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Dog and owner demographics impact dietary choices in Dog Aging Project cohort

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OBJECTIVE
To describe the demographic factors of owners and their dogs associated with owner feeding choices and the regularity with which those diets were fed to a US-based population of dogs.

METHODS
This cross-sectional analysis examined 40,367 initial survey responses from US dog owners participating in the Dog Aging Project. The surveys were collected from January 2, 2020, to December 31, 2022, and included primary and secondary diet component types and dog and owner demographic variables. Each demographic variable was compared across diet type choices with a χ^2 test of independence.

RESULTS
Most owners (82%) fed a commercially prepared extruded dry diet (kibble) as the primary diet component. Most owners (89%) reported that they fed their dogs a consistent diet over time. Owner demographic factors (income, education level) were less correlated with difference in diet choices than dog demographic factors (size, neuter status, purebred status, activity level), but owner age did correlate with choice: younger owners tended to feed kibble more compared to older owners. Home-cooked diets were most often consumed by small (< 30-lb) dogs, purebred dogs in poorer health status, and dogs with owners aged 45 years or older. Raw diets were more commonly fed to purebred, intact, and highly active dogs. Ten percent of service dogs were reportedly fed a raw diet of some sort.

CONCLUSIONS
Demographic variables are associated with statistically significant differences in diet types selected. Nutrition studies examining health outcomes associated with the feeding of different diet types should account for these factors during design or analysis in order to avoid bias. An epidemiological tool, the directed acyclic graph, is presented.

CLINICAL RELEVANCE
This information will help clinicians in their discussions with clients about pet nutrition.

Keywords: dog, diets, fed, choices, nutrition

Understanding the dietary choices owners make for their pet dogs is imperative for veterinary practitioners, companion animal nutrition research, and translational studies in which dogs are used as a model for human nutrition. The Dog Aging Project (DAP) is a revolutionary cohort of over 45,000 dogs located across the US,[1] with longitudinal data collected annually from dog owners through a series of survey instruments. This cohort provides the unique opportunity to study dog nutrition at the large population level and better understand how dietary factors interact with other environmental risk factors to modulate health outcomes. Previous work has demonstrated links between owner dietary choices and health outcomes in dogs, such as the increased risk of enteropathogenic infections with raw feeding practices[2–4] or the association between certain dietary factors and the onset of dilated cardiomyopathy.[5] Studying demographic information is also important from a One Health perspective. For example, we know that the location (urban/suburban/rural) of dogs plays an important role in the understanding of infectious disease epidemiology,[3] and dietary factors are an important but often unexplored variable in

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infectious disease pathogenesis and other health outcomes in dogs and humans.

Dog nutrition studies attempting to compare health outcomes between pet dogs fed those different diet types have not adequately accounted for demographic factors in their analyses. Diet type changes can affect microbiome and health outcomes, as has been demonstrated from crossover designs[6] and randomized controlled trials.[7] While study designs like these are optimal to demonstrate the effect of diet on dog health in a controlled setting, studies involving pets struggle to accommodate this design. Owner perceptions of diets are an emotional decision in many cases, and often perceptions of dietary completeness and appropriateness vary depending on the diet the owner chooses,[8] making a randomized or crossover design untenable. Therefore, most studies that attempt to determine the effect of different diets on health outcomes in pet dogs recruit dogs already being fed the different diet types. Some investigators comparing diet health effects collect demographic factors and demonstrate through statistical tests that the populations of dogs eating different diet types are different[9,10] but do not account for these demographic differences when conducting health analyses. Some account for only 1 or 2 dog demographic factors in their analysis.[11]

As the availability of large datasets increases, the ability to compare diet choices and health outcomes is expanding to a larger category of data researchers. However, epidemiological methods of study design are just as important in these big datasets as in small datasets. For example, a study[12] compared vegan, conventional meat, and raw meat diets and the effect of these diets on owner-perceived health outcomes. Dog demographic factors of age, sex, and neuter status were accounted for in the analysis. While dog size information and owner demographic variables were collected, they were not accounted for in the analysis. A response study[13] using the same data as the previous study assessed which variables were most impactful on the owner-perceived health outcomes and found that demographic factors like breed size category, owner education, and owner age, dog age, and vet visit frequency age were the most significant contributors statistically to the owner-reported health outcomes. In this case, diet type was a negligible contribution to the overall effect on health when appropriate statistical methods were used.

The objective of this study was to describe the diets fed to this US-based cohort of dogs, determine the overall variability of these diet choices, and examine the dog and owner demographic factors collected by the DAP survey that may influence what owners choose to feed their dogs. The identified demographic factors can then be appropriately controlled for in follow-on diet studies.

