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Companion animal and equine clinical research: a Nordic perspective

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Abstract

Background The societal value of cats, dogs and horses is high, and the companion and sport animal health care sector is growing. Clinical research concerning cats, dogs and horses is crucial for the development of evidence-based medical care that benefits animals and their owners, and has implications for human and environmental health from a One Health perspective. Basic information on companion animal and equine research enables more directed measures to improve conditions for research within the area. The aim of the present study was to describe Nordic companion animal and equine clinical research from 2010 to 2019, including bibliometrics, human resources and funding.

Results There were 2 042 published research publications originating from Nordic countries on cats (n = 282), dogs (n = 1 086), and horses (n = 781) from 2010 to 2019. The majority (83%) of the publications came from the four Nordic universities with veterinary programs. Seven percent of the publications were collaborations between two or more Nordic universities. Approximately 18% of the PhD theses (178 out of 970) from veterinary faculties or corresponding units concerned these species, most of them dogs (n = 86), followed by horses (n = 64), cats (n = 15) or a combination of these species (n = 13). The scientific areas cardiology, infectious diseases, reproduction, and surgery were prominent for all three species. A large proportion of grants were received from small- to medium-sized funding bodies, mainly funding running costs and only to a limited degree salaries. During 2010–2019, costs for veterinary and other services for cats and dogs steadily increased. The growth of the veterinary healthcare sector was not reflected in an increasing number of clinical research publications, for which no increase was seen after 2014.

Conclusions Despite a high societal value of the species, veterinary clinical research on sports and companion animals has not increased, in contrast to the veterinary healthcare sector. Activities stimulating the research area, e.g. funding bodies enabling coverage of salaries, are needed. The development of Nordic veterinary clinical care may benefit from strengthened research cooperation between countries.

Keywords Bibliometry, Cat, Clinical, Dog, Equine, Horse, Research, Veterinary

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Background

Companion animals and horses play important roles in society, for instance, by providing companionship, promoting health and well-being, contributing to the economy, preserving cultural heritage, and fostering social connections (e.g. [1–14]). Their presence enriches the lives of individuals and communities, making them valuable members of our society.

Although not all clinical research is of direct relevance to clinical practice, clinical research benefits the well-being and welfare of these animals and is key to support evidence-based development of their diagnostics, treatments and preventive care, and is therefore important to the general society with broader implications for human health. Unfortunately, research funding sources and levels appear limited and the increasing societal and economic importance call for securing research funding for these important areas of veterinary medicine to benefit animal and human health. To support this the following work documents research activities and funding sources for the Nordic countries 2010–2019.

The societal value of cats and dogs is receiving increasing attention [15]. In the Nordic countries, 25–40% of households include companion animals, often regarded as family members [3, 16–18]. Attributes such as companionship and love are related to cats and dogs [2] reflecting strong relationships contributing to human well-being. Approximately 80% of dog owners describe the main function of their dogs as companion animals [19]. During the COVID-19 pandemic, pet owners were reported to have improved mental wellbeing and reduced anxiety due to support from their cats and dogs [6, 11], although contrasting results were also reported [20]. Cats, dogs and horses are beneficial from a One Health perspective and as contributors to public services. They are models for diseases they have in common with people, [9, 12, 13, 21–25], may reduce the risk of childhood asthma and atopy [24, 26, 27], and in older adults, dogs have a positive effect on physical activity and sleep [12]. Companion animals are part of our work force, and in addition to police, military and guide dogs may benefit the rehabilitation of children [8], be reading dogs [5], and scent-detecting dogs [28].

Dogs and cats are increasing in number. In Norway, there has been an estimated 25% increase in the number of dogs from 2001 to 2012, and the number of pet cats increased 50%, from 535 000 to 800 000, between 2001 and 2016 [29]. Many cats and dogs reach an old age, and with increasing age require more veterinary care [19, 30, 31]. Many pet owners expect advanced care for their cats and dogs [32], and veterinary care in the Nordic countries is professionalised, with satisfied clients [33]. A large proportion of cats and dogs in the

Nordic countries are covered by animal insurance. Sweden is the European country with the highest proportion of insured pets [34]. In Sweden, the proportion of insured dogs is estimated to be 60–80%, and the proportion of insured horses only slightly lower [34–36], whereas the proportion of insured cats is approximately 25% [34].

This increasing population of cats and dogs, together with owner expectations and the development of veterinary medicine [32], has stimulated the growth of the companion animal healthcare sector. In Norway, the number and size of clinics and veterinary health services provided have increased [37] from 30 companion animal clinics in 1987 to 520 in 2022 [38]. In Sweden, household spending on pets has surged, rising over 200% from 1993 to 2014, a much greater increase than the 29% rise in consumer price index during the same period [3]. In 2017, the revenue of the cat and dog sector in Sweden was approximately 16 billion SEK, with veterinary care accounting for almost 25% [3]. The net revenue for veterinary limited companies in Sweden increased by 38% between 2013 and 2016, to approximately 4.4 billion SEK [34]. The 155 veterinary clinics that were members of the Swedish Animal Healthcare sector of the Swedish Federation of Green Employers had 1.2 million client visits in 2019 [33].

Horses are both sports animals and beloved companions, representing a several-fold higher economic investment and risk compared to dogs. In Sweden, the number of horses has evolved from approximately 90 000 in 1979 to 355 000 in 2016 [39]. The price of an ordinary pleasure horse in Sweden in 2022 was 30 000–70 000 SEK, and an estimated cost for maintaining a horse was 7 000 SEK/month. In 2019, Swedish equine industry revenue was approximately 30 billion SEK per year, including the revenue of betting [40]. Approximately 80% of Swedish horse owners use their horses for leisure, and one-third of these participate in horse shows [41]. The largest horse sports in Sweden in 2022 were show jumping, harness racing, dressage, and eventing [41, 42].

Equestrian sport is the second largest sport in Sweden, with 0.5 million riders, and one of the largest sports for people with disabilities [43, 44]. Horse riding has a positive effect on e.g. children with autism [7], stroke rehabilitation in adults [4], identity construction in disabled people [10] and quality of life in people with neurological disorders [14].

The Nordic countries, except Iceland, each have had one single national university for research-based veterinary education and, at some universities, of veterinary nurses and technicians. Veterinary educations are offered at the University of Copenhagen (UCPH), Denmark; the University of Helsinki (UH), Finland; the Norwegian

University of Life Sciences (NMBU) and the Swedish University of Agricultural Sciences (SLU).

During the past decade, capital fund-owned companion animal health care providers have changed the private practice landscape significantly. This has created new opportunities for clinical research on cats, dogs and horses, both as collaborations with academia and as company-driven research efforts. However, collated information on companion animal and equine research across Nordic countries is lacking.

The recent development of the companion animal sector is reflected in household costs for veterinary and other services and for purchase of the animals, their feed, equipment and accessories. Information on the development of such costs is available for cats and dogs in Sweden and allows comparisons with the development of clinical research to point to whether research activities are on par with the growing importance of the sector.

Basic information on companion animal and equine research enables more directed measures to improve conditions for research within the area. The aim of the present study was to describe Nordic companion animal and equine clinical research from 2010 to 2019, including bibliometrics, human resources and funding.

