J Vet Sci. 2025 Oct;26(S1):S220-S245
https://doi.org/10.4142/jvs.25227
pISSN 1229-845X·eISSN 1976-555X

Journal of Veterinary Science

Narrative Review
Anti-Aging Strategies and Healthspan Extension

Check for updates

Lifestyle factors affecting aging and healthspan in dogs and cats

Won-Seok Oh [1,2,*], **P. Jane Armstrong** [3,*], **Ho Jae Han** [4,*]

[1]Center for Veterinary Integrative Medicine, College of Veterinary Medicine, Seoul National University, Seoul 08826, Korea
[2]Dr. Oh's Animal Clinic, Geriatric Animal & Dermatology Center, Daegu 41952, Korea
[3]Department of Veterinary Clinical Sciences (Small Animal Internal Medicine), College of Veterinary Medicine, University of Minnesota, St. Paul, Minnesota, MN 55108, USA
[4]Department of Veterinary Physiology, College of Veterinary Medicine, Research Institute for Veterinary Science, and BK21 FOUR Future Veterinary Medicine Leading Education and Research Center, Seoul National University, Seoul 08826, Korea

OPEN ACCESS

Received: Aug 7, 2025
Revised: Aug 20, 2025
Accepted: Aug 29, 2025
Published online: Sep 16, 2025

***Corresponding authors:**
Won-Seok Oh
Center for Veterinary Integrative Medicine, College of Veterinary Medicine, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 08826, Korea.
Email: owsvcs@snu.ac.kr
https://orcid.org/0000-0002-9247-7927

P. Jane Armstrong
Professor Emerita, Department of Veterinary Clinical Sciences (Small Animal Internal Medicine), College of Veterinary Medicine, University of Minnesota, 1365 Gortner Ave, St. Paul, Minnesota, MN 55108, USA.
Email: armst002@umn.edu
https://orcid.org/0009-0002-7302-4073

Ho Jae Han
Department of Veterinary Physiology, College of Veterinary Medicine, Research Institute for Veterinary Science, and BK21 FOUR Future Veterinary Medicine Leading Education and Research Center, Seoul National University, Seoul 08826, Korea.
Email: hjhan@snu.ac.kr
https://orcid.org/0000-0002-0657-1766

ABSTRACT

Importance: Lifestyle factors have emerged as critical modulators of aging and health outcomes in dogs and cats. Beyond genetic and biological determinants, modifiable behaviors—such as nutrition, physical activity, and environmental exposures—play a substantial role in shaping healthspan. On the other hand, veterinary care often underutilizes these levers because of limited awareness, fragmented guidelines, and a lack of integrative frameworks for geriatric management.
Observations: This narrative review examines the impact of lifestyle on the aging process in companion animals, synthesizing current scientific evidence and clinical insights. The key domains examined included dietary quality, physical activity, environmental stressors, social interaction, sleep, and preventive care, each of which affects systemic aging patterns and disease vulnerability. Special emphasis was placed on sedentary behavior, sarcopenia, obesity, toxic exposures, cognitive decline, and caregiver burden. Species-specific considerations are addressed, and the opportunities for veterinarians to intervene through practical, evidence-based strategies are highlighted.
Conclusions and Relevance: A paradigm shift toward proactive, lifestyle-centered veterinary care is supported by reframing aging as a dynamic and modifiable process. Promoting individualized, preventive strategies can improve the functional longevity, mitigate frailty, and support quality of life in senior pets. Veterinarians are uniquely positioned to translate lifestyle science into meaningful clinical outcomes across the lifespan.

Keywords: Nutrition; physical activity; obesity; environmental pollutants; veterinary geriatrics

INTRODUCTION

Aging in companion animals is no longer considered a passive, unmodifiable process [1]. Anti-aging strategies are increasingly understood as attempts to extend healthspan, rather than simply extending lifespan [1,2]. The healthspan refers to the period of life during which an individual maintains functional independence, physiological integrity, and quality of life. This is distinct from lifespan, which denotes the total duration of life [3]. In companion

ORCID iDs
Won-Seok Oh
https://orcid.org/0000-0002-9247-7927
P. Jane Armstrong
https://orcid.org/0009-0002-7302-4073
Ho Jae Han
https://orcid.org/0000-0002-0657-1766

Author Contributions
Conceptualization: Oh WS, Armstrong PJ; Data curation: Oh WS, Armstrong PJ; Formal analysis: Oh WS, Armstrong PJ; Investigation: Oh WS, Armstrong P, Han HJ; Methodology: Oh WS, Armstrong PJ; Project administration: Oh WS, Armstrong PJ, Han HJ; Resources: Oh WS, Armstrong PJ; Software: Oh WS, Han HJ; Supervision: Oh WS, Armstrong PJ, Han HJ; Validation: Oh WS, Armstrong PJ, Han HJ; Visualization: Oh WS, Han HJ; Writing - original draft: Oh WS, Armstrong PJ, Han HJ; Writing - review & editing: Oh WS, Armstrong PJ, Han HJ.

