Values are means ± standard deviations.

4. Dog ownership, cardiovascular disease, and mortality

Two systematic reviews assessing the association between dog ownership and mortality have previously been published, which show remarkably different results. Kramer et al. [28] evaluated the association between dog ownership and all-cause mortality and cardiovascular mortality by reviewing 10 eligible prospective observational studies. They found that dog ownership was associated with a reduced risk of all-cause mortality [relative risk (RR) = 0.76; 95% CI, 0.67–0.86] compared with non-dog ownership, with six of the studies [29–34] demonstrating a significant risk reduction, and that this risk reduction was more significant in individuals with prior coronary artery disease (RR = 0.35; 95% CI, 0.17–0.69). In addition, an analysis of four studies on cardiovascular mortality [30–32,35] showed that dog ownership was associated with a reduced risk of cardiovascular death (RR = 0.69; 95% CI, 0.67–0.71) with no significant heterogeneity. Therefore, the authors concluded that dog ownership was associated with a reduced risk of all-cause mortality, which might be enhanced by a reduction in the risk of cardiovascular mortality.

By contrast, a systematic review and meta-analysis by El-Qushayri et al. [36], which included 26 studies with no restrictions on study design, showed that while pet and cat ownership were associated with a reduced risk of cardiovascular mortality (hazard ratios = 0.73; 95% CI, 0.62–0.87 and 0.79; 95% CI, 0.63–0.99, respectively), dog ownership was not significantly associated with all-cause or cardiovascular mortality based on an analysis of five and six studies, respectively [30–33,35,37].

The inconsistency of these findings may be related to the difference in the inclusion criteria for eligible studies between these systematic reviews and meta-analyses.

Most recently, Krittanawong et al. [38] showed that dog ownership is associated with a lower risk of systemic hypertension (OR = 0.73; 95% CI, 0.55–0.95) but is not associated with the risk of heart failure, coronary artery disease, diabetes, stroke, or cardiovascular events. Thus, there have been conflicting data regarding the association between dog ownership and cardiovascular risks. It should be noted, however, that dog ownership is expected to have health benefits, as an improvement in mood and emotional state as well as increased daily physical activity decrease autonomic nervous activity, improve endothelial function, and lower blood pressure [39] through an as yet undetermined mechanism, which could reduce the risk of cardiovascular disease. Table 2 summarizes these studies investigating the association between dog ownership and cardiovascular disease.

Table 2. Association between dog ownership and cardiovascular disease.

Authors, year	Study design	Subjects	Results
Kramer et al., 2019 [28]	Systematic review with meta-analysis	3,837,005 from 10 observational studies Age: Mean values are not reported. Sex (male/female): Not reported	Dog ownership was associated with a 24% and 31% risk reduction for all-cause mortality and cardiovascular death, respectively.
El-Qushayri et al., 2020 [36]	Systematic review with meta-analysis	14 cohort studies, 8 cross-sectional studies and 4 clinical trials (total number of subjects were not reported) Age: Not reported Sex (male/female): Not reported	No significant association between dog ownership and all-cause or cardiovascular mortality
Krittanawong et al., 2020 [38]	Prospective cohort study	4,577 pet owners and 6,328 non-pet owners Age: 28.2 ± 22.5 years and 27.9 ± 25.0 years, respectively Sex (male/female): 43.9%/56.1% and 50.6%/49.4%, respectively BMI: 25.1 ± 7.7 kg/m^2 and 25.1 ± 7.5 kg/m^2, respectively	Dog ownership was associated with a lower risk of systemic hypertension (OR = 0.73; 95% CI, 0.55–0.95).

OR: odds ratio; CI: confidential interval; BMI: body mass index. Values are means ± standard deviations.