Methods

Bibliometrics

Bibliometric analyses were conducted by the SLU University Library. A search was performed in the Web of Science Core Collection, Indexes—Science Citation Index Expanded, Social Sciences Citation Index, Arts & Humanities Citation Index (Clarivate), and research articles (including review articles) published from 2010 to 2019 with at least one author with an address in a Nordic country were included. The search strategy used TS (topic)=[(cat or cats or feline or kitten or kittens) or (dog or dogs or canine or puppy or puppies or bitch or bitches) or (horse or horses or equine or mare or mares or stallion or stallions or foal or foals or pony or ponies or racehorse or racehorses)] in combination with CU (country/region)=(sweden or denmark or finland or norway or iceland).

All titles were scrutinized in two steps by two researchers (MHG and BSH), first for identification of the chosen animal species (removing articles such as “Algebraic new foundations”—mentioning MLCat in the abstract), and then to distinguish which of these publications should be included as “clinical research”. When needed, the articles’ abstracts and introductions were studied. Clinical research was defined as aiming at preventing, diagnosing, treating, or prognosticating diseases, as well as translating basic science research findings to clinical use. A wide spectrum of articles was included, e.g., physiology studies

and some genetic studies. Articles in which animals were used as models for human disease with no intention of contributing to animal health were excluded (e.g. “Alveolar bone remodeling after tooth extraction in irradiated mandible: An experimental study with canine model”), as well as articles without clinical relevance, e.g., palaeontology studies (e.g. “Sexing Viking Age horses from burial and non-burial sites in Iceland using ancient DNA”). The final dataset was used for descriptive statistics and network analyses.

For an overview of the most prominent research topics in the publications, network visualizations of term co-occurrences were created using the software VOSviewer, version 1.6.16 [45]. Terms, i.e., noun phrases, were extracted from the titles and abstracts of the publications using natural language algorithms [46]. A VOSviewer thesaurus file was used for preprocessing of the extracted terms to merge synonyms (e.g., “anesthesia” and “anaesthesia”) and to remove frequent terms related to person, animal, time/place as well as general terms regarding scientific analysis and reasoning (e.g., “calculation”, “hypothesis”).

For each of the species cat, dog, and horse, network visualizations were created from terms occurring in a minimum of 4 publications (normalization method: association strength; attraction=2, repulsion=0). The 60% most relevant terms, based on their VOSviewer relevance score [46], were included in the term network (cat n=112; dog n=635; horse n=520). The distance between two terms in the network reflects the relatedness of the terms. Node size represents term frequency (binary counting).

Doctoral theses

The university libraries of NMBU, SLU, UCPH and UH were asked for lists of all doctoral theses concerning cats, dogs and horses 2010–2019 from the Department of Veterinary and Animal Sciences and Department of Veterinary Clinical Sciences at UCPH; the Faculty of Veterinary Medicine at UH and NMBU, and the Faculty of Veterinary Medicine and Animal Science at SLU.

Human resources

The mean numbers of clinical professors and senior lecturers with research focused on cats, dogs and/or horses at the Department of Companion Animal Clinical Sciences (at NMBU), Department of Clinical Sciences (at SLU), Department of Veterinary Clinical Sciences (at UCPH), and the Department of Equine and Small Animal Medicine (at UH) in January 2021 were collected from representatives of the clinical departments at the respective universities.

The total number of European Veterinary Specialists™, awarded by EBVS® (European Board of Veterinary Specialization) in Norway, Sweden, Denmark and Finland, registered as of January 2021 was collected from the EBVS® website [47], as well as the number of European Veterinary Specialists™ in colleges that were most closely linked to clinical research in cats, dogs and horses. Defined as most closely linked to clinical research in cats, dogs and horses were the European Colleges of Animal Reproduction, Equine Internal Medicine, Veterinary Anaesthesia and Analgesia, Veterinary and Comparative Nutrition, Veterinary Clinical Pathology, Veterinary Dermatology, Veterinary Diagnostic Imaging, Veterinary Internal Medicine-Companion Animals (internal medicine, cardiology, oncology), Veterinary Neurology, Veterinary Ophthalmologists, Veterinary Pathologists, Veterinary Pharmacology and Toxicology, Veterinary Surgeons, Veterinary Sports Medicine and Rehabilitation, Veterinary Dental College, and the European Veterinary Parasitology College.

Funding of veterinary clinical research

Representatives from the clinical departments at the respective universities contributed information on the most common funding bodies.

From one governmental funding body, the Swedish Research Council Formas, lists with all applications to the annual open call (including research projects, research projects for early-career researchers and mobility grants for early-career researchers) from 2010 to 2019 were obtained. All applications concerning dogs, cats and horses were compiled, and the proportions of granted and rejected applications were calculated.

Information was also directly obtained from the Agria and Swedish Kennel Club (SKK) Research fund, which is open to researchers from Denmark, Finland, Norway, Sweden and Germany.

Household costs

To obtain a measure of the development of the sector, household costs were investigated, with Sweden as an example. Data on costs for “veterinary and other services for animals” and “companion animal feed and equipment” as well as information on the development of the consumer price index (CPI) were obtained from Statistics Sweden (www.scb.se). These statistics are based on data on registered persons that the Swedish Tax Agency supplies to Statistics Sweden. The CPI measures the average price trend for the entire private domestic consumption based on prices consumers pay and is the standard measure of compensation and inflation calculations in Sweden.

Results

Total number of peer reviewed publications

The initial search resulted in 6 201 publications, out of which 2 972 concerned the relevant species. The total number of clinical canine, feline or equine publications in the Nordic countries from 2010 to 2019 was 2 042, 69% of the 2 972 publications that concerned these species. Of these, the majority, 53%, concerned dogs (n = 1086), followed by horses (38%, n = 781) and cats (14%, n = 282) (Some publications concerned more than one species, Table 1). For dogs, publications increased from 2010 and reached the highest number in 2014; for cats, 2015 was the year with the most publications, and in 2016, the number of publications for horses was the highest. An increase in the number of publications per year was noted from 2010 to 2014 and then reached a plateau (Fig. 1).

