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Are mixed-breed dogs healthier than purebred dogs? A review of the current data on diseases and longevity in dogs.

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Abstract

In today's world, more than 400 different dog breeds have been registered and the number continues to increase, as people come up with new ways of breeding dogs. Purebred dogs are prone to many inherited disorders, inbreeding depression and a decreasing gene pool. Mixed-breed dogs, on the other hand, are said to be less prone to these problems, as they have a higher genetic variation. This review combined knowledge from the last 25 years of research in the field of mixed-breed dogs and purebred dogs to see what we know and what we still need to examine further. The literature all in all agrees that mixed-breed dogs have an increased longevity, although other factors determine longevity other than breed. They also have a decreased risk of some of the major diseases such as organ disorders and cancer but are instead prone to other problems such as ruptured cranial cruciate ligament, behavioural problems such as aggression, accidents and diabetes. Future research needs to take the inverse relationship of body mass and longevity into account when measuring longevity between breeds and more studies should be made in the field of canine cancer, as this accounts for most deaths overall in dogs.

Sammanfattning:

I dagens värld har mer än 400 olika hundraser registrerats och antalet fortsätter att öka gradvis, eftersom människor kommer med nya sätt att avla hundar. Renrasiga hundar kan ha stora problem med ett flertal ärftliga störningar, inavelsdepression och en minskande gen pool. Å andra sidan sägs hundar med blandad ras vara mindre benägna för dessa problem, eftersom de har en högre genetisk variation. Denna översyn sammanfattar kunskap från de senaste 25 årens forskning inom området blandade hundar och renrasiga hundar för att se vad vi vet och vad vi fortfarande behöver undersöka ytterligare. Litteraturen är överens om att hundar med blandad ras har en ökad livslängd, även om andra faktorer avgör livslängder än rasen. De har också en minskad risk för några av de huvudsakliga sjukdomarna som organ defekter och cancer, dock kan de ha andra problem såsom brustet kranialkorsband, beteendeproblem som aggression, olyckor och diabetes, vilket påverkar livslängden. Framtida forskning måste ta hänsyn till det omvända förhållandet mellan kroppsmassa och livslängd vid mätning av livslängd mellan raser. Fler studier bör göras inom området cancer hos hundar, eftersom detta står för de flesta dödsfall totalt sett hos hundar.

Key words
Mixed-breed dogs, purebred dogs, health, longevity, disease

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Introduction

More than 15.000 years ago, the wolf (Canis lupus) was the first animal to become domesticated by humans (Savolainen et al. 2002) with the purpose of helping them in scavenging and hunting, but also as food, when necessary, and for the role of pets (Stafford 2006). From then on selective breeding started shaping the dog (Canis Familiaris) as we know it today, with its' more than 400 registered breeds (Patronek et al. 1997) and today dogs are being bred for different purposes such as hunting, herding, guarding, service and companionship. In the year 2000, about 500 million dogs existed in the world (Matters and Daniels 2000). Pedigree dogs, which are being used for breeding, are registered in Kennel clubs and there are many physical and behavioural attributes that must be upheld in order to meet the standards of the specific breeds (Stafford 2006). This type of selective breeding became exceedingly popular in the 19th century (Ott 1996) when dog shows, and the first official Kennel club were founded in England.

Many breeds are selected to have physical conformations which some humans deem to be desirable (Bellumori et al. 2013). This led to serious consequences for the welfare of animals, with both direct and indirect side effects (Fleming et al. 2011). Morphological breed-associated defects were already recognized in 1868 by Charles Darwin, who theorized that muscular defects in Scottish Deerhounds were related to their large body size (Asher et al. 2009). Examples of physical alterations are dogs which are bred with abnormally large heads coupled with small pelvises, such as the English bulldog, which makes natural birth almost impossible, or animals whose faces are so flat, that normal breathing and exercise is a challenge (Rooney & Sargan 2010). Dozens of genetic variants have been identified, which influence the breed -defining traits such as skeleton size (Sutter et al. 2007), coat colour (Candille et al. 2007), hairlessness (Drögemüller et al. 2008), wrinkled skin (Akey et al. 2009) and leg length (Parker et al. 2009). Some of the indirect side effects of selecting for specific phenotypes, is that it also increases the risk of certain diseases within the dog breeds. More than 370 diseases have been listed, that are inherited or have a strong hereditary component in dogs (Patterson 2000). For example, as mentioned above with English bulldogs, a soft elongated palate is associated with a shortened muzzle and entropion (inwards turning eyelid) is associated with skin folds around the eyes (Asher et al. 2009).

Inbreeding and line breeding during the last 150 years, to create specific breeds, that satisfy the desire for designer dogs, has reduced the gene pool and made the occurrence of some diseases more prevalent in certain dog breeds (Patterson 2000). Inbreeding depression is a direct result of this, where fitness decreases as inbreeding increases (Keller And Waller 2002). Hybrid vigour describes the superior average performance of crossbred offspring compared with the purebred parents and has been proposed to have an inverse effect on inbreeding depression. (O'Neill et al. 2013). Mixed-breed dogs are defined as a mix of minimum three different dog breeds, whereas crossbred dogs refer to dogs mixed of a maximum of two breeds (Switzer and Nolte 2007). These dogs are also known under different names (e.g. mutts, mongrels) and are sometimes considered to have a phenotypic advantage over purebred dogs because they possess a higher genetic variation (Akey et al. 2010). Purebred dogs on the other hand, refers to dogs which belong to only one specific registered breed.

