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A current life table and causes of death for insured dogs in Japan

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ABSTRACT

The life expectancies and causes of death were evaluated in 299,555 dogs insured in Japan between 1 April 2010 and 31 March 2011, of which 4169 dogs died during this period. The overall life expectancy of dogs was 13.7 years. The probability of death was high in the first year of life, lowest in the second and third years, and increased exponentially after 3 years of age. The life expectancy was 13.8 years in the <5 kg body weight group, 14.2 years in the 5–10 kg body weight group, 13.6 years in the 10–20 kg body weight group, 12.5 years in the 20–40 kg body weight group and 10.6 years in the ≥40 kg body weight group. As body weight increases, life expectancy tended to decrease except in the <5 kg body weight group. The probability of death increased as dogs got older for most potential causes of death. Neoplasia resulted in the highest probability of death, especially in the large and giant breed groups. Cardiovascular system disorders were the second major cause of death and the toy group had a probability of death significantly higher than the other breed groups at age 12+.

1. Introduction

Knowing the life expectancy of a defined animal population and the risk factors that may affect it, can provide information required to assist in the prevention and control of disease and the education of owners. There have been studies on canine longevity and causes of death using data from veterinary hospitals (Patronek et al., 1997; Bronson, 1982; Fleming et al., 2011), pet insurance data (Bonnett et al., 1997; Egenvall et al., 2000a,b) and data based on questionnaire surveys of pet owners (Michell, 1999; Reid and Peterson, 2000; Proschowsky et al., 2003). Despite the fact that studies using pet insurance data have inherent sampling biases, they provide useful information about the potential risk factors that affect the longevity of dogs. For example, Bonnett et al. (1997) and Egenvall et al. (2000a) reported mortality risks and causes of death for over 200,000 dogs using records from a Swedish pet insurance company. Egenvall et al. (2000b) reported the age patterns for risk of death in selected breeds of insured dogs.

Dogs are the most popular companion animal in Japan with a population estimated to be 11.5 million in September 2012, and with 16.8% of households owning one or more dogs as companion animals (JPFA, 2013). An increasing number of dogs in Japan enjoy improved health than hitherto partly due to the use of commercial pet food and partly to veterinary medical care. As a result, their life expectancy is expected to have been extended in recent years. However, as there is no official system requiring owners to report the birth and death of dogs and there has

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been no study conducted to estimate the life expectancy of dogs in Japan, except for a study conducted by Hayashidani et al. (1988). They used pet cemetery data, constructed a cohort life table and estimated the life expectancy of dogs to be 8.3 years at birth (age zero) and 8.6 years at 1 year old (age one).

Since a pet insurance company, Anicom started its operation in 2000, an increasing number of dogs are enrolled into an insurance program for veterinary care in Japan. At the end of September 2014, 462,102 dogs were insured for veterinary care, more than half being covered by Anicom.

There are two principal forms of the life table: the cohort (or generation) life table and the current life table. The cohort life table records the actual mortality experience of a particular group of individuals (the cohort) over its entire lifetime. The current life table gives a cross-sectional view of the mortality and survival experience of a population during a current year and is dependent on the age-specific death rates prevailing in the year for which it is constructed. The current life table is the most effective means of summarizing the mortality and survival experience of a population, and forms a sound basis for statistical inferences about the population under study (Chiang, 1984).

The purpose of this study was to construct a current life table of dogs in Japan using data from a Japanese company operating veterinary care insurance programs in the fiscal year 2010 and to determine the common causes of death.

2. Materials and methods

2.1. Description of the insurance procedures

Dogs younger than 11 years old are eligible to enter the Anicom insurance program, which provides insurance for veterinary care. The insurance policy term is 1 year from the enrolment and the owner can choose to renew the policy at the end of each policy year until the dog dies. The Anicom pet insurance program covers veterinary care costs. If a dog receives veterinary care, the owner gets between 50 and 70% of the cost reimbursed, depending on the type of insurance program that the dog is covered by. There is a maximum amount of reimbursement set for veterinary care without hospitalization, veterinary care with hospitalization and veterinary care with surgical operation. The insurance claim is usually made electronically or by paper forms by the owner or by the attending veterinarian. Basic data about the dog, such as the date of birth, breed, and gender are submitted at the time of enrolment into the insurance program. Date of visit to the veterinarian, the amount paid for the veterinary care and reason for the claim, including diagnostic categories and diagnosis, are submitted with the claim.