The four Nordic universities, in order, SLU (33%, n = 664), UCPH (28%, n = 565), UH (14%, n = 291) and NMBU (11%, n = 221), authored the majority of the publications. The species publication distribution of articles was similar for SLU and UCPH, with the majority concerning dogs (49% and 53%, respectively), almost as many

Table 1 Veterinary clinical research publications on cats, dogs and horses 2010–2019

University	Total (Total number of publications in country)	With authors from more than one of the universities %	Cat	Dog	Horse
NMBU (Norway)	221 (267)	62 (28)	26	124	75
SLU (Sweden)	664 (897)	105 (15)	89	326	268
UCPH (Denmark)	565 (647)	81 (14)	77	300	236
UH (Finland)	391 (458)	29 (7)	44	256	99
All universities corrected for coauthorship	1691 (Nordic countries total 2042)	127 (7)	282 (88 multiple species)	1086 (97 multiple species)	781 (20 multiple species)

Numbers of veterinary clinical research publications on cats, dogs and horses with authors affiliated with the Nordic universities during the time period 2010–2019. Because some publications concerned more than one species, the sum of publications on cats, dogs and horses does not agree with the total

NMBU Norwegian University of Life Sciences, SLU Swedish University of Agricultural Sciences, UCPH University of Copenhagen, and UH University of Helsinki

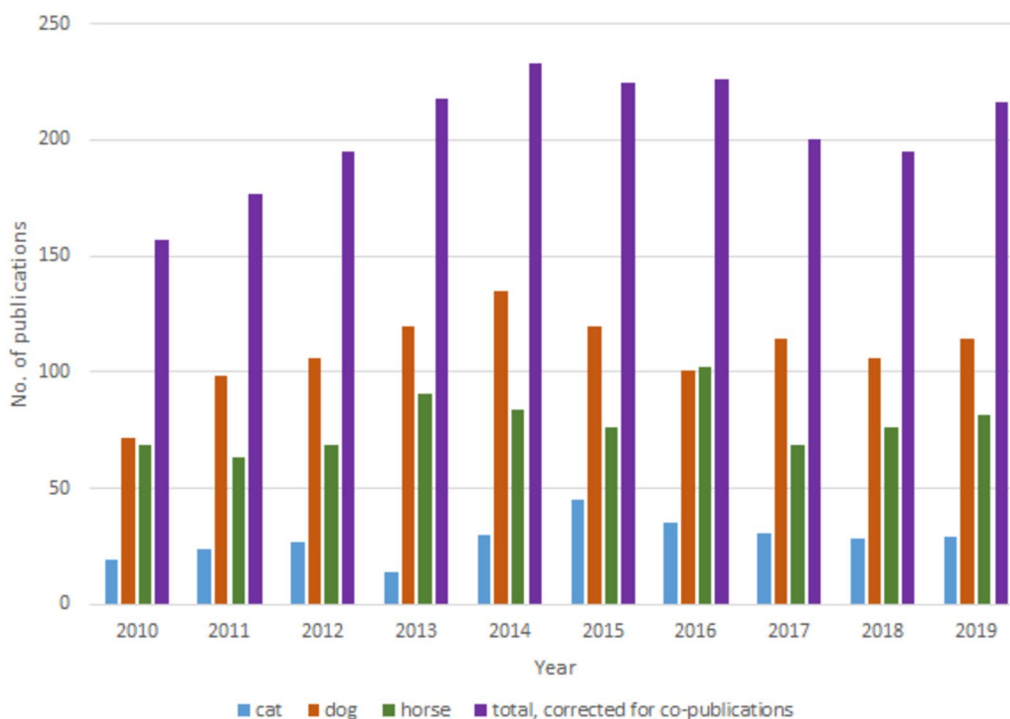


Fig. 1 Clinical articles on cats, dogs and horses 2010–2019. Number of clinical articles on cats, dogs and horses, including total numbers corrected for co-publications, per year 2010–2019

Table 2 Publications authored by AniCura (since 2015) and Evidensia (since 2016) to, and including, 2019

Company	Total publications	Cat	Dog	Horse	Copublications with Nordic universities
Evidensia	53	7	38	11	35
AniCura	23	6	17	0	17

concerning horses (40% and 42%, respectively), and fewest concerning cats (both 13%; Table 1). The dominance for articles concerning dogs was strongest (65%) for UH, with 25% horse articles and 11% cat articles. At NMBU, the corresponding figures were 56% for dogs, 34% horses and 12% cat articles (Table 1). Publications with authors affiliated with the two largest capital-fund owned companion animal health care providers, AniCura (from 2015) and Evidensia (from 2016), mainly concerned dogs (Table 2).

Collaborative peer-reviewed publications with Nordic or other international coauthorships

Out of the 127 Nordic copublications, 77 concerned dogs, 47 horses and 6 concerned cats. Of these, three articles included more than one species. The collaboration between UCPH and SLU resulted in most co-authored

articles (n=60), followed by NMBU-SLU (n=44) and UCPH-NMBU (n=24).

For dogs, the collaborative work resulting in the largest number of publications came from UCPH-SLU (35 articles), followed by NMBU-SLU (n=27) and UH-SLU (n=19). For horses, the collaborative work resulting in the largest number of publications came from UCPH-SLU (24 articles), followed by NMBU-SLU (n=17) and UCPH-NMBU (n=8). Only two publications concerned feline clinical research.

The major overall collaborative partners within canine, feline and equine clinical research were for NMBU: SLU (44 articles), UCPH (24) and University of Oslo (21); for SLU, they were Uppsala University (90 articles), UCPH (60) and NMBU (44); for UCPH, they were SLU (60 articles), University of Kentucky (33) and University of London (including Royal Veterinary College (30)); and for UH, the major collaborative partners were Folkhälsan Research Center (31 articles), Finnish Food Authority (24) and University of Turku (24).

Prominent research areas

Canine visualized research areas included anaesthesiology, cardiology, clinical pathology, genetics, diagnostic imaging, infectious diseases, neurology, oncology, orthopaedics, reproduction and surgery (Fig. 2). Feline