The aim of this review was to create an overview of the current literature regarding the welfare of mixed-breed dogs in comparison to purebred dogs and combine the knowledge on the subject. By doing this, it will become apparent, if there are any differences in the health of these two categories of dogs. In this case health will be measured from the longevity of the dogs and their proneness to different diseases. The review will also hopefully show, which areas of the subject that needs more research in the future in order to improve the welfare of dogs in general.

Methods

In the search for studies to include in this review, one single search engine was used: Web of Science. This was due to the fact, that initial test searches in other search engines yielded the same results (same articles) as on Web of Science and therefore it seemed redundant to use these in addition to the former.
The search was limited to studies performed within the years 1995-2020 with the purpose of only including recent research on the topic and new fields of study for this area. The search was performed in all available databases in the Web of Science library and in the category "topic" in order to get the most possible results. Furthermore, the results were limited to English, Danish and Swedish language articles and only for the occurrence of selected key terms in the title, keywords or abstracts of the publications. This was due to the reasoning, that if relevant keywords were not mentioned in these parts of the article, it was highly improbable that the rest of the article would be within the scope of this review. A combination of the key words "mixed-breed", "mongrel", "purebred", "dog", "lifespan", "longevity", "disease", "health", "welfare", "mortality", "morbidity", "insurance", "behaviour", were applied (both in singular and plural form where possible) and using the Boolean operator AND to combine the keywords, the search field was narrowed down to publications that are within the scope of this review. The texts of publications with restricted access, were obtained through the Linnéuniversitet library "OneSearch" or in some cases, by contacting the authors of the publications directly, if the articles were unavailable otherwise. After collecting the relevant literature for the review, duplicates were eliminated from the list and the remaining articles were assessed further by examining the abstracts. In this process, additional articles were excluded if they fell outside the range of this study. The exclusion criteria in this case would be if other species than dogs were the test subjects in the study, if only the abstract was available in the preferred languages and the rest of the article was in a different language or if the subject examined in the article was not within the scope of this review (e.g. genetic research, medical science or social sciences).
Some articles were retrieved from the references of articles that were found via the above search procedure. This was done to catch any relevant literature that for some reason did not show up in the initial searches and were thought to be important to include in the study. These studies were still limited to the same criteria as in the Web of Science search with regards to language, publication year and the specific keywords present in the title, keywords and/or abstract.
A table of the detailed literature search with elimination criteria and resulting articles can be found in appendix 1. Some of the search terms yielded many results, but the majority of the results had to be eliminated due to many replicates, search areas outside the scope of this review and articles that for some reason were not filtered out when selecting article languages. The appendix only shows search term combinations which yielded new results for articles used in the review.

Literature review

Longevity in dogs

The longevity of dogs, like for any other living creatures, is dependent on a variety of factors, that affect the health of the animal and thereby inevitably also its lifespan.
Before discussing the longevity of mixed-breed dogs and purebred dogs, it is important to note, that there are certain factors that both groups of dogs have in common, when it comes longevity and how it can be affected. These are not breed-specific, but merely a set of ground rules that (as far as we know) applies to all canines.
The first thing to keep in mind, is that according to several studies (Hoffman et al. 2013; Michell 1999 and Waters et al. 2009) female dogs live longer than male dogs, if they are neutered. However, it is not entirely clear how much longer than males they live. This is due to the decreased risk/elimination of certain types of cancer, (e.g. ovarian cancer) that follows with the removal of the ovaries. In a study by Hoffman et al. (2017), it was concluded that in 20 out of 25 breeds tested, males lived longer than females when neither were neutered, but the opposite was true in 21 out of 25 breeds tested, when all animals were neutered. O'Neill et al. (2013) found similar results. The study showed that females, which had been neutered, lived on average 0.8 years longer than intact females, but both neutered males and intact males lived on average 0.4 years longer than intact females. A study within this area was performed on Rottweilers, which showed, that neutering females under the age of 4 years, can remove the survival advantage for females (Waters et al. 2009), because they instead have an increased risk of other health threatening diseases, such as certain forms of cancer.
A different aspect of age-related studies is the longevity to size relationship that exists in the mammalian kingdom. Although the general rule of thumb for mammals is that bigger animals tend to live longer lives, the opposite seems to be the case with dogs, where smaller size generally indicates a longer lifespan ((Narasimhan 2015). The theory does apparently not apply to the height of the dog, but rather the body mass (Greer 2017).
The subject is tricky, as even though larger mammalian species tend to live longer than smaller mammalian species, on an individual level within species, smaller individuals generally outlive the larger individuals (Selman et al. 2013). This decrease in longevity with body mass is especially clear in dogs, because the extensive breeding of them have resulted in more than 400 official breeds (Patronek et al. 1997) which means that we are seeing big genetic variation within this species. In a study on cellular proliferation in different body masses of dog breeds by Li et al. (1996) essentially none of the test subjects belonging to the group "big dogs" survived past the age of 15 years. In the group "middle dogs" an average of 3% survived past 15 years and in the small dogs this number was 10%. This corresponds well with other studies in this research area, (Patronek et al. 1997; Galis et al. 2007) that found the same connection between body mass and longevity in dogs including that small dogs tend to live longer lives. The oldest dogs recorded in

