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ORIGINAL ARTICLE

Association between pet ownership and the risk of dying from colorectal cancer: an 18-year follow-up of a national cohort

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Abstract

Background Despite the popularity of pets, research on the relationship between pet ownership and the risk of cancer remains minimal and inconclusive.

Aim To longitudinally examine the association between pet ownership and the risk of dying from colorectal cancer.

Methods We analyzed the data of a nationally representative cohort of 13,929 adults aged ≥ 19 years who answered the question about pet ownership in the Third National Health and Nutrition Examination Survey (NHANES), 1988–1994. The vital status was followed through 31 December 2010.

Results Approximately, 43% of the participants had pets, 26% with dogs, 20% with cats and 5% with birds. By the end of an 18-year follow-up (mean = 15 years), 70 colorectal cancer deaths were recorded. After adjustment for socio-demographic factors, cigarette smoking, alcohol drinking, body mass index, physical activity, history of atopic conditions and serum cotinine measured at the baseline survey, the hazard ratio (HR) of dying from colorectal cancer associated with having any pets was 2.83 (95% CI = 1.51–5.30) compared with non-pet owners. This association was largely attributed to owning a cat. The HR of dying from colorectal cancer for owning a cat was 2.67 (1.22–5.86). The HR for owning a dog was 0.89 (0.37–2.12).

Conclusions Having a cat was significantly associated with an elevated risk of dying from colorectal cancer among the general population. The observed detrimental effects the cats conferred may not be explained by confounding effects from socio-demographics, cigarette smoking, sedentary life or atopic conditions.

Keywords Longitudinal study · Mortality · Pet ownership · Colorectal cancer · NHANES

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Introduction

About 40% of households in the USA have a dog, roughly over 36 million households have a cat and almost 4 million have a pet bird. The steadily increasing popularity of pets indicates that Americans believe that pets enhance their lives (Pet Ownership: Data from American Pet Products Manufacturers' 2005/2006 National Pet Owners Survey 2006). However, vigorous assessment of the overall health impact of having pets has been overlooked (Levine et al. 2013). A health benefit from pet ownership has been observed in numerous reports (Friedmann and Thomas 1995; Friedmann et al. 2011; Friedmann et al. 2003; Ogechi et al. 2016), and pet therapy is becoming popular for helping people cope with or recover from health problems, especially for cardiovascular diseases (Creagan et al. 2015; Levine

et al. 2013). However, detrimental effects on health outcomes (Moody et al. 1996; Parker et al. 2010; Parslow and Jorm 2003), specifically increased risk of cancer, for pet owners over non-pet owners were also reported elsewhere (Franti et al. 1980; Holst et al. 1988; Laumbacher et al. 2006; Petridou et al. 1997).

To the best of our knowledge, as of today, only one study has longitudinally assessed the relationship between the risk of cancers and pet ownership in the general population of the USA. Almost all previous studies were cross-sectional (Franti et al. 1980) or case-control studies (Alavanja et al. 1996; Gardiner et al. 1992; Holst et al. 1988; Kohlmeier et al. 1992; Laumbacher et al. 2006; Modigh et al. 1996; Morabia et al. 1998; Petridou et al. 1997; Swensen et al. 2001; Tranah et al. 2008). Cancer generally takes a long time to develop, casting substantial concerns over the validity of data collected retrospectively in previous studies. In addition to recall biases, most previous studies also used hospital-based controls, bringing selection bias to the association in question (Kohlmeier et al. 1993). To address these limitations, and fill the gap between the increasing popularity of pets and scarcity of high-quality evidence on the association between pet ownership and cancer, we analyzed the data of a nationally representative cohort from the general population to examine the relationship between pet ownership and the risk of dying from colorectal cancer, one of the most common cancers diagnosed in both men and women in the US (Cronin et al. 2018).

Methods

Study population

We used the data collected in the third National Health and Nutrition Examination Survey (NHANES III) conducted in 1988–1994. The NHANES III consisted of a nationwide probability sample of non-institutionalized civilians. We restricted our analyses to 17,388 adults aged 19 and older whose information related to pet ownership was assessed at the baseline survey in 1988–1994, and the vital statuses were available by the end of 2010. In total, 13,929 participants were retained for the main analyses after exclusions due to various reasons (Fig. 1).

Baseline data collection

NHANES III baseline data were collected during an in-home interview and a subsequent visit to a mobile examination center (MEC). The demographic and health-related information was collected using a standardized questionnaire/protocol. Informed consent was obtained from all NHANES participants by the National Center for Health Statistics, which administrated the survey.

Pet ownership

In the housing characteristics section of the household interview, respondents were asked a two-part question about whether a pet resided in the home: "Does a pet live here? If yes, what type of pet is it?" The response choices included dog, cat, bird, fish, rodent, rabbit, reptile, farm pet and other. Given the relatively small number of persons who had pets other than dogs, cats or birds, the current study examined the association between death of colorectal cancer and the ownership of dogs, cats or birds when looking at the type of pets.