Conflict of Interest
The authors declare no conflicts of interest.

Funding
This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (RS-2023-00208475, RS-2021-NR060088) and BK21 FOUR Future Veterinary Medicine Leading Education and Research Center.

animals, extending the healthspan is increasingly prioritized by veterinarians and pet owners [4]. Although lifespan extension can be achieved with medical intervention and is often viewed as a success, it is the healthspan that genuinely matters, ensuring animals age with preserved mobility, cognitive function, and emotional well-being [5-8].

Veterinary anti-aging frameworks aim to optimize the quality and quantity of life, acknowledging that the last third of an animal's life often sees the greatest disease burden, especially if proactive care is not implemented [1]. Anti-aging approaches embrace a preventive paradigm. Rather than merely treating illness, the goal is to delay the onset of disease or mitigate its severity by targeting aging-associated mechanisms before clinical signs appear [4].

Traditionally, veterinary medicine has focused on chronological aging, defining life stages by arbitrary age thresholds [4]. Emerging evidence now supports a biological aging model, where changes in functional and molecular indicators—such as markers of immune dysregulation, oxidative stress, mitochondrial dysfunction, and cognitive decline—precede the onset of overt clinical disease [9-11]. Recognizing this distinction allows for more timely and proactive medical interventions [2]. This may include addressing subclinical inflammation ('inflammaging'), maintaining muscle mass to prevent sarcopenia and frailty, preserving cognitive function, and sustaining immunological resilience [2].

Anti-aging medicine in this context represents an actionable, integrative clinical approach to managing the functional aspects of aging. It can be operationalized through annual or twice-yearly health visits that should begin at the pre-senior stage [1]. A thorough history taken at each senior health visit should include a detailed nutritional evaluation, ideally with reference to a food diary. In addition to an overall physical examination, special attention should be paid to changes in body weight, assessment of body condition score (BCS) and muscle condition score (MCS), orthopedic evaluation (mobility), and behavioral assessments for cognitive and emotional decline. A routine review of screening complete blood count, chemistry, and urinalysis results is currently sufficient, but the tools to assess biological aging may allow for individualized aging risk profiles in the near future. Lifestyle factors play a significant role in accelerating or slowing the aging process. Healthy behaviors, such as regular exercise, calorie restriction, and maintaining a good social environment, can help delay aging, improve health, and lower the risk of age-related diseases. In contrast, physical inactivity, inadequate diet, chronic stress, and poor sleep all exacerbate the aging processes. Client education emphasizing lifestyle factors and proactive aging care is critical at each visit [12].

Emerging therapeutic approaches in veterinary geroscience emphasize the importance of targeting fundamental mechanisms of aging. In particular, oxidative stress and mitochondrial dysfunction are recognized as key drivers of sarcopenia, metabolic decline, and cognitive impairment in aging dogs and cats [10,11]. Novel pharmacological interventions, including metformin, resveratrol, and NAD^+ precursors, are being explored for their potential to mitigate these mechanisms and extend the healthspan across species [13,14]. Concurrently, the development of biological aging markers, such as epigenetic clocks, telomere length assays, metabolomics, and advanced body composition analyses, may soon enable the earlier detection of frailty and more personalized monitoring of intervention efficacy in companion animals [9,15]. These advances highlight the growing translational bridge between human and veterinary geroscience, underscoring the potential to integrate biomarker-driven preventive strategies into routine geriatric care.

Journal of Veterinary Science

METHODS

This narrative review was developed through an integrative synthesis of the literature and the authors' clinical, academic, and research expertise in veterinary aging, nutrition, behavior, and environmental health. The literature search was conducted between February 1, 2025, and July 31, 2025, using PubMed, Scopus, and Web of Science databases. Keyword combinations included "lifestyle," "aging pets," "healthspan," "physical activity," "nutrition," "environmental exposure," "senior dogs/cats," and "veterinary geriatrics."