Methods

The DAP[1] collects data from cohort participants using password-protected online research portals. The current investigation used data from a survey instrument that was deployed from January 1, 2020, to December 31, 2022, completed by dog owners when they joined the cohort. This cross-sectional study focused on the owner-reported primary (comprising ≥ 51% of the dog's total diet volume) and secondary (comprising < 49% of the dog's total diet volume, if applicable) diet components, owner and dog demographic information, and owner-reported grain-free and organic status of their chosen diet. The survey response options for primary and secondary diet component were the same. Choices that were presented to the respondents, with abbreviated descriptions that will be used throughout this article, were as follows: commercially prepared dry food (also known as kibble or extruded dog food; the term *kibble* will be used throughout), commercially prepared canned (retorted food with a high moisture content in a pouch, plastic tray, or can; will be referred to as *canned*), commercially prepared freeze-dried (either extruded or whole components that have been freeze-dried; will be referred to as *freeze-dried*), commercially prepared refrigerated or frozen raw (diet made with raw meat ingredients; will be referred to as *commercial raw*), commercially prepared semidry or semimoist (extruded diet with a higher moisture content than kibble but less than canned; will be referred to as *semidry*), home-prepared cooked diet (owner-prepared diet made with cooked components; will be referred to as *home-cooked*), home-prepared raw diet (owner-prepared diet made with raw meat components; will be referred to as *home raw*), and other. Respondents also answered 2 questions regarding whether their pet's food was organic (yes/no) or grain free (yes/no), and these binary outcomes were also examined across food types. Respondents were asked to estimate the consistency of the pet's diet over time, with the following response options available: very consistent, somewhat consistent, not at all consistent, and other.

The owner and dog demographic variables were also collected using this survey instrument. The owner demographic variables included owner income level (the pretax household income) in $20,000 increments, owner age in approximately 10-year increment groups, owner highest education level (of the person completing the survey), and home location area (urban, suburban, rural). The dog demographic variables included dog sex, dog neuter status, dog weight range in 10-lb increments, dog breed type (purebred vs mixed), owner-reported dog activity level (not active, moderately active, very active), life stage, and household dog count. The life stage of the dogs were calculated with the 2019 American Animal Hospital Association life stage guidelines[14] and lifespan data from a study of US dogs[15] as previously described[16] so that dogs were classified into the following categories: puppy, young adult, mature adult, and senior. Respondents were also asked to provide the primary, secondary, and additional purposes for their dog with the following response options available: companion animal or pet, obedience, show, breeding, agility, hunting, working (herding, guarding), field trials, search and rescue, service dog, assistance or therapy dog, and other. For this study, only the reported primary purpose was examined. The survey questions are included in **Supplementary Material S1**.

Statistical analysis

Summary statistics are reported as appropriate. The demographic information for dogs and owners was broken down into their respective response options from the survey data (eg, owner income broken into categories of < $20,000, $20,000 to $39,000, etc) and formed into tables on the basis of the number of dogs reportedly fed each diet type within the demographic category. A χ^2 test was performed to investigate a possible association between each demographic variable and feeding choice. For demographic factors that have an apparent rank (ie, owner income, owner age, household person count, dog weight range, dog activity level, life stage, household dog count, reported health status), the χ^2 test for 1 ordinal and 1 nominal variable was run with the R package coin[17,18] to assess trends within those ordered levels. For owner income level, the "prefer not to say" response was not included in the ordered analysis. For nonordered variables (eg, owner education level, dog neuter status, etc), the χ^2 test for 2 nominal variables was run with the R base version. If the overall test was statistically significant, the R package chisq.posthoc.test[19,20] was used to run a post hoc test of the residuals that accounted for multiple comparisons with the Bonferroni adjustment and turned the residual value for each cell into a *P* value, and the statistically significant values for which *P* < .05 were reported. All analyses were performed with R Statistical Software (version 4.4.0; R Core Team). Secondary diet components were analyzed across the same owner and dog demographic factors in the same manner as the primary component analysis.

Results

A total of 43,517 DAP surveys corresponding to a unique dog were initially captured for this project. The primary diet component was not recorded in 3,150 (7.2%) of the surveys, and they were therefore not included in this analysis. The remaining 40,367 survey results are reported here.

Kibble was by far the most common primary diet component owners chose to feed to their dogs at 82% (n = 33,164) of the cohort **(Table 1)**. The next most

Table 1—Income and age range demographic information for 40,367 Dog Aging Project owner participants and the primary diet component fed to their dogs in the US from 2020 to 2022.