Physical activity level and body mass index (BMI)

Sedentary lifestyle has been documented to be associated with the risk of colorectal cancer (Kerr et al. 2017); therefore,

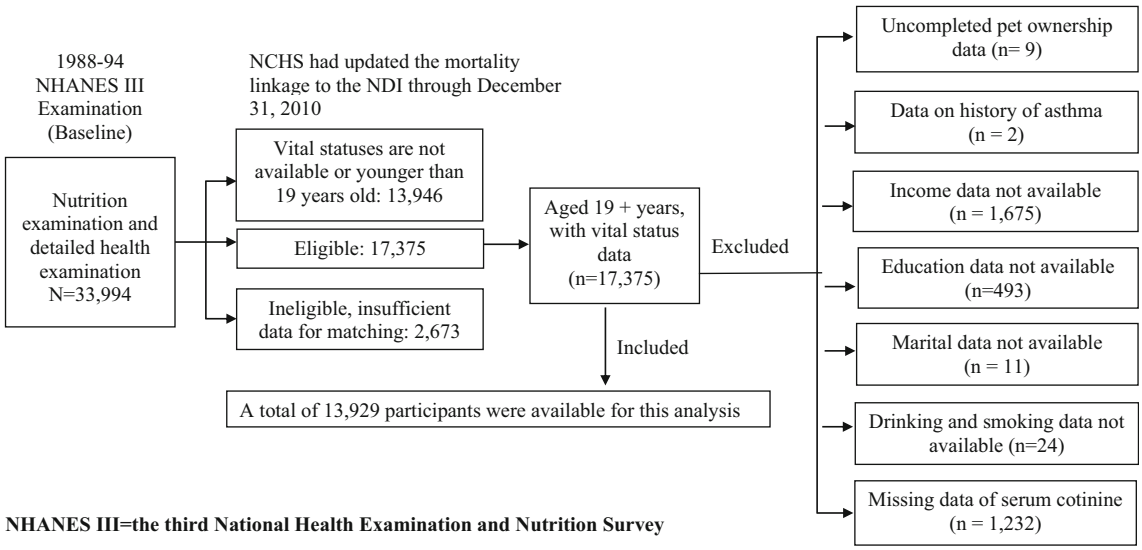

Fig. 1 Flow chart of the study population included; 13,929 adults aged 19+ years, NHANES III follow-up study 1988–2010

physical activity level and body mass index were included as the potential confounders. Physical activity was assessed as the monthly frequency of these activities: walking, jogging, biking, swimming, calisthenics, gardening, weight lifting, aerobics and dancing. Participants listed up to four activities they had engaged in that lasted at least 10 min and involved moderate or vigorous effort. Monthly physical activity was converted to weekly physical activity. The level of physical activity was categorized as "vigorous" as participating in such activity every day, "moderate" if 4–5 times per week and "light" if 1–3 times per week, otherwise as "physically inactive." Body mass index (BMI) was calculated as directly measured weight in kilograms divided by height in squared meters (kg/m^2).

Cigarette smoking, alcohol drinking and atopic conditions

Behavioral risk factors play crucial roles in the development of colorectal cancer, especially alcohol drinking and cigarette smoking (Hamada et al. 2018; Rossi et al. 2018). We defined current alcohol drinking as "heavy" if the respondents reported that, in the last 12 months, five or more drinks were consumed on more than 10 days and "moderate" if the number of days on which five drinks or more were consumed was ≤ 10 days, otherwise as "rare or lighter." Tobacco smoking status was categorized as "never/rare," "former" and "current." The formers and the currents were further classified as "moderate/heavy smokers" if the respondents reported that ten cigarettes or more were smoked per day, otherwise as "light smokers." Serum cotinine, an alkaloid found in tobacco and also the predominant metabolite of nicotine, was used to control for underreporting of cigarette smoking or exposure to environmental tobacco smoke. Self-rated health condition has been associated with total mortality and may serve as a proxy of risk-adjustment effort (Lainscak et al. 2014) . The history of asthma was used as the proxy of atopic diseases and was assessed using the Medical Condition Module (MCM) of NHANES. The MCM interview was conducted at the MECs to collect self-reported data on a broad range of health conditions. The respondents were asked, "Has a doctor or other health professional ever told you that you had any of the following conditions?" This was followed by a list of various chronic and acute conditions, some described with vernacular expressions, representing prevalent conditions in the US population.

Socio-demographics

Race/ethnicity was coded as whites, blacks or Mexican Americans. Regardless of age, educational attainment was measured as the highest completed grade of school and categorized into high school/equivalent or below, some college years and college graduate or above. Family income was assessed using the poverty income ratio (PIR), calculated from the previous year's family income and family size, and compared with the federal poverty line (PIR = 1) (Housing and Household Economic Statistics Division 2009; Lainscak et al. 2014). Marital status was classified into two categories: married or others, which included never married, widowed, divorced and separated.