2.2. Data management

Data on all dogs that entered an insurance program or renewed the insurance policy any time during fiscal year 2010 (1 April 2010–31 March 2011) were entered into a database for this study. Each of these dogs was observed for 1 year from the entrance into the insurance program or renewal of it. As a result, the observation period of each dog varied depending on what date the dog entered or renewed the insurance program. For example, if a dog entered or renewed the insurance program on 1 April 2010, the dog was observed from 1 April 2010 until 31 March 2011. If a dog entered or renewed the program on 2 April 2010, the dog was observed from 2 April 2010 until 1 April 2011, and so on. The variables included in the database were breed, gender, the date of birth and date of entrance into or renewal of the insurance program. Whether the dog renewed the insurance policy at the end of the 1 year observation period was also entered into the database. For dogs that died during the observation period, the date and cause of death and age at death were entered into the database. Anicom provides insurance only for veterinary care and not life insurance for dogs, therefore the dates of death and causes of death are not stated in the claim forms. When the insurance was cancelled due to death of the insured dog, the date of death was confirmed with the owner. The reason for the claim stated on the form submitted in the month before the date of death was assumed to be the cause of death. To validate the data on the causes of death, we randomly selected 106 dogs that left the insurance program in November 2014 with submission of insurance cancellation due to death and asked the owners about the actual cause of death, and examined if the diagnostic information on the veterinary care claim was in agreement with the actual causes of death. This telephone survey revealed that of the 106 dogs that died, 89 had a veterinary care claim within 1 month of death. Of these, 71 dogs (80%) had a diagnostic category in agreement with the actual causes of death, and 18 dogs (20%) had a diagnostic category inconsistent with the actual causes of death or had only symptomatic diagnosis. Thus, the telephone survey supported our assumptions in the majority of cases.

The age at death for each dog was calculated based on the date of birth and the date of death. Those dogs that had the insurance policy renewed at the end of the observation period were considered to have survived the 1 year observation period. Those dogs that left the insurance program without submission of cancellation due to death or did not renew the program were excluded from this study. The number of dogs subjected to the construction of life table and analysis of cause of death is shown in Table 1.

2.3. Construction of life table

In constructing the life table, we used an age interval of 1 year. We calculated the probability of a dog dying in age interval $(x, x+1)$, $\hat{q}_x$ as a proportion of dogs that died during this age interval over the dogs alive at age x. We calculated the fraction of last year of life for age x, a'_x as the average of the fraction of last year of life for dogs that had died during the interval $(x, x+1)$. We constructed a life table from $\hat{q}_x$ and a'_x, in accordance with the method described by Chiang (1984). The life expectancy at age x was calculated, as the number of years, on the average, yet to be lived by a dog of age x. We constructed a life table for all breeds combined and for five groups of breeds grouped according to their ideal body weights: toy (<5 kg), small (5–10 kg), medium (10–20 kg), large (20–40 kg) and giant (≥40 kg). Data on the ideal weight of each breed were obtained from the Japan

Table 1
Summary statistics of the insured dog population used in the study.

	Number	Males (percent)	Mean age	Median age	Age range
Dogs commencing or renewing insurance in fiscal year 2010*	299,555	52.8	3.6	3	0–18
Dogs included in the study	278,441	52.6	3.8	3	0–18
Dogs subjected to cause of death analysis	4169	53.7	8.4	9	0–18

* Fiscal year 2010 is from 1 April 2010 to 31 March 2011.

Kennel Club (2013). We summed up the dogs aged 17 and over to one age interval (17+) in constructing a life table for all breeds combined, and toy, small and medium breeds. We summed up the dogs aged 16 and over to one age interval (16+) for large breed, and the dogs age 13 and over to one age interval (13+) for giant breed group. The number of dogs by age insured in fiscal year 2010 grouped into these five groups is shown in Table 2.

We calculated the variance of life expectancy at each age using the method described by Chiang (1984). The significance of difference of life expectancy between different breed groups was also tested using the method by Chiang (1984), i.e. we first obtained the ratio of the difference of estimated life expectancy between different groups to the standard error of the difference at each age interval and then checked if the value of this ratio exceeded the critical value of $Z_{0.99} = 2.33$ corresponding to $\alpha = 0.01$ level of significance.

Table 2
Number of breeds and dogs by age grouped into five groups according to their body weight*.

Age	Breed groups					Total
	Toy[a]	Small[b]	Medium[c]	Large[d]	Giant[e]	
0	23,466	15,316	5368	1616	321	46,087
1	20,207	15,469	5458	1938	342	43,414
2	12,545	10,105	3621	1191	180	27,642
3	13,661	13,174	4490	1481	240	33,046
4	11,083	13,107	4347	1535	252	30,324
5	9201	12,272	4258	1409	219	27,359
6	6872	11,288	3823	1642	195	23,820
7	4251	8252	2870	1432	160	16,965
8	2127	5047	1929	1226	120	10,449
9	1288	3320	1297	1002	69	6976
10	908	2470	975	772	49	5174
11	539	1609	628	538	19	3333
12	303	922	397	345	7	1974
13	192	466	209	194	3	1064
14	108	250	108	97	1	564
15	53	89	39	15	0	196
16	9	21	9	4	0	43
17	3	4	1	0	0	8
18	0	3	0	0	0	3
Total	106,816	113,184	39,827	16,437	2177	278,441

