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Using the incidence and impact of health conditions in guide dogs to investigate healthy ageing in working dogs

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ABSTRACT

This study aimed to use retirement data from working guide dogs to investigate healthy ageing in dogs and the demographic factors that influence ageing. Using a dataset of 7686 dogs spanning 20 years, dogs withdrawn for health reasons before they reached retirement were identified. Cases of retirement for old age, rather than for health reasons, were also recorded, as was the length of working life for all dogs. Specific health reasons were grouped into 14 different health categories. The influence of purebred or crossbreed, breed, and sex on the incidence of these health categories and the length of working life within each health category was considered.

The majority ($n = 6465/7686$; 84%) of working guide dogs were able to function as guide dogs until they had worked for 8.5 years, when they retired. This working life might constitute a reference for the different breeds considered, with the exception of the German shepherd dog, which had a shorter working life. The most common reason for health withdrawals was musculoskeletal conditions ($n = 387/1362$; 28%), mostly arthritis. Skin conditions (mostly comprised of cases of atopic dermatitis) reduced working life most commonly (mean, approximately 5 years). Nervous sensory conditions (35% of which were cases of epilepsy) reduced working life by 3 years.

Introduction

Ageing, in the latter stages of life, results in physical decline and in an increased vulnerability to disease. Distinguishing normal ageing from the results of disease could inform strategies to maximise health during the latter stages of life (Myint and Welch, 2012). There are likely to be at least 2.25 million ageing dogs in the UK, based on an estimated dog population of 9 million (Murray et al., 2010; Asher et al., 2011), with 25% aged ≥8 years (Thrushfield, 1989). While many researchers have considered the influence of disease on longevity in dogs (Bronson, 1982; Michell, 1999; Bonnett et al., 2005), few have considered the effects on longevity of healthy ageing. Rates of ageing and disease might be differently influenced by whether a dog is a purebred or crossbreed, and the dog's breed and sex.

Heterosis (or hybrid vigour) can confer health benefits on crossbreeds compared to purebreds, since the assumption is that animals of mixed breeds will function better than their parent breeds (Rettenmaier et al., 2002 and references therein). This view is supported by published studies that report lower incidences for certain medical conditions (O'Neill et al., 2014a) or mortality (Bonnett et al., 1997; Egenvall et al., 2000) in crossbreeds than in many purebred breeds. Working dog organisations, such as Guide Dogs (UK), breed first generation crosses because they believe these dogs combine the best traits of both parent breeds. However, not all studies have found differences between purebred and crossbreed dogs (Rettenmaier et al., 2002). Studies that consider crossbreed dogs rarely separate different generations of crosses, which could limit the sensitivity of the analysis to the effects of heterosis (O'Neill et al., 2014a).

There are marked breed differences in longevity (Egenvall et al., 2000; Bonnett et al., 2005) and the incidence or reported predisposition to disease (Asher et al., 2009; Summers et al., 2010). Such differences could result from closed gene pools, inbreeding or conformational aspects of pedigree breeding (Bateson, 2010). O'Neill et al. (2014b) argue that information on canine health is difficult to obtain, and is often unreliable. Yet understanding breed differences in the incidence of disease and predisposing factors is important for welfare, diagnosis, and treatment.

In general, female dogs live longer than males (Michell, 1999; Bonnett et al., 2005). There are disease-specific exceptions; for example, females are more likely to die from tumours than males, presumably (and as the authors report) due to a higher incidence of mammary tumours (Bonnett et al., 2005). To our knowledge there have not been any previous studies investigating sex effects on healthy ageing in dogs.

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Healthy ageing is difficult to define in animals, but it could be summarised by the ability to function unhindered by ill health, based on the definition for healthy ageing in humans by Myint and Welch (2012). This outcome could have particular relevance for working dogs, defined as those that are required, trained, or assessed to fulfil a particular purpose for human benefit beyond a hobby or sport (Serpell, 1995). Working dogs could be retired from their role if they can no longer perform their required purpose, or because continuing to do so would compromise their welfare. Like humans, dogs can be retired when they reach old age, or earlier if a health condition results in retirement. Thus retirement for health reasons prior to retirement for old age could be considered a proxy outcome measure of unhealthy ageing.

Here we consider the incidence of, and reduction in working life due to, health conditions that resulted in (early) retirement in a population of working guide dogs. The impact of three main external factors is considered: (1) sex; (2) whether the dog is a purebred or a crossbreed; and (3) breed. Additionally, we considered whether dogs were bred by Guide Dogs (UK) or sourced from an external breeder, since this has been found to be an important explanatory health factor in other studies of guide dogs (Goddard and Beilharz, 1983).

We aimed to investigate the main conditions that caused dogs to not reach old age healthily, and how much of a reduction in working life these conditions caused. To do so we explored a large dataset of working guide dogs that were either retired (i.e. reached old age) or withdrawn for health reasons. We considered the incidences of different conditions that caused working guide dogs to be withdrawn before reaching a healthy retirement. We then considered what constitutes healthy ageing in this population by examining the ages at which otherwise (apparently) healthy dogs were retired from working life. The impact of these conditions with regard to the length of time they reduced working life was also considered. At each stage we considered the potential effects of dog characteristics, purebred or crossbreed, breed, and sex on healthy ageing.