	All	Kibble	Canned	Freeze-dried	Comm raw	Semidry	Home-cooked	Home raw	Other°
	40,367	33,164	1,600	591	1,532	431	1,670	631	748
		82%	4%	1%	4%	1%	4%	2%	2%
Owner income (USD)									
< 20k	742	601	26	7	28	7	36	12	25
		81%	4%	1%	4%	1%	5%	2%	3%
20k–39k	2,374	1,937	106	37	62	37	111	43	41
		82%	4%	2%	3%	2%	5%	2%	2%
40k–59k	3,833	3,160	168	49	111	46	148	67	84
		82%	4%	1%	3%	1%	4%	2%	2%
60k–79k	4,449	3,658	175	66	153	48	205	71	73
		82%	4%	1%	3%	1%	5%	2%	2%
80k–99k	4,316	3,559	162	59	158	53	194	60	71
		82%	4%	1%	4%	1%	4%	1%	2%
100k–119k	4,469	3,722	167	72	166	41	167	70	64
		83%	4%	2%	4%	1%	4%	2%	1%
120k–139k	3,199	2,658	116	46	129	24	111	63	52
		83%	4%	1%	4%	1%	3%	2%	2%
140k–159k	2,650	2,213	94	39	93	30	111	30	40
		84%	4%	1%	4%	1%	4%	1%	2%
160k–179k	1,809	1,530	63	14	61	18	72	22	29
		85%	3%	1%	3%	1%	4%	1%	2%
> 180k	7,601	6,160	300	135	379	82	304	106	135
		81%	4%	2%	**5%***	1%	4%	1%	2%
Prefer not say	4,925	3,966	223	67	192	45	211	87	134
		81%	5%	1%	4%	1%	4%	2%	**3%***
Owner age (y)									
18–24	750	680	7	4	20	10	14	8	7
		91%*	**1%***	1%	3%	1%	2%	1%	1%
25–34	5,457	4,865	97	53	161	47	115	69	50
		89%*	**2%***	1%	**3%***	1%	**2%***	1%	**1%***
35–44	6,344	5,387	150	84	258	70	184	97	114
		85%*	**2%***	1%	4%	1%	**3%***	2%	2%
45–54	7,225	5,912	248	107	335	63	333	116	111
		82%	3%	1%	**5%***	1%	5%	2%	2%
55–64	10,082	8,101	455	155	378	111	520	169	193
		80%*	5%	2%	4%	1%	**5%***	2%	2%
65–74	8,615	6,797	492	139	313	99	416	143	216
		79%*	**6%***	2%	4%	1%	**5%***	2%	**3%***
≥ 75	1,894	1,422	151	49	67	31	88	29	57
		75%*	**8%***	**3%***	4%	2%	5%	2%	**3%***

Comm raw = Commercial raw.

Bold text* = *P* < .05. °Other category included a mix of primary components including prescription diets, unspecified home-cooked or raw foods, and some unknown.

commonly fed diets were as follows: home-cooked (n = 1,670), canned (1,600), and commercial raw (1,532), with each comprising 4% of the total responses. The least common diets were as follows: home raw (n = 631), freeze-dried (591), and semidry (431). Feeding a secondary diet component was reported by 14,059 owners (34.8%). The most commonly fed secondary diet component was canned, reported by 32% of owners (n = 4,470), followed by home-cooked at 21% (2,961) and kibble at 17% (2,444). The remainder of the secondary diet components fed were as follows: freeze-dried (n = 752 [5%]), commercial raw (688 [5%]), home raw (588 [4%]), and semidry (381 [3%]).

The majority of dog owners reported feeding a very consistent diet (n = 35,872 [89%]), 10% (4,185) of owners reported feeding a somewhat consistent diet, and only 1% (275) reported no consistency with diet feeding. Most owners (n = 26,308 [65%]) reported feeding only 1 diet component, and 73% (29,577) of owners reported no recent food changes. Of the 27% (n = 10,790) of owners that reported a recent food change, the overall proportions of diets chosen stayed relatively the same, with kibble comprising 79% (8,465) of new diet types, followed by canned (579 [5%]), home-cooked (568 [5%]), commercial raw (453 [4%]), freeze-dried (211 [2%]), semidry (163 [2%]), and home raw (90 [1%]). When owners were asked about why they recently changed diets, the majority reported switching brands (n = 3,251 [26%]), stopping grain-free diets (2,109 [17%]), the dog having developed a health condition (1,949 [16%]), changing life stage formulation (eg, switching from adult to senior diet; 1,438 [11%]), and reasons related to dietary allergy (1,321 [11%]).

All χ^2 tests on demographic variables yielded a statistically significant difference for the demographic variable, so post hoc analysis was conducted for all demographics. The χ^2 results were as follows: owner income ($\chi^2 = 49.006$, $df = 7$, $P = 2.263 \times 10^{-8}$), owner age ($\chi^2 = 523.42$, $df = 7$, $P < 2.2 \times 10^{-16}$), owner highest education ($\chi^2 = 165.27$, $df = 49$, $P = 1.615 \times 10^{-14}$), home location ($\chi^2 = 102.37$, $df = 14$, $P = 1.667 \times 10^{-15}$), household person count ($\chi^2 = 231.67$, $df = 7$, $P < 2.2 \times 10^{-16}$), dog sex ($\chi^2 = 29.007$, $df = 7$, $P = 0.0001442$), dog neuter status ($\chi^2 = 514.54$, $df = 7$, $P < 2.2 \times 10^{-16}$), dog weight range ($\chi^2 = 1{,}508.9$, $df = 7$, $P < 2.2 \times 10^{-16}$), dog breed type ($\chi^2 = 206.15$, $df = 7$, $P < 2.2 \times 10^{-16}$), dog activity level ($\chi^2 = 196.51$, $df = 7$, $P < 2.2 \times 10^{-16}$), dog life stage ($\chi^2 = 672.66$, $df = 7$, $P < 2.2 \times 10^{-16}$), household dog count ($\chi^2 = 289.66$, $df = 7$, $P < 2.2 \times 10^{-16}$), reported health status ($\chi^2 = 768.7$, $df = 7$, $P < 2.2 \times 10^{-16}$), and dog primary purpose ($\chi^2 = 119.58$, $df = 42$, $P = 2.246 \times 10^{-9}$).