* The body weight is defined as ideal body weight by the Japan Kennel Club (2013).
[a] Toy group includes 13 breeds of body weight <5 kg, such as Chihuahua, Toy poodle, Yorkshire Terrier, Pomeranian and Maltese.
[b] Small group includes 44 breeds of ideal body weight 5–10 kg, such as Miniature Dachshund, Papillon, Miniature Schnauzer, Shih Tzu, Cavalier King Charles Spaniel and Pug.
[c] Medium group includes 43 breeds of ideal body weight 10–20 kg, such as Shiba, Pembroke Welsh Corgi and French bulldog.
[d] Large group includes 58 breeds of ideal body weight 20–40 kg, such as Golden Retriever and Labrador Retriever.
[e] Giant group includes 24 breeds of ideal body weight ≥40 kg, such as Great Dane, Newfoundland and Saint Bernard.

2.4. Analysis of causes of death

The 4169 dogs that left the insurance program due to death were subjected to the analysis of causes of death. We categorized the causes of death of these dogs into one of the 18 diagnostic categories by body system or type of disease: disorders of cardiovascular, respiratory, digestive, urinary, reproductive, neuromuscular and musculoskeletal systems; hepatobiliary and exocrine pancreatic disorders; diseases of eye, ear, teeth and skin; immunological and endocrine disorders; infectious diseases, parasitic diseases, injuries, neoplasia and unknown. These diagnostic categories are used by veterinarians when they complete the insurance claim form for the owners. The cause was classified as 'unknown' for 548 dogs, where the cause stated on the claim form was only a symptomatic diagnosis, such as loss of appetite, diarrhea, etc. and unclassifiable into any of these categories. There were 940 dogs that died with no claim for veterinary care within 1 month before the date of death. These dogs were also classified as died of 'unknown' causes. The breakdown of these dogs by cause of death is shown in Table 3. We calculated the probability of death

Table 3
Number of dogs dead by cause subjected to analysis of causes of death.

Diagnostic category	Number of dogs	(%)
Neoplasia	622	(14.9)
Cardiovascular system disorders	380	(9.1)
Urinary system disorders	258	(6.2)
Digestive system disorders	245	(5.9)
Neuromuscular system disorders	208	(5.0)
Respiratory system disorders	184	(4.4)
Hepatobiliary and exocrine pancreatic disorders	178	(4.3)
Immunological disorders	110	(2.6)
Musculoskeletal system disorders	102	(2.4)
Injuries	86	(2.1)
Skin diseases	77	(1.8)
Endocrine disorders	76	(1.8)
Infectious diseases	41	(1.0)
Reproductive system disorders	32	(0.8)
Eye diseases	31	(0.7)
Ear diseases	31	(0.7)
Teeth diseases	14	(0.3)
Parasitic diseases	6	(0.1)
Unknown*	1488	(35.7)
Total	4169	(100.0)

* Unknown include dogs which died with no claim for veterinary care submitted within 1 month before the date of death as well as those with claim for veterinary care submitted but no diagnostic category being stated.

of a dog breed group b from a diagnostic category d at age group a, $P_{b,a,d}$ by:

$$P_{b,a,d} = \frac{n_{b,a,d}}{N_{b,a}}$$

where $N_{b,a}$ is the total number of dogs of breed group b that entered into or renewed the insurance policy at age group a, and $n_{b,a,d}$ is the number of dogs of breed group b that entered into or renewed the insurance policy at age group a and died of diagnostic category d during the 1 year observation period. We used age groups of 2 years each up to age 11 (a = 0–1, 2–3, 4–5, 5–7, 8–9, 10–11) to get sufficient numbers of dogs in the denominator to improve the statistical power for comparisons between age groups. We summed up the dogs aged 12 and over to one age group (12+) for toy, small, medium and large breed groups, and the dogs aged 10 and over to one age group (10+) for giant breed group.

In constructing the life tables and analyzing the causes of death, we used spreadsheet software Excel 14.0 (Microsoft Corporation).

3. Results

3.1. Life expectancy of insured dogs in Japan

Table 4 presents the current life table of insured dogs of all breeds combined in Japan. The probability of death was high in the first year of life, lowest in the second and third years of life and increased exponentially after 3 years old. The life expectancy at age zero, or the average lifespan was 13.7 years.

