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Under diagnosis of canine cognitive dysfunction: A cross-sectional survey of older companion dogs

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ABSTRACT

Canine cognitive dysfunction (CCD) is a neurobehavioural syndrome affecting aged dogs. Using a large cross-sectional epidemiological study of older dogs, this study aimed to estimate the prevalence of CCD amongst community based dogs (mean age 11.67 years; range 8–19.75) and to determine the rate of veterinary diagnosis amongst affected dogs. An 84-item questionnaire was used to obtain information across six behavioural domains. Of the eligible survey responses obtained ($n = 957$) a randomly selected one-half ($n = 497$) was used for this study. Using a provisional diagnosis based on 27 significant behavioural items, the prevalence rate of CCD was estimated to be 14.2%. This was in contrast with only 1.9% diagnosed with CCD by a veterinarian. There was an exponential increase in prevalence of CCD with age ($R^2 = 0.9435$), but prevalence did not differ by breed size or between longevity groups. The prevalence rate of CCD reported here is consistent with previous findings, and further supports the contention that the majority of these dogs do not receive a formal diagnosis.

Introduction

Canine cognitive dysfunction (CCD) or 'canine dementia' is a neurobehavioural syndrome in aged dogs characterised by deficits in learning, memory and spatial awareness as well as changes to social interactions and sleeping patterns (Landsberg et al., 2003). Recent improvements in veterinary care and nutrition have increased the life expectancy of modern pets (Reid and Peterson, 2000), and as a result there is increasing emphasis being placed on the treatment and management of age-related diseases.

A number of studies have used structured interviews to determine the prevalence of cognitive impairment in community based dogs (Neilson et al., 2001; Osella et al., 2007; Azkona et al., 2009). The prevalence estimates from these studies ranged from 22.5% to 73.5% but, to date, no study has compared the prevalence of CCD with the rate of pre-existing veterinary diagnosis. We were interested in this issue because there is evidence that CCD may be highly under-diagnosed. For example, in a survey of owners of aged dogs reported by Landsberg and Araujo (2005), 75% of dogs had at least one behavioural symptom indicative of cognitive dysfunction, yet only 12% of owners had reported the change in behaviour to their veterinarian. This is in keeping with the attitude noted by Osella et al. (2007) that many owners were disinclined to believe that their dogs were showing any behavioural changes indicative of senility.

Our aim therefore, was to conduct a large epidemiological study of older companion dogs that covered a broad range of physical, sensory, motor, behavioural, cognitive and social content. Unbiased data-driven analytical techniques were then used to identify potentially undiagnosed dogs with a behavioural profile mirroring that of dogs with veterinary diagnosed CCD.

Materials and methods

Study design

This study used a cross-sectional study design and has been reported in compliance with the STROBE statement (Vandenbroucke et al., 2007). The senior dog survey (SDS) consisted of 84 items covering six sections, namely: (1) dog and owner details, (2) management and health, (3) eating and drinking, (4) activity levels, (5) behaviour (including aggression and house soiling), and (6) phobias. Each item identified both the frequency of a behaviour and the level of change in that behaviour over the preceding 6 months. The questionnaire had approval from the Human Ethics Committee of the University of Sydney (Approval Number 10249).

Study setting and participants

The survey was distributed in online and hard copy formats and owners of dogs 8 years of age or older were invited to participate. An unlimited number of responses were collected from September 2007 to March 2008. A link to the online

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version was distributed via a dog forum[1] and a training website.[2] The survey link was emailed to staff and students at veterinary colleges in Australia, New Zealand, the United Kingdom and North America. A hard copy version of the survey was published in *DogsLife* magazine,[3] which has an estimated readership of 92,000 in Australia and New Zealand. Additional responses from the owners of dogs with veterinary diagnosed dementia (DEM) were obtained by approaching all veterinary clinics in the North Western Sydney area ($n = 20$). Multiple types and areas of distribution were used in an attempt to control for bias towards any particular dog management system.

Data measurement

Unfinished surveys and those describing dogs diagnosed with a neurological disease other than CCD were excluded from any analysis. All missing values were replaced with the mean for that variable. Questions on behaviour frequency were scored from 1 (least) through to 5 (most). Questions on the change in behaviour were also scored 1 (much less) through to 5 (much more), with 'no change' being scored as 3.

