

1 **Vegan versus meat-based dog food: guardian-reported**
2 **indicators of health**

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19 **Abstract**

20 Alternative pet foods may offer benefits concerning environmental sustainability and [the](#) welfare of
21 animals processed into pet foods. However, some worry these may compromise the welfare of pets.
22 We asked 2,639 dog guardians about one dog living with them, for at least one year. Among 2,596
23 involved in pet diet decision-making, pet health was a key factor when choosing diets. 2,536 provided
24 information relating to a single dog, fed a conventional meat (1,370 = 54%), raw meat (830 = 33%) or
25 vegan (336 = 13%) diet for at least one year. We examined seven general indicators of ill health:
26 unusual numbers of veterinary visits, medication use, progression onto a therapeutic diet after initial
27 maintenance on a vegan or meat-based diet, guardian opinion and predicted veterinary opinion of
28 health status, percentage of unwell dogs and number of health disorders per unwell dog. Dogs fed
29 conventional diets appeared to fare worse than those fed either of the other two diets. Dogs fed raw
30 meat appeared to fare marginally better than those fed vegan diets. However, there were statistically
31 significant differences in average ages. Dogs fed raw meat were younger, which has been
32 demonstrated to be associated with improved health outcomes. Additionally, non-health related
33 factors may have improved apparent outcomes for dogs fed raw meat, for three of seven general
34 health indicators. We also considered the prevalence of 22 specific health disorders, based on
35 predicted veterinary assessments. Percentages of dogs in each dietary group considered to have
36 suffered from health disorders were 49% (conventional meat), 43% (raw meat) and 36% (vegan).
37 Significant evidence indicates that raw meat diets are often associated with dietary hazards, including
38 nutritional deficiencies and imbalances, and pathogens. Accordingly, the pooled evidence to date
39 indicates that the healthiest and least hazardous dietary choices for dogs, are nutritionally sound vegan
40 diets.

41

42 Key words

43 Dog, canine; *Canis familiaris*; pet food; diet; raw meat; vegan

44

45 Introduction

46

47 In 2018, the global pet population was estimated to include 471 million dogs, and 373 million cats

48 [1] (p. 4). Pet food sales internationally were worth Euro 131.7

49 billion in 2014 [2]. The UK pet food market was expected to reach

50 GBP 2.8 billion by the end of 2019, having risen 17% over the previous five years [3],

51 and US pet food and treat sales were also rising, being valued at USD 42.0 billion by 2020 [4]

52 .

53

54 A market of such size drives considerable research and product development, and between January

55 2013 and October 2014, over 6,000 new petfood products (3,000 dry and 3,200 wet pet foods), as well

56 as 4,000 new pet snacks, were launched globally [5] (in [6]). Some of

57 the new products being developed include raw meat diets, *in vitro* meat products, and diets based on

58 novel protein sources, including terrestrial plants, insects, yeast, fungi and seaweed. Some of this

59 development may be driven by significant recent concerns about the environmental sustainability of

60 animal agriculture, and of traditional pet foods based on animal produce

61 [7-11]. This market is already

62 large, and is growing fast. The vegan pet food market was worth USD 8.7 billion globally by 2020,

63 and its forecast valuation by 2028 has been estimated at USD 15.7 billion – a compound annual

64 growth rate of 7.7% [12].

65

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66 However, concerns exist that the imposition of human petfood preferences may be suboptimal for the
67 welfare of dogs. Claiming the existence of “almost insurmountable challenges – biological, legal
68 and downright practical – facing anyone attempting to shoehorn dogs and cats into a vegan dietary
69 system”, Loeb [13] stated, “it’s fairly clear that feeding a dog a vegan diet is not
70 recommended.”

71
72 How valid are such concerns about the nutritional suitability for dogs, of vegan diets? There are two
73 clear routes to assess this. The first involves examining steps taken by petfood manufacturers to
74 ensure the quality and nutritional soundness of their products. These were recently examined in a
75 survey of 29 companies producing meat-based (19) and plant-based (10) pet foods
76 [14]. Although there were limited areas in which practices could be improved, most
77 manufacturers had acceptable or superior standards at nearly all stages examined, throughout the
78 design, manufacturing, transportation and storage phases, with plant-based diets slightly superior to
79 meat-based diets overall.

80
81 However, the most important test is always the effect(s), if any, on the animals themselves. This is
82 why feeding trials are considered the gold standard to ensure the nutritional soundness of new
83 formulations [15-16]. The health status of dogs maintained on
84 different diets has been the subject of limited studies to date, some of which we’ve reviewed
85 elsewhere [17]. In 1987, Yamada and colleagues [18] reported the
86 results of a study of eight dogs divided into two groups, maintained on commercial animal or
87 vegetable protein (VP)-based diets. Each comprised around 30% protein, and other macronutrients
88 and energy contents were closely matched. Six weeks of rest was followed by four hours daily of
89 enforced running at 12 km/h for two weeks. This was followed by one week of recovery. Blood tests
90 indicated that the VP-based dogs experienced marked anaemia following this relatively severe
91 exercise regime. This was theorised to be due to changes in circulating lipid levels (reduction of free
92 cholesterol), resulting in lowered erythrocyte resistance to haemolysis.

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93

94 In 2009, Brown and colleagues [19] reported conflicting results, from a marginally larger study of 12
95 sprint-racing Siberian Huskies, fed either a commercial meat-based diet recommended for active dogs
96 (n = 6), or a meat free (although not vegan) diet formulated to the same nutrient specifications (n = 6).
97 The dogs were fed these diets for 16 weeks, including 10 weeks of competitive racing. Blood tests
98 were conducted on four occasions, and veterinary health checks on three occasions. All dogs were
99 assessed as being in excellent physical condition, and none developed anaemia or other detectable
100 health problems.

101

102 Additionally, in 2014 Semp [20] reported a study of vegan companion animals in Austria,
103 Germany and Switzerland. A questionnaire was completed by 174 dog and 59 cat guardians, some of
104 whom had both species. Participating dogs had eaten vegan diets for six months to seven years, with a
105 mean of 2.83 years. Clinical examinations and blood tests were conducted on 20 randomly selected
106 dogs. No diet-related clinical abnormalities were detected. Haematological (complete blood count)
107 and biochemical (liver, kidney, and pancreatic) parameters were assessed, as well as levels of
108 magnesium, calcium, iron, total protein, folic acid, vitamin B12, and carnitine. The serum total
109 protein of all dogs was within normal ranges. No significant differences were evident in any tested
110 parameters, compared to dogs fed a conventional diet. Not even the 10% (2/20) of dogs fed a
111 homemade supplemented diet showed any significant deviations.

112

113 However, the relatively small numbers included in these samples limits their predictive value for
114 wider dog populations. By 2021, no large-scale study of dogs had been published, describing how
115 health indicators vary between dogs maintained on vegan, meat-based, or indeed, other diets.

116 Accordingly, we designed a survey to explore this. Our null hypothesis was that guardian-reported
117 canine health indicators would not significantly vary with diet type. The success of new pet foods
118 under development also depends on the views of consumers. We also sought to determine the
119 importance of pet health as a purchasing determinant, to a large group of dog guardians. Results of

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120 some survey parts were recently reported (palatability of different diets; ~~Knight and Satchell~~
121 ~~2021~~[21]), or are the subject of related, forthcoming studies.

124 Methodology

125
126 We designed a survey for dog or cat guardians using the 'Online surveys' platform
127 (<https://www.onlinesurveys.ac.uk>). Guardians were asked to provide information about themselves
128 and one dog or cat resident within their household for at least one year. Guardians were asked about
129 the main ingredients within their pet's normal diet. They were asked to identify whether the diet was
130 based on conventional, raw or *in vitro* meat, insects, fungi or algae, or whether it was a vegetarian,
131 vegan or some 'other' diet. Respondents could select only one option. Vegetarian diets were
132 explained as including eggs or milk, but not meat, and vegan diets as eschewing any animal products.
133 Where animals were fed a prescription or therapeutic diet, guardians were asked to base answers on
134 the diet in use prior to the commencement of the therapeutic diet. Guardians were also asked about
135 any treats/snacks/scraps or supplements provided.

136
137 Our survey also inquired about human demographics (continental region, urban or rural location,
138 educational qualifications achieved, occupation, household income, age categories in 10 year age
139 bands with the exception of bands for 18-19 and '70 or older', gender, and respondent diet).
140 Information was also obtained about animal demographics. These included role (companion or
141 working animal), age (with any year entry up to 'over 25' possible), sex/neuter status, canine breed
142 (toy, small, medium, large and giant), activity level, health status, reaction to meals, factors of
143 importance to guardians when choosing pet food, and information sources guardians relied on.

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145 Guardians provided information about seven general indicators of health, and about the prevalence of
146 specific health disorders, for the previous year, or the year prior to the commencement of a
147 therapeutic diet if one was currently used. Specifically, guardians were asked to report the frequency
148 of veterinary visits, and medication use (other than routine vaccinations and treatments for external or
149 internal parasites, such as fleas, ticks, lice, heartworm and intestinal worms, or treatments associated
150 with neutering operations, or microchipping). Guardians were asked to report whether their dog had
151 progressed onto a therapeutic diet, after initial maintenance on another diet type. They were asked to
152 report their own opinion of their dog's health status, and also to report what they believed their
153 veterinarian's assessment to be. Guardians were asked to "Think about your veterinarian. Which of
154 the following would most likely describe their opinions about your animal's medical condition over
155 the previous 12 months?" Possible answers for both their own opinions, and for the reported
156 assessments of their veterinarians, ranged from no problems/routine preventative healthcare, to
157 seriously ill. If veterinarians reportedly considered dogs to be suffering from health disorder(s),
158 guardians were asked which disorder(s) these were, from among 18 disorders indicated to be among
159 the most common disorders experienced by companion dogs [22-26]
160 . Guardians were able to select multiple
161 disorders, and to provide details of additional disorders by selecting 'other'. Details for each 'other'
162 entry were examined, with these entries then reclassified into 18 existing or four new disorder types,
163 giving a total of 22 possible health disorders.