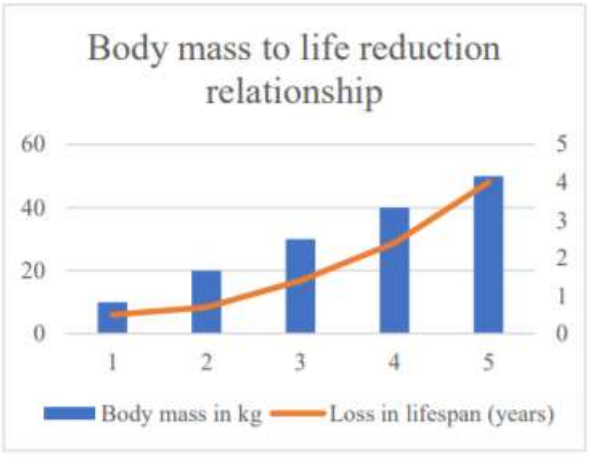

Figure 1: A graphic depiction of data adapted from O'Neill et al. 2013.
The data includes results from dogs > 1 year and both crossbred and purebred dogs from English veterinary clinics.
The y-axis on the left side shows body mass in kg and the y-axis on the right side shows years.
The x-axis shows 5 different body mass categories.

history do indeed belong in the smaller end of the size scale, the oldest one being an Australian sheepdog which lived to the age of 29 years (SKK). O'Neill et al. (2013) found that lifespan decreased exponentially with body mass as shown in 5 table 1 and figure 1. The most acknowledged theory of why large breeds generally have a decreased longevity compared to smaller breeds is that they age faster (Kraus 2003).

Because dogs are a very phenotypically diverse animal, they have equally diverse demographics, with lifespans that vary between 6-16 years (O'Neill et al. 2013) When it comes to longevity between mixed-breed and purebred dogs, most research points to mixed-breed dogs living slightly longer than most purebred dogs (Patronek et al. 1997; Proschowsky et al. 2003; Inoue et al. 2017). In a study by Adams et al (2015) which only included purebred dogs, the median age for all dogs was 11.3 years, ranging from 2 months to 23 years. However, only 20% (of 15881 dogs) of the test subjects were still alive at the age of 14 and this fell drastically to 10% by the age of 15 years. The median age varies with each study and was 10.0 years in a study by Proschowsky et al (2013) and 10.3 years in a study by Lewis et al. (2018). These two studies both included mixed-breed dogs.

In a study of cemetery data in Japan, mixed-breed dogs were calculated to live an average of 1.3 years longer than all purebred dogs (Inoue 2018), while this number was 1.2 years in a study by O'Neill et al. (2013) of dogs in England. Furthermore, the study by Inoue (2018) had mixed-breed dogs divided into two weight categories: one under 10 kg and one above. The study confirmed the before-mentioned theory, that longevity is connected to body mass, as the average longevity for mixed-breed dogs <10 kg was higher than that for mixed-breed dogs >10 kg, which was 15.4 and 14.5 years, respectively. These average longevities are a bit higher than what other studies have concluded, but the longevities of purebred dogs in the same study also had longer than usual average lifespans and therefore the longevity differences between the two groups matched other studies. It could be that dogs in general live longer in Japan than other countries studied, however this is beyond the scope of this review.

While mixed-breeds seem to outlive most purebreds (in the same weight category), some studies (e.g. Inoue et al. 2018) indicate that there are exceptions to this pattern. Although mixed-breed dogs had a higher median lifespan (11 years) than the entire group of test subjects (10 years) in the study by Proschowsky et al (2003), a few dog breeds exceeded this: the Shetland sheepdog, Poodle and Dachshund with median lifespans of 12 years, but as these are only a very small percentage of all the dog breeds in existence, it does not change the overall result which shows increased longevity for mixed-breeds compared to purebred dogs. Further, this result may not be completely reliable, as the study only had one category for mixed-breeds and therefore we do not have information regarding how the body mass in these animals were distributed. If a majority of the dogs had a low body mass, then the resulting median might have been increased while a high body mass in the majority of the dogs would have resulted in a decreased median lifespan. Therefore, when we know these parameters are connected, it is scientifically incorrect to make a direct comparison with the longer living purebred dogs.

Table 1: Median longevity of the 10 most popular breeds in Denmark, England and Sweden plus mixed-breed dogs, taken from the kennel club data from each country. Data on longevity is taken from 4 different sources: Japan (1), England (2, 4) and Denmark (3) and an average longevity is created from these data. The Japanese study included two body mass categories for mixed-breed dogs, this has been calculated to one combined value. The list is organized after highest average longevity. N/A means that the dog breed was not included in the study.