Tables 5–9 present life table for toy, small, medium, large and giant breed groups respectively. The life expectancy at age zero was 13.8 (95%CI: 13.6–14.1) years for the toy group; 14.2 (95%CI: 14.0–14.4) years for the small group; 13.6 (95%CI: 13.4–13.8) years for the medium group; 12.5 (95%CI: 12.3–12.8) for the large group; and 10.6 (95%CI: 9.7–11.5) years for the giant breed group.

Fig. 1 indicates the life expectancy of the five breed groups up to 10 years of age. There was a significant difference in the life expectancy at age zero up to age six between the breed groups with p value <0.01 except for between toy and small groups and between toy and medium groups. The difference in the life expectancy between breed groups became less significant as the age increased further and the number of dogs (n) decreased.

3.2. Causes of death of insured dogs in Japan

Fig. 2 shows the probability of death of insured dogs in Japan at different age groups by six major causes. The probability of death increased as dogs get older for most causes. Neoplasia was the cause of death with the highest probability of death. The probability of death from neoplasia in the large and giant breed groups appeared to be higher than the other groups at both young and old ages. A significant difference was detected between large and giant groups and other breed groups at age groups 6–7, 8–9, 10–11 and 12+.

Cardiovascular system disorders were the second major cause of death. The toy group had the probability of death of 4.7% at age 12+, significantly higher than the medium and large breed groups at the same age group.

The probability of death from musculoskeletal system disorders in the large and giant breed groups at age 12+ and at age 10+ was 1.8% and 2.5% respectively, and appeared to be higher than the other breed groups, but there was no significant difference between breed groups at any age groups (graph not shown).

The probability of death from urinary tract disorders, digestive and respiratory system disorders and neuromuscular disorders also increased with age and reached 2–3% at age 12+, with no significant difference between breed groups.

Table 4
Current life table of insured dogs in Japan (all breeds combined).

Age interval in years x to $x+1$	Probability of dying in interval (x, $x+1$) $\hat{q}_x$	Number living at age x l_x	Number dying in interval (x, $x+1$) d_x	Fraction of last year of life a'_x	Number of years lived in interval (x, $x+1$) L_x	Total number of years lived beyond age x T_x	Expectation of life at age x $\hat{e}_x$
0–1	0.0107	10,000	107	0.48	9945	136,580	13.7
1–2	0.0049	9893	48	0.45	9867	126,636	12.8
2–3	0.0041	9845	41	0.48	9824	116,769	11.9
3–4	0.0048	9804	47	0.54	9783	106,945	10.9
4–5	0.0066	9757	64	0.51	9726	97,163	10.0
5–6	0.0082	9693	79	0.51	9654	87,437	9.0
6–7	0.0102	9614	98	0.53	9568	77,783	8.1
7–8	0.0152	9516	145	0.51	9445	68,215	7.2
8–9	0.0254	9371	238	0.49	9250	58,770	6.3
9–10	0.0388	9133	354	0.49	8952	49,520	5.4
10–11	0.0606	8778	532	0.50	8512	40,568	4.6
11–12	0.0877	8246	723	0.51	7889	32,056	3.9
12–13	0.1266	7523	953	0.48	7024	24,167	3.2
13–14	0.1688	6570	1109	0.45	5961	17,143	2.6
14–15	0.2678	5461	1463	0.49	4708	11,181	2.0
15–16	0.3739	3999	1495	0.45	3178	6473	1.6
16–17	0.4715	2504	1181	0.38	1777	3295	1.3
17+	1.0000	1323	1323	–	1518	1518	1.1

Table 5
Current life table of insured dogs in Japan (toy breeds).

Age interval in years x to x + 1	Probability of dying in interval (x, x + 1) $\hat{q}_x$	Number living at age x l_x	Number dying in interval (x, x + 1) d_x	Fraction of last year of life a'_x	Number of years lived in interval (x, x + 1) L_x	Total number of years lived beyond age x T_x	Expectation of life at age x $\hat{e}_x$
0–1	0.0099	10,000	99	0.46	9946	138,463	13.8
1–2	0.0043	9901	42	0.43	9877	128,517	13.0
2–3	0.0034	9859	33	0.50	9842	118,640	12.0
3–4	0.0036	9826	36	0.58	9811	108,798	11.1
4–5	0.0051	9790	50	0.50	9765	98,987	10.1
5–6	0.0060	9740	58	0.47	9709	89,222	9.2
6–7	0.0074	9682	71	0.53	9648	79,512	8.2
7–8	0.0133	9611	128	0.46	9541	69,864	7.3
8–9	0.0217	9483	206	0.42	9364	60,323	6.4
9–10	0.0272	9277	253	0.42	9130	50,959	5.5
10–11	0.0554	9025	500	0.47	8761	41,829	4.6
11–12	0.0982	8525	837	0.49	8101	33,067	3.9
12–13	0.1377	7688	1059	0.51	7171	24,967	3.2
13–14	0.1531	6629	1015	0.39	6006	17,795	2.7
14–15	0.2804	5614	1574	0.48	4803	11,789	2.1
15–16	0.3579	4040	1446	0.52	3340	6986	1.7
16–17	0.5294	2594	1373	0.36	1711	3646	1.4
17+	1.0000	1221	1221	–	1935	1935	1.6

Table 6
Current life table of insured dogs in Japan (small breeds).