Following up of vital status and death from colorectal cancer

A total of 12 identifiers (social security number, sex, date of birth, etc.) were used to link NHANES III participants with the National Death Index to ascertain vital status and the cause of death. Vital status ascertainment was based upon the results from a probabilistic match between NHANES III and death certificate records. More than 96% of deceased participants and all living participants were successfully followed up and correctly classified. The cause of death was determined using the underlying cause listed on the death certificate. The International Classification of Diseases, Injuries and Cause of Death (ICD) 10th revision was used to code deaths after 1999, and deaths in 1999 and before were originally reported in ICD 9th but recoded using ICD 10th. The codes for colorectal cancers included C18-C21 (malignant neoplasms of the colon, rectum and anus).

Statistical analysis

We used SAS (SAS 9.4, Research Triangle Park, NC) procedures for surveys with appropriate weighting and nesting variables to produce accurate national estimates and adjust for the over-sampling of specific populations. Using Cox proportional hazard regression models, we estimated the adjusted hazard ratios (HRs) for the relative risk and compared the risk among pet owners over non-pet owners (reference). The 95% confidence intervals (95% CIs) of HR were calculated, and the *p* values were two tailed. The Cox models were run to adjust for age, sex, race/ethnicity, family income, education attainment, alcohol drinking, cigarette smoking, marital status, body mass index, physical activity, self-evaluated health status, serum cotinine and history of asthma measured at the baseline survey. The person-year contributions from each participant were calculated as the time between their date of the baseline examination and the date of death (if it occurred), or 31 December 2010 (if still alive), whichever occurred first. To assess reverse causality, we repeated the steps described above but all deaths occurring in the first 2 years of the follow-up were excluded. The participants with cancer diagnosed before the baseline survey were also excluded from the sensitivity analyses. We created time-dependent covariates to test the proportional hazard assumption.

Results

As nationally representative samples, the study population reflected the demographic profile of the American population in the late 1980s and early 1990s (Table 1). Whites, African Americans, Mexican Americans and others accounted for 77.2%, 10.5%, 4.9% and 7.3%, respectively. Dogs were the most popular pet, owned by 25.8% of the study population, followed by cats (20.4%) and birds (4.6%). Pet ownership varied across socio-demographic strata (Table 2). Almost half of adults aged 20–64 years old, but about a quarter (25.8%) of adults ≥ 65 years, owned a pet. About 48% of white families had a pet, along with 22% of African American families. Current heavy or moderate smokers had the highest percentage of owning a pet (50.8%), while adults who never smoked had the lowest percentage (37.9%). Pet owners were generally more physically active and more likely to have a history of asthma than their non-pet owner counterparts.

Table 1 Selected characteristics of the overall weighted study population;13,929 adults aged 19+, NHANES III 1988–1994[a]

Characteristic	Level	n[b]	% (SE)[b]
Follow-up years	Years (mean)	13,929	14.0 (0.23)
Age at interview	Years (mean)	13,929	43.2 (0.44)
Gender	Male	6565	48.4 (0.48)
Age group	20–39	6061	48.7 (0.99)
	40–64	4734	37.2 (0.64)
	65+	3134	14.1 (0.84)
Family income	Poor	3142	12.5 (0.82)
	Near poor	3862	21.0 (0.75)
	Middle income	4528	39.6 (1.06)
	High income	2397	26.9 (1.47)
Race and ethnicity	White American	6025	77.2 (1.25)
	Black American	3846	10.5 (0.61)
	Mexican American	3512	4.9 (0.40)
	Other	546	7.3 (0.81)
Alcohol drinking	Rare/never	12,615	89.7 (0.51)
	Light/moderate	1170	9.2 (0.52)
	Heavy	144	1.0 (0.14)
Current, former smoking	Never	6883	45.6 (0.75)
	Former light	906	5.5 (0.26)
	Former heavy/moderate	2493	19.8 (0.56)
	Current light	941	4.5 (0.31)
	Current heavy/moderate	2706	24.5 (0.84)
4-level body size	Underweight	309	2.5 (0.19)
	Normal weight	5308	42.8 (0.91)
	Overweight	4786	32.6 (0.64)
	Obese	3510	22.1 (0.76)
History of asthma	Yes	999	8.1 (0.38)
Pet ownership[c]	Any pet	4646	43.0 (1.13)
	Dog	2889	25.8 (0.95)
	Cat	1991	20.4 (0.79)
	Bird	577	4.6 (0.40)

NHANES III = Third National Health Examination and Nutrition Survey; SE = standard error

[a] The characteristics were measured at baseline conducted between 1988 to 1994

[b] Presented as percentage (standard error) unless otherwise specified. The n was presented as unweighted but the % and its standard error were weighted

[c] Some participants kept multiple pets in the home

By the end of the 18- year follow-up (mean = 15 years), 70 colorectal cancer deaths were recorded, of which only 3 occurred among bird owners (Table 3). Compared with non-pet owners, the crude hazard of dying from colorectal cancer was significantly higher among neither the owners of any pets nor the owners of any specific type of pets; the crude HR was 1.37 (95% CI = 0.74–2.55) for owning any type of pets. After adjustment for age, the HRs of dying from colorectal cancer were significantly higher in pet owners than in non-pet owners; the HR was 2.58 (1.38–4.81) for owners of any pets and 2.30 (1.06–5.00) for cat owners. Owning a dog was not significantly associated with the hazard of dying from colorectal cancers; the age-adjusted HR was 0.90 (0.38–2.12).