Materials and methods

Guide dogs and data

Guide Dogs (UK) is the working name of the Guide Dogs Association for the Blind. The organisation started in 1931 and is now the '*world's largest breeder and trainer of working dogs*'.[1] Guide Dogs (UK) breeds approximately 1300 puppies each year. Most puppies undergo training and are paired with a visually impaired person at about 2 years of age.

Dogs were included in this study if they had been matched by Guide Dogs (UK) with a person who was blind or partially sighted but were withdrawn for health conditions, or were retired due to old age between 1 January 1994 and 31 December 2013 (a 20-year period). Most guide dogs in this sample set were bred by the Guide Dogs (UK) breeding program, but a minority were sourced from breeders of relevant breeds.

The data were collated and maintained by Guide Dogs (UK) staff. The diagnosis and the associated withdrawal decision were made by relevant staff; the diagnosis was made by the veterinary surgeon or the referral specialist. The decision to withdraw a dog for health reasons was made by the Dog Care and Welfare Manager, based on the diagnosis and the potential implication for the dog's future as a guide dog, as well as the implications for the person who would need to manage the condition.

Data input was controlled by a small number of veterinary-qualified operators who reviewed diagnostic information before coding against agreed criteria.

Classification

In this study we were interested in the health reasons for withdrawal after dogs had qualified and been paired with a blind or partially sighted owner. The study population consisted of 6465 dogs (72%) that reached retirement, 1310 (14.5%) dogs that were withdrawn for behaviour reasons, and 1221 (13.5%) dogs that were withdrawn for health reasons. Dogs were considered to be retired if the reason provided for withdrawal was 'old age', and there was no indication of health (or behavioural) deterioration that affected their ability to function as a working guide dog. For each dog, the (total) working life was recorded as the number of days between the commencement of work and retirement.

For dogs withdrawn for health conditions, a specific reason was recorded for each dog (e.g. arthritis) before they reached retirement (i.e. the end of work). Specific reasons (approximately 150 different reasons) were categorised into 14 health groups according to body functions (e.g. musculoskeletal). Details of the specific reasons and their associated groupings are provided in Supplementary data. Since dogs left the study once they were retired, no data were collected from geriatric dogs.

Dogs with parent stock from the same breed were labelled as purebred, to distinguish them from crossbreed dogs that had parent stock from more than one breed. We considered the eight most common breeds (95% of the population) for analysis and grouped the rest (5%) into an 'Other' category. The number of dogs in each breed, and their abbreviation, were as follows: Labrador (L; $n = 2852$), Golden retriever x Labrador (GRxL; $n = 2087$), Golden retriever (GR; $n = 873$), Labrador x Golden retriever (LxGR; $n = 706$), other breeds (Other; $n = 358$), German shepherd dogs (GSD; $n = 341$), F2 Labrador x Golden retriever (LxGR*; $n = 249$), F2 Labrador cross (LxL*; $n = 120$), F2 Golden retriever cross (GRxGR*; $n = 100$). The sex of a dog was either 'dog' or 'bitch'; spay/neuter status was not considered since all dogs were altered. Dogs were recorded as having being bred by the Guide Dogs (UK) breeding programme or being outside bred (obred) if they were bred outside the organisation's breeding programme.

Data analysis

All statistical and numerical analyses were conducted in R 3.1.x (R Core Team, 2014). There were two outcome variables considered: (1) the number of cases in each of the 14 different health groups; and (2) the length of working life. We considered the effects on these outcome variables of four predictors of interest: purebred, breed, sex, and obred. We defined the incidence as the number of cases (i.e. dogs) in this population during the study period (Last, 2001).

The Pearson's χ^2 test for count data was used to test for independence between each of the different factors of interest (purebred, breed, sex, and obred) and to consider differences in incidence of the 14 health groups (Table 1).

A logistic regression, generalised linear model, was used to test for the likelihood of dogs being withdrawn for each of the 14 health groups, in turn. We used the glm() function with a binomial family. We checked for the influence of each of the predictors (breed, purebred, and sex) on each likelihood. We also tested for the interactions between purebred and sex and between breed and sex. We did not check for the influence of obred, as the test for independence was not statistically significant. The logistic regressions were run as follows: the health group retired (Old) was tested against all the other groups combined (i.e. not retired) thereby testing the likelihood of dogs reaching retirement, and how breed, purebred, or sex, might influence this. However, each other health group (e.g. musculoskeletal) was tested against retired, thereby testing the likelihood of dogs being withdrawn for health problems specific to that particular health group, and how breed, purebred, or sex could influence this.

We used a standard linear model to check for the difference in total working life between the health groups and how the three different predictors (purebred, breed, and sex) might influence these differences in the length of working life. Working life was defined as the time (days) between qualification and withdrawal/retirement (or time spent in service). The retired group was used as the reference group. Throughout this paper, we limit the results presentation to statistically significant results. When factor levels presented no, or few, significant results, they were omitted from the tables or figures. However, all factor levels were kept in the analysis unless stated otherwise. As noted previously, the obred factor was not significant in any analyses and will not be mentioned further.