Statistical analysis

The entire survey sample was randomly split into two equal groups: Development and Test. An equal number of DEM dogs ($n = 9$) were randomly assigned to each group. The Development group was used in this study to estimate the prevalence rate and diagnosis rate of CCD in the community. The Test group was reserved as an independent sample for the validation of a diagnostic questionnaire and will be reported in a later study.

Two-step cluster analysis was used to identify n naturalistic groups within the dataset. Since CCD diagnosis was rare, the SDS sample was assumed to contain three cognitive groups: (1) DEM dogs (i.e. CCD or canine dementia with a veterinary diagnosis); (2) unidentified 'query' CCD (qCCD) dogs with a behavioural profile similar to that of DEM dogs but without a veterinary diagnosis; and (3) animals with no cognitive impairment (NCI).

To identify possible qCCD dogs, each dog was assigned an overall score by summing its scores for the significant behaviours identified in the cluster analysis. The numerical threshold for qCCD diagnosis was set to the overall score of the lowest ranked DEM dog. Non-DEM dogs which scored on or above the threshold were categorised as qCCD.

Dogs were split into three longevity groups based on published estimated life expectancies (Michell, 1999): short-lived, ⩽11 years; medium-lived, 11–13 years; and long-lived, >13 years. All purebred dogs were also split into three size groups based on heights (at the shoulder) stated in the breed standard: small, <35 cm high; medium, 35–55 cm high; and large, >55 cm.

SPSS version 15.0 was used for cluster analysis and v17.0 was used for all remaining statistical analyses. Univariate analysis of variance (ANOVA) was used to determine any age effects in the sample. Multivariate generalised linear model (GLM) was used to correct for multiple testing and age when comparing behaviours between cognitive groups. Binary logistic regression was used to investigate any differences in disease burden between DEM and non-DEM groups. It was also used to determine any difference in CCD prevalence in longevity and size groups after correction for age. Independent samples t tests were used to investigate any age differences in the longevity and size groups. The significance threshold was set at $P = 0.05$ for all analysis unless otherwise specified.

Results

Senior dog survey

A total of 1100 surveys were obtained of which 957 were eligible for inclusion. Eligible responses were obtained from 11 countries, predominantly Australia ($n = 501$), the United States ($n = 342$), New Zealand ($n = 51$) and the UK ($n = 41$). Eight hundred and forty-two eligible responses were obtained via the online version of the survey, 111 eligible responses were returned through *DogsLife* magazine and four eligible responses were obtained through veterinary practices. The average proportion of missing values across all variables was low (1.3%).

In the complete sample, 18 dogs were reported as having a formal diagnosis of 'dementia' or CCD by a veterinarian (DEM). DEM dogs (13 years 8 months) were significantly older than non-DEM dogs (11 years 8 months, $P = 0.004$). The top three most prevalent diseases in all dogs were: arthritis ($n = 518$); deafness ($n = 290$); and blindness ($n = 226$). After correction for age, DEM dogs had a non-significant trend towards increased prevalence of blindness (Odds ratio [OR] = 2.93; confidence interval [CI] = 0.966–8.875; $P = 0.058$).

Sample characteristics

The mean age of surveyed dogs was 11 years 9 months (8 years–19 years 8 m). There were 109 different pedigree breeds and 203 crossbred dogs represented. Female dogs (54.8%) slightly outnumbered male dogs (44.6%). The majority of dogs were desexed: 84.3% of males and 94.1% of females.

On several key basic descriptive criteria (age, sex, disease burden), there were no systematic differences between the Development and Test groups. Only data from the Development group ($n = 479$) were used in this study and subsequently will be exclusively discussed.

Two-step cluster analysis

Cluster analysis distinguished between dogs without (Group I) and with (Group II) behavioural dysfunction: Group I comprised no DEM animals and 75% of the non-DEM dogs, whilst Group II comprised 100% of the DEM dogs and 24.9% of the non-DEM dogs.