It is important to note that adjustment for socio-demographics, risky health behaviors, serum cotinine and atopic conditions at baseline increased rather than decreased the HR estimates (Table 4). For example, the age-adjusted HR of colorectal cancer death for owning any pet was 2.58 (1.38–4.81). After comprehensively adjusting for all the covariates included, the HR increased to 2.83 (1.51–5.30) for owners of any pet. The association was mainly driven by owning a cat, and the fully adjusted HR for owning a cat was 2.67 (1.22–5.86). The adjusted HR for owning a dog was close to the null value, i.e., 0.89 (0.37–2.12). Excluding the study participants with prior diagnosed cancer at the baseline survey ($n = 1232$) made the association stronger, 4.34 (2.26–8.34) for owning any type of pets and 3.33 (1.45–7.64) for owning a cat (data not shown). Excluding the deaths occurring in the first 2 years of follow-up ($n = 338$) did not change the estimates. The adjusted HR was 2.85 (1.51–5.38) for owning any type of pet and 2.67 (1.19–6.02) for owning a cat, almost identical to the corresponding estimates obtained from the main analyses. The p value for the interaction between pet ownership and time was 0.24, indicating no strong evidence of an exponential trend over time in the hazard ratio of dying from colorectal cancer because of having a pet.

Discussion

From a nationally representative cohort, we found that owning a pet, specifically a cat, was associated with an elevated hazard of dying from colorectal cancer. The detrimental effect that

Table 2 Pet ownership by socio-demographic and health behavioral characteristics; 13,929 adults aged 19+, NHANES III 1988–1994

Characteristic		Dog owners		Cat owners		Bird owners		Pet owners	
		(*n* = 2,889)		(*n* = 1,991)		(*n* = 577)		(*n* = 4,646)	
		%[a]	P[b]	%[a]	P[b]	%[a]	P[b]	%[a]	P[b]
Gender	Male	26.0 (1.09)	0.52	19.7 (0.91)	0.14	4.28 (0.44)	0.12	42.2 (1.34)	0.19
	Female	25.5 (0.97)		21.1 (0.92)		4.84 (0.44)		43.7 (1.16)	
Age group (years)	20–39	25.7 (1.17)	< 0.001	20.4 (1.18)	< 0.001	4.48 (0.71)	0.03	44.5 (1.38)	< 0.001
	40–64	29.4 (1.31)		23.4 (1.00)		5.40 (0.53)		47.4 (1.54)	
	65+	16.1 (1.19)		12.4 (0.85)		2.68 (0.44)		25.8 (1.28)	
Family income level	Poor	18.3 (1.57)	< 0.001	14.9 (1.48)	0.01	5.30 (0.87)	< 0.001	34.2 (2.23)	< 0.001
	Near poor	22.6 (1.79)		18.6 (1.79)		4.41 (0.60)		38.7 (2.04)	
	Middle income	27.6 (1.64)		22.3 (1.50)		5.65 (0.71)		46.7 (1.85)	
	High income	29.0 (2.10)		21.6 (1.38)		2.77 (0.60)		44.8 (2.11)	
Race and ethnicity	White American	28.5 (1.21)	< 0.001	23.7 (0.87)	< 0.001	4.83 (0.52)	0.09	47.6 (1.34)	< 0.001
	Black American	13.2 (0.92)		6.91 (0.68)		2.00 (0.36)		22.0 (0.96)	
	Mexican American	19.2 (1.54)		10.7 (1.28)		6.03 (0.55)		30.0 (1.91)	
	Others	18.7 (2.12)		11.2 (2.27)		4.57 (2.09)		32.2 (3.21)	
Alcohol drinking	Rare/never	25.4 (0.91)	0.22	20.3 (0.79)	0.53	4.55 (0.43)	0.66	42.8 (1.10)	0.69
	Light/moderate	28.6 (2.49)		21.7 (2.14)		4.50 (1.00)		44.6 (2.58)	
	Heavy	30.0 (5.81)		15.7 (4.81)		7.35 (3.83)		44.1 (5.99)	
Cigarette smoking	Never	22.5 (1.04)	< 0.001	17.4 (1.11)	< 0.001	3.92 (0.51)	0.05	37.9 (1.36)	< 0.001
	Former light	29.8 (3.04)		17.8 (2.34)		3.22 (0.91)		44.4 (3.72)	
	Former heavy/moderate	25.4 (1.75)		21.8 (1.50)		4.81 (0.65)		45.2 (2.02)	
	Current light	23.0 (2.92)		18.9 (2.63)		7.38 (1.72)		40.2 (2.87)	
	Current heavy/moderate	31.7 (1.68)		25.7 (1.20)		5.37 (0.82)		50.8 (1.85)	
Physical activity level	No activity	22.3 (1.50)	0.01	16.9 (1.30)	< 0.001	5.25 (0.70)	0.50	37.5 (1.61)	< 0.001
	1–3 sessions per week	27.2 (1.79)		22.7 (1.21)		4.37 (0.54)		45.4 (1.92)	
	4–6 sessions per week	28.7 (1.52)		23.9 (2.12)		3.48 (0.95)		48.2 (1.86)	
	Daily	25.8 (0.89)		19.6 (0.88)		4.70 (0.73)		42.6 (1.15)	
Body mass index	Underweight	21.1 (2.61)	0.46	21.3 (4.01)	0.07	4.21 (2.20)	0.29	40.0 (4.17)	0.19
	Normal weight	26.0 (1.07)		21.7 (1.06)		4.56 (0.62)		44.5 (1.40)	
	Overweight	25.3 (1.39)		18.2 (1.00)		3.92 (0.43)		41.2 (1.77)	
	Obesity	26.4 (1.41)		21.2 (1.50)		5.57 (0.70)		43.0 (1.36)	
History of asthma	No	25.3 (0.95)	0.02	20.2 (0.76)	0.40	4.41 (0.41)	0.16	42.3 (1.12)	0.01
	Yes	30.9 (2.61)		22.1 (2.37)		6.38 (1.59)		49.9 (3.02)	