164
165 When analysing health disorders, cases were excluded, where veterinary visits had not occurred at
166 least once in the previous year, or where guardians were unsure of the assessments of their
167 veterinarians. The remaining subset comprised guardians who had recently seen their veterinarians,
168 and were sure of their health assessments. This subset was used to calculate the percentage of unwell
169 dogs, and the average number of cases of disorder, per dog. It was also used to calculate the
170 prevalence of the 22 specific health disorders.

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173 Potentially confounding factors

174 Health status may be affected by age, sex, desexing (neutering) status and breed [25-28]
175 . Hence, we sought to ascertain
176 differences between major dietary groups, in age, sex and neuter status. We decided not to attempt to
177 account for the possible effects of certain additional factors, on health outcomes. Breed, for example,
178 can affect health status [27-28]. However, we were
179 concerned that small numbers within breed groups would limit our ability to statistically analyse
180 subsequent results, and so ultimately elected not to discriminate by breed within this study. We also
181 chose not to exclude dogs who received treats regularly, expecting most to receive such treats.

182

183 Survey pilot and distribution

184 Our survey piloting and distribution were described in Knight and Satchell [21]. The ‘Online
185 surveys’ platform we chose to use complies with the UK General Data Protection Regulation,
186 following the UK Data Protection Act 2018, and was used by 88% of UK higher education
187 institutions by 2019 [29], including our University of Winchester.

188

189 We piloted our survey to 25 respondents in April 2020. Improvements were then made to both survey
190 structure and questions. With respect to structure, changes were made to the ordering of survey parts,
191 to minimise inadvertently biasing answers to questions about health. These survey sections were
192 moved toward the beginning, to eliminate chances that answers might be affected by prior answers
193 about pet diet choices, particularly where unconventional diets were used, e.g., if a guardian reporting
194 use of an unconventional diet might subsequently be more likely to consciously or unconsciously
195 downplay any health problems. Similarly, changes were made to the ordering of questions about
196 veterinary opinions about animal health. In general, the variable most likely to be dependent, was

197 positioned prior to any possibly corresponding independent variable. Various questions were also
198 clarified and simplified. The final survey steps were those in Figure 1.

199

200

201 **[[Figure 1]]**

202

203 **Figure 1. Survey parts.**

204

205

206 The final survey was made available from May – December 2020. It was widely advertised through
207 social media to dog and cat interest groups. Paid Facebook advertising and several volunteers were
208 utilised to increase survey exposure. Facebook advertising demographics were unlimited, other than
209 to include terms relating to dogs and cats. In anticipation of lower levels of unconventional diets, and
210 the need to achieve group numbers sufficient for statistical analysis, volunteers and the authors made
211 some efforts to reach unconventional pet food interest groups, as well as conventional dog and cat
212 interest groups. However, by careful wording choice, no bias for or against any particular diet choice
213 was implied within advertising materials, or within the survey questions or explanatory text.

214

215 Statistical analysis

216 We reported demographic results for survey respondents, and for their dogs. With respect to mean
217 dog ages, we used T-tests to explore differences between dietary groups. When significant differences
218 were found, effect size interpretations were provided using the Cohen's d statistic, with small,
219 medium or large effects interpreted when |d| was close to 0.2, 0.5 and 0.8, respectively [30](~~Vaeha-~~
220 ~~Haase and Thompson 2004~~). With respect to sex/neuter status, where chi-squared results indicated the
221 existence of significant differences, we provided effect size interpretations using the Cramer's V
222 statistic, with small, medium or large effects interpreted when V was close to 0.2, 0.5 and 0.8,
223 respectively [31](~~Ferguson 2009~~). Where such significant differences existed, we then compared each

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224 main dietary group combination, calculating p-values. Where these indicated significant differences
225 between dietary groups, we provided odds ratios, indicating relative differences in the likeliness of
226 outcomes, between dietary groups.

227

228

229 After initial examination of dog diets, we limited further analysis to dogs maintained on three main
230 diets: conventional meat, raw meat, and vegan pet food. We excluded smaller dietary groups to avoid
231 potentially substantial differences in variances between dietary groups of small and larger sizes,
232 which could adversely affect our statistical analysis.

233

234 We investigated the impacts of these three main diet types on dog health. Guardians provided
235 information about seven general indicators of health, and about the prevalence of 22 specific health
236 disorders, as described previously. Similarly to our analysis of sex/neuter status, for the main dietary
237 groups identified, we investigated associations between diet type and the seven general health
238 indicators using chi-squared tests, reporting test statistics and p-values. Where chi-squared results
239 indicated the existence of significant differences, we similarly provided effect size interpretations
240 using the Cramer's V statistic, with small, medium or large effects interpreted when V was close to
241 0.2, 0.5 and 0.8, respectively [31]. Where such significant differences existed, we
242 then compared each main dietary group combination, calculating p-values. Where these indicated
243 significant differences between dietary groups, we provided odds ratios, indicating relative
244 differences in the likeliness of outcomes, between dietary groups.

245

246 For most general health indicators, our data were categorical. However, assessments or opinions of
247 health status were ordinal. These data were coded into levels 1 to 4 (indicating no health problems, up
248 to seriously ill, respectively). We then used Kruskal-Wallis tests to explore differences between
249 dietary groups. Dunn's pairwise tests were carried out to explore differences within the three pairs of
250 dietary comparisons, with the Bonferroni correction for multiple tests applied to p-values.

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252 When investigating the significance of the association between diet and the number of disorders
253 suffered by unwell dogs, we initially conducted an ANOVA test. Finding a significant difference, we
254 calculated the effect size using eta squared. Following Cohen [32], we interpreted a small,
255 medium or large effect depending on the proximity of eta squared to 0.01, 0.06 or 0.14 respectively.
256 We also
257 included a test for homogeneity of variance. Finding a lack of homogeneity, we then conducted a
258 Games-Howell post hoc comparison to test the significance of apparent differences between dietary
259 groups.

260
261 As well as exploring associations between diets and the seven general health indicators, we also
262 explored associations with the 22 specific health disorders. Binomial response models provided odds
263 ratios and p-values indicating differences between dietary groups. We used software packages R-
264 studio and SPSS, v26. Significance was interpreted when $p < 0.05$.

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267 Ethical approval and data availability

268 Our research complied with the University of Winchester Ethics Policy [33] (approval reference
269 RKEEC200304_Knight).

272 Results

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274 Of 4,060 respondents to our combined cat and dog survey, 4,057 confirmed they met the survey
275 conditions (18 years or older, with answers relating to one dog or cat resident within their household,

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276 for at least one year). The following results are limited to the 2,639 dogs and their guardians who
277 responded. Results concerning 1,418 cats and their guardians are the subject of a related, forthcoming
278 study.

279

280 Dog guardians

281 Of the 2,610 human respondents who provided their sex, 92% (2,412) identified as females, 7% (194)
282 as males, and 0% (4) as other. Most age brackets from 18 to 70+ were well represented, other than the
283 extreme ends where numbers were low. The majority of the 2,639 total respondents identified their
284 geographical region as the UK (71%, 1,884) or Europe (15%, 398), with North America (6%, 150)
285 and Australia/New Zealand/Oceania (4%, 117) being the next most prevalent continental regions. A
286 minority (18%, 488/2,639) worked in the pet or veterinary industries. The most common diet
287 reportedly followed by these 2,639 survey respondents was omnivorous (40%, 1,066), followed by
288 vegan (22%, 586), reducetarian (omnivore reducing animal product consumption) (21%, 567),
289 vegetarian (10%, 266) and pescatarian (consuming fish but no other meats) (5%, 134).

290

291 Importance of health to guardians

292 Of the 2,612 respondents who indicated their involvement in pet diet decision-making, 95% (2,489)
293 were primary decision-makers, 4% (107) played some lesser role, and 1% (16) played no role. Those
294 99% (2,596) playing at least some role were asked which factors were important when choosing pet
295 diets. Among 13 options including 'other', health and nutrition was considered the most important
296 factor, being of importance to 94% (2,453) of 2,596 respondents to this question. These 2,596
297 individuals were asked which health and nutrition factors were important to them. Maintenance of pet
298 health was considered the most important factor among five health and nutrition options including
299 'other'. It was cited as important by 90% (2,211) of 2,449 respondents to this question.

300

301 The importance of health was similarly highlighted by the 1,370 respondents who used a conventional
302 meat formulation as their dog's normal diet, and the 830 who used a raw meat formulation. These
303 combined 2,200 respondents were asked whether they would realistically choose alternative diets, if
304 these offered their desired attributes. The alternatives offered for consideration were vegetarian and
305 vegan diets, as well as those based on laboratory grown meat, insects, fungi and algae. Of 2,181 who
306 answered this question, 44% (955) confirmed they would realistically choose such alternative diets.
307 'Confidence about pet health' was the second most important among 14 desired attributes (including
308 'other'), that any alternative diet would need to provide. It was cited as essential by 83% (789) of
309 these 955 respondents, after 'Confidence about nutritional soundness' (84%, 805).

310

311

312 Dogs

313

314 Diets

315 2,639 dog guardians responded, each describing a single dog. 2,612 indicated the main diet their dog
316 was maintained on. 2,536 dogs were jointly maintained on the three main diets identified. These were
317 conventional meat (1,370 – 54%), raw meat (830 – 33%) and vegan (336 – 13%) diets (Fig. 2).