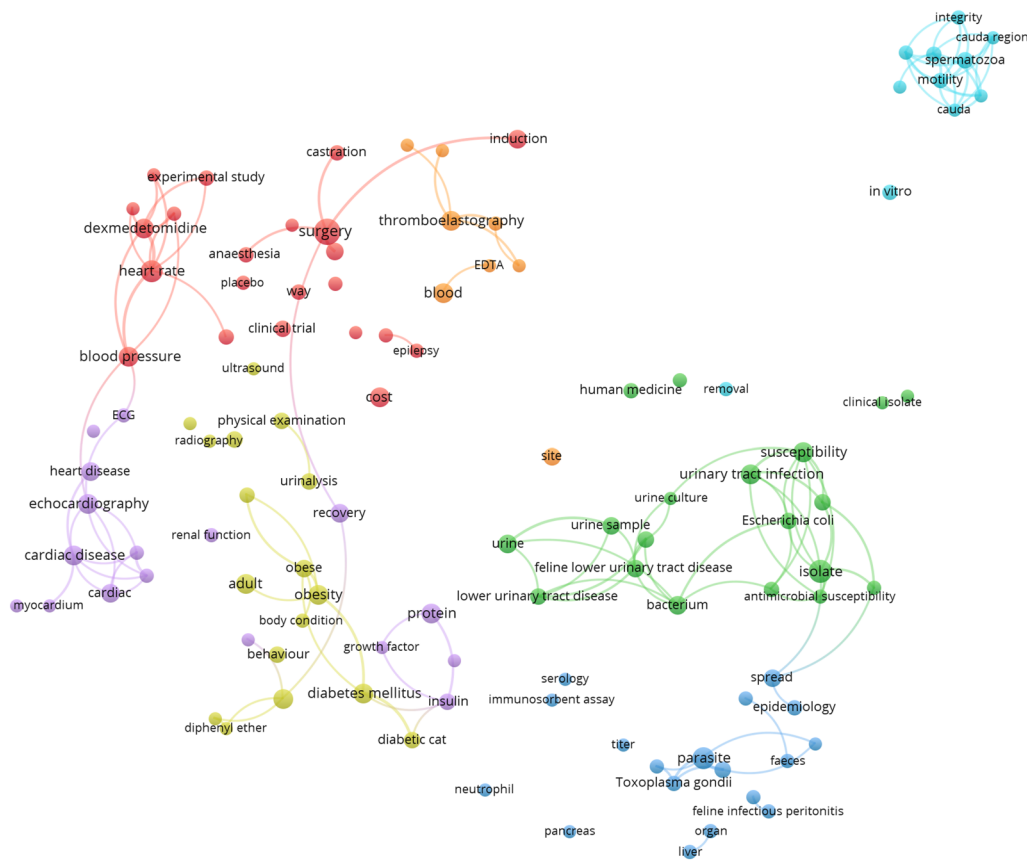


Fig. 2 Term maps of the fields of clinical research on cats in the Nordic countries. The networks are based on term co-occurrences in the titles and abstracts of published clinical articles. The distance between two terms in a map reflects the relatedness of the terms, and colours represent clusters of related terms. The networks were created from terms occurring in a minimum of four articles. The 60% most relevant terms, based on their VOSviewer relevance score, were included in the maps (n = 112). Links are shown for pairs of terms which co-occur in at least three articles

research areas included cardiology, clinical pathology, diagnostic imaging, infectious diseases, metabolic diseases, reproduction, urinary tract diseases and surgery (Fig. 3). Visualized research areas for horses were anaesthesiology, cardiology, genetics, infectious diseases, metabolic diseases, orthopaedics, pathology, reproduction and surgery (Fig. 4).

Preferred scientific journals

Studies in cats and horses were most commonly published in a journal focusing on the actual species, whereas it was a broader species scope in the top journal for canine studies (Table 3). The second most popular journal for each of the species was Acta Veterinaria Scandinavica. Several publications were in journals with a wide scope, but there were also discipline-oriented journals among the ten journals that featured the most articles. For studies in dogs, these were journals focusing on internal medicine, clinical pathology, oncology and reproduction; for cats, medicine and surgery, clinical pathology, reproduction, cardiology and emergency and

critical care; and for horses, they covered veterinary education, reproduction, parasitology and internal medicine (Table 3). Among the ten journals with the highest number of published articles on horses, three were exclusively dedicated to equine studies.

Doctoral theses on cats, dogs and horses 2010–2019

In total, 970 PhD theses were published by Nordic veterinary faculties from 2010 to 2019. Of these, 178 (18%) concerned cats, dogs, horses or a combination of these species (Table 4). The highest proportion of doctoral theses on cats, dogs and horses in relation to other species was produced by SLU, followed by UH and UCPH. At NMBU, only 10% of theses from the veterinary faculty focused on cats, dogs and/or horses. For UCPH and UH, most of these theses concerned dogs (46% and 64%, respectively), followed by horses (26% and 22%) and cats (11% and 6%). For SLU, most theses (49%) concerned horses, followed by dogs (38%) and cats (11%). For NMBU, the number of theses was very similar for dogs

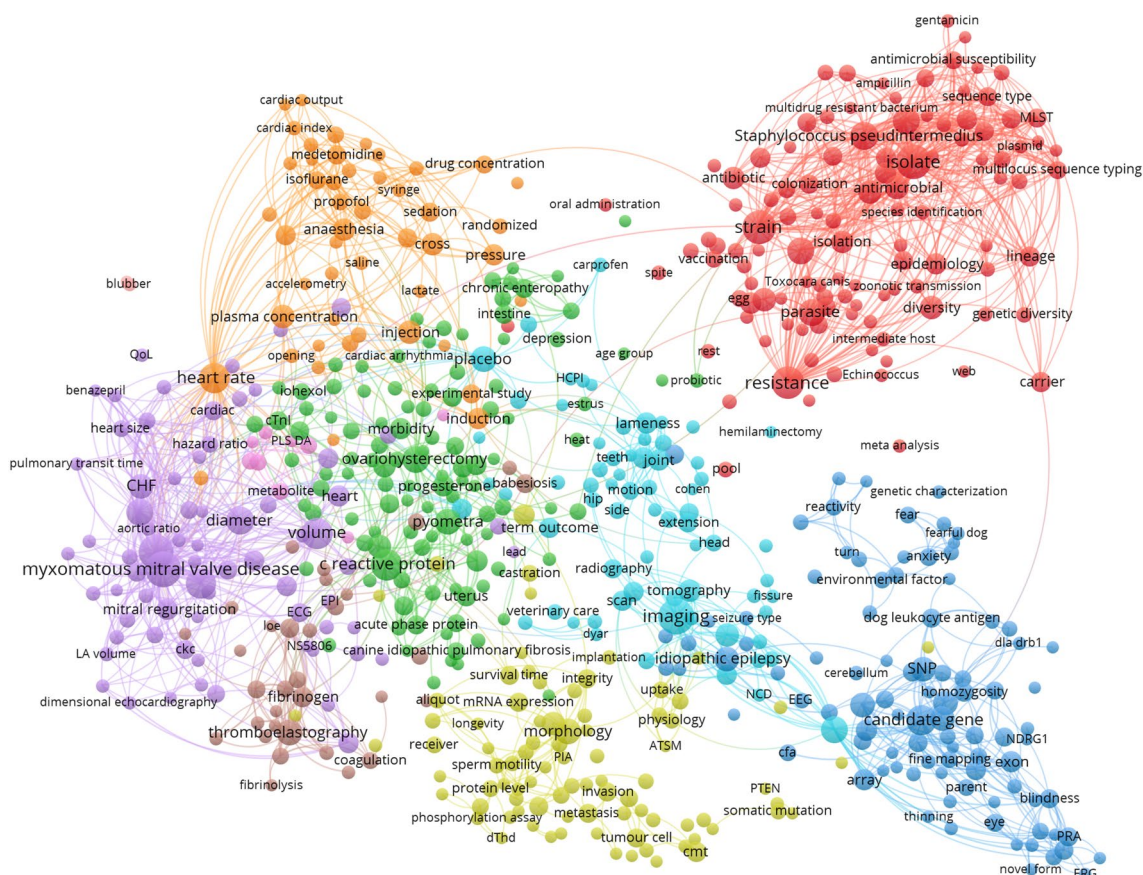


Fig. 3 Term maps of the fields of clinical research on dogs in the Nordic countries. The networks are based on term co-occurrences in the titles and abstracts of published clinical articles. The distance between two terms in a map reflects the relatedness of the terms, and colours represent clusters of related terms. The networks were created from terms occurring in a minimum of four articles. The 60% most relevant terms, based on their VOSviewer relevance score, were included in the maps (n = 635). Links are shown for pairs of terms which co-occur in at least three articles

and horses (46% and 43%, respectively) whereas only one thesis (3.5%) concerned cats only.

Human resources

There were 252 Danish, Finnish, Norwegian and Swedish European EBVS® Veterinary Specialists in 2021. When compared to the total number of European Veterinary Specialists™ in the country, the percentage of European Veterinary Specialists™ of colleges most closely linked to clinical research in cats, dogs and horses was 42% (20/48) for Denmark, 74% (29/39) for Finland, 76% (34/55) for Norway and 74% (81/110) for Sweden. For a distribution between the different colleges, see Fig. 5.