Owner demographics

Regardless of income level, approximately 82% (33,164/40,367) of owners reported that they fed their dogs kibble diets. The proportion of owners feeding kibble diets varied only slightly from 81% to 85% across income levels (Table 1). There was, however, a slight difference related to income with regard to commercial raw diets, which were fed more commonly in the ≥ $180,000 annual income level.

The similarity in diet choice across income levels was also true with organic and grain-free diets. The majority of owners (80% [32,315/40,367]) chose nonorganic foods, and this was similar across income levels. Grain-free diet choices similarly did not correspond with owner income level. A relatively large minority of dogs in the study (16,259/40,367 [40.3%]) were reported to be fed grain-free diets, which was also similar across owner income levels.

Owner age, however, did correlate with diet choice. Older owners were less likely to report feeding their dogs kibble; these diets comprised the primary diet component for 91% of dogs with owners aged between 18 and 24 years and only 75% of dogs with owners aged > 75 years (Table 1). Frequency of reporting of canned, freeze-dried, and home-cooked diets all tended to increase with the owner age category, with older owners more commonly feeding these diets compared to a kibble diet. However, owner age and dog age did appear to be associated: older dog owners reported older ages of their dogs ($P \leq .01$; **Figure 1**).

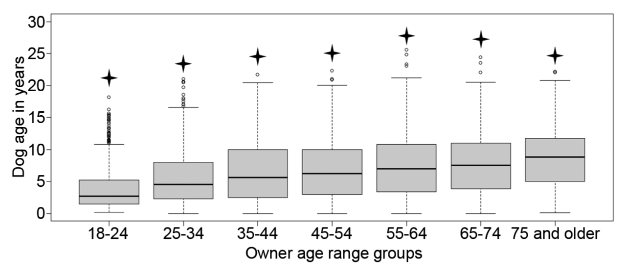

Figure 1—Box plot showing the Dog Aging Project dog participant age as compared to the owner participant age for 40,367 dog-owner pairs. The lowest whisker of each box represents the minimum, the bottom of the box represents the first quartile, the middle black bar of each box represents the median, the top of the box represents the third quartile, and the top whisker of each box represents the maximum, with outliers represented by circles. The stars indicate that each box was statistically significantly different from every other box in a pairwise Wilcoxon test with Bonferroni adjustment for multiple comparisons. Each pairwise comparison was statistically significant, with each $P < 1.5 \times 10^{-5}$.

Overall, the owner's education level did not appear to correlate with diet choice, although some specific diet types were associated with education level **(Table 2)**. Commercial raw diets were fed in a lower proportion by owners with professional and doctorate degrees and in a higher proportion by owners with only some college education. Likewise, home-cooked diets were fed more commonly by owners with some college or trade education. However, these differences across education levels were small.

Regarding home location (Table 2), the proportion of dogs fed home raw diets was significantly greater for dogs living in rural locations than dogs living in either urban or suburban settings. By contrast, commercial raw diets were proportionally more common in urban locations. In general, kibble diets were less commonly fed on the coastal states as compared to the middle of the country **(Figure 2; Supplementary Table S1)**.

Table 2—Education, home location, and household people count demographic information for 40,367 Dog Aging Project owners and the primary diet component fed to their dogs in the US from 2020 to 2022.

	All	Kibble	Canned	Freeze-dried	Comm raw	Semidry	Home-cooked	Home raw	Other°
		82%	4%	1%	4%	1%	4%	2%	2%
Owner highest education									
HS or equivalent	1,016	810	47	11	40	20	41	21	26
		80%	5%	1%	4%	2%	4%	2%	3%
Some college	3,765	2,952	166	54	186	44	200	81	82
		78%*	4%	1%	**5%***	1%	**5%***	2%	2%
Trade	1,058	816	46	21	48	13	61	26	27
		77%*	4%	2%	5%	1%	6%	2%	3%
Associate	2,489	2,039	94	38	89	36	112	30	51
		82%	4%	2%	4%	1%	4%	1%	2%
Bachelor's	13,990	11,530	499	213	568	147	553	240	240
		82%	4%	2%	4%	1%	4%	2%	2%
Master's	11,283	9,288	475	153	407	120	454	160	226
		82%	4%	1%	4%	1%	4%	1%	2%
Professional	3,613	3,055	132	55	120	24	133	39	55
		85%*	4%	2%	3%	1%	4%	1%	2%
Doctorate	3,153	2,674	141	46	74	27	116	34	41
		85%*	4%	1%	**2%***	1%	4%	1%	1%
Home location†									
Urban	7,151	5,775	291	123	328	81	315	93	145
		81%*	4%	2%	**5%***	1%	4%	1%	2%
Suburban	24,716	20,384	1,008	358	906	261	1,019	319	461
		82%	4%	1%	4%	1%	4%	**1%***	2%
Rural	8,500	7,005	301	110	298	89	336	219	142
		82%	4%	1%	4%	1%	4%	**3%***	2%
Household person count									
1	8,198	6,456	394	169	336	91	392	150	210
		79%*	**5%***	**2%***	4%	1%	**5%***	2%	**3%***
2	22,077	17,979	882	319	918	230	968	376	405
		81%*	4%	1%	**4%***	1%	4%	2%	2%
3	5,247	4,449	191	48	152	65	203	57	82
		85%*	4%	**1%***	**3%***	1%	4%	1%	2%
4	3,452	3,049	93	38	91	31	78	34	38
		88%*	**3%***	1%	**3%***	1%	**2%***	1%	**1%***
≥ 5	1,393	1,231	40	17	35	14	29	14	13
		88%*	3%	1%	3%	1%	**2%***	1%	1%

HS = High school.