Breeds	**Lifespan (years)**				**Average Longevity**
Source	Inoue et al. 2018 (Japan)	O'Neill et al. 2013 (England)	Proschowsky et al. 2003 (Denmark)	Adams et al. 2010 (England)	a+b+c+d/n

Mixed breed	15.0	13.1	11.0	N/A	13.0
Labrador retriever	14.0	12.5	10.5	12.3	12.3
Golden retriever	12.9	12.5	11.0	12.3	12.2
Staffordshire bullterrier	N/A	10.7	11.0	12.7	11.5
Cocker spaniel	12.8	11.5	10.0	11.1	11.4
Pug	12.6	N/A	9.0	11.0	10.9
Havanese	N/A	12.7	9.0	10.3	10.7
King Charles Spaniel	13.0	9.9	8.0	11.3	10.6
Chihuahua, long-haired	11.8	7.1	9.0	12.4	10.1
German Shepherd	N/A	11.0	9.0	N/A	10.0
French bulldog	10.2	N/A	9.0	9.0	9.4

In this study the median longevity for the 10 most popular dog breeds in Denmark, England and Sweden (from kennel club data) was calculated in comparison to the longevity for mixed-breed dogs (Table 1 and Fig. 2). The Japanese study by Inoue et al. (2018) showed the highest median lifespan for all breeds, while the Danish study by Proschowsky et al. (2003) have the lowest median lifespans. This seems to indicate that dog longevity is higher in Japan than in Denmark and England, as almost all breeds studied have longer lifespans here. Each separate study showed an increased longevity for mixed-breed dogs compared to purebreds regardless of the differing overall lifespans between the studies. It is interesting to see, that the small breeds in the table do not seem to live longer than large and medium-sized breeds, even though this is what the data in the previous section suggests. For example, according to the data, Chihuahuas have a decreased longevity compared to Labrador and Golden Retrievers, which should not be the case by body mass-longevity reasoning. Although the two studies focusing on data from England are only published three years apart, they differ quite a lot in the lifespan medians for some species. This can possibly be explained by the methods applied in the two papers, as Adams et al. (2010) collected data by public questionnaires and O'Neill et al. (2013) used data collected from veterinary records. Veterinary records will only include data from animals who were euthanised and/or autopsied while the questionnaires apply all data from owners, regardless of veterinary help was given.

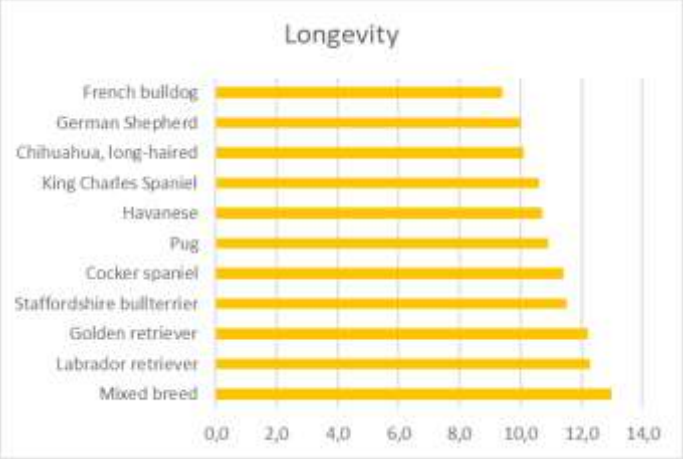

Figure 2: A graphic depiction of the average longevity calculated from results by: Inoue et al. 2018, O'Neill et al. 2013, Proschowsky et al. 2003 and Adams et al. 2010.

As a last note on this subject, it is of course important to underline, that having a longer life cannot be regarded as being more healthy, as it is possible that these dogs are victims to a long and distressing period of decline in health prior to the point of death/euthanasia. Therefore, in order to better understand the underlying mechanisms and nature of ageing, decline and death within breeds, longevity variation should be seen in contrast to the welfare costs that are a part of the specific causes of death within dogs.

Diseases in dogs

In a study by Bellumori et al. (2013) 27.254 dogs of various breeds and the inherited disorders they all possessed, were studied. In 13 out of 25 recorded inherited disorders, the prevalence did not differ between mixed-breeds and purebreds. However, the study found that 10 disorders had a higher occurrence in purebreds and 2 disorders were more common in mixed-breeds. The disorders in purebreds included epilepsy, heart and aortic diseases, dermatitis/allergic reactions, elbow dysplasia, cataracts, IVDD (Intervertebrate Disc Disease) and hypothyroidism. Mixed-breed dogs had a greater probability of suffering from Ruptured cranial cruciate ligament, which is also the conclusion reached in a small Croatian study, where mixed breeds ranked highest (29%) compared to purebred dogs in the study with this disorder (Pecin et al. 2017). However, all disorders were present in both groups of dogs, in Bellumori et al.'s (2013) study.
A study by Oberbauer et al. (2015) found that occurrence of IVDD, hypothyroidism and allergic dermatitis was also more prevalent in purebred dogs, however, the remaining disorders studied, did not differ among the two groups.
Interestingly, the research from Bellumori et al.'s (2013) study shows signs that breeds that have recently derived from each other or from similar lineages, appeared to be more susceptible to disorders that affected all closely related purebred dogs, whereas disorders that did not differ in occurrence between the two groups, suggested that these disorders derived from more ancient mutations that have spread out through the entire dog population.
In a study by Egenvall et al. (2000) disorders of the integumentary, gastrointestinal and genital systems are most responsible for death in the studied dogs. However, also here mixed-breed dogs were on the lower end of the scale when it comes to occurrence of disorders in all the studied areas of the body.
A study performed in Denmark (Lund 2007) which (among other things) showed the difference in reasons for euthanisation between purebred and mixed-breed dogs (fig. 2). Purebred dogs were significantly more at risk of being euthanised due to heart-, lung-, kidney- and liver disorders and also disorders of the central nervous system. On the contrary, mixed-breed dogs were more at risk of being euthanised due to behavioural disorders such as aggression, separation problems and other behavioural problems. This is supported by the results in a study by Proschowsky et al. (2003) where mixed-breed dogs also ranked high on the list of euthanisations due to behavioural problems. Because many mixed-breed dogs are euthanised due to reasons not necessarily concerning their health, their average longevity might actually be higher than studies show, as the many behavioural-caused euthanisations can contribute to a decreased average longevity. Other behavioural problems in the study by Lund (2007) refers to problems such as too noisy, too active, does not like children and so