5. Dog ownership and diabetes

Dog ownership appears to bring a range of health benefits, but is it beneficial for patients with diabetes? A qualitative analysis has suggested that promoting dog walking in patients with T2D is

beneficial for improving their lifestyle [40], but the magnitude of the effect of dog walking on the health status of patients with diabetes remains unknown. Therefore, this section reviews current evidence for the association between dog ownership and benefits in the following areas: (1) hypoglycemia or diabetes alert dogs (DADs) and (2) glycemic control.

5.1. Hypoglycemia alert dogs

Dogs may be able to detect cancer, seizures, and hypoglycemia by using their olfactory, auditory, and visual senses [41,42]. In an online survey of 36 DAD owners to assess the accuracy of detecting hypoglycemia and the change in glycemic control, Gonder-Frederick et al. [43] found that 91.7% of study subjects reported that their DADs alerted them when their blood glucose levels were between 3.3 and 3.9 mmol/l and that the frequency of hypoglycemia and hemoglobin A1c (HbA1c) levels decreased after DAD placement. Furthermore, the patients' anxiety about hypoglycemia, quality of life, and ability to engage in physical activity were also improved. The calculated sensitivity and specificity for detecting hypoglycemia in DADs based on data from this study were 56% and 53%, respectively [44]. However, since this study was a self-reported online survey, it had a number of limitations, including around data correctness and biases.

Rooney et al. [45] interviewed 17 patients with type 1 diabetes (T1D) to investigate whether trained DADs were reliable for detecting hypoglycemia and their owners received health benefits. They found that the majority of patients reported a favorable effect of their DADs on the frequency of hypoglycemia, glycemic control, and quality of life. The calculated sensitivity for identifying hypoglycemia based on data from this study was 80% [44]. However, similar to the study by Gonder-Frederick et al. [43], this study was also a small-scale, interview survey that used self-reported data, so the study outcomes may have been affected by various biases.

To reduce the possibility of trainer bias, Hardin et al. [46] evaluated six DADs that had received standard training for 6 months using perspiration samples from patients with T1D and positive reinforcement methods. They found that the sensitivity and specificity of the DADs for detecting hypoglycemic samples were 50–87.5% and 89.6–97.9%, respectively.

To test the accuracy of a DADs' ability to detect hypoglycemia, it is necessary to objectively measure glucose levels rather than use self-reported glucose values. Continuous glucose monitoring (CGM) devices can show the ambulatory glucose profiles of patients with diabetes, and Gonder-Frederick et al. [47] assessed the accuracy of DAD alerts by comparing them with the ambulatory glucose profiles of 14 patients with T1D who had owned DADs for more than 6 months. They found that the overall (i.e., both hyperglycemia and hypoglycemia) sensitivity, specificity, and positive predictive value of the DAD alerts were 29.1%, 65.5%, and 61.5%, respectively, during waking hours and 10.9%, 83.0%, and 68.9%, respectively, during sleeping hours. In particular, the hypoglycemia sensitivity was 35.9% during waking hours and 22.2% during sleeping hours. However, the accuracy of the DADs was highly variable depending on the individual dog. Thus, this study did not support the hypothesis that DADs were as reliable as glucose monitoring devices for detecting hypoglycemia.

In another study that used CGM to examine the reliability of DADs for alerting hypoglycemia in eight patients with T1D who experienced 45 episodes of hypoglycemia during the study period [48], the DADs gave alerts 3.2 times more frequently during hypoglycemia than during euglycemia. However, the sensitivity and positive predictive value of the DADs were only 36% and

12%, respectively, and the false positive rate was high (14.5), indicating that DADs were not helpful for differentiating between hypoglycemia, euglycemia, and hyperglycemia. By contrast, the CGM device alerted the patient before the DADs in 73% of hypoglycemic events (median difference = 22 min). Based on the results of this study, Gonder-Frederick et al. [49] reexamined the accuracy and variability of DADs in a real-world setting and found that although individual DAD performance was highly variable, the total sensitivity, specificity, true positive rate, and positive likelihood ratio were 57.0%, 49.3%, 69.1%, and 1.12, respectively, leading to the conclusion that DADs may be able to detect hyperglycemia and/or hypoglycemia but were not more accurate than glucose monitoring devices.