Table 1
P values for independence test (χ^2, degrees of freedom) between each health group and predictors.[a]

Health group (*n*)	Purebred (χ^2, d.f.)	Breed (χ^2, d.f.)	Sex (χ^2, d.f.)
Old (6465)	<0.001 (25.88, 1)	<0.001 (192.87, 8)	0.007 (7.33, 1)
Can (141)	NS (0.91, 1)	<0.001 (53.47, 8)	0.01 (6.6, 1)
Car (31)	NS (0.21, 1)	0.003 (23.11, 8)	NS (0, 1)
Eye (71)	0.014 (5.99, 1)	NS (10.98, 8)	NS (2.56, 1)
Gas (38)	NS (1.37, 1)	<0.001 (71.16, 8)	NS (0, 1)
Gen (174)	0.044 (4.07, 1)	NS (7.33, 8)	NS (2.71, 1)
Mus (387)	<0.001 (15.67, 1)	<0.001 (169.85, 8)	0.022 (5.22, 1)
Ner (180)	NS (2.31, 1)	0.002 (24.97, 8)	NS (0.09, 1)
Non (36)	NS (0.01, 1)	0.005 (22, 8)	NS (1.44, 1)
Ski (74)	NS (0.42, 1)	<0.001 (36.11, 8)	NS (0.74, 1)

NS, non-significant; Old, retired; Can, cancer; Car, cardiovascular; Gas, gastrointestinal; Gen, general health deterioration; Mus, musculoskeletal; Ner, nervous/sensory; Non, nonspecific; Ski, skin.
[a] Only health groups with statistically significant results are shown.

[1] See: Guide Dogs, 2015. http://www.guidedogs.org.uk/ (accessed 3 October 2015).

We checked the model fits by visually inspecting the distribution, and the homogeneity, of the residuals. All fits were considered acceptable as described and recommended in Zuur et al. (2009).

Results

The data contained 7686 working guide dogs; 6465 dogs reached old age, which represented 84% of the dataset. The remaining 16% were withdrawn because of health conditions. The dataset contained 3568 crossbreed dogs and 4118 purebred dogs. Labradors were the most common breed ($n = 2852$), followed by Golden retriever x Labrador ($n = 2087$). There was an even sex ratio ($n = 3872$ dogs, $n = 3814$ bitches; ratio, 1.02). Most dogs were bred by Guide Dogs (UK; $n = 7307$), with <5% ($n = 379$) bred outside the Guide Dogs (UK) breeding programme.

Incidence of health groups

The three health groups with the most cases were, in decreasing order, musculoskeletal ($n = 387$), nervous/sensory ($n = 180$), and general health deterioration ($n = 174$). Ten of the 14 health groups were more or less likely to occur based on one of three predictors; purebred, breed or sex (Table 1). All three predictors were statistically significant for reaching retirement or being withdrawn for a musculoskeletal condition ($P < 0.05$). Four health groups (endocrine, immune, respiratory, and urogenital) showed no significant results for any of the predictors.

Purebred dogs were less likely to reach retirement and more likely to be withdrawn for endocrine or musculoskeletal reasons (compared to female crossbreeds; Table 2). Dogs (males) were more likely to be withdrawn for cancer, but less likely to be withdrawn for eye conditions. Male purebred dogs were less likely to be withdrawn for endocrine reasons, but more likely to be withdrawn for eye conditions, compared to the reference group of female crossbreeds.

Golden retriever x Labrador were more likely (odds ratio [OR], 1.19; 95% confidence intervals, [CI], 1.01, 1.41), and Golden retrievers (OR, 0.779; 95% CI, 0.64, 0.95) and German shepherds (OR, 0.247; 95% CI, 0.19, 0.31) were less likely, to reach retirement than the reference category of Labradors. Since Golden retrievers and German shepherds were less likely to reach retirement, they were more likely to be withdrawn for health reasons. Compared to the reference category of Labradors, 'Other' breeds had increased odds (OR, 8.14; 95% CI, 2.25, 29.42) of being withdrawn for gastrointestinal conditions; Labrador x Golden retrievers had increased odds of being withdrawn for a nonspecific reasons (OR, 3.06; 95% CI, 1.09, 8.24); and Labrador cross Golden retriever cross (LxGR*) had increased odds of being withdrawn for cardiovascular reasons (OR, 3.94; 95% CI, 0.87, 13.34). There was a small sex effect on odds of reaching retirement, with dogs (males) less likely to reach retirement but more likely to be withdrawn for cancer or musculoskeletal reasons (Table 3).