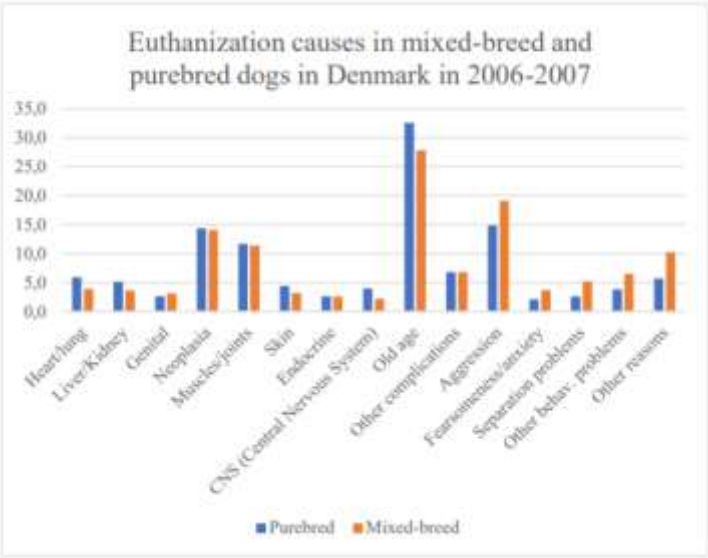

Figure 2: A graphic depiction of data adapted from Lund 2007.
The figure shows the cause of euthanisation in Denmark in 2006-2007.
The y-axis shows the percentage euthanisations due to the disease/disorder.
The x-axis shows the categories of diseases/disorders.

on. Aggression problems were most often seen in male dogs, which is supported by similar studies (Bamberger et al. 2006; Lund et al. 1996). A reason for the high number of euthanisations due to behavioural problems in mixed-breed dogs, is believed to be because the behaviour of these dogs are harder to predict, as it is not always clear which DNA the dog contains and therefore some owners realize later in the dog's life, that their behaviour does not fit their lifestyle or did not meet their expectations. (Lund 2007). When mixing behavioural traits from dogs that differ in character (e.g. herding dog, guarding dog, hunting dog and companion dog) these behavioural characteristics might be conflicting in a way that causes problems for both dog and owner. The current literature does not seem to include specifics in this area, but it could be an important research subject that might help to decrease the occurrence of behavioural problems and thereby euthanisations in mixed-breed dogs.

An important part of the study by Lund (2007) showed the differences between reported euthanisation-causing disorders in mixed-breed dogs in Sweden and in Denmark. The data showed that there is a considerable difference between the two countries and why people choose to have their dogs euthanised. Swedish mixed-breeds were put down due to tumours in 19% of the cases, while this number was only 14% in the Danish dogs. On the other hand, the difference in musculoskeletal disorders was 6% for Sweden and 11% for Denmark. Heart disorders as the cause of euthanisations was similar between the two countries with 3% and 4% for Sweden and Denmark respectively, while neurological disorders showed the biggest difference with 8 % for Sweden and 2% for Denmark. The reason for the variation between the countries is likely because differences exist in the breed dispersal on a national basis and therefore also the relative frequency with which the individual breeds are combined in mixed-breed dogs (Lund 2007). It is important to bear these differences in mind when comparing data in this area of science, as these variations are likely to occur in general between countries.

In a study by Proschowsky et al. (2003) both purebred and mixed-breeds were included in a questionnaire regarding cause of death in Danish dogs. The 6 categories of cause of death were: cancer, behaviour, accident, hip dysplasia, heart disease and spinal disease. The study showed that mixed-breeds were at a higher risk compared to purebreds to die from behavioural causes, which was not surprising as this was also covered later in the study by Lund (2007) regarding, in particular, aggression as a behavioural issue. Accidents cover everything from car crashes and self-inflicted damages and the data from the study showed, that mixed-breeds have a higher risk (7.6 %) than the average of purebreds (5.0 %) to die from this cause. This is also reflected in a study by Switzer and Nolte (2007) who found that mixed-breeds accounted for 32.5 % of the fractured limbs in dogs seen in an animal clinic in Hannover, Germany. In a similar study, accidents in mixed-breeds were more common than the average in purebreds with 14.1% and 6.8 % respectively (Eichelberg and Seine 1996). The speculative explanation given for the increase of accidents in mixed-breeds is that mixed-breeds, more often than purebreds, are running off the leash which could result in them being involved in more accidents (Switzer and Nolte 2007).