Rooney et al. [50] also assessed the reliability of DADs for responding to hyperglycemia and hypoglycemia (out-of-range glucose levels) and raised the following three concerns regarding a previous report [48]: (1) alerting hyperglycemia should not be classified as incorrect; (2) the performance of individual DADs should be considered; and (3) DADs will alert when blood glucose levels fall rapidly even though they are within the normal range, and this pre-alert phenomenon is important. In this study, a total of 27 DADs that had been adequately trained by a single accredited agency were assessed. These DADs had a median sensitivity to out-of-range glycemia of 70% and a median sensitivity to hypoglycemia and hyperglycemia and a positive predictive value of 83% (66–94%), 67% (17–91%), and 81%, respectively. Each individual DAD's performance was influenced by the characteristics of the dog, the partnership between the dog and its owner, and the household environment. While these results appear to be quite good, hyperglycemia and hypoglycemia were not verified using a glucose monitoring device such as a CGM device but rather used owner-recorded data.

A recent experimental study investigated whether DADs could transfer the detection of hypoglycemic breath samples across two different individuals [51]. Breath samples during hypoglycemia, normoglycemia, and hyperglycemia were collected from three different patients with T1D and two trained DADs were presented with three samples (hypoglycemic, normoglycemic, and hyperglycemic) from the same individual and trained to detect the hypoglycemic sample. The ability to transfer detection of the odor of hypoglycemia across breath samples was then examined by presenting both DADs with new samples from the same individual and one DAD with samples from a different individual. One of the two DADs could detect hypoglycemic samples from the same individual with a sensitivity of 89% and a specificity of 62%. However, it did not appear that the detection of hypoglycemia could be transferred to new samples from a different individual.

There is remarkable inconsistency among the results of studies to date due to the small sample sizes and confounding factors, such as the individual performances of DADs, relationships between the dogs and owners, and household environments. Recent evidence suggests that DADs are not as reliable as glucose monitoring devices, so the development of new technologies for managing diabetes may reduce the role of DADs in patients with diabetes. However, DAD ownership has a number of benefits beyond avoiding hypoglycemia, such as increased physical activity, reduced cardiovascular risks and stress, and social benefits. Furthermore, DAD owners show high satisfaction with their dogs [52]. Therefore, further longitudinal studies with large sample sizes and long durations are warranted to investigate the effects of DADs on hard endpoints, such as cardiovascular disease and mortality.

5.2. Glycemic control

Literature pertaining to the effect of dog ownership on glycemic control is sparse and no intervention studies have been conducted to date. However, it is reasonable to assume that dog ownership would have a beneficial impact on glycemic control by increasing daily physical activity in patients with diabetes. To our knowledge, only three studies have investigated the association between dog ownership and glycemic control in patients with diabetes (Table 3).

Table 3. Association between dog ownership and glycemic control in patients with type 1 and type 2 diabetes.

Authors, year	Study design	Subjects	Results
Maranda et al., 2016 [53]	Case-control study	223 individuals aged 9–19 years with type 1 diabetes Age: 15.18 ± 2.53 years Sex (male/female): 120/103 BMI: Not reported HbA1c (cases vs. controls): 7.14 ± 0.61% vs. 9.01 ± 1.19%*	Active dog care was positively associated with control over HbA1c levels (OR = 2.59; 95% CI, 1.14–5.87).
Laine et al., 2019 [54]	Observational cohort study	731 individuals from the Helsinki Birth Cohort Study Age: 71 ± 2.7 years Sex (male/female): 307/424 BMI: 27 ± 4.7 kg/m^2 HbA1c: Not shown	Dog owners had a greater risk of having type 2 diabetes than non-dog owners (OR = 2.23; 95% CI, 1.12–4.44).
Riske et al., 2020 [55]	Cross-sectional study	143 patients with type 1 diabetes and 303 patients with type 2 diabetes Age: 50 ± 16 years and 63 ± 11 years, respectively Sex (male/female): 71/72 and 183/120, respectively BMI: 25.7 ± 4.5 kg/m^2 and 33.7 ± 7.3 kg/m^2, respectively HbA1c: 8.6% ± 1.6% and 9.0% ± 1.6%, respectively	There was no difference in HbA1c levels between dog owners and non-dog owners.