NHANES III = Third National Health Examination and Nutrition Survey

[a] Percentage of pet owners within each category of variables. Percentage and its standard errors were weighted

[b] Statistics were generated from chi-square tests to test the differences of the pet ownership percentages between the level within each of socio-demographics and behavioral factor

pets conferred on increasing the risk of colorectal cancer was primarily attributed to owning a cat and cannot be explained by the history of smoking and drinking, exposure to environmental tobacco smoke or atopic conditions of the owners. No such association was observed among dog owners.

There are a limited number of studies examining the relationship between having a pet in the home and the risk of developing cancers and dying from cancers. Ecologically, mortality from lung cancer was much higher in The Netherlands than in Sweden, and The Netherlands has a higher percentage of households with birds as pets compared with Sweden. At the time of interrogation, more than twice the number of breast cancer patients had kept dogs permanently in the last 10 years compared with the control individuals (Laumbacher et al. 2006). An increased risk of childhood leukemia was observed to be associated with pet ownership among 153 incident cases in Greece (Petridou et al. 1997). An elevated risk of lung cancer among bird keepers was reported 2 decades ago (Gardiner

Table 3 Rates and unadjusted HRs (95% CI) of dying from colorectal cancer; 13,929 adults aged 19+, NHANES III follow-up study 1988–2010

Pet ownership[a]	Sample size[b] (N)	Deaths[b] (n)	Rate [c] (1/1000 person years)	Hazard ratio (95% confidence interval)
Total	13,929	70	0.23	
Any pet				
Yes	4,646	22	0.27	1.37 (0.74–2.55)
No	9,283	48	0.19	1.00 (reference)
Dog				
Yes	2,889	10	0.15	0.59 (0.25–1.35)
No	11,040	60	0.25	1.00 (reference)
Cat				
Yes	1,991	12	0.31	1.47 (0.65–3.30)
No	11,938	58	0.21	1.00 (reference)
Bird				
Yes	577	3	0.39	1.74 (0.26–11.4)
No	13,352	67	0.22	1.00 (reference)

NHANES III = the Third National Health and Nutrition Examination Survey

[a] Ownership was assessed at baseline, conducted between 1988 to 1994

[b] *N*s and *n*s were presented as unweighted

[c] Rates were presented as weighted

et al. 1992; Holst et al. 1988; Kohlmeier et al. 1992). A recent prospective analysis of 123,560 postmenopausal women enrolled in the Women's Health Initiative revealed that among never-smokers, there were non-statistically significant associations between cat ownership and lung cancer (Garcia et al. 2016). It is worth noting that all previous studies were case-control studies and were conducted with participants > 40 years old (Gardiner et al. 1992; Holst et al. 1988; Modigh et al. 1996; Morabia et al. 1998) or only postmenopausal women (Garcia et al. 2016). In addition to the recall bias, misclassification of covariates caused by impaired memory among the elderly may also contribute to the inconsistent findings.