The selection criteria prioritized recent reviews, clinical studies, consensus reports, and cohort data that explored the effects of modifiable lifestyle factors—such as diet, exercise, social interaction, and environmental enrichment—on the aging trajectories in dogs and cats. Publications addressing cross-species evidence, including translational insights from human and rodent aging studies, were also considered where relevant.

The findings were organized thematically across lifestyle domains, with emphasis on their physiological, behavioral, and systemic impacts on aging companion animals. The key recommendations are grounded in current evidence and the authors' multidisciplinary experience in clinical geriatrics, preventive veterinary medicine, and animal welfare. During the preparation and revision of this manuscript, the authors utilized ChatGPT-4o (OpenAI, USA) for language assistance, including grammar correction, stylistic refinement, and the organization of complex content into clear English. The authors reviewed and verified all scientific content for accuracy and integrity. **Fig. 1** was generated using Gemini 2.5 Pro (Google AI, USA) to illustrate the conceptual framework.

Fig. 1. Conceptual framework of lifestyle factors influencing healthspan in dogs and cats. Domains include nutrition, physical activity, weight management, gut microbiome, stress, environment, and integrative care. Each contributes to delaying disease onset and promoting functional longevity.
This image was generated using Gemini 2.5 Pro (Google AI, USA).

https://doi.org/10.4142/jvs.25227

Journal of Veterinary Science

OBSERVATIONS

The emerging field of lifestyle medicine focuses on helping individuals adopt and maintain healthy behaviors to prevent, delay, or even reverse chronic diseases. Indeed, aging in dogs and cats is shaped by intrinsic biological mechanisms and modifiable lifestyle factors that influence the healthspan and clinical outcomes. This study highlights the collective impact of nutrition, physical activity, environmental exposures, stress, sleep, social interactions, and preventive care on the trajectory of aging in companion animals (**Fig. 1**). By organizing these domains into a comprehensive lifestyle-based framework, the manuscript provides veterinarians with practical insights for optimizing geriatric care.

Each section connects the foundational concepts to real-world applications, beginning with definitions and the role of lifestyle in aging biology and extending to evidence-based discussions of how diet, exercise, and environment affect mobility, cognition, immunity, and disease risk. Special attention is given to sedentary behavior, sarcopenia, environmental toxins, and the clinical implications of caregiver burden. The species-specific considerations for dogs and cats are emphasized. Ultimately, aging is not solely a matter of time, but a dynamic process shaped by daily choices and veterinary guidance. Clinicians can more effectively promote resilience, prevent decline, and support quality of life in aging pets by recognizing the central role that lifestyle plays in their care.

Nutrition: a central determinant in healthy aging

Nutrition is a cornerstone in modulating the aging process and preventing the onset of chronic diseases in companion animals [16-19]. As pets age, their dietary requirements evolve because of changes in metabolism, immune function, and organ reserve, necessitating proactive nutritional strategies tailored to the geriatric life stage [4,19,20]. In addition, diets may be formulated with nutrients that help manage age-related disorders such as osteoarthritis (OA) and cognitive decline. Protein metabolism undergoes significant changes with age. Although older dogs and cats may require equal or greater protein intake than adults to maintain lean mass, their ability to utilize protein may be reduced [21]. Inadequate protein intake in aging pets is linked to muscle loss, impaired immunity, and delayed wound healing [22].

Excessive dietary fat intake, particularly from energy-dense or ultra-processed commercial diets, has been consistently linked to obesity and insulin resistance,particularly in sedentary or neutered pets [23]. In cats, an inappropriate macronutrient balance may predispose the animal to gastrointestinal dysfunction [24-26]. The role of dietary carbohydrates in feline diabetes is controversial, but current evidence, including Laflamme et al. [27], indicates no direct association, and traditional dry kibble diets may even be protective against diabetes mellitus.

Micronutrient deficiencies, particularly of vitamin E, B_{12}, thiamine, taurine, and omega-3 fatty acids, may be underrecognized in clinical practice in older pets and contribute to oxidative stress, cognitive dysfunction, cardiac disease, and anemia [20,28]. Excessive phosphorus intake, especially from inorganic additives, can exacerbate renal damage, particularly in aging cats prone to chronic kidney disease (CKD) [29]. Sodium, potassium, calcium, and magnesium also require individualized adjustments in senior diets, depending on comorbidities such as kidney, cardiac, or endocrine disease [30,31].