Bold text* = $P < .05$. °Other category included a mix of primary components including prescription diets, unspecified home-cooked or raw foods, and some unknown. †"Urban" is defined in the survey as "residing inside the city"; "suburban" is defined as "residing outside of an urban center, inside a neighborhood"; and "rural" is defined as "living outside of the city and suburbs, often on a sizeable lot or acreage."

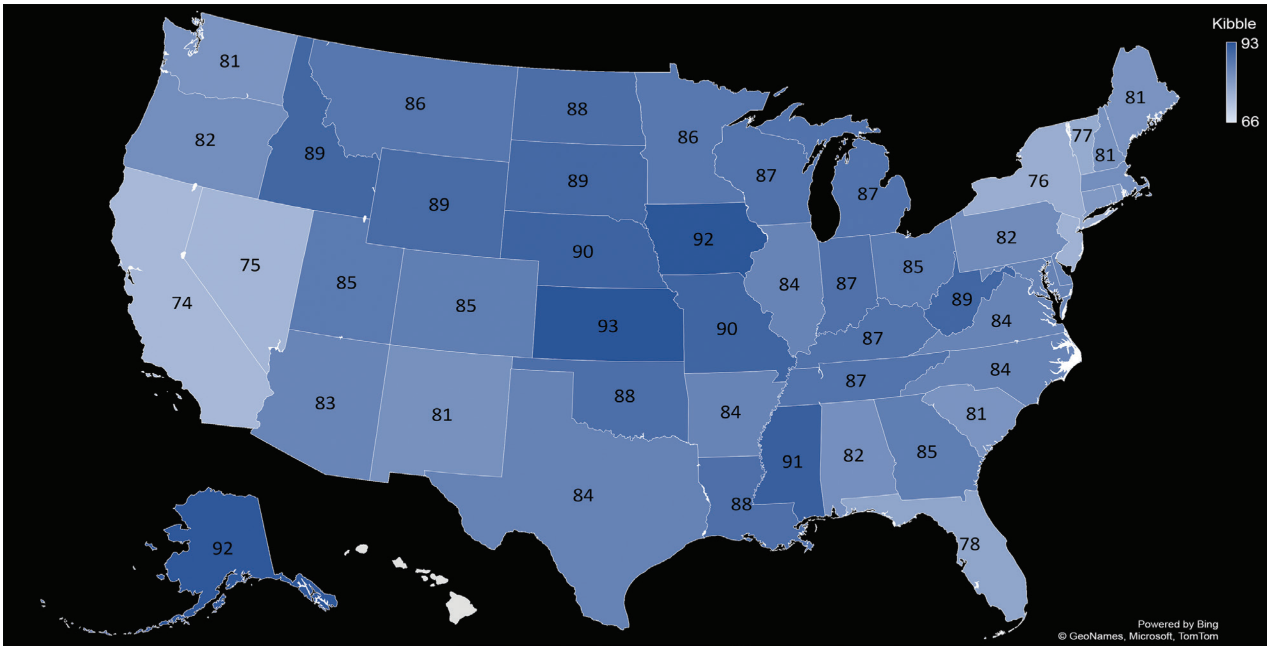

Figure 2—Percent of each state's population of Dog Aging Project participant dogs that are fed kibble as a primary diet component.

The proportion of dogs fed kibble diets in households with more people was higher than that for single-person households (Table 2). As the number of people in the household increased, the proportion of dogs being fed primarily canned, commercial raw, home-cooked, and home raw diets decreased.

Dog demographics

The size of the dog correlated markedly with diet choice, with smaller dogs more likely to be fed canned, freeze-dried, commercial raw, semidry, or home-cooked diets compared to larger dogs **(Table 3)**. Only the proportion of home raw diets increased with increasing dog size. Purebred dogs were more likely to be fed raw diets (both commercial and home). Among dogs consuming raw diets (n = 2,163), purebred dogs were 1.8 times more common (1,391 purebred compared to 772 mixed-breed dogs).

The proportion of intact dogs fed raw diets (both commercial and home) was higher than that of neutered dogs, while neutered dogs were more likely than intact dogs to be fed kibble or canned diets. There were no differences between the other diet types. The proportion of purebred dogs fed raw diets (both commercial and home) were higher than the proportion of mixed-breed dogs fed raw diets, and the proportion of mixed-breed dogs fed kibble was higher than purebred dogs.

Owner-reported activity level corresponded with diet choices in various ways **(Table 4)**. More active dogs were more likely to be fed home raw diets compared to sedentary dogs. Sedentary dogs were more likely to be fed canned or home-cooked diets when compared to active dogs. Puppies were primarily fed a kibble diet (89% [1,666/1,862]) and very few other diet types. Canned and home-cooked diets were

Table 3—Sex, neuter status, weight range, and breed type demographic information for 40,367 Dog Aging Project dogs and the primary diet component fed in the US from 2020 to 2022.