Table 2
Odds ratios (95% confidence intervals) from generalised linear model testing for the impact of purebred, dog sex, and their interaction, on the likelihood of dogs being withdrawn under the different health groups (including old age).[a]

Health group	Purebred[b] (95% CI)	Dog[b] (95% CI)	Interaction (95% CI)
Old	0.74[c] (0.62, 0.89)	0.87 (0.72, 1.05)	0.96 (0.75, 1.23)
Cancer	1.50 (0.88, 2.64)	1.97[d] (1.17, 3.41)	0.68 (0.34, 1.37)
Endocrine	2.97[d] (1.16, 9.1)	2.48 (0.92, 7.8)	0.25[d] (0.06, 0.89)
Eye	1.29 (0.7, 2.41)	0.29[d] (0.09, 0.72)	3.19[d] (1.07, 10.97)
Musculoskeletal	1.40[d] (1.03, 1.93)	1.15 (0.83, 1.62)	1.17 (0.76, 1.79)

[a] Only health groups with statistically significant results are shown.
[b] The reference being female crossbreed dogs. 'Purebred' refers to purebred rather than crossbreed. 'Dog' refers to male dogs.
[c] $P < 0.01$.
[d] $P < 0.05$.

Table 3
Odds ratios (95% confidence intervals) from generalised linear model testing for the impact of breed and dog sex[a,b] on the likelihood of dogs being withdrawn under the different health groups (including old age).[c]

Health group	German shepherd dog	Golden retriever	Dog
Old	0.25[d] (0.19, 0.31)	0.78[e] (0.64, 0.95)	0.83[f] (0.73, 0.94)
Can	6.09[d] (3.33, 10.76)	2.27[f] (1.34, 3.78)	1.60[f] (1.14, 2.27)
Car	6.73[d] (2.05, 19.7)	NS	NS
Gas	21.89[d] (7.49, 71.88)	6.13[f] (2.11, 20)	NS
Mus	5.56[d] (3.96, 7.76)	NS	1.32[f] (1.07, 1.63)
Ner	2.95[d] (1.62, 5.07)	NS	NS
Non	6.92[d] (2.11, 20.26)	NS	NS
Ski	6.18[d] (2.85, 12.67)	NS	NS

NS, non-significant; Old, retired; Can, cancer; Car, cardiovascular; Gas, gastrointestinal; Gen, general health deterioration; Mus, musculoskeletal; Ner, nervous/sensory; Non, nonspecific; Ski, skin.
[a] Possible sexes are bitch (reference) and dog.
[b] Their interaction term did not return any significant result and was therefore removed.
[c] Only health groups with statistically significant results are shown. The breeds Golden retriever x Labrador, Labrador x Golden retriever, F2 Labrador x Golden retriever, and Other had only a few statistically significant results and are mentioned in the text only.
[d] $P < 0.001$.
[e] $P < 0.05$.
[f] $P < 0.01$.

Reduction in working life

Dogs that retired (the old age group) had a mean working life of 3119 (standard error [SE], 8.36) days. All other health groups for which dogs were withdrawn had a statistically shorter working life, ranging from approximately 1200 days to approximately 2200 days (Fig. 1). The variable Purebred changed the working life of four health groups: urogenital (+976 days for purebred; t value, 4.20; $P < 0.001$), cardiovascular (+724 days for purebred; t value, 4.28; $P < 0.001$), general health deterioration (–221 days for purebred; t value, –3.04; P, 0.002), and old age (–29 days for purebred; t value, –2.56; P, 0.011).

The sex of dogs resulted in different lengths of working life in five different health groups (Fig. 2). Dogs (males) worked longer in the eye group (+227 days; t value, 2.00; P, 0.045), the general health group (+224 days; t value, 3.11; P, 0.002), and the respiratory group (+591 days; t value, 2.02; P, 0.042). Conversely, dogs seemed to have shorter working lives when withdrawn in the nervous (–231 days; t value, –3.29; $P < 0.001$) and urogenital (–708 days; t value, –3.04; P, 0.002) groups.

When considering the effect of breed on working life, retired Labradors had a mean working life of 3107 days (SE, 9.32 days; Fig. 3). German shepherds were the only breed to differ from Labradors, by approximately –190 days (t value, –5.68; $P < 0.001$). German shepherds worked longer than Labradors in the non-specific, nervous, and immune groups, with +593 days (t value, 2.30; P, 0.022), +421 days (t value, 3.18; P, 0.001), and +1390 days (t value, 2.76; P, 0.006), respectively. Golden retrievers with eye conditions had shorter working lives than Labradors, by –358 days (t value, –2.22; P, 0.026). In a number of health groups, compared to Labradors, the first generation crosses (GRxL and LxGR) had shorter working lives, and second generation crosses (GRxGR*, LxGR*, and LxL*) had longer working lives (Supplementary data).

Discussion

This study aimed to use data from withdrawals and retirements in working guide dogs to investigate healthy ageing in dogs. We were able to identify the most common health groups that caused dogs not to reach retirement age without being withdrawn for a health reasons. While 84% of dogs reached retirement, of those that were withdrawn before retirement, the most common