Spinal and heart diseases also seem to occur in greater numbers in purebred dogs than in mixed-breed dogs both according to Proscowsky et al (2003) and Bellumori et al (2013).

Besides from old age, cancer is the most common cause of death in pet dogs (Bonnet et al. 2005; Lewis et al. 2018; O'Neill et al. 2013). The study by Proschowsky et al (2003), showed that mixed-breed dogs have a 12.6% risk of dying of cancer-related causes, which is lower than the average for the 18 pure breeds (16.3%) whereas breeds such as Bernese mountain dog, Golden retriever and Beagles have around a 33 % risk of dying from cancer diseases. Eichelberg and Seine (1996), on the other hand, found that mixed breeds' risk of cancer was above average with 29,4% and an average of 27.3% in purebreds. There seems to be differing results in this research area, but an

explanation could be, that mixed-breeds and purebreds are affected more or less by different kinds of cancer.

Females are estimated to be up to two times more at risk of dying from tumours (Bonnett et al. 2005) due to their increased risk of mammary cancer, which accounted for up to 70 % of all cancer cases in females in an Italian study (Merlo et al. 2008). A different study by Jitpean et al. (2012) which analysed the occurrence of mammary gland tumours in 260.000 female dogs of 110 different breeds, found that the number of cases within each breed differed between breeds, and mixed-breed females were at the lower end of the scale with 16% risk. (Table 5). Other studies (e.g. Switzer and Nolte 2007; Jitpean et al. 2012) shows opposite results, suggesting mixed-breed dogs were over-represented in cases of mammary tumours with 24% compared to purebreds which were represented with single-digit percentages (Jitpean et al. 2012). The study by Jitpean et al. (2012) had a much bigger sample size with a total of 260.000 dogs compared to the study by Switzer and Nolte (2007) which only had a sample size of 60835 dogs. Furthermore, the first study was comprised of insurance data and had a higher degree of breed versatility. These factors could explain the difference in results for the two studies.

In male mixed-breed dogs, 1.3 % were diagnosed with testicular cancer in a study by Nødtvedt et al. (2011) (Table 2). This is slightly below the average for purebred dogs of 1.4 %, which means mixed-breeds and purebreds have more or less the same risk when it comes to this disease. A few breeds, the Collie and the Shetland Sheepdog, are over-represented in this study and have a relatively high risk compared to all other species, mixed-breeds included.

Small, female dogs with low body mass have been shown to have a decreased risk of malign tumours compared to dogs with large body mass in a study showing 25.5% risk in small dogs and 58.8% risk in large dogs (Itoh et al. 2004). However the sample size of this study was rather small with a total of 101 dogs and as there does not seem to be other studies within this area, this is something that should be studied more closely in order to verify the results.

In a study on gastric carcinoma with data from the canine cancer register of Norway, mixed-breed dogs were the most frequent “breed” with 1932 tumours registered (Seim-Wikse et al. 2013). However, there was evidently a lack of cases of this form of cancer in mixed-breed dogs, which is an interesting observation for further research into what could cause this anomaly.

Table 2: Occurrence of Pyometra and mammary tumours in female dogs and testicular tumours in male dogs. The data is replicated from (A-C) Jitpean et al. 2012 and D from Nødtvedt et al. 2011.

	A	**B**	**C**	**D**
Breed	**Pyometra (F)**	**Mammary tumour (F)**	**Pyometra/Mammary tumour (F)**	**Testicular tumour (M)**
Mixed-breed	24.0	16.0	35.0	1.3
Cocker Spaniel	36.0	35.0	56.0	0.7
Dachshund	15.0	16.0	28.0	1.9
Golden Retriever	36.0	10.0	42.0	1.3
Labrador Retriever	28.0	11.0	35.0	0.4
Bernese Mtn. Dog	66.0	14.0	69.0	0.6
Boxer	28.0	35.0	51.0	0.7
German Shepherd	31.0	26.0	47.0	0.8
Collie	44.0	2.0	45.0	4.9
Dobermann	43.0	42.0	62.0	0.3
Flatcoated Retriever	28.0	16.0	38.0	0.1
Newfoundland	50.0	8.0	54.0	0.9

Rottweiler	58.0	22.0	65.0	0.2
Shetland Sheepdog	23.0	7.0	28.0	5.7

Diabetes is another well-known problem in domestic dogs (Fall et al. 2007) and the literature overall agrees, that mixed-breeds and purebreds differ in their risk. One study showed that mixed-breed dogs had an increased risk of developing diabetes compared to purebred dogs as a combined group, even though some breeds are more at risk than others (e.g. Australian Terrier, Standard Schnauzer and Samoyed, Guptill et al. 2003). A similar study from the UK canine diabetes register showed that mixed-breeds were over-represented in the register with a proportion of 18.5% of the total register (purebred average 3% from 0.1%-12.2%, Catchpole et al. 2013). Mixed-breeds dogs were, however, seen to have a decreased risk of diabetes compared to breeds of Scandinavian origin (Fall et al. 2007). It is not known exactly why the latter is the case, but a theory is, that species that are adapted to a colder climate, may have an altered glucose metabolism that makes them more withstanding to the cold climate, but more prone to diabetes (Fall et al. 2007). As mixed-breed dogs seem to have a high risk of diabetes compared to purebreds in general, it would be interesting to see more studies in the future with focus on this subject, so it might become more apparent what causes the difference in prevalence between the two groups of dogs.