Age interval in years x to x + 1	Probability of dying in interval (x, x + 1) $\hat{q}_x$	Number living at age x l_x	Number dying in interval (x, x + 1) d_x	Fraction of last year of life a'_x	Number of years lived in interval (x, x + 1) L_x	Total number of years lived beyond age x T_x	Expectation of life at age x $\hat{e}_x$
0–1	0.0112	10,000	112	0.49	9943	141,961	14.2
1–2	0.0048	9888	47	0.47	9863	132,018	13.4
2–3	0.0043	9841	43	0.51	9820	122,155	12.4
3–4	0.0048	9798	47	0.52	9776	112,335	11.5
4–5	0.0059	9751	58	0.51	9723	102,559	10.5
5–6	0.0067	9693	65	0.52	9662	92,836	9.6
6–7	0.0096	9628	92	0.51	9583	83,174	8.6
7–8	0.0118	9536	113	0.51	9480	73,592	7.7
8–9	0.0158	9423	149	0.50	9348	64,111	6.8
9–10	0.0284	9274	263	0.50	9143	54,763	5.9
10–11	0.0445	9011	401	0.51	8814	45,620	5.1
11–12	0.0666	8610	573	0.53	8339	36,807	4.3
12–13	0.0972	8037	781	0.46	7615	28,467	3.5
13–14	0.1348	7256	978	0.46	6732	20,853	2.9
14–15	0.1949	6277	1224	0.51	5673	14,121	2.2
15–16	0.3477	5054	1757	0.42	4029	8448	1.7
16–17	0.4031	3297	1329	0.39	2483	4418	1.3
17+	1.0000	1968	1968	–	1936	1936	1.0

The probability of death from hematological/immunological disorders, endocrine disorders, infectious diseases, parasitosis or injury was below 1% for most age groups in all breed groups. The probability of death from infectious diseases was 0.05% in the first 2 years of life, but remained lower than 0.01% at older age groups. The probability of death from ophthalmological disorders, otic diseases, dentistry, parasitosis, and dermatological disorders was below 0.1% at all age groups in all breed groups.

4. Discussion

To examine how much we can generalize from our data, we compared the dog population insured by Anicom with the general dog population in Japan. The number of insured dogs used in our study represents only 2% of the total dog population in Japan, and therefore the dog population used in our study might not be representative of the general dog population in terms of breed and age distributions. According to the result of a survey conducted by the Japan Pet Food Association in 2011, Miniature Dachshund, Toy Poodle, Shiba, Chihuahua and mongrels represent 15.7%, 7.9%, 6.9%, 6.6% and 18.9% respectively of the dog population in Japan (JPFA, 2013), while these breeds represent 16.8%, 15.1%, 4.9%, 15.5% and 5.0% respectively of the insured dog population used in our study. This indicates that the purebred dogs might be over-represented in our study. Also, considering the fact that most insured dogs are enrolled into an insurance program at in their first year of life when they are sold from pet shops and breeders to owners and that the number of insured dogs is on the increase in Japan, young dogs are over-represented in our study. Given the fact that the proportion of insured dogs is higher in urban

Table 7
Current life table of insured dogs in Japan (medium breeds).

Age interval in years x to x+1	Probability of dying in interval (x, x+1) $\hat{q}_x$	Number living at age x l_x	Number dying in interval (x, x+1) d_x	Fraction of last year of life a'_x	Number of years lived in interval (x, x+1) L_x	Total number of years lived beyond age x T_x	Expectation of life at age x $\hat{e}_x$
0–1	0.0137	10,000	137	0.52	9934	136,114	13.6
1–2	0.0061	9863	60	0.48	9832	126,180	12.8
2–3	0.0047	9802	46	0.36	9773	116,349	11.9
3–4	0.0061	9756	59	0.54	9729	106,576	10.9
4–5	0.0095	9697	92	0.52	9653	96,847	10.0
5–6	0.0112	9605	107	0.49	9550	87,194	9.1
6–7	0.0117	9497	111	0.58	9450	77,644	8.2
7–8	0.0161	9386	151	0.56	9319	68,194	7.3
8–9	0.0365	9235	337	0.52	9072	58,875	6.4
9–10	0.0384	8898	342	0.51	8731	49,803	5.6
10–11	0.0583	8556	499	0.54	8325	41,071	4.8
11–12	0.0767	8057	618	0.51	7755	32,747	4.1
12–13	0.1270	7439	945	0.48	6947	24,992	3.4
13–14	0.1568	6494	1018	0.44	5921	18,044	2.8
14–15	0.2058	5476	1127	0.46	4870	12,123	2.2
15–16	0.3238	4349	1408	0.46	3588	7253	1.7
16–17	0.5316	2941	1563	0.38	1966	3666	1.2
17+	1.0000	1378	1378	–	1700	1700	1.2

Table 8
Current life table of insured dogs in Japan (large breeds).