318 Smaller dietary groups were excluded from further analysis. The largest excluded group was dogs
319 reportedly fed vegetarian diets (n = 35). We also excluded 41 dogs reportedly maintained on fungi-

320 (1) and insect-based diets (6), laboratory-grown meat (7), mixtures of other dietary types (17) and

321 diets listed as 'unsure' (10). These groups were excluded due to low numbers, lack of clarity

322 concerning the main ingredient type, or current unavailability of these sources as canine maintenance

323 diets (as distinct from treats, snacks or supplements). Included within the set of 2,612 were 46

324 dog diets identified as 'other'. These were examined and reclassified into conventional meat,

325 mixture or unsure, depending on further details provided in textual answers.

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[[Figure 2]]

Figure 2. Three main diets fed to 2,536 dogs.

As mentioned, we chose not to exclude dogs who received treats regularly, expecting most would fall within this group. This turned out to be true, with 76% (1,935) of these 2,536 dogs receiving treats/snacks/scraps at least once daily. Treats provided to these 2,536 dogs were most commonly vegetables or fruit (1,315), commercial treats (1,174), dental/oral bars or chewable sticks (1,129), human food prepared at home (901), and raw meat or bones (758). Some dogs received more than one kind of treat.

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Thirty seven percent (926) of these 2,536 dogs were also regularly offered dietary supplements other than treats/snacks/scraps. These included products for joint health (558), fatty acids (e.g., omega-3 fatty acids) (364), probiotics or prebiotics (349), vitamins (235), minerals (198), digestive enzymes (130), amino acids (101) such as taurine, and other products. Some dogs received more than one kind of supplement.

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Ages

Considering the 2,536 dogs fed the three main diets, guardians were unsure of dogs' ages in two cases. Ages of the remaining 2,534 dogs are indicated in Figure 3. The mean ages in years, were: overall – 6.18, raw meat – 5.52, conventional meat – 6.31, vegan – 7.30. Differences between all diet groups were significant, and of small to medium size (Table 1).

[[Figure 3]]

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Figure 3. Ages of 2,534 dogs fed three main diets.

Table 1. Age differences between 2,534 dogs fed three main diets.

Age	Conventional - Raw meat	<u>Conventional - Vegan-</u> <u>Conventional!</u>	<u>Raw meat - Vegan</u>
T-value	-5.078	4.439	<u>7.672</u>
P-value	0.000	0.000	<u>0.000</u>
Cohen's d	-0.218	0.268	<u>0.513</u>
Effect size	small	small	<u>medium</u>

362
363

Sex/neuter status

The sex/neuter status of these 2,536 dogs is provided in Table 2 and Figure 4. Females comprised around 47%, and males around ~~52~~53% of this sample. A chi-square test of independence showed a significant association between diet type and sex/neuter status, overall: $\chi^2(6) = 57.23, p < 0.05$. The effect size was small (Cramer's $V = 0.106$). Within this sample, dogs fed vegan diets were slightly more likely to be female, than either of the other two dietary groups. However, sex and diet type were not statistically significantly associated: $\chi^2(2) = 3.9468, p=0.139$.

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[[Figure 4.]]

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Figure 4. Sex/neuter status of 2,536 dogs fed three main diets.

Table 2. Sex/neuter status of 2,536 dogs fed three main diets.

Sex/neuter status	Conventional meat	Raw meat	Vegan	Total
Female, sexually intact	95	104	23	222
Female, spayed	547	276	152	975
Male, sexually intact	166	149	25	340
Male, castrated	562	301	136	999
Total	1370	830	336	2536
P-value				
Conventional <u>meat</u>	---	0.000	0.043	
Raw meat	0.000	---	0.000	
Vegan	0.043	0.000	---	
Odds ratio				
Conventional <u>meat</u>	---	0.537	1.412	
Raw meat	1.863	---	2.631	
Vegan	0.708	0.380	---	

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Note: p-values and odds ratios reflect the likelihood of dogs being sexually intact.

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384

385 Statistically significant differences were apparent however, with respect to desexing. The odds of
386 being sexually intact were significantly different between all dietary groups (Table 2). Dogs fed vegan
387 diets were less likely, and dogs fed raw meat were more likely, to be sexually intact, than
388 conventionally fed dogs. Dogs fed raw meat were more than twice as likely to be sexually intact, than
389 dogs fed vegan diets. Additionally, the odds of being sexually intact were significantly different
390 between males and females, with males significantly more likely to be sexually intact (Table 3).

391
392

393 **Table 3. Differences in odds of being sexually intact, between males and females, for 2,536 dogs**
394 **fed three main diets.**

395

	Male	Female
P-value		
Male	---	0.000
Female	0.000	---
Odds ratio		
Male	---	1.495
Female	0.669	---

396
397

398 General health indicators

399 The results in this section consider the 2,536 dogs in the three main dietary groups.

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401

402 Number of veterinary visits

403 After excluding 16 'unsure' responses, 2,520 guardians reported frequency of veterinary visits within
 404 the last year (Fig. 5, Table 4). Routine health checks are normally conducted annually, whereas
 405 multiple veterinary visits within a single year may sometimes indicate a health problem. We were
 406 interested in those dogs who saw veterinarians more than once in the previous year. A chi-square test
 407 of independence showed that there was a significant association between diet type and veterinary
 408 visits more or less than once in the last year: $\chi^2(2) = 84.75, p < 0.05$. The effect size was small
 409 (Cramer's $V = 0.183$).

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411

412 **[[Figure 5]]**

413

414 **Figure 5. Veterinary visits of 2,520 dogs fed three main diets, in the last year.**

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415

416

417 **Table 4. Veterinary visits of 2,520 dogs fed three main diets, in the last year.**

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418

Veterinary visits in the last year	Conventional meat	Raw meat	Vegan	Total
0	169	222	55	446
1	501	350	148	999
2	333	132	74	539
3	128	58	29	215
<u>>=4 or more</u>	227	64	30	321
Total	1358	826	336	2520

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419

420

421 There were significant differences ($p < 0.05$) in the likelihood of seeing veterinarians more than once
422 in the previous year, between all dietary groups (Table 5). Dogs fed vegan diets were less likely, and
423 dogs fed raw meat less than half as likely, to meet this criterion, than conventionally fed dogs. Dogs
424 fed vegan diets were more likely to meet this criterion, than dogs fed raw meat.

425

426

427 **Table 5. Likelihood of seeing veterinarians more than once in the previous year, for 2,520 dogs**
428 **fed three main diets.**

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429

	Conventional meat	Raw meat	Vegan
P-value			
Conventional meat	---	0.000	0.000
Raw meat	0.000	---	0.004
Vegan	0.000	0.004	---
Odds ratio			
Conventional meat	---	2.312	1.567
Raw meat	0.432	---	0.678
Vegan	0.638	1.475	---

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432 Medication use

433 All 2,536 guardians provided information about medication use in the previous year (Fig. 6, Table 6).

434 A chi-square test of independence showed a significant association between diet type and medication

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435 use: $\chi^2(2) = 56.002, p < 0.05$. The effect size was small (Cramer's $V = 0.149$). There were significant
 436 differences ($p < 0.05$) in the likelihood of medication usage in the previous year, between dogs fed
 437 vegan and conventional diets, and between dogs fed raw meat and conventional diets, but not between
 438 dogs fed vegan and raw meat diets. Dogs fed vegan and raw meat diets each had a lower risk of
 439 meeting this criterion, compared to conventionally fed dogs.

440

441

442 **[[Figure 6]]**

443

444 **Figure 6. Medication use in 2,536 dogs fed three main diets.**

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445

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447 **Table 6. Medication use in 2,536 dogs fed three main diets.**

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448

Medication use	Conventional meat	Raw meat	Vegan	Total
No	723	559	227	1509
Yes	647	271	109	1027
Total	1370	830	336	2536
P-value				
Conventional meat	---	0.000	0.000	
Raw meat	0.000	---	0.945	
Vegan	0.000	0.945	---	
Odds ratio				
Conventional meat	---	1.846	1.863	

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Raw meat	0.542	---	1.010
Vegan	0.537	0.990	---

Note: p-values and odds ratios reflect the likelihood of medication being used.

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Progression onto a therapeutic diet

All 2,536 guardians provided information about whether or not their dog progressed onto a therapeutic diet, after initial maintenance on one of the three main diets (Fig. 7, Table 7). A chi-square test of independence showed a significant association between initial diet type and subsequent progression onto a therapeutic diet: $\chi^2(2) = 35.659, p < 0.05$. The effect size was small (Cramer's $V = 0.119$). There were significant differences ($p < 0.05$) in likelihood of subsequent progression onto a therapeutic diet, between dogs initially fed raw meat and conventional diets, and between dogs initially fed vegan diets and raw meat, but not between dogs initially fed vegan and conventional diets. Dogs initially fed raw meat were less than one fifth as likely to meet this criterion, as dogs initially fed conventional diets, and dogs initially fed vegan diets had more than three times the risk of this outcome, compared to those initially fed raw meat.

[[Figure 7]]

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Figure 7. Subsequent progression onto a therapeutic diet in 2,536 dogs maintained on an initial diet as specified.

472 **Table 7. Subsequent progression onto a therapeutic diet in 2,536 dogs maintained on an initial**
 473 **diet as specified.**

474

Progressed to therapeutic diet	Conventional meat	Raw meat	Vegan	Total
No	1276	819	322	2417
Yes	94	11	14	119
Total	1370	830	336	2536
P-value				
Conventional meat	---	0.000	0.072	
Raw meat	0.000	---	0.004	
Vegan	0.072	0.004	---	
Odds ratio				
Conventional meat	---	5.485	1.694	
Raw meat	0.182	---	0.309	
Vegan	0.590	3.237	---	

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475

476 **Note:** p-values and odds ratios reflect the likelihood of subsequent progression onto a therapeutic diet.