In total, there were 27 professors and 55 associate professors (docents) working with companion animals and equine research in January 2021 in the veterinary clinical departments in Finland, Denmark, Sweden and Norway. They were distributed as follows: NMBU: 2 professors and 15 associate professors; SLU: 9 professors and 14 associate professors; UCPH: 8 professors and

14 associate professors and in addition 4 professors and 5 associate professors working cross species; and UH, 4 professors and 7 associate professors.

Funding of veterinary clinical research in cats, dogs and horses

The top funding bodies for clinical research on cats and dogs in Denmark were Independent Research Fund Denmark, Agria and SKK Research Fund, Royal Canin, and Antech Imaging Systems, and for horses: Independent Research Fund Denmark, Horse Levy Foundation, Kustos, Xintela and Antech Imaging Systems.

In Finland, the most important funding bodies for dogs and cats were Academy of Finland, Agria and the Finnish Kennel Club Research Fund, The American Kennel Club Canine Health Foundation (USA), Nylands nation, Svenska Kulturfonden, Finnish Veterinary foundations and pharmaceutical companies, and for horses: the Academy of Finland, Finnish Veterinary Foundations and pharmaceutical companies.

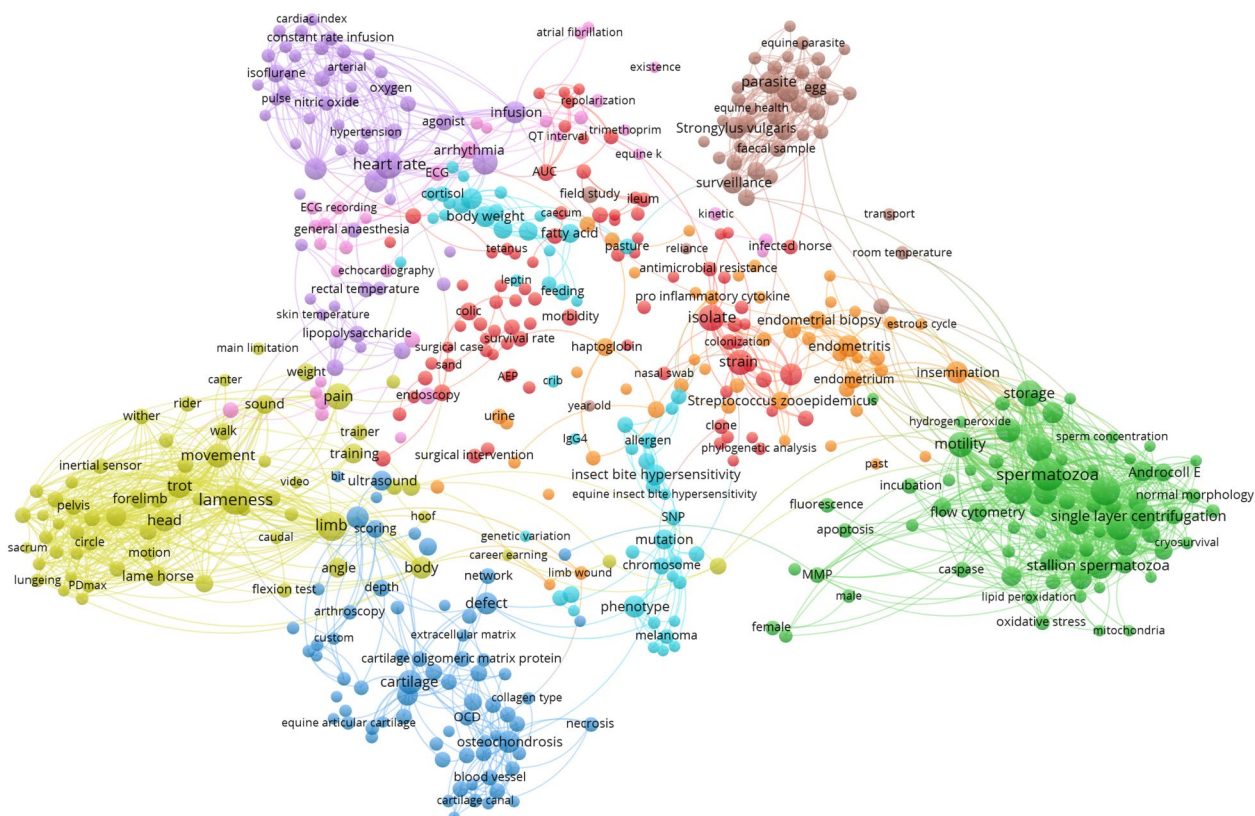


Fig. 4 Term maps of the fields of clinical research on horses in the Nordic countries. The networks are based on term co-occurrences in the titles and abstracts of published clinical articles. The distance between two terms in a map reflects the relatedness of the terms, and colours represent clusters of related terms. The networks were created from terms occurring in a minimum of four articles. The 60% most relevant terms, based on their VOSviewer relevance score, were included in the maps (n = 520). Links are shown for pairs of terms which co-occur in at least three articles

Table 3 Journals with most publications on clinical veterinary research concerning dogs, cats and horses 2010–2019

Publications on cats		Publications on dogs		Publications on horses	
Name	n	Name	n	Name	n
Journal of Feline Medicine and Surgery	42	Journal of Veterinary Internal Medicine	101	Equine Veterinary Journal	79
Acta Veterinaria Scandinavica	18	Acta Veterinaria Scandinavica	94	Acta Veterinaria Scandinavica	55
Journal of Veterinary Internal Medicine	17	Veterinary Journal	70	Veterinary Journal	42
Veterinary Clinical Pathology	12	PLOS One	61	Journal of Equine Veterinary Science	36
Theriogenology	8	BMC Veterinary Research	43	Equine Veterinary Education	36
Veterinary Journal	8	Veterinary Clinical Pathology	31	Reproduction In Domestic Animals	24
Journal of Veterinary Cardiology	7	Veterinary Record	26	Theriogenology	22
Reproduction in Domestic Animals	7	Journal of Small Animal Practice	22	Veterinary Parasitology	21
Journal of Veterinary Emergency and Critical Care	7	Veterinary and Comparative Oncology	21	American Journal of Veterinary Research	20
BMC Veterinary Research	6	Theriogenology	21	Journal of Veterinary Internal Medicine	20

In Sweden, the most important funding bodies for dogs and cats were The Greater Stockholm Veterinary Care Foundation (Stiftelsen Stor-Stockholms djursjukhus), Agria and The Swedish Kennel Club Research foundation, research foundations administered by SLU, Thure

F and Karin Forsberg’s foundation, Jan Skogsborg’s foundation, and pharmaceutical companies, and for horses: The Swedish-Norwegian Foundation for Equine Research (Stiftelsen Hästforskning) and Formas (a Swedish government research council for sustainable development).