Group II behavioural profile

We further investigated whether the 24.9% of the non-DEM dogs included in Group II were exhibiting a behavioural profile similar to diagnosed DEM animals. Multiple (uncorrected) univariate t test comparisons found 30 significantly different behavioural items between Groups I and II. This was reduced to 27 items after correction for age and multiple comparisons (Table 1).

Neurobehavioural similarity of qCCD and DEM

The mean sum of behavioural scores for the 27 significant behaviours were 111 (range 88–141) for DEM dogs and 73 (range 59–141) for non-DEM dogs (Fig. 1). The threshold for qCCD was therefore set at a summed behavioural score of 88 or above. One hundred percent of qCCD dogs were from the Group II DEM cluster.

The behavioural profile of qCCD and DEM dogs was significantly different from NCI dogs across all 27 significant behaviours. After correction for multiple comparisons and age, DEM and qCCD dogs were not significantly different across all 27 behaviours.

Estimated prevalence and diagnosis rates

Fifty-nine non-DEM dogs were classified as qCCD, giving an estimated prevalence rate for CCD (qCCD + DEM) of 14.2% (68/479). The rate of veterinary diagnosis reported was, by contrast, much lower at 1.9% (9/479). There was an exponential increase in the estimated prevalence of CCD with increasing age ($F = 54.62$; df = 478, $P < 0.0001$; linear contrast $P < 0.0001$, quadratic contrast $P < 0.0001$, cubic contrast, $P = 0.373$; see Fig. 2).

Breed differences

Breed longevity estimates could be applied to 386 dogs and size categories to 376 dogs. As expected, dogs of short-lived breeds were significantly younger than those of long-lived breeds ($P = 0.001$) and large dogs were significantly younger than small dogs ($P < 0.001$). After correction for age differences, however, there was no significant difference in the estimated prevalence of

[1] See www.dogzonline.com.au

[2] See http://www.apdt.com.au

[3] Universal Magazines (North Ryde, NSW, Australia), Issue 86, November/December 2007

Table 1
List of 30 behavioural items identified as significant in exploratory two-step cluster analysis and their levels of significance after correction for age differences.[a]

Behaviour	*P*-value
Abnormal locomotion: pacing; circling; and/or wandering	0.000*
Staring blankly at the walls or floor	0.000*
Change in abnormal locomotion	0.000*
Change in staring blankly	0.000*
Failure to recognise familiar people or pets	0.000*
Getting stuck behind objects or furniture	0.000*
Walking into walls or furniture	0.000*
Change in obedience/response to commands	0.000*
Change in recognition of familiar people or pets	0.000*
Change in getting stuck behind objects or furniture	0.000*
Orientating to the hinge side of doors to be let out	0.000*
Change in walking into walls or furniture	0.000*
Standing over the water bowl but not drinking	0.000*
Frequency of house soiling	0.000*
Difficulty finding dropped food	0.000*
Change in excitement for walks or outings	0.000*
Frequency of waking during the night	0.000*
Avoiding being petted or touched	0.000*
Change in the frequency of house soiling	0.000*
Time taken to learn new tasks	0.000*
Level of excitement for walks or outings	0.000*
Change in the percentage of active time spent in activities other than playing	0.000*
Change in difficulty finding dropped food	0.000*
Change in vocalising at nothing or for no reason	0.000*
Enthusiasm to greet the owner after a separation	0.000*
Change in time spent inactive per day	0.000*
Obedience/response to commands	0.000*
Frequency of breed-typical behaviours displayed	NS
Time spent inactive per day	NS
Time spent chewing bones or toys	NS

[a] Alpha level set at $P < 0.0017$ to control for multiple comparisons.
* Denotes a significant item after correction for age and multiple comparisons.

CCD (qCCD and DEM) across longevity ($P = 0.185$) or size ($P = 0.243$) groups. There was also no age × longevity group interaction on CCD prevalence ($P = 0.447$) or age × size group interaction ($P = 0.623$) (Fig. 3).