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478

479 **Reported veterinary assessments of health status**

480 2,074 dogs saw a veterinarian at least once in the previous year (Table 4). After excluding 12 'unsure'

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481 respondents, the 2,062 remaining guardians were reportedly sure of the assessments of their

482 veterinarians regarding the health status of their dogs (Fig. 8, Table 8). A chi-square test of

483 independence showed a significant association between diet type and reported veterinary assessment:

484 $\chi^2(6) = 16.770, p = 0.0101$. The effect size was small (Cramer's $V = 0.064$).

485

486

487 **[[Figure 8]]**

488

489 **Figure 8. Guardian-reported veterinary assessments of the health status of 2,062 dogs fed three**
490 **main diets.**

491

492

493 **Table 8. Guardian-reported veterinary assessments of the health status of 2,062 dogs fed three**
494 **main diets.**

495

Reported veterinary assessments	Conventional meat	Raw meat	Vegan	Total
No problems or routine preventative healthcare	606	339	178	1123
Minor or infrequent problems	447	200	76	723
Significant or frequent problems	114	54	21	189
Seriously ill	15	7	5	27
Total	1182	600	280	2062

496

497
498 After coding into 1 to 4 (indicating no health problems (1), up to seriously ill (4), respectively),
499 significant differences existed between dogs fed vegan and conventional meat diets, but not between
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500 other dietary groups. A Kruskal-Wallis test provided very strong evidence of a difference ($p = 0.002$)
 501 between the means ranks of at least one pairing (Table 9). Dunn's pairwise tests were carried out for
 502 the three pairs of groups. There was very strong evidence ($p = 0.002$, adjusted using the Bonferroni
 503 correction) of a difference between dogs fed a vegan and a conventional meat diet. There was no
 504 evidence of differences between dogs fed vegan and raw meat diets, or for dogs fed raw or
 505 conventional meat diets (Table 10).

508 **Table 9. Differences in guardian-reported veterinary assessments of the health status of 2,062**
 509 **dogs fed three main diets.**

	Conventional meat	Raw meat	Vegan
Mean Rank	1062.92	1011.13	942.51
Kruska-Wallis H	12.901		
df	2		
P-value	0.002		

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513 **Table 10. Pairwise comparison of guardian-reported veterinary assessments of the health status**
 514 **of 2,062 dogs fed three main diets.**

Diet 1 – Diet 2	Test Statistic	Std Error	Std Test Statistic	P-value	Adjusted P-value
Conventional - Raw meat	51.799	26.604	1.947	0.052	0.155

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Conventional - Vegan	120.417	35.274	3.414	0.001	0.002
Raw meat - Vegan	68.618	38.411	1.786	0.074	0.222

¹ Significance values have been adjusted by the Bonferroni correction for multiple tests.

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When comparing each main diet group combination and calculating odds ratios, there were significant differences ($p < 0.05$) in the likelihood that reported veterinary assessments of health status would indicate poorer health, between dogs fed vegan and conventional diets, but not between the other dietary groups (Table 11). Dogs fed vegan diets were less likely to meet this criterion, than conventionally fed dogs.

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Table 11. Likelihood of guardian-reported veterinary assessments indicating poorer health, in 2,062 dogs fed three main diets.

	Conventional meat	Raw meat	Vegan
P-value			
Conventional meat	---	0.053	0.001
Raw meat	0.053	---	0.064
Vegan	0.001	0.064	---
Odds ratio			
Conventional meat	---	1.208	1.585
Raw meat	0.828	---	1.312
Vegan	0.631	0.762	---

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531 Guardian opinions of health status

532 After excluding six 'unsure' responses, 2,530 guardians reported their own opinions of the health
 533 status of their dogs (Fig. 9, Table 12). A chi-square test of independence showed a significant
 534 association between diet type and guardian opinion: $\chi^2(6) = 52.875, p < 0.05$. The effect size was
 535 small (Cramer's $V = 0.102$).

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536

537

538 **[[Figure 9]]**

539

540 **Figure 9. Guardian opinions of the health status of 2,530 dogs fed three main diets.**

541

542

543 **Table 12. Guardian opinions of the health status of 2,530 dogs fed three main diets.**

544

Guardian opinions	Conventional meat	Raw meat	Vegan	Total
Healthy	758	568	235	1561
Generally healthy with minor or infrequent problems	516	226	86	828
Significant or frequent problems	85	31	11	127
Seriously ill	10	2	2	14
Total	1369	827	334	2530

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545

546

547 After coding into 1 to 4 (indicating no health problems (1), up to seriously ill (4), respectively),
 548 statistical analysis indicated significant differences between dogs fed vegan and conventional diets. A
 549 Kruskal-Wallis test provided very strong evidence of a difference ($p < 0.0001$) between the means
 550 ranks of at least one pairing (Table 13). Dunn's pairwise tests were carried out for the three pairs of
 551 groups. There was very strong evidence ($p < 0.0001$, adjusted using the Bonferroni correction) of
 552 differences between dogs fed vegan and conventional meat diets, and between dogs fed conventional
 553 meat and raw meat diets. There was no evidence of a difference between dogs fed vegan and raw
 554 meat diets (Table 14).

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557 **Table 13. Differences in guardian opinions of the health status of 2,530 dogs fed three main**
 558 **diets.**

	Conventional meat	Raw meat	Vegan
Mean Rank	1347.77	1174.32	1154.07
Kruska-Wallis H	52.088		
df	2		
P-value	<0.0001		

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560
 561
 562 **Table 14. Pairwise comparison of guardian opinions of the health status of 2,530 dogs fed three**
 563 **main diets.**

Diet 1 – Diet 2	Test Statistic	Std Error	Std Test Statistic	P-value	Adjusted P-value

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Conventional - Raw meat	173.451	27.487	6.310	< 0.0001	< 0.0001
Conventional - Vegan	193.703	38.088	5.086	< 0.0001	< 0.0001
Raw meat - Vegan	20.252	40.462	0.501	0.617	1.000

¹ Significance values have been adjusted by the Bonferroni correction for multiple tests.

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When comparing each main dietary group combination and calculating odds ratios, there were significant differences ($p < 0.05$) in the likelihood guardians would assess their dogs as having worse health, between dogs fed vegan and conventional diets, and between dogs fed raw meat and conventional diets, but not between dogs fed vegan and raw meat diets (Table 15). Dogs fed vegan and raw meat diets were both less likely to meet this criterion, compared to conventionally fed dogs.

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Table 15. Likelihood of guardian opinions indicating poorer health, in 2,530 dogs fed three main diets.

	Conventional meat	Raw meat	Vegan
P-value			
Conventional meat	---	0.000	0.000
Raw meat	0.000	---	0.590
Vegan	0.000	0.590	---
Odds ratio			
Conventional meat	---	1.770	1.909

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Raw meat	0.565	---	1.079
Vegan	0.524	0.927	---

578

579

580 Specific disorders

581 2,074 dogs saw veterinarians at least once in the previous year (Table 4). After excluding 12 cases in
582 which guardians were unsure what veterinary opinions would be, guardians were reportedly sure of
583 the opinions of 2,062 veterinarians (Table 8). 1,123 of these dogs were considered entirely healthy.
584 The remaining 939 dogs were considered to suffer from one or more disorders. In eight cases
585 (conventional meat – 3, raw meat – 4, vegan – 1), details were not provided or veterinarians
586 reportedly considered dogs to be ‘healthy’, ‘old’, or variations of these – i.e. not truly unwell. These
587 dogs were excluded. The remaining 931 dogs were analysed. In 161 of these cases, details of ‘other’
588 disorders were reported. These were examined, and then reclassified into the 18 existing, or four new
589 disorder types. In total, respondents reported that these 931 dogs were considered by their
590 veterinarians to be suffering from 1,477 cases of 22 specific disorders (Table S1).

591

592 For five disorders, guardians had the option to provide additional information. With respect to
593 skin/coat problems, further information was provided about 140 of these 147 cases. The most
594 common causes, in order, were atopic/allergic dermatitis (inflamed skin due to allergies), moist
595 dermatitis, and pruritis (itchiness) of unspecified origin. With respect to mobility problems, further
596 information was provided about 123 of these 135 cases. The most common causes, in order, were
597 osteoarthritis/arthritis, and a variety of ‘other’ causes. With respect to dental/oral problems, further
598 information was provided about 109 of these 110 cases. The most common causes, in order, were
599 dental calculus/plaque/tartar, gingivitis, and a variety of ‘other’ causes, particularly damaged, broken
600 or worn teeth. With respect to body weight problems, all 80 respondents described whether dogs were
601 over- or underweight. Eighty five percent (68) of reported cases were overweight, and 15% (12) were

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602 underweight. With respect to eye problems, further information was provided about 57 of these 58
603 cases. The most common causes included eye ulcers and related conditions such as dry eye and
604 entropion, conjunctivitis, infections, blindness/vision loss and cataracts.
605

606 Percentage of unwell dogs and average number of disorders per unwell dog

607 In addition to these 931 dogs with 1,477 cases of 22 specific disorders, respondents reported that the
608 remaining 1,123 dogs were considered by their veterinarians to be healthy. Overall, 45% were
609 suffering from at least one disorder, and the average number of disorders per unwell dog was 1.59
610 (Table 16).
611
612

613 **Table 16. 1,477 occurrences of 22 specific disorders, in 2,054 dogs fed three main diets.**
614

Health status	Conventional meat	Raw meat	Vegan	Total
Unwell	573	257	101	931
Healthy	606	339	178	1123
Total dogs	1179	596	279	2054
% unwell	49%	43%	36%	45%
Cases of disorders	947	377	153	1477
Average cases/unwell dog	1.65	1.47	1.51	1.59
P-value				
Conventional meat	---	0.029	0.000	

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Raw meat	0.029	---	0.052
Vegan	0.000	0.052	---
Odds ratio			
Conventional meat	---	1.247	1.666
Raw meat	0.802	---	1.336
Vegan	0.600	0.748	---

615

616 **Note:** p-values and odds ratios reflect the likelihood of dogs being assessed as unwell.