Age interval in years x to x+1	Probability of dying in interval (x, x+1) $\hat{q}_x$	Number living at age x l_x	Number dying in interval (x, x+1) d_x	Fraction of last year of life a'_x	Number of years lived in interval (x, x+1) L_x	Total number of years lived beyond age x T_x	Expectation of life at age x $\hat{e}_x$
0–1	0.0112	10,000	112	0.70	9966	125,332	12.5
1–2	0.0071	9888	70	0.38	9845	115,366	11.7
2–3	0.0065	9818	64	0.47	9784	105,522	10.7
3–4	0.0081	9754	79	0.39	9706	95,737	9.8
4–5	0.0181	9675	176	0.38	9566	86,031	8.9
5–6	0.0150	9500	143	0.49	9428	76,465	8.0
6–7	0.0213	9357	200	0.50	9258	67,037	7.2
7–8	0.0416	9157	381	0.52	8975	57,780	6.3
8–9	0.0584	8777	513	0.52	8530	48,805	5.6
9–10	0.0831	8264	686	0.50	7920	40,275	4.9
10–11	0.1140	7577	864	0.51	7151	32,355	4.3
11–12	0.1355	6713	910	0.51	6266	25,204	3.8
12–13	0.1665	5803	966	0.51	5328	18,938	3.3
13–14	0.2852	4837	1380	0.49	4134	13,610	2.8
14–15	0.3296	3458	1140	0.49	2875	9476	2.7
15–16	0.3279	2318	760	0.49	1928	6601	2.8
16+	1.0000	1558	1558	–	4673	4673	3.0

Table 9
Current life table of insured dogs in Japan (giant breeds).

Age interval in years x to x+1	Probability of dying in interval (x, x+1) $\hat{q}_x$	Number living at age x l_x	Number dying in interval (x, x+1) d_x	Fraction of last year of life a'_x	Number of years lived in interval (x, x+1) L_x	Total number of years lived beyond age x T_x	Expectation of life at age x $\hat{e}_x$
0–1	0.0233	10,000	233	0.46	9875	105,697	10.6
1–2	0.0151	9767	148	0.34	9669	95,822	9.8
2–3	0.0130	9620	125	0.48	9554	86,153	9.0
3–4	0.0142	9494	135	0.49	9426	76,599	8.1
4–5	0.0476	9359	446	0.36	9074	67,173	7.2
5–6	0.0666	8914	594	0.56	8655	58,099	6.5
6–7	0.1106	8320	920	0.50	7856	49,444	5.9
7–8	0.0800	7400	592	0.51	7108	41,587	5.6
8–9	0.1204	6808	820	0.49	6394	34,479	5.1
9–10	0.1724	5989	1033	0.48	5453	28,085	4.7
10–11	0.2470	4956	1224	0.39	4205	22,632	4.6
11–12	0.1794	3732	669	0.51	3404	18,427	4.9
12–13	0.3419	3063	1047	0.30	2326	15,023	4.9
13+	1.0000	2015	2015	–	12,698	12,698	6.3

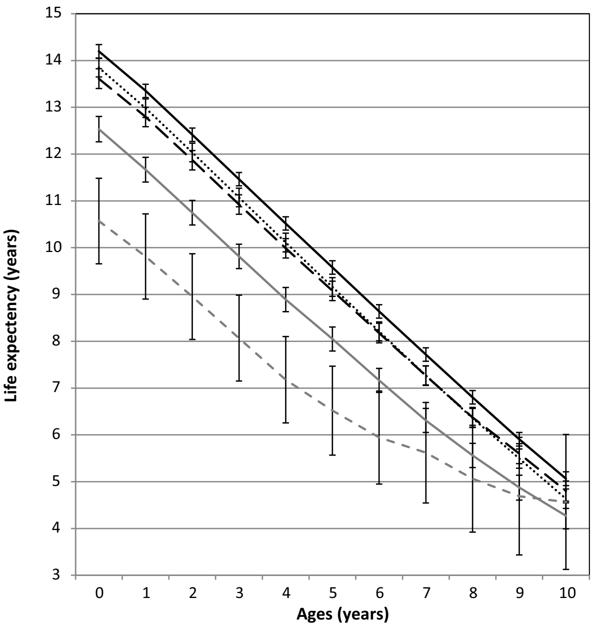

Fig. 1. Life expectancy up to 10 years of age of toy, small, medium, large and giant breeds of insured dogs in Japan. Dotted, solid, dashed, gray and gray dashed lines indicate toy, small, medium and large breed groups respectively. The error bars indicate 95% confidence intervals.

areas than in rural areas, dogs living in urban areas are over-represented in the insured dog population.