Nutrition plays a disease-specific role in geriatric care, with targeted dietary interventions shown to slow disease progression and improve the quality of life of aging pets. In CKD,

https://doi.org/10.4142/jvs.25227

dietary phosphorus restriction, enhanced hydration, and controlled protein intake have been shown to delay progression and reduce clinical complications [31-34]. Similarly, age-related cognitive decline may be mitigated by interventions that enhance mitochondrial function and reduce oxidative stress, including antioxidants and medium-chain triglycerides [35-40]. Among the most common comorbidities in older pets, obesity and diabetes respond favorably to calorie restriction, increased protein intake, and a reduction of the dietary glycemic load [41-44]. In addition, OA management benefits from weight control and targeted nutrients, such as eicosapentaenoic acid (EPA)/docosahexaenoic acid (DHA) and glucosamine, which can be used synergistically with pharmacological therapies for OA and pain management [45-49]. Collectively, these interventions show how nutritional strategies can directly influence the progression of age-associated diseases, supporting longevity and healthspan in companion animals.

Recently, the development of disease-specific therapeutic diets for aging pets has expanded considerably, particularly in the form of liquid formulations designed for very old or critically ill patients. Multiple global and domestic companies, including Hill's Pet Nutrition, Royal Canin, Purina, and Medivia, are actively engaged in this field. These products play a key role in veterinary clinical practice, providing essential nutritional support and facilitating recovery in geriatric and hospitalized patients.

Age-appropriate diets should emphasize highly digestible protein, moderate calories, and antioxidant fortification, tailored to BCS, MCS, and individual risk factors [21,50]. A regular re-evaluation of dietary adequacy is very important in aging pets, particularly during illness or hospitalization, and is essential to maintain nutritional resilience in geriatric animals [16,51]. This evaluation must include the trends in body weight, BCS, and MCS, as well as information on diet type(s). It should also involve regular evaluation of intake, including a feeding history, in-home quantification of food consumption, a review of food diaries, and calorie estimation. This in-depth review is critical in households with multiple pets or with shared feeding responsibilities [52].

Many owners believe that homemade diets are healthier for their pets, but most of these diets are nutritionally incomplete and may lack essential nutrients or even contain toxic ingredients. Furthermore, owners often modify recipes provided by an expert, a phenomenon known as 'diet drift,' which poses an even greater risk of nutritional imbalance for older pets, whose nutritional requirements vary significantly among individuals. Stockman et al. [53] reported that nine recipes for home-prepared diets exceeded the upper safe limit for vitamin D, underscoring the risk of nutrient toxicity in such diets [54,55]. Owners should also be advised against indiscriminate supplementation, in particular fat-soluble vitamins or calcium, which may result in toxicity or iatrogenic disease [56,57]. Conversely, strategic supplementation with omega-3 fatty acids, B-complex vitamins, L-carnitine, or specific amino acids (e.g., taurine) may enhance organ function and the quality of life [58-61].

Breed-specific and lifestyle-driven dietary recommendations are increasingly advocated. Breed predispositions, such as CKD in Persian cats [62] or diabetes mellitus in Burmese cats [63], highlight the potential value of proactive dietary management [41]. Similarly, the integration of nutritional genetics, metabolomics, and personalized feeding plans may represent the future of geriatric nutrition in companion animals [16,64,65].

https://doi.org/10.4142/jvs.25227

Obesity: a modifiable driver of disease and lifespan reduction

Obesity is one of the most significant and preventable contributors to age-related morbidity and reduced lifespan in dogs and cats [26]. It is defined as the excessive accumulation of body fat that impairs health and functional capacity. The prevalence exceeds 50% in senior companion animals in many developed countries [26,66]. Recent large-scale data from more than 4.9 million dogs and 1.3 million cats across the United States reported that the prevalence of overweight or obesity increases progressively from young adulthood and peaks during the mature life stage, affecting more than 60% of dogs and 66% of cats at this stage [67]. In particular, being obese during the growth period significantly increased the likelihood of remaining overweight in adulthood (by 1.85 times in dogs and 1.52 times in cats) [67].

These epidemiological patterns mirror the human-observed obesity impacts of obesity on chronic disease and aging mechanisms [68]. Human and animal studies suggest several shared mechanisms between the pathophysiology of obesity and the hallmarks of aging, reinforcing the translational relevance of companion species models [69]. Comparative geroscience research further shows that the molecular and tissue-level mechanisms of aging, including adipose-driven inflammaging, insulin resistance, and proteostasis decline, are conserved across humans, laboratory models, and companion dogs and cats [1,70]. The shared biology underscores the translational value of companion animals: adipose tissue functions as an active endocrine organ in all three species, producing adipokines that contribute to systemic inflammation and metabolic dysregulation [65-69].