	All	Kibble	Canned	Freeze-dried	Comm raw	Semidry	Home-cooked	Home raw	Other°
		82%	4%	1%	4%	1%	4%	2%	2%
Dog sex									
Male	20,360	16,695	727	304	795	223	897	343	376
		82%	**4%***	1%	4%	1%	4%	2%	2%
Female	20,007	16,469	873	287	737	208	773	288	372
		82%	**4%***	1%	4%	1%	4%	1%	2%
Dog neuter status									
Intact	4,406	3,449	106	58	297	43	161	217	75
		78%*	**2%***	1%	**7%***	1%	4%	**5%***	2%
Neutered	35,961	29,715	1,494	533	1,235	388	1,509	414	673
		83%*	**4%***	1%	**3%***	1%	4%	**1%***	2%
Dog weight range (lb)									
0–10	1,996	1,272	255	55	129	44	164	15	62
		64%*	**13%***	**3%***	**6%***	**2%***	**8%***	1%	**3%***
11–20	5,966	4,196	514	174	320	132	408	52	170
		70%*	**9%***	**3%***	**5%***	**2%***	**7%***	**1%***	**3%***
21–30	4,104	3,219	214	78	197	55	218	44	79
		78%*	**5%***	2%	**5%***	1%	**5%***	1%	2%
31–40	3,594	2,979	127	54	149	38	125	51	71
		83%	4%	2%	4%	1%	3%	1%	2%
41–50	4,831	4,143	139	57	152	30	152	80	78
		86%*	**3%***	1%	3%	1%	**3%***	2%	2%
51–60	5,366	4,627	105	59	174	41	196	94	70
		86%*	**2%***	1%	3%	1%	4%	2%	1%
61–70	5,292	4,648	99	40	157	38	145	95	70
		88%*	**2%***	**1%***	3%	1%	**3%***	2%	1%
71–80	3,807	3,384	47	32	95	20	103	61	65
		89%*	**1%***	1%	**2%***	1%	**3%***	2%	2%
81–90	2,234	1,958	46	18	61	15	64	45	27
		88%*	**2%***	1%	3%	1%	3%	2%	1%
91–100	1,315	1,141	25	12	39	6	44	22	26
		87%*	**2%***	1%	3%	0%	3%	2%	2%
> 100	1,862	1,597	29	12	59	12	51	72	30
		86%*	**2%***	1%	3%	1%	3%	**4%***	2%
Dog breed type									
Purebred	20,386	16,474	751	305	935	222	854	456	389
		81%*	4%	1%	**5%***	1%	4%	**2%***	2%
Mixed	19,981	16,690	849	286	597	209	816	175	359
		84%*	4%	1%	**3%***	1%	4%	**1%***	2%

Bold text* = $P < .05$. °Other category included a mix of primary components including prescription diets, unspecified home-cooked or raw foods, and some unknown.

Table 4—Activity level, life stage, household dog count, and health status demographic information for 40,367 Dog Aging Project dogs and the primary diet component fed in the US from 2020 to 2022.

	All	Kibble	Canned	Freeze-dried	Comm raw	Semidry	Home-cooked	Home raw	Other°
All		82%	4%	1%	4%	1%	4%	2%	2%
Dog activity level									
Not active	5,168	4,061	346	86	168	77	277	50	103
		79%*	**7%***	2%	3%	**1%***	**5%***	**1%***	2%
Mod active	27,106	22,397	1,049	395	1,016	270	1,080	402	497
		83%*	4%	1%	4%	1%	4%	1%	2%
Very active	8,093	6,706	205	110	348	84	313	179	148
		83%	**3%***	1%	4%	1%	4%	**2%***	2%
Dog life stage‡									
Puppy	1,862	1,666	26	23	59	4	39	28	17
		89%*	**1%***	1%	3%	**0%***	**2%***	2%	1%
Young adult	8,287	7,145	169	116	307	61	251	128	110
		86%*	**2%***	1%	4%	**1%***	**3%***	2%	**1%***
Mature adult	22,714	18,788	802	335	885	240	856	374	434
		83%*	**4%***	1%	4%	1%	**4%***	2%	2%
Senior	7,464	5,527	603	117	281	126	522	101	187
		74%*	**8%***	2%	4%	**2%***	**7%***	1%	**3%***
Household dog count									
1	23,584	19,189	1,052	392	854	297	1,064	254	482
		81%*	**4%***	**2%***	4%	**1%***	**5%***	**1%***	**2%***
2	11,251	9,404	404	146	419	92	418	185	183
		84%*	4%	1%	4%	1%	4%	2%	2%
3	3,402	2,834	97	27	156	25	110	99	54
		83%	**3%***	**1%***	5%	1%	3%	**3%***	2%
4	1,193	981	28	13	50	12	44	48	17
		82%	2%	1%	4%	1%	4%	**4%***	1%
5	431	353	9	5	28	2	15	14	5
		82%	2%	1%	6%	0%	3%	3%	1%
≥ 6	403	10	8	25	3	19	31	7	506
		80%	2%	2%	5%	1%	4%	**6%***	1%
Reported health status									
Excellent	19,777	16,694	505	272	764	168	674	407	293
		84%*	**3%***	1%	4%	**1%***	**3%***	**2%***	**1%***
Very good	13,827	11,461	540	204	501	153	529	165	274
		83%	4%	1%	4%	1%	4%	**1%***	2%
Good	4,959	3,773	373	82	199	72	299	47	114
		76%*	**8%***	2%	4%	1%	**6%***	**1%***	2%
Fair	1,470	1,017	145	26	59	32	127	8	56
		69%*	**10%***	2%	4%	**2%***	**9%***	1%	**4%***
Poor	277	181	31	5	7	5	36	4	8
		65%*	**11%***	2%	3%	2%	**13%***	1%	3%
Very poor	57	38	6	2	2	1	5	0	3
		67%	11%	4%	4%	2%	9%	0%	5%