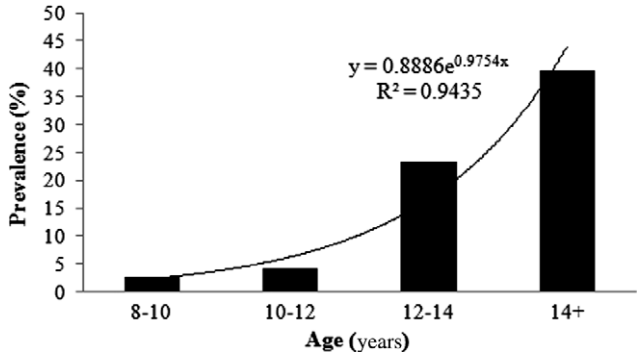

Fig. 2. The prevalence of CCD (qCCD and DEM) in dogs aged: 8–10 years (3.4%); 10–12 years (5%); 12–14 years (23.3%); and >14 years (41%). An exponential trend line with the equation $y = 1.1873e^{0.9008x}$ and an R^2 value of 0.9454 was fitted.

Discussion

CCD is an age-related cognitive disorder that is becoming increasingly prevalent due to the ageing of the domestic canine population. Although some reports suggest that CCD is a common disorder of aged dogs (Neilson et al., 2001; Osella et al., 2007; Azkona et al., 2009), neurocognitive behavioural changes are commonly ignored or regarded by owners as part of the normal ageing process (Landsberg and Araujo, 2005; Osella et al., 2007). In our study, the estimated CCD prevalence rate amongst older community based dogs was 14.2%, in contrast to a veterinary diagnosis rate of only 1.9%.

Whilst previous prevalence studies used veterinary records to rule out the presence of other organic causes of behavioural change, we relied on the owners' notification of co-morbid disease. It is possible that organic causes of behavioural change not identified by owners could have decreased the precision of our prevalence estimate. It is, however, unlikely that our estimate of prevalence was artificially inflated since previous studies have reported considerably higher figures (Neilson et al., 2001; Osella

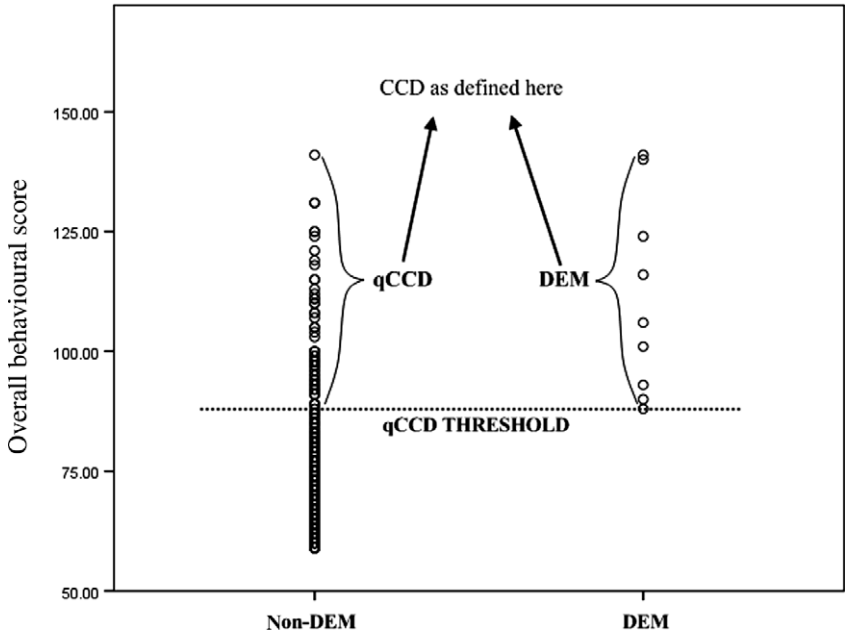

Fig. 1. Relative distributions of the summed behavioural scores of 27 significant items for dogs with a veterinary diagnosis of dementia (DEM) and dogs without a diagnosis of dementia (non-DEM). The considerable overlap is likely due to the low rate of disease diagnosis within the community.