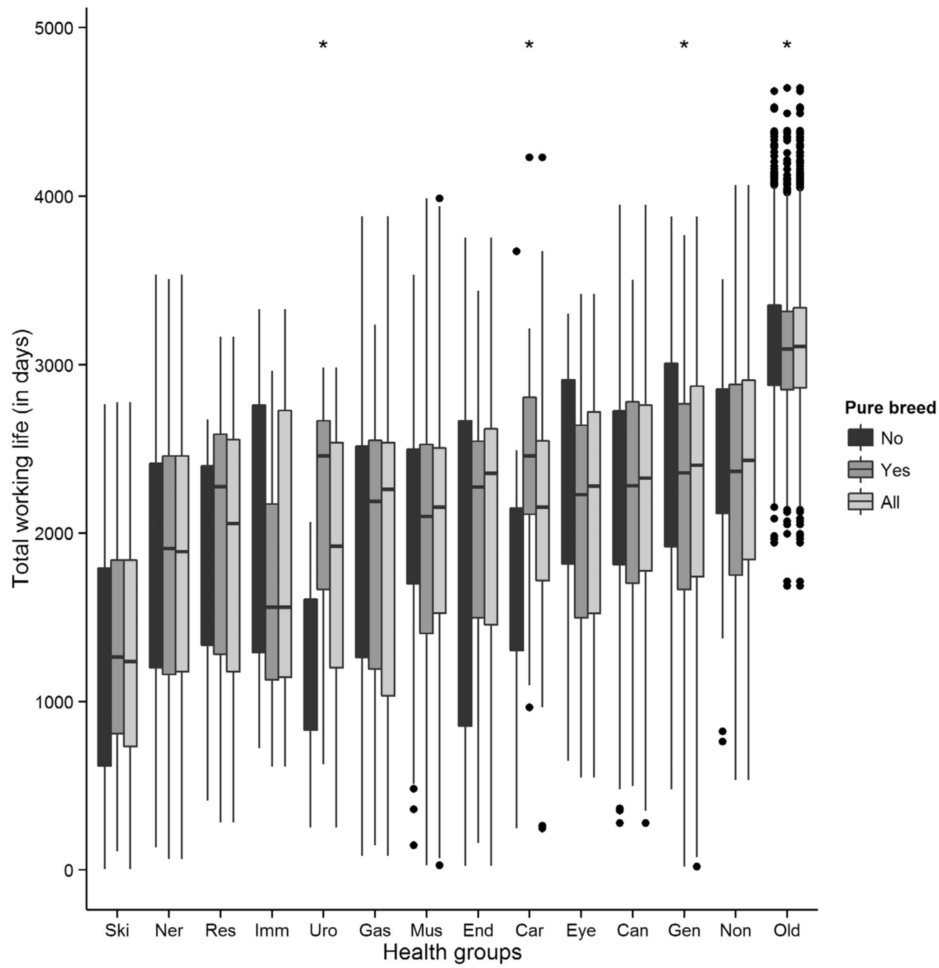

Fig. 1. Boxplot of the total working life (days) of working dogs for each of the health groups under which dogs were withdrawn. The stars at the top of the figure represent statistical differences from the standard linear model between crossbreed and purebred in the associated health group. Black bars, Crossbreed; Dark grey bars, purebred; Light grey bars, all dogs. Ski, skin; Ner, nervous/sensory; Res, respiratory; Imm, immune; Uro, urogenital; Gas, gastrointestinal; Mus, musculoskeletal; End, endocrine; Car, cardiovascular; Can, cancer; Gen, general health deterioration; Non, nonspecific; Old, retired.

reason was musculoskeletal. Withdrawals represented 28% (n = 387/1362) of dogs not reaching retirement, and were comprised mostly of dogs with arthritis (n = 174/387; 45%). Nervous sensory was the second most common reason for withdrawal (n = 170/1362; 12%).

We were also able to identify health reasons that resulted in the greatest reduction in healthy (working) life. Skin conditions (mostly atopic dermatitis) reduced working life the most, by an average of approximately 5 years. While a skin condition might not allow a guide dog to continue its working life due to difficulties in treatment, such conditions could be more easily managed when dogs perform another role e.g. pet dog or other service dog. Nervous sensory conditions (35% of which were epilepsy), which reduced working life by 3 years on average, might be considered more generally applicable causes of major reductions in healthy life. Musculoskeletal conditions also had important impacts on length of working life. The breeds that comprised the dataset (i.e. Labradors, Golden retrievers, and German shepherd dogs), have an increased risk of developing joint disease (Ubbink et al., 2000; Wilke et al., 2006; Coopman et al., 2008; Corr, 2009).

Overall, our results suggest that crossbreed dogs were more likely to have longer healthy lives than purebred dogs, although there were marked differences depending on which health group was considered. With respect to breed differences, German shepherds were less likely to have long healthy working lives than Labradors, Golden retrievers, and their first generation crosses. This aspect mirrors the findings of Bonnett et al. (2005), which demonstrated that German shepherds have a higher risk of mortality than Labradors and Golden retrievers. Similarly, Michell (1999) reported that German shepherd dogs died 2 years earlier than the two retriever breeds after analysing median age at death data. In that study, very few guide dogs died during their working lives (mainly because younger dogs were studied), but this further confirms that German shepherds seem to have more health problems than their retriever counterparts. Concern over pedigree dog health (Asher et al., 2009; Bateson, 2010; Collins et al., 2010, 2011) and the increasing popularity of F1 ‘designer dog’ crosses (or ‘crossbreed dogs bred to be cute’), makes understanding differences in breed and crossbreed health important and timely.