Mod = Moderately.

Bold text* = *P* < .05. °Other category included a mix of primary components including prescription diets, unspecified home-cooked or raw foods, and some unknown. ‡Forty dogs had insufficient information to classify their life stage: 38 of those were fed kibble and 2 home-cooked diets.

more commonly reported for older dogs, with senior dogs consuming canned or home-cooked diets more frequently than at any other life stage. Similarly, dogs with poorer health status were more likely to be fed canned, home-cooked, or semidry diets than dogs in excellent health.

Raw diets (both commercial and home) were more frequently fed to dogs with a primary purpose of agility or breeding as compared to other purposes (15% for both [17/112 agility and 9/61 breeding]; **Supplementary Table S2**). Working dogs were more likely to be fed home raw diets (6% [7/122]), and service dogs were more likely to be fed commercial raw diets (8% [30/387]) as compared to all the other purposes. However, kibble diets were the most common diets overall, regardless of the dogs' purpose as reported by the owner.

Secondary diet component analysis revealed some trends, but there were not as many; they were sometimes consistent with the primary component analysis and other times not. For example, canned diets as a primary component decreased in proportion as the number of people in the household increased, while as a secondary component they increased **(Supplementary Table S3)**. However, neutered dogs were more likely to consume canned diets as both a primary and secondary component than intact dogs **(Supplementary Table S4)**. Full secondary diet analyses are available in **Supplementary Tables S3 to S6**.

Within this cohort, kibble and canned diets were less likely to be specified by owners as organic (68% [5,485/8,052] and 3% [251/8,052], respectively), while freeze-dried, commercial raw, home-cooked, and home raw diets were more likely to be specified as organic (4% [353/8,052], 10% [777/8,052], 7% [597/8,052], and 3% [239/8,052], respectively; **Supplementary Table S7**). Similarly, the proportion of grain-free kibble diets was lower (72% [11,676/16,259]) compared to grain-inclusive kibble diets (89% [21,488/24,108]), while the proportion of grain-free canned, freeze-dried, raw (both commercial and home), and home-cooked diets was higher compared to grain-inclusive versions of those diets.

Discussion

The majority of dogs in this study were fed a kibble diet, but 1 owner-related and several dog-related demographic variables were associated with dietary choices. The owner-related variable associated with dog diet choice was owner age (ie, diets other than kibble were more commonly reported by older owners). It might be that as owners age, they have more time to prepare foods for their dog and the convenience of a kibble diet is less of a driver for their diet choices. Or, since dog and owner age are correlated with each other as older owners tend to own older dogs, it may be that the dog's age and associated physical or health conditions are a driver for these dietary choices. This study's findings of the proportion of overall owners feeding kibble diets and that both owner and pet age were associated with diets other than kibble were consistent with findings by Morelli et al[21] for a population of Italian owners. This may suggest that despite dietary choice differences within human populations, dog owners from different geographic regions may make similar dietary choices if available options are similar.

Dog size was significantly associated with diet choices, with smaller dogs much more likely to be fed diets other than kibble diets. This may be due to economic reasons, since it is likely more cost prohibitive to feed a large dog primarily canned food as compared to a small dog. However, owner income was not associated with diet choice, making this at least appear to be a less important factor in the decision to feed canned diets. Another potential reason may be that health-related issues more commonly diagnosed in small dogs, such as periodontal disease[22] or urolithiasis,[23] compel owners to select foods with a higher moisture content. Further studies are necessary to clarify what factors influence this trend.

Several factors associated with feeding raw diets were discovered in this analysis. Purebred, intact, or highly active dogs were more likely to be fed a raw diet than were mixed-breed, neutered, or less active dogs. However, the composition of raw diets varied on the basis of where dogs lived, with commercial raw diets being more commonly fed to dogs living in urban environments, while home raw diets were more commonly fed to dogs in rural environments. Home raw diets were also more likely to be fed in households with > 1 dog. The health status of dogs fed commercial raw diets did not vary, but home raw diets were less commonly fed to dogs in poor health condition. The owner-reported primary purpose of the dog was associated with feeding raw diets (both commercial and home), with dogs used for agility and breeding purposes being more likely to be fed raw diets compared to dogs with other purposes. Although this study had a relatively small population of dogs that had a primary purpose listed as breeding, the percentage of breeders feeding raw diets in this population (15%) was consistent with the 2014 survey of 2,067 breeders by Connolly et al,[24] which found that approximately 15% of breeders were feeding raw diets.