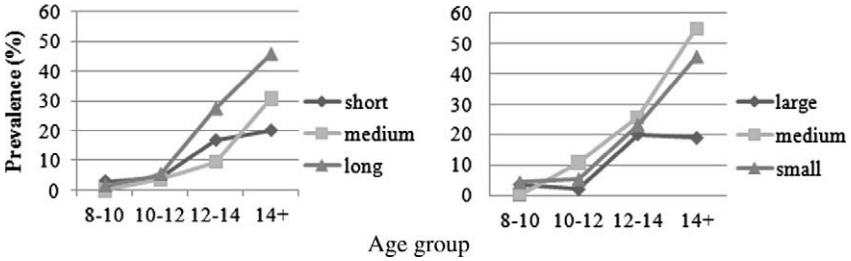

Fig. 3. The interaction between age groups: 8–10; 10–12; 12–14; and 14+ years, and the prevalence of CCD (qCCD and DEM) in dogs belonging to short-lived (⩽11 years), medium-lived (11–13 years) and long-lived (>13 years) longevity groups and large (>55 cm high), medium (35–55 cm high) and small (<35 cm high) size groups.

et al., 2007; Azkona et al., 2009). The use of the Internet to disseminate the survey also introduces the possibility that a more highly educated, higher income, urban population of dog owners was sampled compared to the general population (Australian Bureau of Statistics, 2007). However, both the large sample size and our recruitment of community based (rather than veterinary clinic based) dogs greatly increase the generalised nature of this study.

Our approach also had some methodological strengths over previous studies. The behavioural items were highly specific and had objective anchors to the five response options. Our estimates were also based on a larger sample size than any previous studies (which ranged in size from 102 to 325 dogs). Additionally the SDS was distributed to a wide range of dog owners through several media types and the sex and de-sexing distribution aligned well with previous surveys (McGreevy et al., 2005; Masters and McGreevy, 2007). Data-driven analytical techniques allowed grouping of dogs into naturalistic clusters instead of relying on a preconceived definition of CCD.

This automated approach appears to have captured important aspects of the CCD profile. Behaviours which contributed to the qCCD cluster overlap significantly with those identified as relevant based on clinical expertise. For example, the DISHA domains, developed by a veterinarian to identify behavioural changes indicative of cognitive dysfunction, cover disorientation, social interactions, sleep/wake cycle disturbances, loss of housetraining/other learned behaviours and changes in activity levels (Landsberg et al., 2003). All of these broad behavioural domains were represented in the 27 behavioural items which defined our qCCD group. Furthermore, cluster analysis aggregated qCCD and veterinary-diagnosed DEM animals into one group in contradistinction to cognitively-intact animals, and qCCD dogs were significantly different from NCI dogs across all 27 behavioural items after correction for age. Finally, as found in previous studies, the rate of CCD appeared to increase exponentially with age (Neilson et al., 2001; Azkona et al., 2009). Query CCD as defined here is therefore suggested to be indicative of an undiagnosed age-related cognitive dysfunction syndrome. Under diagnosis of CCD is a potentially significant issue in older companion animals.

Somewhat unexpectedly there was no evidence that age-related cognitive dysfunction varied across dog breeds. It is well established that small dogs live longer than large dogs (Patronek et al., 1997) and an 'accelerated cell ageing' hypothesis (Galis et al., 2007) would have predicted that larger dogs have an increased prevalence of CCD at a younger age than small dogs. In contrast, the results here suggest that prevalence of age-related neurobehavioural dysfunction is similar across the size and longevity groups. These findings are consistent with those of Azkona et al. (2009) who found that size was not identified as a predictor for CCD.

Finally, it is relevant to speculate on the reasons for the low rate of formal diagnosis of CCD in community-dwelling dogs. Many factors may contribute, including a lack of awareness about this disorder, and an unwillingness to accept and report behavioural changes indicative of CCD. In addition, the lack of a clear and validated diagnostic assessment tool limits diagnosis of CCD in veterinary practice, and helps perpetuate the misplaced assumption that CCD is part of '*normal*' age-related change. These areas clearly warrant further research as the prevalence estimates in this and other studies suggest that CCD has a major impact on the lives and welfare of a large proportion of aged dogs.

Conclusions

The estimated prevalence rate of CCD in community based dogs was 14.2% in dogs over the age of 8 years, yet the rate of diagnosis was extremely low with only 1.9% of older dogs having been clinically diagnosed. CCD does not appear to discriminate between breed groups and is an international problem. Given the increasing number of older dogs in the community and the strong link between dogs and their carers, it is hoped that this research will facilitate an increase in the awareness of CCD within the community and in veterinary practice.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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