BMI: body mass index; HbA1c: hemoglobin A1c; OR: odds ratio; CI: confidential interval. Values are means ± standard deviations. *The cases are subjects who achieved target HbA1c levels (Children aged 6–12 years: 8% or less, Adolescents aged 13–19 years: 7.5% or less).

Maranda et al. [53] investigated the relationship between pet ownership and glycemic control in 223 children aged 9–19 years with T1D. A pet ownership questionnaire showed that 180 of the children's households had pets, with 60.6% of these owning dogs. Active care for a pet was strongly associated with lower HbA1c values (OR = 2.49;95% CI, 1.08–5.75) compared with non-pet owners after adjusting for the child's age, duration of disease, socio-economic status, and self-management score, and comparable results were observed for the association between active dog care and HbA1c levels (OR = 2.59; 95% CI, 1.14–5.87).

Laine et al. [54] reported on the association between dog ownership and the odds of having T2D in 731 older subjects from the Helsinki Birth Cohort Study, 13% of whom had T2D. Dog ownership was not associated with the existence of T2D at baseline, but subjects with T2D had lower amounts of LTPA (7.5 MET-hours per week) than those without. After adjusting for age, sex, socio-economic status, LTPA, smoking, and chronic diseases, the current dog owners had a greater risk of T2D than non-dog owners (OR = 2.23; 95% CI, 1.12–4.44), particularly for men (OR = 3.32; 95% CI, 1.28–8.79). However, no information was obtained regarding whether dog owners walked with their dogs or their dietary intakes, which may affect the risk of T2D.

Riske et al. [55] recently assessed the effects of dog ownership on physical activity and metabolic control in 143 patients with T1D and 303 patients with T2D. They found that 91.1% of dog owners with T1D and 87.1% of dog owners with T2D regularly walked their dogs, with dog walking accounting for a significant amount of the total physical activity in both groups [19.0 ± 3.3 MET-hour per week (61.3%) and 19.8 ± 2.6 MET-hours per week (62.9%), respectively]. However, while total physical activity was significantly higher in dog owners with T2D than non-dog owners, there was no difference in total physical activity between dog owners with T1D and non-dog owners. Furthermore, there were no differences in BMI, waist circumference, or HbA1c levels between dog owners and non-dog owners, and self-reported hypoglycemic episodes were not affected by dog ownership. Consequently, the authors concluded that dog ownership had no impact on glycemic control.

The findings of these studies suggest that the effect of dog ownership on glycemic control differs depending on the form of diabetes. A key difference between patients with T1D and T2D is age, with patients with T1D generally being younger than those with T2D. Consequently, patients with T1D can be driven to perform higher intensity physical activity and non-dog owners with T1D may carry out exercise other than dog walking, which would explain the lack of difference in daily physical activity between dog owners and non-dog owners observed by Riske et al. [55]. In addition, physical activity was evaluated using self-reported questionnaires rather than being objectively measured using wearable devices such as accelerometers in all three studies, which may have affected the results. However, the reason why dog owners had an increased risk of T2D in the study by Laine et al. [54] is unknown, and the effect of dog ownership on glycemic control remains controversial.