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617

618

619 Percentage of unwell dogs

620 A chi-square test of independence showed that there was a statistically significant association between
 621 diet type and the number of unwell dogs: $\chi^2(2) = 15.65$, $p < 0.0001$. The effect size was small
 622 (Cramer's $V = 0.087$). There were significant differences ($p < 0.05$) in the likelihood of being
 623 considered unwell between dogs fed vegan and conventional **meat** diets, and between dogs fed raw
 624 and conventional **meat** diets, but not between dogs fed vegan and raw **meat** diets. Dogs fed both vegan
 625 and raw meat diets had less risk of this outcome compared to conventionally fed dogs (Table 16).

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627

628 Number of disorders per unwell dog

629 The number of disorders per unwell dog ranged from one to eight (Table 17). An ANOVA test
 630 revealed a significant difference between the number of disorders suffered by unwell dogs, depending
 631 on diet type ($F = 3.953(2, 928)$, $p = 0.02$). The effect size was small ($\eta^2 = 0.008$). A test of
 632 homogeneity of variances indicated that variances were not homogenous. Accordingly, a Games-
 633 Howell post hoc comparison test was used. This revealed that unwell dogs fed a raw meat diet

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634 suffered less disorders than unwell dogs fed a conventional meat diet. This difference was statistically
635 significant ($p = 0.022$). Unwell dogs fed a vegan diet did not significantly differ in the number of
636 disorders suffered, compared to unwell dogs fed conventional or raw meat diets.

637

638

639 **Table 17. Number of disorders per unwell dog, among 931 unwell dogs fed three main diets.**

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Number disorders per dog	1	2	3	4	5	6	7	8
Conventional meat	330	160	50	21	7	2	2	1
Raw meat	181	54	12	5	1	1	3	0
Vegan	64	25	10	1	1	0	0	0

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643 Prevalence of 22 specific disorders

644 The prevalence of these 22 specific disorders in these 2,054 dogs is indicated in Table S2 and Figure
645 10.

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647

648 **[[Figure 10]]**

649

650 **Figure 10. Prevalence of 22 specific disorders or affected bodily systems in 2,054 dogs fed three**
651 **main diets, based on reported assessments of veterinarians.**

652 **Note:** Vertical axis order reflects overall prevalence of disorders (combining all diets).

653

654

655 Differences between dietary groups

656 Based on probability of occurrence, the 10 most common disorders found within each dietary group
657 are listed in Table 18. Some significant differences in the prevalence of certain disorders between
658 dietary groups were detected. There are indicated in Table S3 and summarised in Table 19.
659

660

661

662 **Table 18. The 10 most common disorders or affected bodily systems among 2,054 dogs fed three**
663 **main diets, and overall, based on reported assessments of veterinarians.**

664

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Rank	Conventional meat	Raw meat	Vegan	Overall
1	Gastrointestinal (e.g.e.g. diarrhoea, vomiting) (11%)	Ears (8%)	Skin/coat (6%)	Gastrointestinal (e.g.e.g. diarrhoea, vomiting) (9%)
2	Other musculoskeletal (muscle or bone) disease (8%)	Skin/coat (8%)	Mobility (6%)	Skin/coat (7%)
3	Mobility (8%)	Other musculoskeletal (muscle or bone) disease (7%)	Gastrointestinal (e.g.e.g. diarrhoea, vomiting) (5%)	Other musculoskeletal (muscle or bone) disease (7%)

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4	Skin/coat (7%)	Gastrointestinal (e.g.e.g., diarrhoea, vomiting) (6%)	Other musculoskeletal (muscle or bone) disease (4%)	Ears (7%)
5	Ears (7%)	Mobility (5%)	Dental/oral (teeth/mouth) (4%)	Mobility (7%)
6	Dental/oral (teeth/mouth) (6%)	Dental/oral (teeth/mouth) (4%)	Ears (3%)	Dental/oral (teeth/mouth) (5%)
7	Anal glands (6%)	Anal glands (4%)	Anal glands (3%)	Anal glands (5%)
8	Body weight (5%)	Cancer/tumours (3%)	Heart (3%)	Body weight (4%)
9	Behavioural (4%)	Other medical (3%)	Internal parasites (3%)	Eyes (3%)
10	Eyes (3%)	Eyes (3%)	Cancer/tumours (3%)	Cancer/tumours (2%)

665

666 **Note:** Percentages provide the prevalence of each disorder within each dietary group, and overall (all
667 diets combined).

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669

670 **Table 19. Disorders or bodily system effects with significantly different prevalences between**
671 **dietary groups, among 2,054 dogs, based on reported assessments of veterinarians.**

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672

Conventional – Raw meat	Conventional - Vegan	Raw meat - Vegan
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Raw less likely (5): Gastrointestinal, Mobility, Dental/oral, Body weight, Behavioural	Vegan less likely (3): Gastrointestinal, Other musculoskeletal, Ears	Vegan less likely (1): Ears
Raw more likely (1): Other medical	Vegan more likely (1): Internal parasites	Vegan more likely (1): Internal parasites

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675 Discussion

676

677 Importance of health to guardians

678 Our results affirmed the importance of pet health to guardians. Among 2,596 respondents, health and
679 nutrition was the factor considered most important in purchasing decisions. These results concur with
680 other studies. ‘Health & Nutrition’ was the most important among 24 pet food characteristics ranked
681 by 2,181 pet guardians, in a US-based study from 2015 to 2016 by Schleicher [et al. and colleagues](#)
682 [\[34\]\(2019\)](#).

683

684 It was noteworthy that 44% of our respondents feeding conventional or raw meat-based diets, stated
685 they would realistically consider alternatives. These results were similar to those of Dodd [et al. and](#)
686 [colleagues \(2019\)\[35\]](#), who surveyed 3,673 primarily Canadian and US pet guardians. They found
687 that 35% (1,083/3,130) of responding guardians who did not already feed a plant-based diet to their
688 [pet dog or cat](#), indicated interest in doing so. Our respondents reported that the most important
689 attributes such an alternative diet would need to provide, were ‘confidence about nutritional
690 soundness’, closely followed by ‘confidence about pet health’ (cited as necessary by 84% and 83% of
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691 these respondents, respectively). Dodd ~~and colleagues et al.~~ found that the most important attributes such
692 an alternative diet would need to provide, were ‘further evidence of nutritional sufficiency’ (45% -
693 269/559/599), followed by veterinary approval (20% - 122/599), and greater availability (20% - 117/599).
694

695 Canine demographics

696 Health outcomes for animals fed different diets may be affected by age, sex and desexing (neutering)
697 status [26, 36], and so it was important for us to understand
698 whether these varied between different diets, and how they compared to normal dog populations, in
699 our sampled dogs.

700
701 All three of the dietary groups we studied (conventional meat, raw meat, vegan) appeared to have had
702 an age distribution broadly representative of normal dogs [26, 37]
703 , with the exception of the first five years of life, in which there was a higher
704 percentage of dogs fed raw meat diets, and a lower percentage fed vegan diets (Fig. 3). This resulted
705 in significant differences between the average ages of these dietary groups. Within our studied
706 sample, on average, the youngest dogs were those fed raw meat, and the oldest dogs were those fed
707 vegan diets, with statistically significant differences between all dietary groups. Given that younger
708 dogs generally have fewer health problems, this may have positively influenced the general health
709 outcomes of dogs fed raw meat diets. In contrast, dogs fed vegan diets could be expected to have
710 relatively worse health outcomes. Due to their shorter lifespans, a single canine year of life equates to
711 many years of human life [38], from a veterinary healthcare perspective.

712
713 Females comprised just under half and males just over half of our 2,536 dogs (Table 2). This was
714 consistent with a 2016 study of 22,333 UK dogs [26](O’Neill et al. 2021), which found just over half
715 to be male. Variations in sex distributions between dietary groups within our sample were not
716 statistically significant. Statistically significant differences did exist with respect to desexing. Around
717 three quarters of all dogs in our sample were desexed (Table 2). This differed from the findings of
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718 O'Neill ~~et al.~~ and colleagues [26] (2021), who found 45% of all dogs to be desexed. Within our sample, male dogs
719 were more likely than females to be sexually intact (Table 3). This was consistent with the findings of
720 O'Neill and colleagues ~~et al.~~ (2021), who found desexing to be slightly less common for males. We also found that
721 desexing was most common for dogs fed vegan diets, and least common for dogs fed raw meat diets.
722 Significant differences existed between all dietary groups in this respect (Table 2). Lowered desexing
723 rates in guardians feeding raw meat diets may relate to the reduced likelihood of such guardians
724 visiting veterinarians (Fig. 5). Such guardians may be less likely to receive, or to comply with,
725 veterinary advice, and routine preventative healthcare advice commonly includes desexing
726 recommendations.

727

728

729 General health indicators

730

731 Number of veterinary visits

732 At least in the UK, routine health checks and administration of preventative healthcare, such as
733 vaccinations, are normally conducted annually [39-41]
734 . Seventy-one per cent of our respondents were based in the UK. Visit numbers
735 may increase somewhat for puppies or geriatric animals, but these comprised a low proportion of
736 studied animals (Fig. 3). Hence, zero or one veterinary visits in the previous year would normally be
737 consistent with good health, for our sample. In contrast, two, three or more visits could indicate a
738 health concern. Dogs fed conventional meat diets appeared more likely to fall within the latter group,
739 than those fed raw meat or vegan diets (Fig. 5). Effects were most notable for dogs fed raw meat diets,
740 who were less than half as likely as conventionally fed dogs, to experience two or more veterinary
741 visits (Table 5).