The mechanisms underlying the association observed in the current study are to be illustrated. The health hazards of mycotoxins to humans and animals have been examined extensively in recent years (Di et al. 2014; Wang et al. 2014) and may be a part of the biological mechanism. Ingesting foodstuffs contaminated with aflatoxin could be a source of aflatoxin exposure (Cortes et al. 2010) because aflatoxins can be excreted in the litter. Organic dusts present in unhygienic

Table 4 Hierarchically adjusted HR of colorectal cancer deaths associated with pet ownership; 13,929 adults aged 19+, NHANES III follow-up study 1988–2010[a,b,c]

Hierarchical steps	Bird owners	Cat owners	Dog owners	Owners of any pet
Crude (adjusted for nothing)	1.74 (0.26–11.4)	1.47 (0.65–3.30)	0.59 (0.25–1.35)	1.37 (0.74–2.55)
Adjusted for age	3.09 (0.47–20.2)	2.30 (1.06–5.00)	0.90 (0.38–2.12)	2.58 (1.38–4.81)
Further adjusted for socioeconomic status	3.27 (0.48–22.3)	2.76 (1.28–5.96)	0.92 (0.39–2.16)	2.89 (1.54–5.42)
Further adjusted for smoking and drinking	3.41 (0.51–22.9)	2.71 (1.25–5.87)	0.90 (0.38–2.11)	2.82 (1.49–5.34)
Further adjusted for atopy [d]	3.43 (0.51–22.9)	2.68 (1.22–5.85)	0.88 (0.37–2.10)	2.80 (1.48–5.32)
Further adjusted for PA level and BMI	3.37 (0.51–22.2)	2.62 (1.18–5.82)	0.89 (0.38–2.11)	2.79 (1.49–5.25)
Further adjusted for serum cotinine	3.38 (0.51–22.2)	2.67 (1.22–5.86)	0.89 (0.37–2.12)	2.83 (1.51–5.30)

BMI = body mass index; HR = hazard ratio; NHANES III = Third National Health and Nutrtion Examination Survey; PA = physical activity

[a] Ownership was assessed at baseline conducted between 1988 and 1994

[b] Non-pet owners were used as the reference group

[c] ICD10 codes for colorectal cancers included C18–C21 (malignant neoplasms of the colon, rectum and anus)

[d] Using history of asthma to proxy atopic conditions

homes could be a source of molds, and aflatoxin exposure through these pollutants is very likely. Therefore, handling of contaminated feeds, litters and organic dust associated with pets may cause inhalation exposure to aflatoxin and pose a serious health threat to pets and their owners. Inhalation exposure of airborne contaminants can be absorbed from the lungs and translocated to many tissues, including the gastrointestinal tract (Bond et al. 1986; Harrison et al. 1993). Existing data support a role of food-associated mycotoxins in the induction and/or persistence of human chronic intestinal inflammatory diseases in genetically predisposed patients (Maresca and Fantini 2010). Certainly, a serious long-term complication of chronic inflammation is a part of the development of colorectal cancer (Song et al. 2015). It is difficult to interpret why cat owners rather than dog owners showed more vulnerability to colorectal cancer. In general, proteins released from cat dander and skin cells in the indoor environment are smaller and lighter than those of dogs and can easily penetrate into the human body and contaminate other household items. These proteins may serve as a carrier of aflatoxin from contaminated pet food and may increase the aflatoxin exposure for home occupants. Alternately, a lack of physical activity is causally related to colon cancer (Slattery 2004). Dog owners were relatively more physically active; the residual confounding from physical activity may counteract the detrimental effects of keeping a dog.

As an observational study, the current report cannot make any causal inferences about the association between having a cat and an elevated hazard of dying from colorectal cancer. However, by controlling for the socio-demographics and behavior-related carcinogenic risk factors, including cigarette smoking, exposure to environmental tobacco smoke and sedentary lifestyle, we obtained a stronger rather than weakened association. Therefore, the current study provides additional evidence to rule out the possibility that the relationship between pet ownership and hazard of dying from colorectal cancer was spuriously generated from confounding effects. The most interesting findings of the current report might be that the association was mainly driven by having a cat, or potentially a bird. The pet type-specific association sheds light on the direction for future research to identify the pet-harbored carcinogenic risk factors.

The relatively healthy study population made the current study unique, but it was also a major limitation. The small number of deaths (3 colorectal cancer deaths among birth owners) due to colorectal cancer among a healthy study population prevented further stratification by ethnicity and other potential effect modifiers. The small number of colorectal deaths also made the estimates less precise. Using deaths rather than incident cases presented an issue. Mortality data reflect the biological effects of risk factors as well as the quality of health services available to participants. Colorectal cancer is historically prevalent among socioeconomically disadvantaged populations who have limited access to healthcare. Finally, the risk factors, including pet ownership, were assessed from the baseline survey without repeated measurements; misclassification may occur and statistical power was consequently compromised—generating underestimations instead of a spurious association. The duration (i.e., how long they kept pets in their household) and intensity (i.e., how many pets were kept in household) are especially important in determining associations between environmental exposures and chronic outcomes, such as colorectal cancer (White et al. 1998). However, these data were not available from the baseline survey, preventing us from assessing the dose-response association.