6. Conclusion

In conclusion, dog ownership is beneficial for increasing daily physical activity and reducing the risk of cardiovascular disease and mortality. Furthermore, DAD ownership can help to lower the risk of hypoglycemia and ameliorate glycemic control in young patients with T1D. However, it remains unclear whether dog ownership has a beneficial effect on glycemic control in patients with

T2D and older patients with T1D. The ability of DADs to detect hypoglycemia/hyperglycemia is highly variable, depending on the individual dog, and the accuracy and reliability of DADs remain controversial. However, it is clear that DADs are not as reliable for detecting hypoglycemia/hyperglycemia as advanced glucose monitoring devices, indicating that they are not useful for alerting owners with diabetes in our time. However, beyond the physical health benefits of dog ownership, dogs can have a favorable influence on the quality of life of their owners, so dog ownership has overall health benefits for patients with diabetes.

Conflict of interest

The author declares no conflicts of interest.

References

1. Vilà C, Savolainen P, Maldonado JE, et al. (1997) Multiple and ancient origins of the domestic dog. *Science* 276: 1687–1689.
2. 2017–2018 U.S. Pet Ownership & Demographics Sourcebook. Available from: https://www.avma.org/resources-tools/reports-statistics/us-pet-ownership-statistics/
3. Colberg SR, Sigal RJ, Fernhall B, et al. (2010) Exercise and Type 2 diabetes: the American college of sports medicine and the American diabetes association: joint position statement. *Diabetes Care* 33: e147–e167.
4. Christian H, Bauman A, Epping JN, et al. (2016) Encouraging dog walking for health promotion and disease prevention. *Am J Lifestyle Med* 12: 233–243.
5. Ainsworth BE, Haskell WL, Herrmann SD, et al. (2011) 2011 Compendium of physical activities: a second update of codes and MET values. *Med Sci Sports Exerc* 43: 1575–1581.
6. Hamasaki H (2016) Daily physical activity and type 2 diabetes: a review. *World J Diabetes* 7: 243–251.
7. Thorpe RJ Jr, Kreisle RA, Glickman LT, et al. (2006) Physical activity and pet ownership in year 3 of the Health ABC study. *J Aging Phys Act* 14: 154–168.
8. Levine GN, Allen K, Braun LT, et al. (2013) Pet ownership and cardiovascular risk: a scientific statement from the American Heart Association. *Circulation* 127: 2353–2363.
9. Maugeri A, Medina-Inojosa JR, Kunzova S, et al. (2019) Dog ownership and cardiovascular health: results from the Kardiovize 2030 Project. *Mayo Clin Proc Innov Qual Outcomes* 3: 268–275.
10. Westgarth C, Christley RM, Marvin G, et al. (2017) I walk my dog because it makes me happy: a qualitative study to understand why dogs motivate walking and improved health. *Int J Environ Res Public Health* 14: 936.
11. Taniguchi Y, Seino S, Nishi M, et al. (2018) Physical, social, and psychological characteristics of community-dwelling elderly Japanese dog and cat owners. *PLoS One* 13: e0206399.
12. Mein G, Grant R (2018) A cross-sectional exploratory analysis between pet ownership, sleep, exercise, health and neighbourhood perceptions: the Whitehall II cohort study. *BMC Geriatr* 18: 176.
13. Mičková E, Machová K, Daďová K, et al. (2019) Does dog ownership affect physical activity, sleep, and self-reported health in older adults? *Int J Environ Res Public Health* 16: 3355.

14. Soares J, Epping JN, Owens CJ, et al. (2015) Odds of getting adequate physical activity by dog walking. *J Phys Act Health* 12: S102–S109.

15. Westgarth C, Christley RM, Christian HE (2014) How might we increase physical activity through dog walking?: A comprehensive review of dog walking correlates. *Int J Behav Nutr Phys Act* 11: 83.

16. Toohey AM, Rock MJ (2011) Unleashing their potential: a critical realist scoping review of the influence of dogs on physical activity for dog-owners and non-owners. *Int J Behav Nutr Phys Act* 8: 46.