Adipose tissue is not merely a fat reservoir but a dynamic endocrine organ that secretes hormones, cytokines, and pro-inflammatory mediators collectively known as adipokines [71,72]. In aging pets, the expansion of fat mass leads to the dysregulation of leptin, adiponectin, tumor necrosis factor factor [TNF]-α, and interleukins [ILs], promoting a chronic, low-grade inflammatory state known as inflammaging [71,72]. Emerging pilot data in dogs support the important role of inflammaging in aging [73]. This systemic inflammation contributes to oxidative stress, insulin resistance, and impaired immune function, accelerating cellular senescence and the onset of multiple chronic diseases [16,71,72].

Longitudinal studies in dogs have shown that even a mild to moderate overweight status reduces the median lifespan by up to 2.5 years in certain breeds [66]. Obesity is associated with diminished physical activity, delayed recovery from illness or surgery, and increased all-cause mortality. Moreover, obesity exacerbates age-related decline in mobility, cognition, and cardiovascular fitness, directly impacting the healthspan [26,66,71]. Notably, emerging research has revealed a compelling link between obesity and cognitive decline in aging pets, suggesting that adiposity-driven neuroinflammation and metabolic dysregulation may contribute to the onset and progression of cognitive dysfunction syndrome (CDS) [74,75]. Thesetrends are not limited to dogs. Middle-aged cats (5–11 years) are especially prone to overweight and obesity, which are associated with systemic inflammation and a higher incidence of metabolic disorders such as insulin resistance, OA, and urinary tract disease [76]. In dogs, obesity has been associated with an increased risk of frailty and cognitive impairment [74]. In cats, cognitive dysfunction is recognized as an age-related syndrome [76], but the direct links to adiposity are less clear.

Obesity is a key risk factor for numerous age-associated conditions:

- Diabetes mellitus, particularly in cats, is tightly linked to insulin resistance driven by excess adiposity and chronic inflammation [77,78]. As mentioned above, the role of

https://doi.org/10.4142/jvs.25227

dietary carbohydrates in feline diabetes is controversial, but current evidence suggests no direct association [27].

- The severity of OA increases with body weight because mechanical overload and cytokine-mediated cartilage degradation act synergistically [79]. Obese dogs, especially of certain at-risk breeds, are prone to cruciate ligament rupture and intervertebral disc disease [11,80].
- Cardiovascular compromise, including systemic hypertension, myocardial remodeling, and congestive heart failure, is more common in obese senior dogs [81,82].
- CDS has been associated with metabolic syndrome and adiposity-induced neuroinflammation in aging pets [74,83].
- Respiratory compromise, dermatologic disease, urinary incontinence, and hepatopathies are also more frequent and severe in obese animals [84].

The use of BCS (**Supplementary Figs. 1** and **2**) and MCS (**Supplementary Figs. 3** and **4**) systems remains critical components of geriatric evaluations, particularly for detecting obesity, sarcopenia, and sarcopenic obesity. For practical implementation, validated reference charts are included as supplemental figures (**Supplementary Figs. 1**-**4**) and are also accessible through widely recognized clinical guidelines, such as the WSAVA Global Nutrition Toolkit [44,85-87]. An assessment of obesity in veterinary medicine commonly relies on semi-quantitative scoring systems, such as the BCS and MCS, which remain indispensable for routine clinical practice by the veterinary team, including clinicians, technicians, nurses, and support staff [21,22]. On the other hand, more objective techniques have been applied in research and specialized practice. Dual-energy X-ray absorptiometry (DEXA), quantitative magnetic resonance imaging, and bioelectrical impedance analysis enable the precise quantification of fat mass, lean tissue, and bone mineral content. Studies in dogs and cats have shown that DEXA validates BCS and detects subclinical sarcopenia and sarcopenic obesity that may be overlooked during routine examinations [86,88,89]. Similarly, the original validation of the nine-point BCS scale in dogs highlighted its strong correlation with DEXA measurements [90]. These technologies parallel human approaches, where DEXA is considered the gold standard for body composition analysis, strengthening cross-species comparisons and the translational relevance of obesity research in companion animals.