742

743 The apparent difference of raw meat diets in this respect, appears to have been heavily influenced by a
744 large increase in the proportion of dogs who did not see a veterinarian at all in the last year, compared
745 to the other two dietary groups. For dogs fed raw meat, these comprised 27%, compared to those fed
746 conventional (12%) and vegan (16%) diets respectively (Fig. 5). The unusually high proportion of
747 dogs fed raw meat diets, who did not see a veterinarian at all within the last year, may indeed indicate
748 a lack of healthcare problems. However, there is reason to believe that guardians of dogs fed raw meat
749 are less likely to visit veterinarians, for reasons not directly related to the health of their animals. The
750 overwhelming majority of veterinarians are critical of guardian choices to feed raw meat, due to well-
751 documented concerns about nutritional soundness and pathogen contamination [42-51]
752 . It is known that those who feed a raw meat diet are less likely to seek advice from their veterinarian,
753 . It is known that those who feed a raw meat diet are less likely to seek advice from their veterinarian,
754 . It is known that those who feed a raw meat diet are less likely to seek advice from their
755 veterinarian, and more inclined to gather information from other sources, such as online resources
756 [52] – which vary greatly in their reliability. The perceived opposition of most
757 veterinarians to the feeding philosophy and choices of guardians feeding raw meat diets, may make
758 these people less trusting of veterinary advice, and less likely to visit veterinarians, in general. This is
759 likely to have altered this apparent general health indicator, for reasons unrelated to the health of these
760 dogs.

761

762 Medication use

763 Medication use was similarly considered to indicate a probable health concern. This was significantly
764 more prevalent among dogs fed conventional meat diets, compared with those fed raw meat or vegan
765 diets (Fig. 6, Table 6). Veterinary clinics are major sources of companion animal medications, and
766 nearly the only source of prescription medications. It is a requirement in most jurisdictions, that
767 animals receiving prescription medications be examined at least once by a veterinarian, within the
768 preceding year. Accordingly, the markedly decreased proportion of veterinary visits by dogs fed raw

769 meat, compared to other dietary groups (Fig. 5), may have lowered the proportion of such dogs
770 receiving medications in the previous year.

771

772 Progression onto a therapeutic diet

773 Guardians were asked whether their dog progressed onto a therapeutic diet, after being initially
774 maintained primarily on a conventional meat, raw meat or vegan diet for at least one year. Such
775 progression was also considered indicative of a possible health concern. This was reported by 5%
776 (119/2536) of respondents, and was significantly more likely in dogs initially fed conventional and
777 vegan diets, than in those initially fed raw meat (Table 7). As with medications, veterinary clinics are
778 the major sources of therapeutic diets. Similarly to medication use, the markedly decreased proportion
779 of veterinary visits by dogs fed raw meat, compared to other dietary groups (Fig. 5), may have
780 lowered the proportion of such dogs who received therapeutic diets. Additionally, to the authors'
781 knowledge, by late 2021 few therapeutic diets were marketed as 'vegan' and none as 'raw meat'.
782 Hence, even where dogs fed these diets were seen by veterinarians and recommended a therapeutic
783 diet, it is possible guardians feeding these diets might not have complied with the recommendation.

784

785 Reported veterinary assessments of health status

786 When considering the veterinary healthcare assessments of their dogs, by their veterinarians,
787 guardians of dogs fed conventional diets were significantly more likely to report that veterinarians
788 considered dogs to be suffering from healthcare problems, than guardians of dogs fed vegan diets.
789 Differences between other dietary groups were not statistically significant (Table 11).

790

791 Guardian opinions of health status

792 A similar pattern was revealed when guardians were asked for their own assessments of their dogs'
793 health status – albeit with a shift of roughly 5% in all groups, toward considering dogs to be healthier
794 than veterinarians were expected to rate them (Fig. 9). Guardians were significantly more likely to

795 assess their dogs as having worse health, when fed conventional diets, compared to dogs fed vegan or
796 raw meat diets. Differences between the latter two groups were not statistically significant (Table 15).
797

798 Percentage of unwell dogs

799 After limiting to dogs who had seen a veterinarian at least once in the previous year, and excluding
800 dogs for whom guardians were unsure of their veterinarians' assessments, and eight instances in
801 which details were not provided or veterinarians reportedly did not consider dogs to be truly unwell,
802 2,054 dogs remained (Table 16). Forty five percent of these dogs were considered to suffer from at
803 least one health disorder. This is lower than the 66% of 22,333 UK dogs reported by O'Neill [and](#)
804 [colleagues \[26\]](#) to suffer from at least one disorder during 2016. This may be attributable to
805 our active efforts to recruit participants feeding unconventional diets. Forty six percent of our sampled
806 dogs were fed raw meat or vegan diets, and our combined results indicate that these dogs appeared to
807 suffer from disorders less commonly than dogs fed conventional meat diets. The likelihood of being
808 considered unwell, was significantly greater for dogs fed conventional diets compared to those fed
809 raw meat or vegan diets, but there was no significant difference between dogs fed vegan and raw meat
810 diets (Table 16).

811

812 Number of disorders per unwell dog

813 The number of health disorders per unwell dog varied from one to eight (Table 17), with the average
814 number of disorders per unwell dog being 1.59 (Table 16). Unwell dog fed a raw meat diet suffered
815 from fewer disorders than unwell dog fed a conventional meat diet, but differences between the other
816 dietary groups were not statistically significant.

817

818 General health indicators overall

819 We compared the dogs in each diet group with those of the other two diet groups (Table 20). Those
820 dogs fed conventional diets appeared to fare worse than those fed either of the other two diets.

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821

822

823 Table 20. Performance of each dietary group compared to the other two diets, with respect to seven
824 general indicators of health.

825

	Conventional meat	Raw meat	Vegan
Superior	0	8	75
Equivalent	3	6	57
Inferior	11	0	2

Formatted Table

826

827 **Note:** Comparing each diet group with the other two diets, for seven general indicators of health,
828 results in 14 comparisons; hence each column totals 14.

829

830

831 On the face of it, dogs fed raw meat appeared to fare slightly better than those fed vegan diets.

832 However, there was a statistically significant, medium-sized difference between the average ages of

833 dogs in these two groups. This is likely to have improved the general health indicators of dogs fed raw

834 diets, and to have lowered the prevalence of certain specific disorders [26](O'Neill et al. 2021). In our

835 study dogs fed raw meat appeared less likely to suffer from certain specific disorders (Table 19) –

836 one, when compared to dogs fed vegan diets, and five, when compared to dogs fed conventional diets.

837 However, for at least three of these six (dental/oral, body weight and mobility disorders), the younger

838 ages of dogs fed raw meat, is likely to have decreased the prevalence of these disorders [36](Tilley &

839 Smith 2015).

840

841 Additionally, there appear to be reasons unrelated to health, which significantly decrease the

842 likelihood guardians of dogs fed raw meat, will trust the opinions of their veterinarians, and seek

843 veterinary visits. The proportion of dogs who never saw veterinarians in the last year was markedly

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844 higher for those fed raw meat, compared with those fed vegan or conventional diets (Fig. 5).
845 Decreased veterinary visits also affects the likelihood dogs will receive medication or progress to
846 therapeutic diets. Jointly, these three health indicators comprise nearly half of the seven general health
847 indicators studied.

848
849 In light of these potentially confounding factors, and that the effect size was statically small, for every
850 general health indicator examined, we cannot conclude that dogs fed raw meat diets would be likely
851 to have health outcomes superior to those fed vegan diets, if ages were equalised, and non-health
852 related barriers to visiting veterinarians, were accounted for.

853

854 Consistency with prior related studies

855 When considering previous research in this field, by 2021 only Semp [20] had
856 similarly published guardian-reported health outcomes in dogs. Some of those guardians reported a
857 range of specific health benefits associated with vegan diets, as noted in the following ('Specific
858 disorders'). Semp and other investigators have also reported veterinary clinical examination and
859 laboratory test results exploring the health of dogs maintained on vegan diets. Semp reported that
860 clinical examinations and blood tests of 20 vegan dogs did not reveal any abnormalities associated
861 with diet. Not even the 10% (2/20) dogs fed a homemade supplemented diet showed any significant
862 deviations.

863

864 Yamada ~~et al and colleagues [18](1987)~~ conducted research on eight dogs, divided into two groups
865 maintained on animal or vegetable protein-based diets. It was not clear whether the latter was a vegan
866 diet. The VP-based dogs developed marked anaemia following exercise. However, the experimental
867 regime was particularly severe: six weeks of rest followed by four hours daily of enforced running at
868 12 km/h, for two weeks. This deviates markedly from the normal experience of domesticated dogs,
869 and so is of limited relevance to them. The sample size was also too small for reliable extrapolation of
870 results to wider dog populations.

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871

872 Brown [and colleague](#)'s 2009 study of sprint racing Siberian Huskies [\[19\]](#), did not record anaemia
873 or other detectable health problems, in dogs fed either meat or VP-based diets (each n = 6) over 16
874 weeks, including 10 weeks of competitive racing. Both timeframe and sample size were larger than
875 those used by Yamada [and colleagues](#) [\[18\]](#), although this sample size remained limited.

876

877 Specific disorders (22)

878 The ten most common specific health disorders or affected bodily systems overall (i.e., regardless of
879 diet), within these 2,054 dogs, were assessed as: gastrointestinal (e.g., diarrhoea, vomiting), skin/coat,
880 musculoskeletal (muscle or bone), ears, mobility problems, dental/oral (teeth/mouth), anal glands,
881 body weight, eyes and cancer/tumours (Table 18). Several previous studies have provided similar
882 results. Among 22,333 UK dogs in 2016, the most prevalent disorder groups were dental, skin,
883 enteropathy and musculoskeletal. When considered individually, the most common disorders were
884 periodontal disease, otitis externa, obesity, overgrown nails and anal sac impaction
885 [\[26\]](#). An earlier 2009 – 2013 study of 3,884 English dogs identified the most prevalent disorders
886 as otitis externa, periodontal disease, anal sac impaction, overgrown nails and degenerative joint
887 disease [\[25\]](#). Analyses of pet insurance records in Sweden indicated skin and
888 gastrointestinal disorders were among the most prevalent [\[22-23\]](#).
889 And a telephone survey indicated that the most common disorders in US dogs were musculoskeletal,
890 dental, and gastrointestinal tract or hepatic disease [\[24\]](#).