Despite the limitations, this study has strengths as well. To the best of our knowledge, the current study might be the first cohort study performed among a national cohort and therefore provides evidence with better generalizability. The comprehensive information collected made it possible to control for various socio-demographic and behavioral factors. Equally important, NHANES collected data using a rigorous protocol with extensive quality control procedures. The current study adds to the existing literature, which mainly consists of case-control studies derived from hospital-based studies. Future work should concentrate on the etiology and preventive strategies to mitigate the detrimental effects of having a pet in households, and larger studies with adequate statistical power are needed to investigate this issue in a more robust manner.

Compliance with ethical standards

Conflict of interest No conflict of interest needs to be disclosed.

References

Alavanja MC, Brownson RC, Berger E, Lubin J, Modigh C (1996) Avian exposure and risk of lung cancer in women in Missouri: population based case-control study. BMJ 313:1233–1235

Bond JA, Ayres PH, Medinsky MA, Cheng YS, Hirshfield D, McClellan RO (1986) Disposition and metabolism of [14C]dibenzo[c,g]carbazole aerosols in rats after inhalation. Fundam Appl Toxicol 7:76–85

Cortes G, Carvajal M, Mendez-Ramirez I, vila-Gonzalez E, Chilpa-Galvan N, Castillo-Urueta P, Flores CM (2010) Identification and quantification of aflatoxins and aflatoxicol from poultry feed and their recovery in poultry litter. Poult Sci 89:993–1001

Creagan ET, Bauer BA, Thomley BS, Borg JM (2015) Animal-assisted therapy at Mayo Clinic: the time is now. Complement Ther Clin Pract 21:101–104

Cronin KA et al (2018) Annual report to the nation on the status of cancer, part I: national cancer statistics. Cancer 124:2785–2800. https://doi.org/10.1002/cncr.31551

Di Stefano V, Pitonzo R, Cicero N, D'Oca MC (2014) Mycotoxin contamination of animal feeding stuff: detoxification by gamma-irradiation and reduction of aflatoxins and ochratoxin A concentrations. Food Addit Contam Part A Chem Anal Control Expo Risk Assess 31:2034–2039

Franti CE, Kraus JF, Borhani NO, Johnson SL, Tucker SD (1980) Pet ownership in rural northern California (El Dorado County). J Am Vet Med Assoc 176:143–149

Friedmann E, Thomas SA (1995) Pet ownership, social support, and one-year survival after acute myocardial infarction in the cardiac arrhythmia suppression trial (CAST). Am J Cardiol 76:1213–1217

Friedmann E, Thomas SA, Stein PK, Kleiger RE (2003) Relation between pet ownership and heart rate variability in patients with healed myocardial infarcts. Am J Cardiol 91:718–721

Friedmann E, Thomas SA, Son H (2011) Pets, depression and long term survival in community living patients following myocardial infarction. Anthrozoos 24:273–285. https://doi.org/10.2752/175303711X13045914865268

Garcia DO, Lander EM, Wertheim BC, Manson JE, Volpe SL, Chlebowski RT, Stefanick ML, Lessin LS, Kuller LH, Thomson, CA (2016) Pet ownership and cancer risk in the women's health initiative. Cancer Epidemiol. Biomark. Prev. 25:1311–1316. https://doi.org/10.1158/1055-9965.EPI-16-0218

Gardiner AJ, Forey BA, Lee PN (1992) Avian exposure and bronchogenic carcinoma. BMJ 305:989–992

Hamada T, Nowak JA, Masugi Y, Hamada T, Nowak JA, Masugi Y, Drew DA, Song M, Cao Y, Kosumi K, Mima K, Twombly TS, Liu L, Shi Y, da Silva A, Gu M, Li W, Nosho K, Keum N, Giannakis M, Meyerhardt JA, Wu K, Wang M, Chan AT, Giovannucci EL, Fuchs CS, Nishihara R, Zhang X, Ogino S (2018) Smoking and risk of colorectal cancer sub-classified by tumor-infiltrating T cells. J Natl Cancer Inst. https://doi.org/10.1093/jnci/djy137

Harrison JC, Carvajal M, Garner RC (1993) Does aflatoxin exposure in the United Kingdom constitute a cancer risk? Environ Health Perspect 99:99–105

Holst PA, Kromhout D, Brand R (1988) For debate: pet birds as an independent risk factor for lung cancer. BMJ 297:1319–1321

Housing and Household Economic Statistics Division USCB (2009) How the Census Bureau Measures Poverty(Official Measure)

Kerr J, Anderson C, Lippman SM (2017) Physical activity, sedentary behaviour, diet, and cancer: an update and emerging new evidence. Lancet Oncol 18:e457–e471. https://doi.org/10.1016/S1470-2045(17)30411-4