Effective obesity prevention begins with education during puppy or kittenhood and continues through adulthood with life-stage-appropriate feeding, portion control, and the encouragement of physical activity [91]. In senior pets, caloric needs decline with reduced activity. Energy-dense foods or frequent treats often result in progressive weight gain [16,21,92]. Weight management diets should incorporate lower energy density, increased protein-to-calorie ratio, and enhanced fiber and L-carnitine content [93]. Behavioral modification techniques, such as structured feeding times, automated food dispensers (especially for cats), treat limitation, and environmental enrichment, are crucial for successfully achieving and maintaining long-term weight control [94]. Moreover, some home-prepared diets may be nutritionally imbalanced.In addition to calorie and nutrient density, the dietary fatty acid composition plays a critical role in the aging of pets. Diets enriched with long-chain omega-3 fatty acids, particularly EPA/DHA, have anti-inflammatory and joint-supportive benefits in senior dogs and cats [49,95]. These effects are believed to mitigate OA progression and improve mobility, but responses can vary. Similarly, nutraceuticals such as glucosamine are commonly used for joint health, but the scientific evidence for their efficacy is mixed across veterinary and human studies [96,97].

Equally important is client communication. Owners should be informed that obesity is a chronic disease requiring structured, measurable, and compassionate management [98,99]. Prochaska et al. [100] provided a practical transtheoretical model framework to tailor communication strategies to the owner's readiness for change. It is also important to make owners aware, however, that as pets enter their geriatric years, they are at greater risk of losing weight and muscle mass than of developing obesity.

Physical activity and sedentary behavior: role in healthy aging and disease prevention

In human medicine, physical activity is considered one of the most effective anti-aging strategies, with several studies showing that regular exercise can delay biological aging and extend the healthspan by preserving mobility, metabolic health, and cognitive performance [13,101-103]. Cardiovascular health, which is closely intertwined with metabolic regulation and the broader benefits of exercise, represents an equally critical domain of functional preservation in aging. Physical activity is also a fundamental determinant of the healthspan and functional aging in dogs and cats [11,104]. As companion animals age, their spontaneous activity levels decline due to physiological, behavioral, and environmental factors, contributing to the development of multiple chronic diseases [105-107]. Older dogs and cats often exhibit reduced voluntary movement, lower playfulness, and longer periods of rest. This decline is multifactorial, driven by sarcopenia, OA, cardiopulmonary changes, and decreased sensory input (e.g., visual or auditory loss) [18,19,108]. Sedentary behavior is not merely a reflection of age; it is also a modifiable risk factor for disease progression and a loss of independence in pets [109].

Physical activity stimulates muscle protein synthesis, improves mitochondrial function, and helps preserve lean body mass, preventing or attenuating sarcopenia [14,87]. Regular exercise enhances insulin sensitivity, lipid metabolism, and immune competence, reducing the risk of obesity, diabetes, and chronic inflammation [18,68,110]. Cognitive function also benefits from exercise, as evidenced by increased cerebral blood flow, neurogenesis, and modulation of oxidative stress and inflammation in the aging brain [111,112]. Recent large-scale data from the Dog Aging Project, which surveyed more than 11,000 companion dogs, reported that higher physical activity levels are associated with reduced severity and slower progression of cognitive dysfunction. In particular, even after adjusting for age and comorbidities, active dogs were approximately half as likely to be diagnosed with canine cognitive dysfunction compared to their less active peers [110]. Observational studies using gait speed and activity monitors have also shown that reduced daytime activity and increased nighttime pacing are associated with cognitive decline in senior dogs, and that biological age and working memory correlate with overall physical activity levels [113]. These results suggest that maintaining physical activity may serve as a protective factor against age-related cognitive decline in companion dogs.

Sedentary behavior has been linked to obesity and cognitive decline in dogs [66,110]. Evidence from human studies suggests additional associations with diabetes, hypertension, and musculoskeletal decline, but veterinary-specific data remain limited. Inactivity can exacerbate joint stiffness and pain, leading to a vicious cycle of disuse, immobility, and further atrophy. In cats, inactivity is a hidden but significant driver of undiagnosed degenerative joint disease and behavioral changes [79,114].

The goal of geriatric exercise is to maintain function rather than performance. Low-impact, moderate-intensity activities, such as leash walks, underwater treadmill therapy, balance

training, and supervised play, are ideal for most aging dogs [115,116]. Studies that would provide guidelines for the intensity, duration, and frequency of exercise in pets have not yet been conducted. Most guidelines for human geriatric patients recommend 75–150 min a week of moderate-intensity aerobic exercise, such as walking [103]. For cats, interactive play using wands, elevated perches, and puzzle feeders can encourage movement and mimic predatory behavior, as can access to "outdoor catios", thus promoting neuromuscular activation. Novel enrichment concepts, such as feline gyms, have also been described [117,118], but peer-reviewed evidence is lacking. A future trend may be access to gyms designed specifically for cats [117,118] (**Supplementary Figs. 5** and **6**).