Table 4 Number of PhD theses concerning the species cats, dogs and horses, all scientific areas

University	Total number	Cats/dogs/ horses (% of total ^a %)	Cats only	Dogs only	Horses only	Combination of species ^b
NMBU	268	28 (10)	1	13	12	2
SLU	258	65 (25)	7	25	32	1
UCPH	192	35 (18)	4	16	9	6
UH	255	50 (20)	3	32	11	4
Total	973	178 (18)	15	86	64	13

Number of PhD theses from *NMBU* (Faculty of Veterinary Medicine), *SLU* (Faculty of Veterinary Medicine and Animal Science), *UCPH* (Departments of Veterinary and Animal Sciences and of Veterinary Clinical Sciences), and *UH* (Faculty of Veterinary Medicine)

^a PhD theses on cats, dogs and horses related to the total number of PhD theses

^b PhD theses including more than one of the species cats, dogs, horses

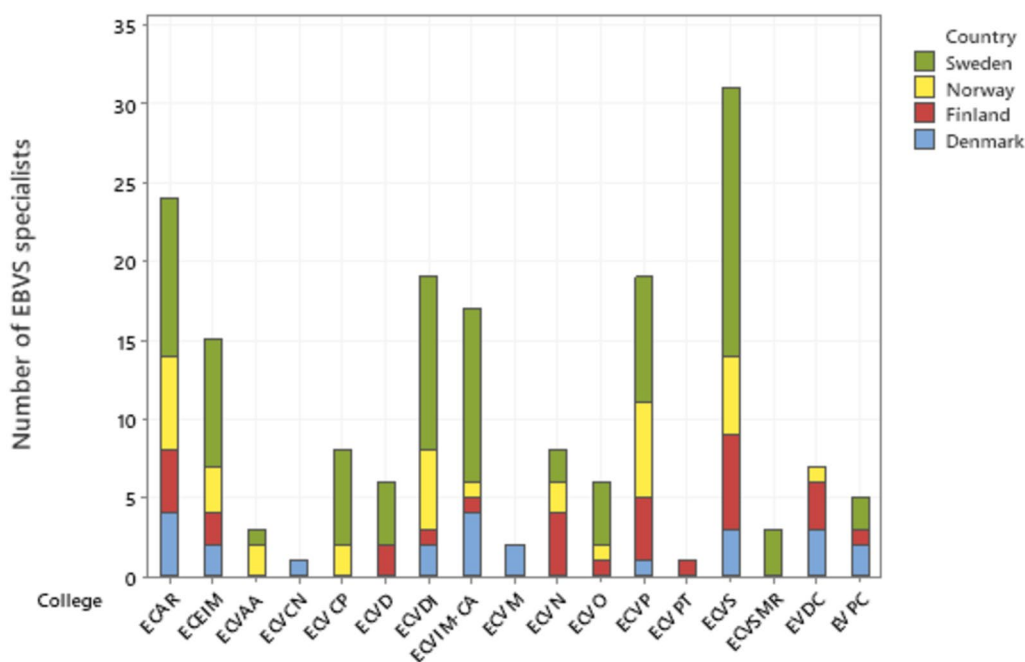


Fig. 5 Number of EBVS™ specialists from the different countries within European colleges. The number of European Veterinary Specialists™ in colleges that were most closely linked to clinical research in cats, dogs and horses were European Colleges of: *ECAR* Animal Reproduction, *ECEIM* Equine Internal Medicine, *ECVA* Veterinary Anaesthesia and Analgesia, *ECVCN* Veterinary and Comparative Nutrition, *ECVCN* Veterinary Clinical Pathology, *ECVD* Veterinary Dermatology, *ECVDI* Veterinary Diagnostic Imaging, *ECVIM-CA* Veterinary Internal Medicine-Companion Animals, *ECVN* Veterinary Neurology, *ECVO* Veterinary Ophthalmologists, *ECVP* Veterinary Pathologists, *ECVP* Veterinary Pharmacology and Toxicology, *ECVS* Veterinary Surgeons, *ECVSMR* Veterinary Sports Medicine and Rehabilitation, and *EVDC* Veterinary Dental College, and *EVPC*: European Veterinary Parasitology College

In Norway, the Ministry of Education and Research and the Swedish-Norwegian Foundation for Equine Research (Stiftelsen Hästforskning) were the most important funding bodies. In addition, there were nongovernmental bodies such as Agria, Norwegian Veterinary foundations, Stiftelsen forskningsfondet kreft hos hund and private memorial funds.

During 2010–2019, Formas funded 30 clinical veterinary research projects on sports and companion animals

in the annual open call. The success rate for applications for the different species varied between 5% (cats) and 14% (a combination of more than one of the species) (Table 5). The overall success rate from Formas during the period was 14%.

The SKK and Agria research fund granted 122 projects in total during 2011–2019, with 9–19 projects per year. Most projects (74%, n=90) concerned dogs, 19% (n=23) concerned cats and 0.8% (n=1) both cats and dogs

Table 5 Outcome for applications to Formas annual open call (Sweden) 2010–2019

Cat	19
Rejected	18
Granted	1 (5%)
Dog	97
Rejected	84
Refused by Formas	1
Granted	12 (12%)
Horse	135
Rejected	118
Refused by Formas	3
Granted	14 (10%)
Multiple species	22
Rejected	18
Withdrawn by author	1
Granted	3 (14%)
Total granted concerning dogs, cats or horses	30/273 (11%)

Numbers in bold describe the total number of applications for the respective species. The percentage granted applications out of the total number of grant applications for that specific species is given within parentheses. The overall percentage of granted applications from Formas during the period was 14%

(Fig. 6). Four percent of the projects (n=5) concerned the value of companion animals for humans or for society, and 2% (n=3) concerned rabbits or guinea pigs. The

grants were distributed to the main applicants affiliated with 18 different organizations, most to SLU (n=45), UCPH (n=33) and NMBU (n=17). Most granted projects had applicants from Sweden (n=65), followed by Denmark (n=34), Norway (n=18) and Finland (n=3). Two projects were collaborations between Sweden and Denmark and between Sweden and Norway. Most grants were for 1-year projects (n=43), followed by 2- or 3-year projects (n=39 for both). Information on duration was missing for one project.

The Agria and SKK Research Fund has a two-step process for research applications. According to the research fund, the fund receives 50–75 applications in the first step, and approximately 2/3 of these are rejected. Approximately 80% of the 20–25 applications in the second step were granted, leading to an approximate overall acceptance rate of 25%.

Household costs

Household costs for veterinary and other services for dogs and cats in Sweden increased 121%, from 2 905 000 000 SEK in 2010 to 6 407 000 000 in 2019. The costs for the animals, their feed and equipment increased 19%, from 7 118 000 000 SEK in 2010 to 8 449 000 000 SEK in 2019 (Fig. 7). As can be seen in Fig. 7, from 2000 onward these costs increased far beyond the consumer price increase.