Kohlmeier L, Arminger G, Bartolomeycik S, Bellach B, Rehm J, Thamm M (1992) Pet birds as an independent risk factor for lung cancer: case-control study. BMJ 305:986–989

Kohlmeier L, Bellach B, Thamm M (1993) Pet birds and lung cancer. BMJ 306:60

Lainscak M, Farkas J, Frantal S, Singer P, Bauer P, Hiesmayr M, Schindler K (2014) Self-rated health, nutritional intake and mortality in adult hospitalized patients. Eur J Clin Investig 44:813–824. https://doi.org/10.1111/eci.12300

Laumbacher B, Fellerhoff B, Herzberger B, Wank R (2006) Do dogs harbour risk factors for human breast cancer? Med Hypotheses 67:21–26

Levine GN, Allen K, Braun LT, Christian HE, Friedmann E, Taubert KA, Thomas SA, Wells DL, Lange RA (2013) Pet ownership and cardiovascular risk: a scientific statement from the American Heart Association. Circulation 127:2353–2363. https://doi.org/10.1161/CIR.0b013e31829201e1

Maresca M, Fantini J (2010) Some food-associated mycotoxins as potential risk factors in humans predisposed to chronic intestinal inflammatory diseases. Toxicon 56:282–294

Modigh C, Axelsson G, Alavanja M, Andersson L, Rylander R (1996) Pet birds and risk of lung cancer in Sweden: a case-control study. BMJ 313:1236–1238

Moody WJ, Fenwick DC, Blackshaw JK (1996) Pitfalls of studies designed to test the effect pets have on the cardiovascular parameters of their owners in the home situation: a pilot study. Appl Anim Behav Sci 47:127–136

Morabia A, Stellman S, Lumey LH, Wynder EL (1998) Parakeets, canaries, finches, parrots and lung cancer: no association. Br J Cancer 77:501–504

Ogechi I, Snook K, Davis BM, Hansen AR, Liu F, Zhang J (2016) Authors' response: health benefits/hazards associated with companion animal-exposure might be endpoint-and-animal specific. High Blood Press Cardiovasc Prev 23:263–264. https://doi.org/10.1007/s40292-016-0165-0

Parker GB, Gayed A, Owen CA, Hyett MP, Hilton TM, Heruc GA (2010) Survival following an acute coronary syndrome: a pet theory put to the test. Acta Psychiatr Scand 121:65–70. https://doi.org/10.1111/j.1600-0447.2009.01410.x

Parslow RA, Jorm AF (2003) Pet ownership and risk factors for cardiovascular disease: another look. Med J Aust 179:466–468

Pet Ownership: Data from APPMA's 2005/2006 National Pet Owners Survey (2006) American Pet Products Manufacturers Association, Greenwich, CT, USA

Petridou E, Trichopoulos D, Kalapothaki V, Pourtsidis A, Kogevinas M, Kalmanti M, Koliouskas D, Kosmidis H, Panagiotou JP, Piperopoulou F, Tzortzatou F (1997) The risk profile of childhood leukaemia in Greece: a nationwide case-control study. Br J Cancer 76:1241–1247

Rossi M, Jahanzaib Anwar M, Usman A, Keshavarzian A, Bishehsari F (2018) Colorectal cancer and alcohol consumption-populations to molecules. Cancers (Basel) 10. https://doi.org/10.3390/cancers10020038

Slattery ML (2004) Physical activity and colorectal cancer. Sports Med 34:239–252

Song M Song M, Nishihara R, Wu K, Qian ZR, Kim SA, Sukawa Y, Mima K, Inamura K, Masuda A, Yang J, Fuchs CS, Giovannucci EL, Ogino S, Chan AT (2015) Marine omega-3 polyunsaturated fatty acids and risk of colorectal cancer according to microsatellite instability. J Natl Cancer Inst 107(4). pii: djv007 https://doi.org/10.1093/jnci/djv007

Swensen AR, Ross JA, Shu XO, Reaman GH, Steinbuch M, Robison LL (2001) Pet ownership and childhood acute leukemia (USA and Canada). Cancer Causes Control 12:301–303

Tranah GJ, Bracci PM, Holly EA (2008) Domestic and farm-animal exposures and risk of non-Hodgkin's lymphoma in a population-based study in the San Francisco Bay Area. Cancer Epidemiol Biomark Prev 17:2382–2387. https://doi.org/10.1158/1055-9965.EPI-08-0373

Wang Z, Wu Q, Kuca K, Dohnal V, Tian Z (2014) Deoxynivalenol: signaling pathways and human exposure risk assessment—an update. Arch Toxicol 88:1915–1928. https://doi.org/10.1007/s00204-014-1354-z

White E, Hunt JR, Casso D (1998) Exposure measurement in cohort studies: the challenges of prospective data collection. Epidemiol Rev 20:43–56