Individualized activity programs should be tailored based on BCS, MCS, orthopedic status, cardiovascular function, and comorbidities. Joint supplements, pain management (e.g., non-steroidal anti-inflammatory drugs (NSAIDs), gabapentin, and omega-3 fatty acids), and flooring modifications can support exercise adherence [119,120]. A new treatment for osteoarthritis, bedinvetmab, a monoclonal antibody that targets nerve growth factor to block pain signals, has entered the veterinary market, as have intra-articular injections of stem cells, platelet-rich plasma, and matrices designed to mimic natural cartilage.

Owner involvement is a critical determinant of activity in aging pets [121]. Reduced interaction, absence of routines, overuse of confinement, and a lack of stimulation lead to physical and cognitive withdrawal [122]. Educating pet owners about environmental enrichment, daily routines, and the importance of regular movement is essential for sustainable outcomes [121,123]. Veterinarians should offer activity monitoring tools (e.g., step counters and activity collars), encourage owners to maintain activity logs, and review changes in play, walking, and movement as part of senior checkups [12].

Sarcopenia, the progressive age-related loss of skeletal muscle mass and function, is a critical determinant of frailty in humans, as well as in dogs and cats. In people, a diagnosis combines body composition measures with functional tests such as gait speed [101,103]. Veterinary practice lacks standardized thresholds but uses MCS to identify early muscle loss [87-89]. Underlying mechanisms, including mitochondrial dysfunction, chronic inflammation, and impaired regenerative capacity, are conserved across species [10,11,14]. In companion animals, sarcopenia predicts greater susceptibility to disease, impaired recovery, and reduced survival, with risks compounded when combined with obesity ("sarcopenic obesity") [22,68,73]. Preventive strategies emphasize regular low-impact physical activity, rehabilitation, and environmental enrichment to preserve lean mass [101,102,104,115,116]. Adequate protein, omega-3 fatty acids, and L-carnitine further support muscle maintenance [21,58,60]. Novel interventions such as mitochondrial and microbiome modulation are under investigation [14,58,124]. Collectively, sarcopenia is a shared characteristic of aging, underscoring the need to integrate MCS monitoring, tailored nutrition, and structured activity into geriatric care to preserve function and healthspan [22,87,101].

Microbiome and gut health: modulating aging through the gut ecosystem

The gut microbiome is a dynamic and complex ecosystem that plays a key role in maintaining health and preventing disease across all life stages [125]. In aging dogs and cats, changes in the gastrointestinal microbial composition and metabolic activity significantly influence systemic inflammation, immunity, and the risk of age-related disease development [125-127].

With aging, the gut microbiota of dogs and cats undergoes reduced diversity, increased interindividual variability, and a shift toward pro-inflammatory bacterial species—a state commonly referred to as microbial dysbiosis [127,128]. Beneficial taxa, such as *Faecalibacterium*, *Bifidobacterium*, and *Lactobacillus*, tend to decline, while opportunistic organisms, including *Clostridium* and *Escherichia coli*, may increase [129].

Dysbiosis contributes to the age-related chronic low-grade inflammation known as age-related inflammaging. Bacterial endotoxins, such as lipopolysaccharide, can translocate across a compromised gut barrier, triggering systemic inflammatory responses via toll-like receptors [128]. Emerging data suggest possible links to diseases such as CKD, CDS, and chronic enteropathy (CE) [130,131], but most evidence remains preliminary or extrapolated. In addition, the microbiota influences immune homeostasis by training regulatory T cells and modulating cytokine production. Dysregulated microbial populations can impair this function, contributing to immune senescence [128].