We then considered if there was any potential bias in calculating the life expectancy from our data. Firstly, we can well assume that the insured dogs receive better veterinary care than non-insured dogs, indicating that the life expectancy might have been overestimated in our study. Secondly, we did not consider the puppy mortality in calculating the probability of death in the first year of life, because there were no data on the mortality of the dogs between birth and purchase from pet shops and breeders when insurance would start. This might have resulted in underestimation of the probability of death in the first year of life and consequently overestimation of the life expectancy.

In our study those dogs that left the insurance program without the owners either renewing the policy or, notifying that their dog had died were excluded from analysis. Some owners left the program probably because they thought that it was not worthwhile continuing because they had no veterinary treatment for their pet for an extended period. As a result of this censoring not due to death, with healthy dogs being removed from the study population, the probability of death might have been overestimated and consequently life expectancy might have been underestimated.

In our study, we constructed a current life table and estimated an overall life expectancy of 13.7 at age zero, while a previous study by Hayashidani et al. (1988) constructed a cohort life table by estimating the target population from data of only dead dogs brought to a cemetery in Tokyo from June 1981 through May 1982 and estimated an overall life expectancy of 8.3 and 8.6 years at ages zero and one respectively. Data collected in this way are generally subject to bias because not all dead dogs are brought to cemeteries. The proportion brought to the cemeteries might vary with age (*e.g.*, the proportion of young dead dogs brought to cemeteries might be smaller than that of old dead dogs), and those still alive were not included in the data. Thus, the data used in their study might not have represented the general dog population. Moreover, the cemetery records they used may not be accurate because they were based on the memory of dog owners, who might have forgotten the exact age of their dogs as the dogs got older (Hayashidani et al., 1988).

Because of these methodological differences and presence of biases in our and their studies, we cannot make a direct comparison between the results of the two studies. Nevertheless, one can assume an extension of life expectancy of dogs in Japan in the past three decades to some extent due to the increased provision of veterinary care and the assumed improved nutrition as a result of increasing use of well-balanced commercial pet food as well as promotion of animal welfare among Japanese people in recent years.

The results of our study showed that small breeds have the longest longevity, followed by toy breeds, medium breeds, large breeds and giant breeds. Many previous studies that reported longevity difference between breeds of dogs of different body weights showed that the breeds with smaller body weights have longer longevity (Li et al., 1996; Patronek et al., 1997; Kraus et al., 2013). These studies suggested that the breeds of smaller body weights live longer, without comparing the longevity between toy and small breeds (Li et al., 1996; Patronek et al., 1997; Kraus et al., 2013; Adams et al., 2010; O'Neill et al., 2013). Adams et al. (2010) compared the longevity of dogs between five breed groups (toy, small, medium, large and giant), and concluded that the breeds of smaller body weights live longer, although small breeds were dominant in the 14 breeds with the highest median age at death. O'Neill et al. (2013) reported the median age at death of 36 dog breeds, of which the 10 breeds with the highest median age at death were six small breeds, one medium breed and three large breeds. In Japan, the toy breeds are represented by a small number of popular breeds such as Chihuahua and Toy poodle.

Further research is needed to identify factors affecting the difference in longevity between breed groups, although some genetic basis for dog size variation and lifespan has been reported previously: Sutter et al. (2007) examined genetic variation in small and giant breeds of dogs and found evidence that a single gene (IGF1), encoding insulin-like growth factor 1 (IGF-1) single-nucleotide polymorphism haplotype is common to all small breed and is almost absent from giant breeds, suggesting that the same causal sequence variant is major contributor to body size in all small dogs. Holzenberger et al. (2003), using heterozygous knockout mice, reported that the IGF-1 receptor may be a central regulator of mammalian lifespan.