A summary of the most commonly reported diseases in the literature used in this study, suggests a difference in purebreds and mixed-breeds when it comes to diseases/disorders they are affected by (fig. 3). The prevalence of six categories of diseases/disorders differed for purebreds and mixed-breeds according to studies by Egenvall et al. (2000) and Bonnett et al. (2005) (Table 3). Both studies used data retrieved from Swedish dogs insured in Agria in 1995 and 1995-2000, respectively. The data showed that mixed-breed 12 dogs were less prone to these four categories of diseases compared to purebred dogs. Data on locomotor and neurological disorders showed a slightly higher risk of neurological disorders in mixed-breed dogs, but on the other hand a more than two times smaller risk of locomotor disorders compared to purebred dogs.

Table 3: 6 disease categories in mixed-breed and purebred dogs and their prevalence (%) from Egenvall et al (2000) and Bonnett et al. (2005). Purebred dog data has been calculated to an average from the breeds in figure 3.

	Intergumentary	Gastrointestinal	Genital	Respiratory	Locomotor	Neurological
Purebred	3.9	3.2	3.0	1.2	14.7	5.2
Mixed-breed	2.8	2.0	1.8	0.6	6.0	8.0

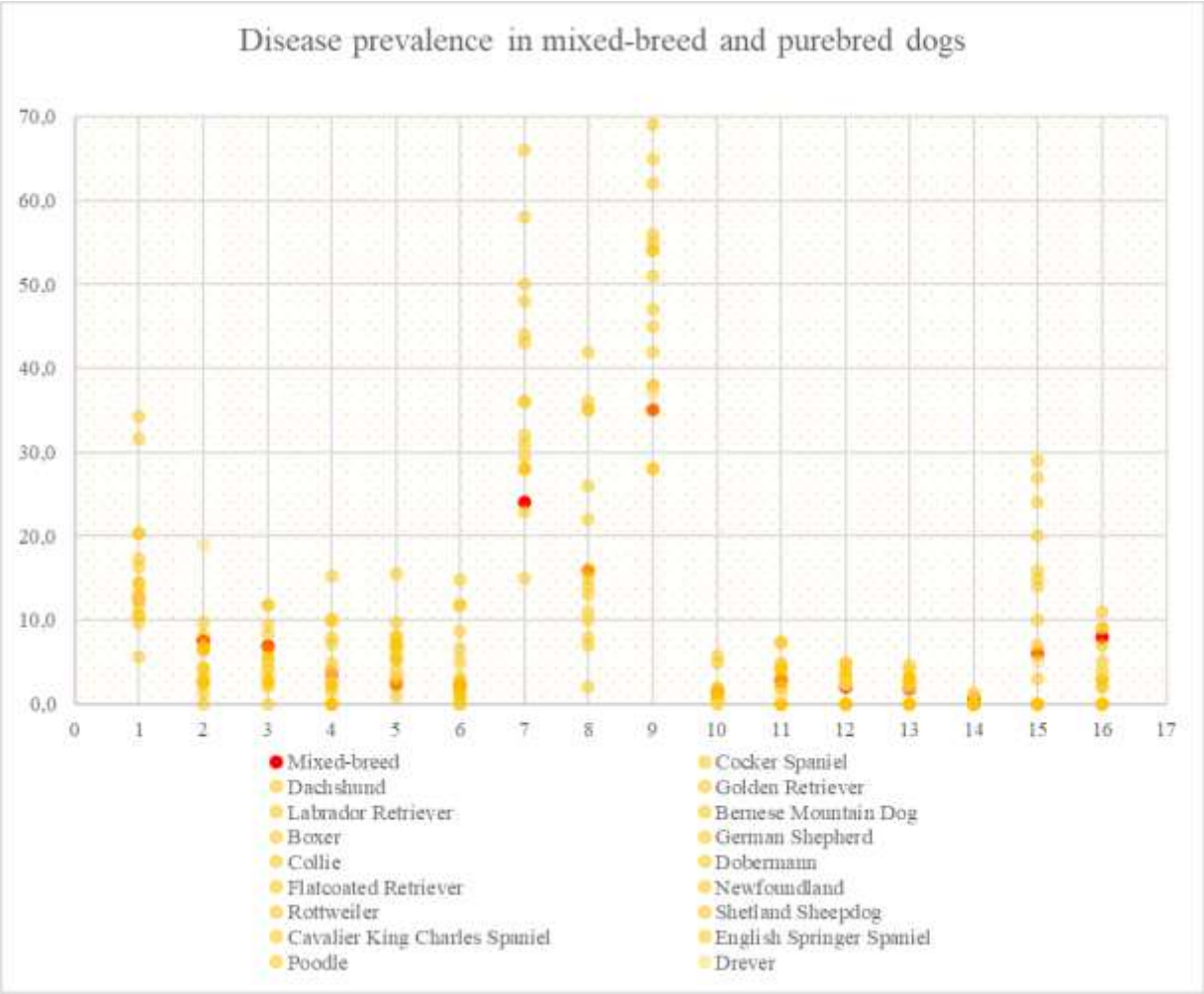

Fig 3. Summary diagram of most mentioned diseases/disorders in mixed-breed and purebred dogs. The y-axis shows percentage prevalence in each breed and the x-axis shows the different diseases/disorders, which are in number order: Cancer, behaviour, accident, hip dysplasia, heart disease, spinal disease, Pyometra, mammary tumour, Pyometra/mammary tumour, testicular tumour, integumentary diseases, gastrointestinal diseases, genital diseases, respiratory diseases, locomotor diseases and neurological diseases. Mixed-breed dogs are marked with red in the figure to show the differences between these dogs and purebred dogs. Data is retrieved from: Bonnett et al. (2005); Egenvall et al (2000); Jitpean et al. 2012; Nødtvedt et al. 2011 and Proschowsky et al. (2003). The first three articles gathered data from insurance claims, the fourth article from the Norwegian canine cancer register and the fifth article from a questionnaire from the Danish kennel club (DKC).

Conclusion

Longevity is dependent on a variety of factors and in dogs, these factors include body mass, gender, fertility status (neutered or not) and breed. Smaller body mass is inversely correlated with longevity and neutered females have an increased longevity. Mixed-breed dogs on average live longer than purebred dogs, with a few exceptions. Mixed-breed dogs are more susceptible to Ruptured cranial cruciate ligament and to be euthanised due to behavioural problems such as aggression and are also more likely than purebred dogs, to die from accidents. Purebred dogs are more likely to die from organ disorders and cancer. Some of the studies had interesting results but needed a bigger sample size, in order to achieve significant results.

More studies are needed which compare longevity of mixed-breed dogs in various body mass categories compared to purebred dogs, in order to get a clear view of the longevity differences between them and purebred dogs. Moreover, as cancer is the second largest cause of death in dogs, future research could include studies which examined this more closely. A before-mentioned small study showed, that small, female dogs are less prone to malign tumours, and it could be interesting to see this type of study on a bigger scale with a larger sample size, in order to find more significant results.