891

892 These results from our 2,054 dogs were broadly consistent with these previous studies, although
893 disorders that were lower in the 'top 10' rankings in our sample, seemed to include dental/oral and
894 obesity problems. These differences were even more noteworthy, when considering that our sample
895 included significantly more desexed animals (~~77~~78% vs 45%) than reported by O'Neill ~~et al and~~
896 ~~colleagues~~ [\(2021\[26\]\)](#), yet desexed animals are at greater risk of obesity and dental disorders
897 [\[26\]\(O'Neill et al. \(2021\)\)](#). Dental disease and obesity are poorly recognized by pet guardians, which

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898 may have contributed to this, although we sought to minimise such impacts by relying on reported
899 opinions of veterinarians. Slight differences between our results and those reported in previous studies
900 may also be attributable to the changing prevalence of certain diseases over time, and to differing
901 answer options provided to survey respondents. For example, we did not provide ‘overgrown nails’ as
902 an answer option, although participants had the option to identify musculoskeletal, mobility, or ‘other’
903 problems, with free text responses allowed for the latter.

904
905 When considering these 22 specific disorders individually, very small numbers of affected dogs fed
906 vegan diets in particular (Table S1), meant that differences compared with other dietary groups, were
907 often not statistically significant. In a small number of cases however, statistically significant
908 differences in disorder prevalence were detectable (Table S3). Despite the limited generalisability of
909 small numbers, results within our sample were nevertheless interesting in some other cases. The
910 probabilities of suffering from a disorder respectively appeared highest in conventional meat-based
911 dogs (for 11 disorders), raw meat-based dogs (for eight disorders), and vegan dogs (for three
912 disorders) (Fig. 10). In some cases, observed differences appeared marked. The dogs in our sample
913 fed vegan diets appeared to have around half the risk of those fed conventional meat diets, of
914 suffering from gastrointestinal disorders (e.g., diarrhoea, vomiting), musculoskeletal (muscle or bone)
915 disorders, ear disorders, anal gland problems, body weight problems, eye problems, behavioural
916 problems, and epilepsy. In all but two of these (body weight and behavioural problems), risks also
917 appeared less than for dogs fed raw meat diets, and sometimes by large margins. Dogs fed vegan diets
918 also appeared to have substantially lowered risks of allergies, compared to either of the other two
919 dietary groups (Fig. 10, Table S2). Some of these differences were particularly noteworthy, given that
920 dogs fed vegan diets were more likely to be neutered, and neutering normally increases risks of
921 obesity, musculoskeletal and behavioural problems [26]. And yet, the dogs in our
922 sample fed vegan diets appeared less likely to suffer from these disorders.

923

924 Dogs in our sample fed raw meat diets also appeared to have around half the risk of those fed
925 conventional meat diets, of suffering from gastrointestinal disorders (e.g., diarrhoea, vomiting), body
926 weight problems, hormonal problems (e.g., diabetes, hyper-/hypothyroidism, Addison's disease,
927 Cushing's disease), lower urinary tract problems, internal parasites and liver problems. Dogs fed raw
928 meat diets appeared to have substantially lowered risks of behavioural problems, compared to those
929 on either of the other two dietary groups (Table S2, Fig. 10).

930
931 The dogs in our sample fed conventional meat diets appeared to have lowered risks of 'other medical'
932 problems, injuries and respiratory tract (airways/lungs) problems, than dogs fed raw meat diets,
933 although not in comparison to dogs fed vegan diets. Dogs fed conventional meat diets appeared to
934 have lowered risks of kidney disease when compared to either of the other two dietary groups (Table
935 S2, Fig. 10).

936
937 Some of these results match current understanding that some of these disorders may be related. With
938 respect to body weight problems, 85% of affected dogs were reportedly overweight, and such dogs
939 are more likely to experience musculoskeletal problems [36] (p. 783). Dogs

940 who suffer from allergies are more likely to experience skin/coat and ear disorders, all of which
941 appeared less prevalent in dogs fed vegan diets [36] (p. 525).

942
943 In some cases, dietary aetiological explanations may exist. Diet is an important allergen source in
944 dogs, and vegan diets lack animal-sourced allergens, such as beef, chicken, fish, pork and lamb [36]
945 (Tilley & Smith 2016, p. 526). In other cases, no immediately obvious aetiological explanation is

946 available, such as apparently increased risks of internal parasites in dogs fed vegan diets, or
947 apparently decreased risks of behavioural disorders in dogs fed raw meat diets. However, vegan pet
948 guardians also appear more likely to feed vegan diets [35] (Dodd et al. 2019). The vegan lifestyle
949 adhered to by such guardians commonly involves a commitment to minimising harm to living
950 creatures, and it is possible some vegan guardians consider internal parasites to be living creatures

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951 deserving of consideration, reducing their use of anthelmintics (de-wormers). It also appears true that
952 certain appetitive behaviours are increased in dogs fed raw meat diets, compared to those fed a
953 conventional diet [21](Knight and Satchell 2021). Perhaps rates of behavioural disorders could also be
954 affected, although we are not aware of studies assessing this.

955

956 Consistency with prior studies of vegan dogs

957 The apparently decreased rates of certain specific disorders in vegan dogs observed in our sample,
958 concur with the results of Semp's 2014 study [20]. Her questionnaire to 174 vegan dog and 59 vegan
959 cat guardians resulted in 38 reports of healthier and shinier coats after transitioning to vegan diets, and
960 16 guardians described improved odours of their pets. Some dermatological problems reportedly
961 resolved. As noted, the dogs in our sample fed vegan diets had markedly lowered rates of allergies,
962 compared to either of the other two dietary groups (Fig. 10), and in dogs, allergies often manifest as
963 skin conditions [36] (pp. 525-526). And indeed, within our study sample, the
964 probabilities of a dog suffering from a skin/coat condition were 7% in dogs fed conventional meat,
965 8% in those fed raw meat, and 6% in those fed vegan diets (Table S2).

966

967 Some of Semp's respondents also noted improved stool consistency. Our results indicated that dogs
968 fed vegan diets also had significantly lowered rates of gastrointestinal problems. Within our study
969 sample, probabilities of dogs suffering from gastrointestinal problems were 11% for dogs fed
970 conventional meat, 6% for those fed raw meat, and 5% for those fed vegan diets (Table S2).

971

972 Study limitations

973 When reporting diets fed, guardians were asked to "consider the main ingredients within your pet's
974 normal diet". These diets were usually not fed exclusively. Of the 2,536 dogs in the three main diet
975 groups, 76% received a variety of treats at least once daily, and 37% were also regularly offered
976 dietary supplements. Accordingly, our results indicate health outcomes when dogs are fed the three

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977 main diet types within normal households, with normal feeding regimes, rather than when dogs are
978 exclusively fed each of the three main diet types, as might occur within a controlled study ~~with~~ a
979 research institute.

980
981 Additionally, our study relied on both quantitative information and opinions provided by guardians.
982 The most reliable medical studies are large-scale, prospective studies, that utilise relatively objective
983 assessments of unambiguous data. Veterinary clinical examinations, and veterinary assessments of
984 animal health status, would normally be more reliable than guardian opinions alone, and laboratory
985 results of physiological parameters such as blood and urine tests can provide particularly objective
986 data. However, when large animal numbers are involved, as is necessary for statistical validity of
987 results, such studies become expensive. Unfortunately, such studies were well in excess of our limited
988 research budget.

989
990 Accordingly, we were forced to rely on other health indicators. One of these was the answers of
991 guardians (82% of who did not work in the veterinary or pet industries), about health indicators
992 relating to their dogs. We acknowledge that reliance on guardians limits the reliability of results, for
993 example, due to lapses in memory. Our guardians most at risk of this, were those 5% (119/2536)
994 whose animals subsequently progressed onto a therapeutic diet, after initial maintenance on one of the
995 three main diets investigated (Table 7). These guardians were asked to “answer all questions about
996 your animal and their diet, using the 12 months prior to starting their therapeutic or prescription (i.e.,
997 medical) diet.” Hence, these guardians were asked to recall details more historical in nature. However,
998 these key instructions were highlighted within the survey, and respondents were also instructed, “If
999 you cannot recall details, please provide your best estimates, or answer 'unsure' etc. as appropriate.”

1000
1001 Another source of potential error, when relying on guardian answers, is unconscious bias. This could
1002 occur if a guardian using a conventional or unconventional pet diet expected a better health outcome
1003 as a result, and if this expectation exerted an unconscious effect on their answers about pet health

1004 indicators. Our study included more vegans than reported in some other studies [53](Leahy et al. 2010). It is conceivable
1005 that vegans, or respondents following other dietary groups, such as omnivores, might have had greater
1006 subconscious expectations of good health, when animals were fed diets similar to their own. We
1007 acknowledge such possible unconscious bias effects cannot be fully eliminated, but to minimise their
1008 effects on reported results, we ensured that survey questions asking about animal health were
1009 positioned prior to questions about animal diets. This minimises chances that answers might be
1010 affected by prior answers about dietary choices, e.g., if a guardian reporting use of an unconventional
1011 diet, subsequently became more likely to consciously or unconsciously under-report health problems.
1012 Additionally, by careful wording choice, no bias for or against any particular diet was implied within
1013 survey advertising materials, or within the survey questions or explanatory text. We do not consider
1014 that any remaining unconscious bias effects would be appreciably greater in one dietary group than
1015 another; hence consider that their effect on our results was probably minimal, overall.