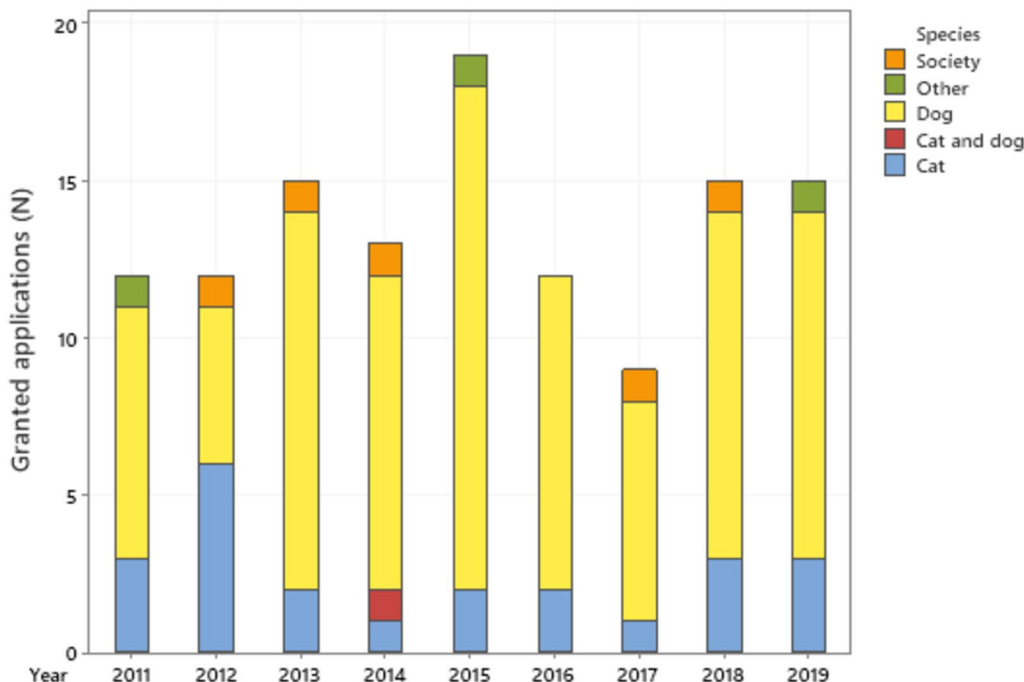


Fig. 6 Number of granted applications from the SKK and Agria Research Fund. Number of granted applications years 2011–2019 for projects concerning cats, dogs, both species, "other": (rabbits or guinea pigs) or "society": projects on different benefits of cats or dogs for society

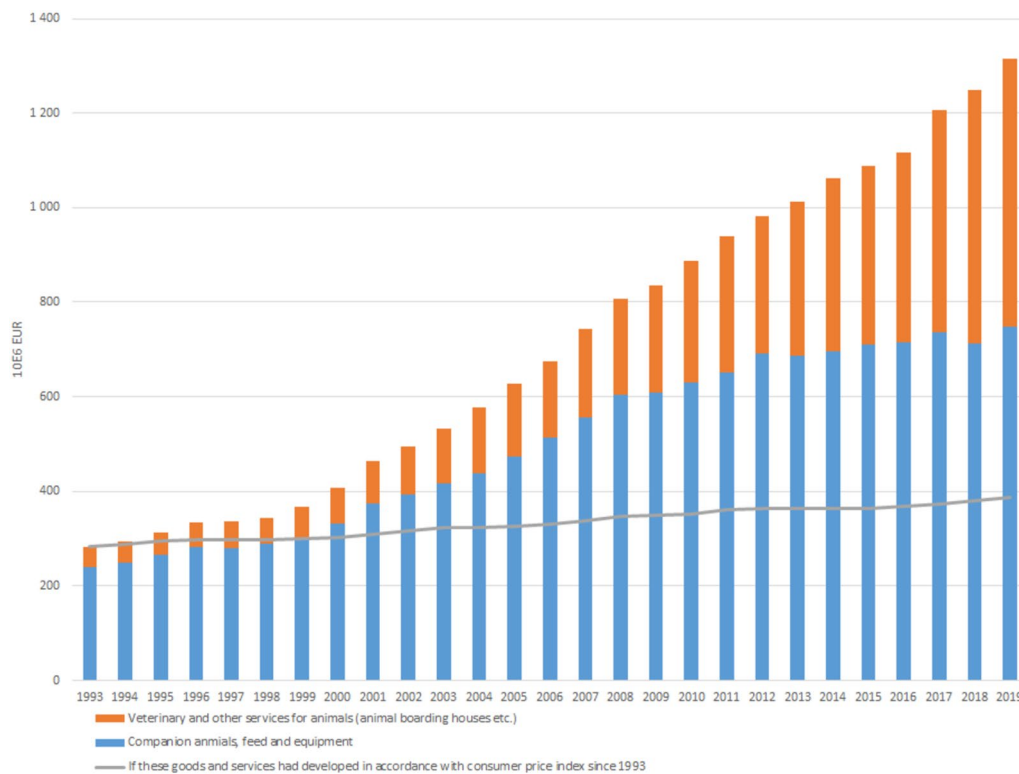


Fig. 7 Costs for veterinary and other services for animals and for companion animals, their feed and equipment in Sweden 1993–2019. The line shows what the costs would have been if they had followed the consumer price index since 1993. Data from Statistics Sweden (SCB)

Discussion

From 2010 to 2019, the output of canine, feline and equine clinical research across the Nordic countries amounted to more than 150 publications per year, the majority from the four universities with veterinary education. During the same period, costs for veterinary and other services steadily increased. The growth of the companion animal sector can be expected to drive an increased demand for veterinary services, necessitating clinical research to develop new treatments, products, and technologies. However, the expansion of the veterinary healthcare sector, as shown in Fig. 7, did not correspond to a rise in the number of clinical research publications, which remained stagnant after 2014 (Fig. 1). While there typically exists a delay of 2 years or more between funding and publication, this stagnation suggests that research funding has not kept pace. Given the significant societal and economic importance in the field, there is a compelling case for revising the approach to funding to stimulate research within the area.

Because there was only one university in each Nordic country educating veterinarians during the study period, except for Iceland, which does not have a veterinary medicine programme, promoting collaboration between them may be an efficient way to increase the critical mass

within the different clinical research areas. Seven percent of the publications had authors from more than one Nordic university, with the most productive collaborations being between UCPH and SLU and between NMBU and SLU. The universities are also important research partners for private organizations; 68% of the publications on dogs, cats and horses that had authors from the two largest private organizations were authored in collaboration with at least one of the universities. The different Nordic countries have a similar view of animals, research culture, a tradition of evidence based veterinary care, and a similar tradition of restrictive use of antibiotics, which is beneficial for clinical collaborations. The universities contributing with the largest number of publications within the area, SLU and UCPH, produced 14–15% of their publications in collaboration with one of the other universities, and for NMBU, the corresponding figure was 28%. The Nordic universities that educate veterinarians were important collaborators for veterinary clinical research, but SLU, UCPH and NMBU all had additional collaborations with another national university among their top three collaborators. All Nordic universities had at least one international collaborator among their top three except for UH, whose top three collaborators were national. In a relatively small field, it should be kept in

mind that individuals or groups with unusually high output may largely influence the results.