Mixed-breed dogs, according to current studies, have a higher risk of dying and sustaining injuries from accidents, but as of now, the reason for this is simply speculation and more research is needed if this number is to be brought down. Additionally, mixed-breed dogs have a tendency to develop more behavioural problems, which result in euthanisation. The reason for this could be that some breeds of different groups such as working, guarding, companion and so on do not mix well and create a dog with problematic behaviour, but as this is not something the current literature has shed light on, it is definitely something that should be examined further, to improve the well-being of these dogs and ultimately maybe bring down the numbers of behavioural-caused euthanisation.

Current literature on diseases in dogs are very focused on purebred dog diseases and therefore it is hard to make comparisons with mixed-breed dogs. As it seems mixed-breeds are very numerous in most countries, more research should include this group of dogs in their studies. Moreover, a difference in the amount of deaths due to certain diseases in mixed-breed dogs might exist between countries due to differences in their genetic material (breed popularity varies across countries) and this would be relevant to look into in future research, as it would affect the way data can be compared across countries.

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Appendix

	Search word(s)		
	Mixed-breed* AND dog* AND disease* AND purebred*	Mixed-breed AND dog* AND longevity	Purebred* AND dog* AND lifespan
Total results	88	11	10
Elimination criteria			
Year	79	11	10
Language	78	11	10
Article	75	11	10
Key terms in title, abstract and/or keywords, elimination of duplicates and examination of abstract	5	2	3
Remaining articles	Switzer & Nolte 2007; Oberbauer et al. 2015; Proschowsky et al. 2003; Bellumori et al. 2013; Eichelberg & Seine 1996	Patronek et al. 1997; Greer et al. 2011	Lewis et al. 2018; Adams et al. 2010; O'Neill et al. 2013

	Search word(s)	
	Mongrel* AND dog* AND longevity	dog* AND insur* AND longevity
Total results	12	33
Elimination criteria		
Year	10	28
Language	10	28
Article	10	27
Key terms in title, abstract and/or keywords, elimination of duplicates and examination of abstract	2	3
Remaining articles	Egenvall et al. 2000; Michell 1999	Hoffman et al. 2017; Fall et al. 2007; Inoue 2018

	Search word(s)	
	dog*AND (cause of death) AND breed* AND longevity	dog*AND (cause of death) AND breed* AND mortality AND gender*
Total results	38	14
Elimination criteria		
Year	35	14
Language	35	14
Article	35	13
Key terms in title, abstract and/or keywords, elimination of duplicates and examination of abstract	2	1
Remaining articles	Waters et al. 2009; Hoffman et al. 2013	Bonnett et al. 2005

	Search word(s)	
	Dog* AND size* AND longevity* AND large*	Dog* AND behav* AND mixed-breed* AND aggress*
Total results	47	21
Elimination criteria		
Year	41	20
Language	41	16
Article	39	16
Key terms in title, abstract and/or keywords, elimination of duplicates and examination of abstract	3	2
Remaining articles	Galis et al. 2007; Kraus et al. 2013; Selman et al. 2013	Bamberger et al. 2006; Lund 1996

	Search word(s)
	Dog* AND (gender OR sex) AND neuter AND longevity
Total results	8
Elimination criteria	
Year	8
Language	8
Article	8
Key terms in title, abstract and/or keywords, elimination of duplicates and examination of abstract	1

Remaining articles	Greer et al. 2011