1016
1017 Despite such steps, reliance on guardian-reported answers is vulnerable to error. We sought to
1018 minimise the impact of this unavoidable limitation, by also asking guardians to additionally report the
1019 assessment of their veterinarians, concerning their animals' health. To increase the reliability of such
1020 reported veterinary assessments, we included only those guardians whose animals had seen a
1021 veterinarian at least once in the previous year, and who were certain of their veterinarian's
1022 assessment. Responses from those who were uncertain, were excluded. And as mentioned, guardians
1023 were also given the opportunity to report their own opinion. It was expected the knowledge they
1024 would be able to provide their own opinion, if they disagreed with their veterinarian, would encourage
1025 them to more accurately report the assessments of their veterinarian. However, we ensured that the
1026 analysis of specific health disorders relied on reported veterinary assessments alone, rather than on
1027 guardian opinions.

1028
1029 We also asked about several more objective general health indicators, including the frequency of
1030 veterinary visits, and the use of any medications, within the previous year, as well as progression onto

1031 a therapeutic diet, after being initially fed a conventional meat, raw meat or vegan diet for at least one
1032 year. While we accept that a small proportion of these reported data and assessments may have been
1033 incorrect, we do not consider it plausible that a significant proportion of them were incorrect.

1034
1035 Our survey was made available from May – December 2020, during the global coronavirus (COVID-
1036 19) pandemic. Subsequent lockdowns may have decreased the frequency of veterinary visits in some
1037 regions, and potentially, the use of medications or therapeutic diets prescribed by veterinarians. For
1038 example, 71% of respondents stated they were from the UK, and in 2020, UK lockdowns occurred
1039 during all or part of March, April, July, and September to December

1040 [54]. The implementation of remote veterinary consultations and prescribing in many
1041 regions may have partly mitigated this effect. Nevertheless, we acknowledge this may have lowered
1042 the frequency of some health indicators such as the number of veterinary visits, and medication or
1043 therapeutic diet use, to a degree. However, because these were generally indicative of a possible
1044 health problem, decreased rates of these would have made our results more conservative overall. We
1045 also know of no reason why any one dietary group would be more affected, than any other, in these
1046 respects.

1047
1048 We also acknowledge that our respondents were not fully representative of the dog-owning
1049 population. Those who lacked easy internet access would have been less likely or unable to complete
1050 this internet-based survey. And although most ages were well represented, men were not, representing
1051 only 7% of respondents. Most of our participants were also located in the UK (71%) or Europe (15%).
1052 However, we do not consider that these anomalies would have significantly affected reported data or
1053 opinions concerning the health status of these animals.

1054
1055 Finally, although our participant numbers were sufficient to draw conclusions concerning the overall
1056 health of dogs maintained on the three main diets, numbers affected by certain medical disorders may
1057 have been insufficient to detect statistically significant differences in risks between diet groups.

1058

1059 Recommendations for safeguarding health

1060 Within this sample of 2,536 dogs fed three main diets, the reported data and opinions of guardians
1061 indicated that dogs that were least healthy when fed conventional meat diets. The health outcomes
1062 appeared slightly better for those fed raw meat, than vegan diets. However, the former group enjoyed
1063 the health protective effect of being significantly younger, and there were other non-health related
1064 factors that may have improved the apparent general health indicators of dogs fed raw meat diets, in
1065 three out of seven cases. Accordingly, it is unclear from our study which of these two diets would
1066 produce better health outcomes, if these confounding factors were eliminated.

1067

1068 Additionally, all dietary choices may include certain hazards. Those feeding unconventional diets
1069 should take special care to ensure their diets are nutritionally complete and reasonably balanced, and
1070 appropriate for life stage (e.g., young, old) and physiological status (e.g., pregnant, heavily
1071 exercising). Several studies of vegan or vegetarian diets [20, 55-56]
1072 , as well as conventional meat diets [57], have demonstrated
1073 that some diets in all of these groups have previously been formulated with nutritional deficiencies.
1074 Consumers should be encouraged to check labelling claims of nutritional adequacy, and to ask
1075 manufacturers what steps they take, and what evidence they can provide, to ensure nutritional
1076 soundness and consistency of their diets [17].

1077

1078 Raw meat diets have also been found to have nutritional deficiencies, such as calcium/phosphorous
1079 imbalances, and specific vitamin deficiencies [42, 47](Freeman and Michel 2001, Freeman et al.
1080 2013). There are also case reports of clinical nutritional disease associated with raw feeding
1081 [(Schlesinger and Joffe 201146, Lenox et al. 201548)]. Additionally, a sizeable body of evidence has
1082 indicated that raw meat diets are associated with increased risks of bacterial pathogens, as well as
1083 non-bacterial pathogens and zoonoses, with both dogs and their human guardians at increased risk
1084 [(Stiver et al. 2003, Finley et al. 2007, Marks et al. 201143-45, Giacometti et al. 2017, dos Reis et al.

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1085 [2017, Davies et al. 2019\(49-51\)](#). For these reasons, raw meat diets are not commonly recommended by veterinarians, and are
1086 not recommended by us. Special care should be exercised with respect to food hygiene, by those
1087 preparing raw meat diets.

1088

1089 In summary, when jointly considering health outcomes and dietary hazards, our results and those of
1090 other studies indicate that the healthiest and least hazardous dietary choices for dogs, are nutritionally
1091 sound vegan diets.

1092

1093 **Suggestions for further research**

1094 Large-scale cross-sectional, or ideally, longitudinal studies of dogs maintained on different diets,
1095 utilising more objective data, such as results of veterinary clinical examinations, veterinary medical
1096 histories, and laboratory data, should yield results of greater reliability, if sufficient research funding
1097 could be sourced. Whether utilising such an improved research design, or an internet survey,
1098 significantly larger numbers might also allow detection of statistically significant differences in risks
1099 of specific veterinary medical disorders, between dietary groups. Health consequences [within](#)
1100 smaller dietary groups, such as vegetarian animals, and of new diets as these become available, could
1101 also be investigated. Finally, larger numbers might also allow controlling for possible effects on
1102 specific disorders, of factors such as breed, age, sex, neutering status, body condition and weight,
1103 exercise levels, seasonality or social factors. This could require limiting to specific groups of interest,
1104 rather than dogs in general as in this study, to ensure sample sizes were sufficient to allow detection
1105 of statistically significant differences between groups.

1106

1107

1108 **Conclusions**

1109

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1110 Vegan diets are among a range of alternative diets being formulated to address increasing concerns of
1111 consumers about traditional pet foods, such as their ecological ‘pawprint’, perceived lack of
1112 ‘naturalness’, health concerns, or impacts on ‘food’ animals used to formulate such diets [
1113 8-9, 35]. Critics have asserted, albeit without evidence,
1114 that biological and practical challenges in formulating nutritionally adequate canine vegan diets mean
1115 their use should not be recommended [13, 58].
1116

1117 By 2021, no large-scale study of dogs had been published, describing how health outcomes vary
1118 between dogs maintained on vegan or meat-based diets. Our study of 2,639 dogs and their guardians
1119 is among the first such studies. Among 2,596 respondents who played some role in pet diet decision-
1120 making, pet health was one of the most important factors considered.
1121

1122 In total, 2,536 respondents provided information, each relating to a single dog who had been fed a
1123 primarily conventional meat (1,370 = 54%), raw meat (830 = 33%) or vegan (336 = 13%) diet for at
1124 least one year. Information was provided about seven general health indicators, and 22 specific
1125 disorders. Considering all seven general indicators of health, dogs fed conventional meat appeared
1126 less healthy than either of the other two dietary groups. They had poorer health indicators in nearly all
1127 cases. Considering dogs fed raw meat or vegan diets, the former group had marginally better health
1128 indicators overall. However, there was a statistically significant, medium-sized difference in ages,
1129 with dogs fed raw meat diets being younger on average. This can provide health protective effects.
1130 Other non-health related factors may also have improved the apparent health outcomes of dogs fed
1131 raw meat, for three of seven general health indicators. Additionally, a significant body of studies have
1132 indicated that raw meat diets commonly include significant dietary hazards, particularly nutritional
1133 deficiencies or imbalances, and pathogens. When considering these 22 specific disorders individually,
1134 different prevalence levels were apparent between the dietary groups. However, very small numbers
1135 of affected dogs fed vegan diets, may have prevented the detection of statistically significant
1136 differences in some cases.

1137
1138 Accordingly, when considering health outcomes in conjunction with dietary hazards, the pooled
1139 evidence to date from our study, and others in this field, indicates that the healthiest and least
1140 hazardous dietary choices for dogs, among conventional, raw meat and vegan diets, are nutritionally
1141 sound vegan diets. Regardless of ingredients used, diets should always be formulated to be
1142 nutritionally complete and balanced, without which adverse [health effects](#) may
1143 eventually be expected to occur.

1144

1145

1146 **Supporting information**

1147

1148 **Table S1. 1,477 cases of 22 specific disorders or affected bodily systems, in 931 dogs fed three**
1149 **main diets, based on reported assessments of veterinarians.**

1150 **Table S2. Prevalence of 22 specific disorders or affected bodily systems in 2,054 dogs fed three**
1151 **main diets, based on reported assessments of veterinarians.**

1152 **Table S3. Differences in the likelihood of 22 specific disorders or bodily system effects occurring**
1153 **among 2,054 dogs fed three main diets, based on reported assessments of veterinarians.**

1154

1155 **Acknowledgements**

1156

1157 We are grateful to the research assistants, volunteers and companies who helped outreach our research
1158 survey through social media, including Natalie Light, Megan Orledge, Anesa Kratovac, Yuki Ng,

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1159 Angel Lau, Mathilde Alexandre and others, and to digital marketing agencies Pinky Digital and Ardor
1160 SEO. Initial statistical support was also kindly provided by Jo Anderson, Research Director at
1161 Faunalytics.

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1167 ~~references once no further changes are required.~~

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