Raw diets were also reportedly fed more commonly to dogs engaged in therapy and service work than to companion dogs. This is concerning, given previous studies that demonstrate the zoonotic risk posed to immunocompromised individuals from dogs fed raw diets and that dogs fed raw diets are more likely to shed enteric pathogens such as *Salmonella* spp, *Escherichia coli*, *Clostridium perfringens*, and *Clostridioides difficile*.[2–4] However, the total number of service and therapy dogs in the DAP cohort at this time is small, so findings may not be representative of the total population of service and therapy dogs. Given this preliminary information, veterinary practitioners should consider owners of therapy and service dogs to be a priority population to discuss dietary choices, given that both the AVMA[25] and American Animal Hospital Association[26] discourage raw feeding due to the zoonotic risk and Pet Partners, the largest therapy dog organization in the US, prohibits raw feeding as a condition for participating in their activities.[27]

Poorer dog health status was associated with a higher likelihood of a diet other than kibble. This could be due to many factors. For instance, dogs that have developed chronic health conditions and are in poorer overall health may be less likely to eat kibble, and so their owners may select more palatable diets to feed them. Alternatively, dogs with multiple comorbid conditions may be fed special home-cooked diets as directed by a veterinarian or veterinary nutritionist, as these may be the best option for dogs that have multiple chronic conditions with overlapping dietary requirements. It is also possible that owners who perceive their dogs to be in worse health may choose to feed them a diet other than kibble diets in an attempt to increase quality of life.

The number and representativeness of the DAP population is a strength of this analysis. However, due to the size of the dataset, it was possible to find statistically significant differences between demographic categories that may not be meaningfully different in a real-world context. For example, there was a statistically significant difference in the proportion of female and male dogs fed canned diets; however, that proportion rounded to 4% for both sexes.

As these data were collected via a survey instrument from dog owners who chose to participate in the DAP of their own initiative, this study may be limited by selection bias. For example, the owner demographics regarding education level are not representative of the US population, and perhaps this selection bias may influence the lack of owner demographics contributing to diet choice. Additionally, this survey did not ask for the motivations behind diet choices being made by the dog owners. Follow-up studies should consider assessing owner motivations, as that may inform veterinary conversations with dog owners. Also, this survey instrument, used from 2020 to 2022, did not include a commercial cooked fresh/frozen option, which is an emerging section of the pet food market. This response option has been added to subsequent versions of the survey and will be incorporated in future analyses. Finally, the data collection for this survey did occur over the COVID-19 pandemic, and what effect that may have had on respondents during that time is uncertain. Follow-on studies with this cohort will be able to assess whether the population-level feeding choices change significantly compared to the initial 2 years of data collection.

Importantly, it was demonstrated that demographic factors do associate with diet choice, and those owner and dog factors must be considered when nutrition studies among pet dogs are conducted, as these factors may act as confounders in analyses. For example, a study aiming to examine health outcomes of dogs eating kibble versus canned diets should account for demographics like dog size, since dog size is associated with diet choice and small and large dogs have different health outcomes. In addition, pet dog nutrition studies taking place in specific regions of the country may find outcomes that are not as generalizable as previously assumed, as we have discovered that there are geographic differences in feeding patterns identified across the US. For example, if a nutrition study that did not account for diet type was carried out in California, where 26% of the population consumes a diet other than kibble, those results may not be generalizable to the dog population of Kansas, where only 7% of the population consumes something other than kibble as a primary diet component. On the basis of these results, and the previous work by Barrett-Jolley,[13] we propose a directed acyclic graph for future diet type comparison studies to consider when attempting to compare health outcomes **(Supplementary Figure S1)**. Owner beliefs, attitudes, and behaviors (as influenced by many factors) are the confounding factors in the causal model. These beliefs, attitudes, and behaviors are difficult to measure and account for statistically. However, demographic factors like pet neuter status (pet health choice), pet breed, and pet purpose are mediator variables and therefore can be used to correctly adjust the model without needing to measure the beliefs, attitudes, and behaviors. Social determinants of health (eg, owner education, owner age, etc) likewise are owner-level demographic factors that should be accounted for in these analyses. Different diets types also have different nutrient profiles (eg, canned diets have a higher moisture content than kibble diets), and these nutrient differences and their individual causal mechanisms on health outcomes are not fully explored when diet-level analyses are conducted.

This description of demographic variables associated with diet choices will inform veterinarians as to which owners may be more likely to feed a particular diet type. Multiple follow-up studies have been initiated as a result of this analysis and will help to further quantify and examine nutrition in dogs and their health outcomes and to clarify the motivations behind owner diet choices and demographic differences. Furthermore, by demonstrating that these owner- and dog-level demographics are statistically associated with differences in diet choices, and by providing an epidemiological causation model, this study asserts that any diet type/health outcome analysis must include both dog- and owner-level variables to appropriately account for confounding bias.

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Supplementary Materials

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