17. Rhodes RE, Murray H, Temple VA, et al. (2012) Pilot study of a dog walking randomized intervention: effects of a focus on canine exercise. *Prev Med* 54: 309–312.

18. Hamasaki H (2018) Efficacy of wearable devices to measure and promote physical activity in the management of diabetes. *EMJ Diabet* 6: 62–69.

19. Salmon J, Timperio A, Chu B, et al. (2010) Dog ownership, dog walking, and children's and parents' physical activity. *Res Q Exerc Sport* 81: 264–271.

20. Christian H, Trapp G, Villanueva K, et al. (2014) Dog walking is associated with more outdoor play and independent mobility for children. *Prev Med* 67: 259–263.

21. Engelberg JK, Carlson JA, Conway TL, et al. (2016) Dog walking among adolescents: correlates and contribution to physical activity. *Prev Med* 82: 65–72.

22. Sirard JR, Patnode CD, Hearst MO, et al. (2011) Dog ownership and adolescent physical activity. *Am J Prev Med* 40: 334–337.

23. Garcia DO, Wertheim BC, Manson JE, et al. (2015) Relationships between dog ownership and physical activity in postmenopausal women. *Prev Med* 70: 33–38.

24. Feng Z, Dibben C, Witham MD, et al. (2014) Dog ownership and physical activity in later life: a cross-sectional observational study. *Prev Med* 66: 101–106.

25. Wasenius NS, Laine MK, Savola S, et al. (2018) Dog ownership from a life course perspective and leisure-time physical activity in late adulthood: The Helsinki Birth Cohort Study. *Am J Health Behav* 42: 11–18.

26. Dall PM, Ellis SLH, Ellis BM, et al. (2017) The influence of dog ownership on objective measures of free-living physical activity and sedentary behaviour in community-dwelling older adults: a longitudinal case-controlled study. *BMC Public Health* 17: 496.

27. Potter K, Teng JE, Masteller B, et al. (2019) Examining how dog "Acquisition" affects physical activity and psychosocial Well-Being: findings from the buddy study pilot trial. *Animals* 9: 666.

28. Kramer CK, Mehmood S, Suen RS (2019) Dog ownership and survival: a systematic review and meta-analysis. *Circ Cardiovasc Qual Outcomes* 12: e005554.

29. Friedmann E, Katcher AH, Lynch JJ, et al. (1980) Animal companions and one-year survival of patients after discharge from a coronary care unit. *Public Health Rep* 95: 307–312.

30. Chowdhury EK, Nelson MR, Jennings GL, et al. (2017) ANBP2 Management Committee. Pet ownership and survival in the elderly hypertensive population. *J Hypertens* 35: 769–775.

31. Ding D, Bauman AE, Sherrington C, et al. (2018) Dog ownership and mortality in england: a pooled analysis of six population-based cohorts. *Am J Prev Med* 54: 289–293.

32. Mubanga M, Byberg L, Nowak C, et al. (2017) Dog ownership and the risk of cardiovascular disease and death—a nationwide cohort study. *Sci Rep* 7: 15821.

33. Torske MO, Krokstad S, Stamatakis E, et al. (2017) Dog ownership and all-cause mortality in a population cohort in Norway: The HUNT study. *PLoS One* 12: e0179832.

34. Sørensen IK, Bidstrup PE, Rod NH, et al. (2018) Is dog ownership associated with mortality? A nationwide registry study. *Eur J Public Health* 28: 1169–1171.

35. Ogechi I, Snook K, Davis BM, et al. (2016) Pet ownership and the risk of dying from cardiovascular disease among adults without major chronic medical conditions. *High Blood Press Cardiovasc Prev* 23: 245–253.

36. El-Qushayri AE, Kamel AMA, Faraj HA, et al. (2020) Association between pet ownership and cardiovascular risks and mortality: a systematic review and meta-analysis. *J Cardiovasc Med* 21: 359–367.