The number of articles and doctoral theses was highest for dogs and lowest for cats. The number of dogs is higher than the number of horses, but there are more cats than both dogs and horses, and this is not reflected in the number of published papers. There are several possible explanations for this. Traditionally, the perceived value of a cat has been lower, as shown by a considerably lower proportion of insured cats compared to dogs and horses [34, 35]. Additionally, the demand for advanced veterinary care for cats has historically been lower than for dogs [32]. This perception may also be mirrored in the underdeveloped field of feline research and the very low proportion of successful funding applications for cat-related studies submitted to the Swedish Research Council Formas. However, other factors could also be contributing to this trend. The economic values of individual horses and the horse industry are larger than the respective figures for cats or dogs [40]. The equine research funding collaboration between Norway and Sweden, with both private and governmental contributions, possibly enables the granting of larger projects. No equivalent to this research funding body has been made available for canine and feline research. However, as many veterinary visits concern cats, clinical research for better veterinary care of cats is an area with potential for development.

Cats, dogs and horses are highly treasured, and their economic value includes both use and non-use values, i.e. values for people that come in direct contact with the animals and people that do not but still consider their value [1, 2, 40]. Despite their value and the large-sized animal healthcare sector, the mean proportion of PhD theses concerning these animals was only 18% of all PhD theses at the veterinary faculties or corresponding departments at the Nordic universities. The proportion varied between the universities, from 10% at NMBU to 25% at SLU. Several factors affect research topics for PhD theses, including the teaching and clinical service workload for faculty that work clinically compared to those that do not. In addition, the research interest of the academic staff, tradition, and especially the limited possibility to achieve full external funding for salaries of PhD students are at play. At NMBU, the percentage of time delegated to research for the staff has been described as low compared to other veterinary universities [48], which may contribute to the low number of theses concerning cats, dogs and horses. A survey at UCPH describes a similar situation. Finding funding for PhD students is a challenge. For Denmark and Finland, the proportion of doctoral theses for the different species mirrors the proportion of publications within these countries. In

Denmark the number of scholarships funded by the university has decreased. Interestingly, in Norway and Sweden, the proportion of doctoral theses concerning horses was comparatively higher. At SLU, there were more theses concerning horses than dogs, and at NMBU, the numbers for the species were similar. This is crucial to consider because a doctoral thesis, comprising a series of studies focusing on a specific area, both serves as the cornerstone of a developing researcher's scientific education and enables a more comprehensive exploration and generation of research outcomes within a scientific domain. However, it is important to note that the translation of these findings into clinical implications may have a considerable turnaround time. Although there may be other reasons for the relatively high number of PhD theses on horses at NMBU and SLU, the Swedish-Norwegian Foundation for Equine Research most likely has had a strong positive impact. Larger governmental funding bodies, such as Formas in Sweden, are important sources for funding PhD students and postdocs within several scientific areas and for all domesticated species. For applications concerning cats, dogs, and horses as single species, the success rate was lower than average for Formas open calls. Several criteria are assessed by Formas: novelty and originality, scientific approach, societal value, work plan and competence. It was not within the scope of the present study to evaluate the assessments of these individual criteria, but such an evaluation would be valuable to enable directed measures for increased success rate, at least from this specific fund.

To develop all aspects of companion animal and equine veterinary care, research is key. The sector considers a lack of veterinarians and veterinary nurses as a major obstacle for continuing development [33]. Teaching, clinical and administrative work makes up a large proportion of the workload within academia, and in Norway, the limited time for research for personnel working at NMBU has been highlighted [48]. Funding for salaries is thus needed not only for PhD students but also after the PhD defence. For postdoctoral research activities, research tasks can be a limited part of the workload, together with clinical work, teaching and administrative duties. Unfortunately, many of the most important funding bodies for clinical research, especially for dogs and cats, generally do not cover costs for salaries but consider funding of running costs as a better value-for money. Consequently, salary for the researcher must be sought from other sources. The situation is similar in the UK, where research centring canine health and welfare largely rely on canine specific funding, stressing the importance of strategically directing such funding as effectively as possible [49]. The overhead costs of the universities are considered high by some funding bodies

that as a consequence fund overhead costs to a lower degree, making it difficult to fully finance the studies. Within academia, there is a high demand and competition for external funding, and the situation is similar for veterinarians interested in performing research while in clinical practice. Except for those within a residency programme, who generally will have time allotted for education, including their research projects, veterinary practitioners will generally not have time dedicated for research. Several residency programmes are performed at university clinics. However, the number of European Veterinary Specialists™ is not related to the research output of a country; for example, Denmark, with the second highest publication output, has the lowest number of European Veterinary Specialists™. European Veterinary Specialists™ are a prerequisite for residency training, and residents perform research studies within their education, but their relative contribution to the research output within the Nordic countries thus seems limited.

Academic staff is a prerequisite for PhD education. There was a similar number of professors and associate professors focused on dogs, cats and horses in UCPH and SLU and approximately half as many in UH, but the number of PhD theses within these species was much higher at UH than at UCPH. Simple counting of professors and associate professors is a very blunt tool for comparing human resources because the time allocated for research may vary heavily between persons. The results indicate that the possibility for professors to obtain internal or external financing for PhD students and other research projects, and the amount of time for research within their positions, are better associated with research output than their sole number.

For all three animal species, research was published in both topic-oriented and general scientific journals. The value of a Nordic scientific journal is reflected by the fact that *Acta Veterinaria Scandinavica* is the second most used journal for all three species. Some scientific areas, such as cardiology, infectious diseases, reproduction and surgery, were prominent for all three species, whereas pathology was only prominent for horses, neurology and oncology were only prominent for dogs, and urinary tract diseases were only prominent for cats. For certain areas, interspecies collaborations may thus be more fruitful, whereas for others, collaborations between disciplines may have a greater value. Veterinary clinical research in Nordic countries is broad, with several prominent scientific areas, constituting a possible basis for collaboration. The fact that several areas are internationally prominent and competitive for more than one species also emphasizes the possibility for comparative studies.

The majority of veterinarians in the Nordic countries work in clinical practice, predominantly companion

animal clinical practice [50]. Research funding is a prerequisite not only for the development and advancement of the field, but also for increasing the competence of the faculty and staff, ensuring an increase in the evidence-based provision of healthcare to the animals and thus increasing animal welfare and quality of life. Research funding is also a driver for veterinarians to stay within the sector—a sector desperately needing more animal healthcare personnel.

Conclusion

Despite a high societal value of the species, veterinary clinical research on sports and companion animals has not increased, in contrast to the veterinary healthcare sector. Activities stimulating the research area, e.g. funding bodies enabling coverage of salaries, are needed. The development of Nordic veterinary clinical care may benefit from strengthened cooperation between countries.

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Prior publication

Data have not been published previously, except for Figure 5, for which parts of the information (data for 1993-2014) have been published in [3].

Author contributions

BSH and MHG developed the idea of the article in collaboration with Carenet's steering group and coordinated the study. BSH drafted the manuscript, except for the materials and methods that were drafted by MHG, MS and YT. Data were collected and analysed by AE, BSH, MHG, MS and YT. Visualizations of prominent research areas were made by YT. AKHB, AHH, ATK, BSH, GG, LM and MHG contributed national data from their respective countries. All authors participated in the manuscript discussions and revisions of the text, and all have read and approved the final version of the manuscript.

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Availability of data and materials

The datasets supporting the conclusions of this article are available in the Swedish National Data Service at: <https://doi.org/https://doi.org/10.5878/8cng-q629>.

Declarations

Ethics approval and consent to participate

This study did not require official or institutional ethical approval.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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