Separate analysis of cases in each health withdrawal group provides insight into two different parameters: incidence of health problems and length of working life. To decrease the incidence of health problems, Guide Dogs (UK) could try to improve the breeding stock so that these health problems could be ‘bred out’ of the working dogs, thereby reducing the number of cases. To maximise the length of working life, Guide Dogs (UK) could seek to improve the veterinary care for health conditions, to reduce their impact. However, these strategies would not have the same impact on each withdrawal health group. For instance, the cancer withdrawal group had more cases but a shorter reduction in working life than the skin condition withdrawal group, which had fewer cases but a more

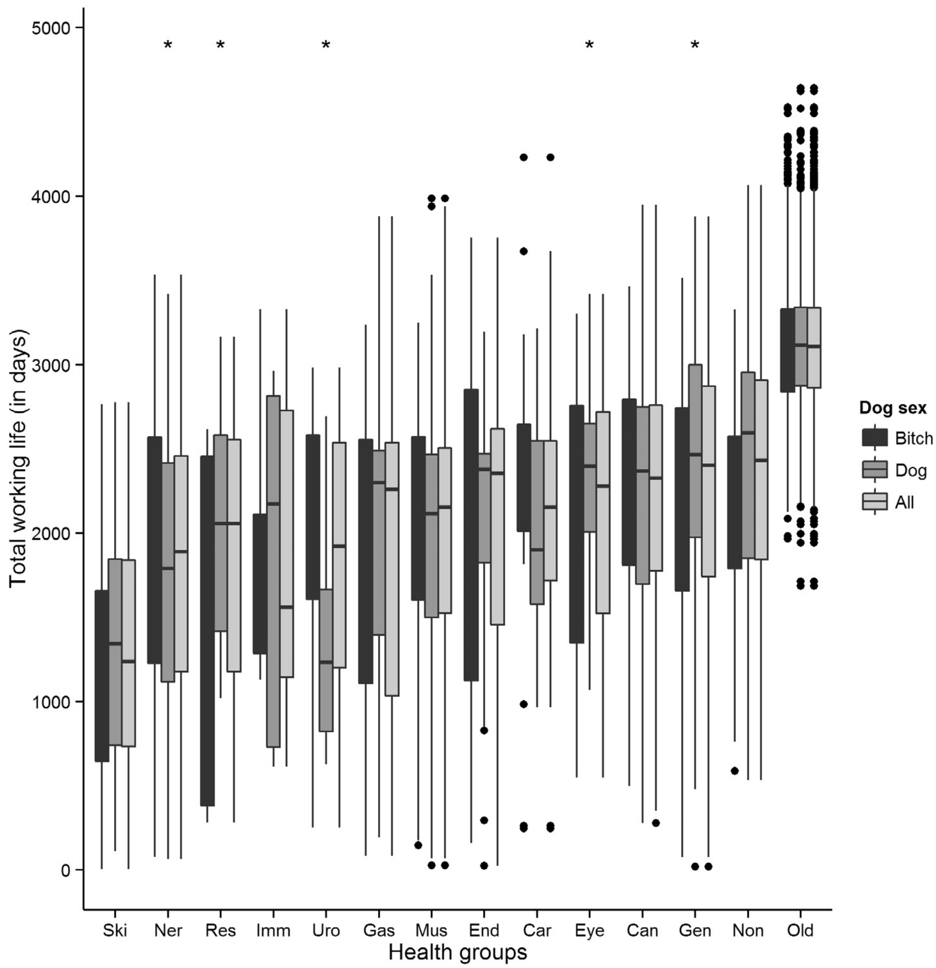

Fig. 2. Boxplot of the total working life (days) of working dogs for each of the health groups under which dogs were withdrawn. The stars at the top of the figure represent statistical differences from the standard linear model between dogs and bitches in the associated health group. Black bars, Bitch group; Dark grey bars, Dog group; Light grey bars, all dogs. Ski, skin; Ner, nervous/sensory; Res, respiratory; Imm, immune; Uro, urogenital; Gas, gastrointestinal; Mus, musculoskeletal; End, endocrine; Car, cardiovascular; Can, cancer; Gen, general health deterioration; Non, nonspecific; Old, retired.

pronounced reduction in working life. Similar to welfare impact and population-level decisions (Collins et al., 2010, 2011; Buckland et al., 2013), there might be a need for a metric that can incorporate the frequency and impact of conditions on the population. Such a metric could aid decision-making and aid the prioritisation of limited resources on disease prevention, monitoring and selection against health conditions. This metric should be devised to give a uniform, and normalised, measurement of the impact of a given health group on the work force of the guide dog population.