The results of our study showed that the probability of death from major diseases such as neoplasia, cardiovascular, musculoskeletal, digestive and respiratory system disorders, hepatobiliary and exocrine pancreatic disorders

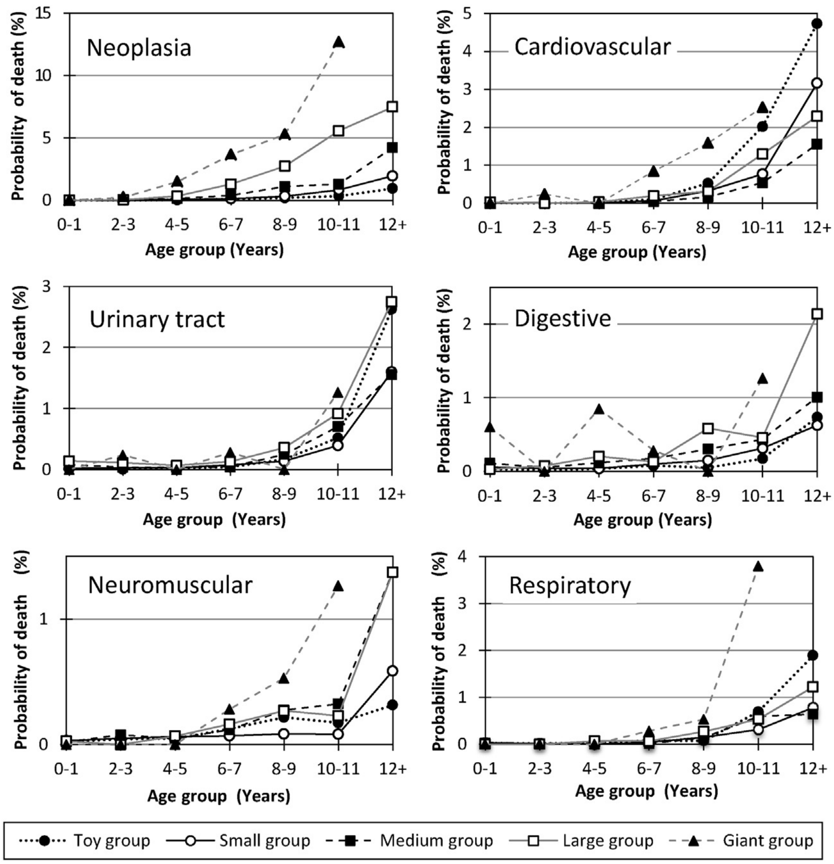

Fig. 2. Probability of death of insured dogs in Japan at different age groups by six major causes. The age group '10–11' on the *X*-axis should read '10+' for giant breed group.

and neuromuscular and urinary tract disorders increased as dogs aged, while that from infectious and parasitic diseases is highest in the first year of life. This finding is consistent with most previous studies (Bonnett et al., 1997; Egenvall et al., 2000a,b; Adams et al., 2010; O'Neill et al., 2013). Fleming et al. (2011) reported that the relative frequency of death in young dogs in North America was high not only from infectious diseases but also from cardiovascular, gastrointestinal, musculoskeletal, respiratory disorders and traumatic diseases. This difference might be caused by the different environment in which dogs are kept between Japan and North America but should be subjected to further studies.

In analyzing the causes of death in our study, we assumed that the diagnosis stated on the claim form for veterinary care submitted within 1 month before the date of death was the cause of death, because Anicom provides insurance for only veterinary care and not life insurance for dogs and causes of death are not stated in the claim forms. Therefore some of the causes of death in our database might have differed from the actual causes of death. Also, in our study those dogs that died with no claim for veterinary care within 1 month before the date of death were classified as died from 'unknown' causes. The telephone survey that we conducted in November 2014 to validate the data on the causes of death revealed that of the 106 randomly selected dogs that died, 17 dogs (16%) did not submit a veterinary care claim within 1 month before the date of death. Of these, seven dogs died from accident, seven suddenly from an unidentified cause, and three from senile decay. The result of our telephone survey showed that those dogs which died without submission of claim mostly died suddenly or by accident with no chance to receive veterinary care. This might have resulted in the underestimation of the probability of death from injuries and other diseases that cause sudden death. While several studies have been conducted to validate the insurance data mostly for agreement between diagnostic information in insurance claims and practice records (Egenvall et al., 1998, 2009; Penell et al., 2007; Heske et al., 2014), no study has been conducted to validate the insurance data for the agreement between reasons for veterinary care submitted before death and the causes of death. Further studies are needed to address this issue.

There was no significant difference detected between different breed groups of dogs at most old age groups in the probabilities of death for most diagnostic categories. This was probably because the number of dogs (n) in our database subjected to analysis was not large enough and the statistical power of detection was insufficient at most age groups and for most diagnostic categories. Further analyses are needed using data of a larger number of dogs to test if there are significant differences in the probability of death between different breed groups.

This study attempted to estimate the life expectancy and causes of death of dogs in Japan, by using data of insured dogs. This study provides useful epidemiological information on possible risk factors affecting the longevity of pet dogs in Japan, which could be used by pet owners, veterinary clinicians and breeders, to introduce measures to their impact and so promote the health care of dogs in general and of certain breeds at different ages in particular.

Conflicts of interest

The authors have no conflicts of interest to declare.

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