37. Qureshi AI, Memon MZ, Vazquez G, et al. (2009) Cat ownership and the risk of fatal cardiovascular diseases. Results from the second national health and nutrition examination study mortality follow-up study. *J Vasc Interv Neurol* 2: 132–135.

38. Krittanawong C, Kumar A, Wang Z, et al. (2020) Pet ownership and cardiovascular health in the us general population. *Am J Cardiol* 125: 1158–1161.

39. Arhant-Sudhir K, Arhant-Sudhir R, Sudhir K (2011) Pet ownership and cardiovascular risk reduction: supporting evidence, conflicting data and underlying mechanisms. *Clin Exp Pharmacol Physiol* 38: 734–738.

40. Peel E, Douglas M, Parry O, et al. (2010) Type 2 diabetes and dog walking: patients' longitudinal perspectives about implementing and sustaining physical activity. *Br J Gen Pract* 60: 570–577.

41. Wells DL (2007) Domestic dogs and human health: an overview. *Br J Health Psychol* 12: 145–156.

42. Wells DL (2012) Dogs as a diagnostic tool for ill health in humans. *Altern Ther Health Med* 18: 12–17.

43. Gonder-Frederick L, Rice P, Warren D, et al. (2013) Diabetic alert dogs: a preliminary survey of current users. *Diabetes Care* 36: e47.

44. Lippi G, Cervellin G, Dondi M, et al. (2016) Hypoglycemia alert dogs: a novel, cost-effective approach for diabetes monitoring? *Altern Ther Health Med* 22: 14–18.

45. Rooney NJ, Morant S, Guest C (2013) Investigation into the value of trained glycaemia alert dogs to clients with type I diabetes. *PLoS One* 8: e69921.

46. Hardin DS, Anderson W, Cattet J (2015) Dogs can be successfully trained to alert to hypoglycemia samples from patients with Type 1 diabetes. *Diabetes Ther* 6: 509–517.

47. Gonder-Frederick LA, Grabman JH, Shepard JA (2017) Diabetes alert dogs (DADs): an assessment of accuracy and implications. *Diabetes Res Clin Pract* 134: 121–130.

48. Los EA, Ramsey KL, Guttmann-Bauman I, et al. (2017) Reliability of trained dogs to alert to hypoglycemia in patients with Type 1 diabetes. *J Diabetes Sci Technol* 11: 506–512.

49. Gonder-Frederick LA, Grabman JH, Shepard JA, et al. (2017) Variability of diabetes alert dog accuracy in a real-world setting. *J Diabetes Sci Technol* 11: 714–719.

50. Rooney NJ, Guest CM, Swanson LCM, et al. (2019) How effective are trained dogs at alerting their owners to changes in blood glycaemic levels?: Variations in performance of glycaemia alert dogs. *PLoS One* 14: e0210092.

51. Reeve C, Cummings E, McLaughlin E, et al. (2020) An idiographic investigation of diabetic alert dogs' ability to learn from a small sample of breath samples from people with Type 1 diabetes. *Can J Diabetes* 44: 37–43.e1.

52. Petry NM, Wagner JA, Rash CJ, et al. (2015) Perceptions about professionally and non-professionally trained hypoglycemia detection dogs. *Diabetes Res Clin Pract* 109: 389–396.

53. Maranda L, Gupta OT (2016) Association between responsible pet ownership and glycemic control in youths with Type 1 diabetes. *PLoS One* 11: e0152332.

54. Laine MK, Wasenius NS, Lohi H, et al. (2019) Association between dog ownership and Type 2 diabetes in later life: the Helsinki birth cohort study. *Int J Circumpolar Health* 78: 1611328.

55. Riske J, Janert M, Kahle-Stephan M, et al. (2019) Owning a dog as a determinant of physical activity and metabolic control in patients with Type 1 and Type 2 diabetes mellitus. *Exp Clin Endocrinol Diabetes* 124.