This study illustrates the utility of data from Guide Dogs (UK), which records information on health and behaviour of guide dogs from birth to working retirement. The age at which dogs are retired, the most common health conditions that affect retirement, and age of retirement are of interest for several reasons. Firstly, in an applied context such information is important to working dog organisations to help inform selection of dogs and disease prevention strategies. Secondly, such data can provide information about the incidence of healthy ageing and factors that could influence these. Thirdly, such information could help the understanding of what age could be considered old age in different dog breeds. Dogs that were withdrawn from life as a working guide dog were no longer able to perform their role without hindrance. Over the last 20 years veterinary care has improved, so that dogs that are currently working probably have a better standard of care than dogs that were working 15 years ago. While the data presented in this study are clear, we cannot be certain of any interactions between what appears to be a changing spectrum of disease and a likely change in veterinary diagnosis and care. In our study, original case records were not retrieved and there is also a possibility that diagnostic criteria differed over time. Additionally, the large number of veterinarians involved probably introduced some heterogeneity in the data. As a result, the dogs' lives were adjusted to protect their welfare. In similar cases in the wider pet population, pet dogs might need similar adjustments in their environment and care to maximise their quality of life.

Conclusions

The results suggest that we can use retirement and withdrawal information from working guide dogs to investigate healthy ageing in (working) dogs. This study highlights that even the pet population could also be considered for retirement; pet dogs over 10–11 years old should have their lifestyle adjusted to meet the needs of advanced age.

Conflict of interest statement

None of the authors has any other financial or personal relationships that could inappropriately influence or bias the content of the paper.

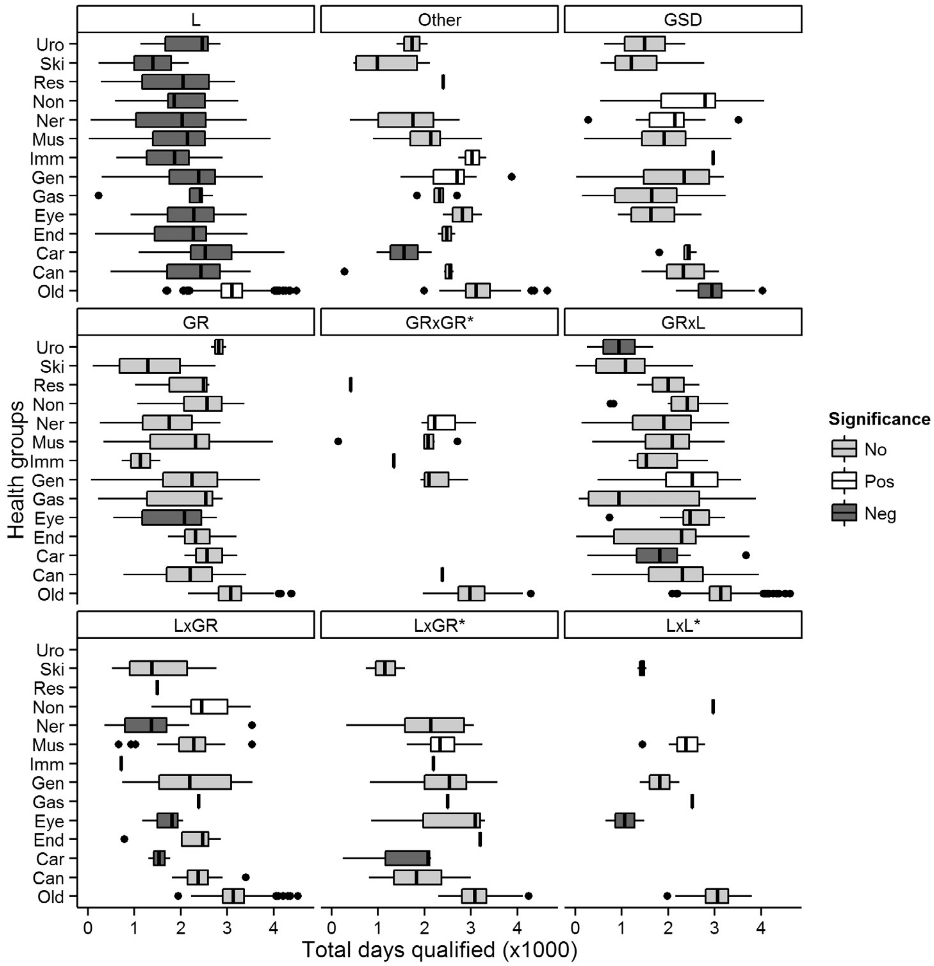

Fig. 3. Total working lives (days) of working dogs in the different breeds when withdrawn for the different health groups, from the standard linear model. The first bar of interest is the reference Retired for Labrador, which is in white (significant positive difference). From this, the other health groups within Labrador (L) are compared against the Retired group. They are all black in this case (significant negative difference). When moving across the figure to the other breeds, each health group is compared to the same group for the Labrador (L). Grey bars are non-significant results. Ski, skin; Ner, nervous/sensory; Res, respiratory; Imm, immune; Uro, urogenital; Gas, gastrointestinal; Mus, musculoskeletal; End, endocrine; Car, cardiovascular; Can, cancer; Gen, general health deterioration; Non, nonspecific; Old, retired.

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Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.tvjl.2015.10.046.

References

Asher, L., Diesel, G., Summers, J.F., McGreevy, P.D., Collins, L.M., 2009. Inherited defects in pedigree dogs. Part 1: Disorders related to breed standards. The Veterinary Journal 182, 402–411.
Asher, L., Buckland, E.L., Phylactopoulos, C.I., Whiting, M.C., Abeyesinghe, S.M., Wathes, C.M., 2011. Estimation of the number and demographics of companion dogs in the UK. BMC Veterinary Research 7, 74.
Bateson, P., 2010. Independent inquiry into dog breeding. London: Dogs Trust.
Bonnett, B., Egenvall, A., Olson, P., Hedhammar, A., 1997. Mortality in insured Swedish dogs: Rates and diagnostic category of death in various breeds. Veterinary Record 141, 40–44.
Bonnett, B., Egenvall, A., Hedhammar, A., Olson, P., 2005. Mortality in over 350,000 insured Swedish dogs from 1995–2000: I. breed-, gender-, age- and cause-specific rates. Acta Veterinaria Scandinavica 46, 105–120.
Bronson, R., 1982. Variation in age at death of dogs of different sexes and breeds. American Journal of Veterinary Research 43, 2057–2059.
Buckland, E., Whiting, M., Abeyesinghe, S., Asher, L., Corr, S., Wathes, C., 2013. A survey of stakeholders' opinions on the priority issues affecting the welfare of companion dogs in Great Britain. Animal Welfare 22, 239–253.
Collins, L., Asher, L., Summers, J., Diesel, G., McGreevy, P., 2010. Welfare epidemiology as a tool to assess the welfare impact of inherited defects on the pedigree dog population. Animal Welfare 19, 67–75.
Collins, L.M., Asher, L., Summers, J., McGreevy, P., 2011. Getting priorities straight: Risk assessment and decision-making in the improvement of inherited disorders in pedigree dogs. The Veterinary Journal 189, 147–154.
Coopman, F., Verhoeven, G., Saunders, J., Duchateau, L., Van Bree, H., 2008. Prevalence of hip dysplasia, elbow dysplasia and humeral head osteochondrosis in dog breeds in Belgium. Veterinary Record 163, 654–658.
Corr, S., 2009. Decision making in the management cruciate disease in dogs. In Practice 31, 164–171.
Egenvall, A., Bonnett, B., Olson, P., Hedhammar, A., 2000. Gender, age, breed and distribution of morbidity and mortality in insured dogs in Sweden during 1995 and 1996. The Veterinary Record 146, 519–525.
Goddard, M.E., Beilharz, R.G., 1983. Genetics of traits which determine the suitability of dogs as guide-dogs for the blind. Applied Animal Ethology 9, 299–315.
Last, J.M., 2001. A Dictionary of Epidemiology, Fourth Ed. Oxford University Press, Oxford.
Michell, A.R., 1999. Longevity of British breeds of dog and its relationships with sex, size, cardiovascular variables and disease. Veterinary Record 145, 625–629.
Murray, J., Browne, W., Roberts, M., Whitmarsh, A., Gruffydd-Jones, T., 2010. Number and ownership profiles of cats and dogs in the UK. Veterinary Record 166, 163–168.
Myint, P.K., Welch, A.A., 2012. Healthier ageing. BMJ (Clinical Research Ed.) 344, e1214.

O'Neill, D.G., Church, D.B., McGreevy, P.D., Thomson, P.C., Brodbelt, D.C., 2014a. Post-Bateson: Have pedigree dogs become exposed? Recent advances in animal welfare science, from: Universities Federation of Animal Welfare conference in York, UK.
O'Neill, D.G., Church, D.B., McGreevy, P.D., Thomson, P.C., Brodbelt, D.C., 2014b. Prevalence of disorders recorded in dogs attending primary-care veterinary practices in England. PLoS ONE 9, e90501.
R Core Team, 2014. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.
Rettenmaier, J.L., Keller, G.G., Lattimer, J.C., Corley, E.A., Ellersieck, M.R., 2002. Prevalence of canine hip dysplasia in a veterinary teaching hospital population. Veterinary Radiology and Ultrasound 43, 313–318.
Serpell, J. (Ed.), 1995. The Domestic Dog: Its Evolution, Behaviour and Interactions with People. Cambridge University Press, New York.
Summers, J.F., Diesel, G., Asher, L., McGreevy, P.D., Collins, L.M., 2010. Inherited defects in pedigree dogs. Part 2: Disorders that are not related to breed standards. The Veterinary Journal 183, 39–45.
Thrushfield, M.V., 1989. Demographic characteristics of the canine and feline populations of the UK in 1986. Journal of Small Animal Practice 30, 76–80.
Ubbink, G.J., Hazewinkel, H.A.W., Rothuizen, J., van de Broek, J., Wolvekamp, W.T.C., 2000. Prediction of the genetic risk for fragmented coronoid process in Labrador retrievers. Veterinary Record 147, 149–152.
Wilke, V.L., Conzemius, M.G., Kinghorn, B.P., Macrossan, P.E., Cai, W., Rothschild, M.F., 2006. Inheritance of rupture of the cranial cruciate ligament in Newfoundlands. Journal of the American Veterinary Medical Association 228, 61–64.
Zuur, A., Ieno, E.N., Walker, N., Saveliev, A.A., Smith, G.M., 2009. Mixed Effects Models and Extensions in Ecology with R. Springer-Verlag, New York.