Beyond the compositional changes, the gut microbiome influences aging by modulating the key cytokines and metabolites. Elevated levels of IL-6 and TNF-α are consistently linked with inflammaging in humans and companion animals, contributing to muscle catabolism, insulin resistance, and neuroinflammation [128,132]. Conversely, microbiota-derived short-chain fatty acids (SCFAs), particularly butyrate, exert anti-inflammatory and immunoregulatory effects by enhancing the gut barrier integrity, suppressing pro-inflammatory cytokine production, and modulating microglial activation in the brain [133-135]. These mediators provide a mechanistic link between gut dysbiosis and systemic aging phenotypes, highlighting the potential of microbiome-targeted interventions to mitigate frailty and cognitive decline across species [132,136]. In aging dogs, dysbiosis has been associated with increased markers of CDS with neuroinflammation and oxidative stress as the main pathological mechanisms [112,137-139]. A microbial imbalance can lead to decreased gut barrier function and increased systemic inflammation, exacerbating the inflammatory environment in the brain [15].

Recent studies have underscored the connection between the gut microbiota and brain aging, commonly referred to as the gut-brain axis [140,141]. In particular, a pet's diet can directly influence behavior by modulating the gut microbiome [142]. Therefore, functional foods and additives designed to improve behavior are gaining traction in the pet food market. Microbial metabolites, such as SCFAs, tryptophan derivatives, and neurotransmitter precursors, can influence mood, cognition, and behavior [133]. These molecules are absorbed in the gut and regulate brain function through neurological signaling via the vagus nerve [132,136,143]. For example, SCFAs can help alleviate neuroinflammation by modulating the permeability of the blood-brain barrier and inducing a switch to an anti-inflammatory phenotype of microglia [134,135]. Dysbiosis impairs the production of these beneficial metabolites, which can lead to nervous system dysfunction and behavioral changes via the gut-brain axis [144,145]. This shift is correlated with a decrease in the production of SCFAs, especially butyrate, a key anti-inflammatory metabolite essential for colonocyte health and intestinal barrier integrity [128,129].

The composition of the gut microbiome and its metabolites can influence a range of behaviors, including aggression, fear response, memory, depression, and anxiety [146,147]. A balanced gut microbiome stabilizes the gut-brain axis, promoting emotional stability and stress resilience, while also improving nutrient absorption and energy metabolism

https://doi.org/10.4142/jvs.25227

[148]. Thus, understanding the gut microbiome in dogs and cats is essential for regulating physiological functions, modulating behavior, and developing effective strategies for disease prevention and management. In this regard, targeted interventions such as probiotics, prebiotics, and dietary modifications play an important role in maintaining a symbiotic state in the gut, which in turn enhances the overall health and quality of life of pets and have the potential to enhance the human-companion-animal bond [149].

Nutritional modulation of the gut microbiota offers promising strategies in geriatric care. Prebiotics (e.g., inulin, fructooligosaccharides, probiotics [e.g., *Enterococcus faecium*, *Lactobacillus acidophilus*]), and synbiotics have been shown to have efficacy in restoring the microbial balance and enhancing gastrointestinal health in older pets [150]. Dietary fiber enrichment promotes SCFA production and supports healthy fermentation profiles [128,133]. Exercise was associated with changes in gut microbial composition, including an increase in butyrate-producing bacteria and an increase in fecal butyrate concentrations, independent of diet, in rodents and humans [124]. Fecal microbiota transplantation (FMT), although still investigational in veterinary medicine, has shown potential in rejuvenating immune responses and reversing dysbiosis in experimental aging models [131,151,152]. Protocols for donor selection, safety, and regulatory oversight are essential [131,152].

Recent developments in microbiome-targeted veterinary nutrition include disease-specific probiotic formulations and organ-targeted supplements for aging or critically ill companion animals, e.g., renal-support probiotics such as Azodyl, Kidney Helper, and GI/Allergy Helper [153,154]. FMT and even encapsulated FMT preparations, such as Animal Biome, CanineBiome Caps, and FelineBiome Caps, are gaining traction, with pilot studies showing safety and clinical benefits in dogs with CE [155-158]. These microbiome-based strategies are increasingly applied in veterinary practice to support nutritional resilience and manage chronic comorbidities.

The emerging field of veterinary microbiome diagnostics offers tools for individual profiling of gut health [131,159]. Combining this with genomic, metabolic, and lifestyle data may enable precision nutrition for older pets, optimizing diet composition based on the microbiota phenotype [160,161]. Such strategies could help prevent disease onset, support cognitive and metabolic function, and extend the healthspan in companion animals [162].

Environmental and psychosocial stress: hidden drivers of aging in companion animals

Aging in companion animals is a biological process and profoundly influenced by environmental and psychosocial stressors [137]. It has been shown in other species that c hronic stress exposure, especially when cumulative and unmanaged, accelerates physiological aging, impairs cognitive function, and predisposes animals to a wide range of age-related diseases [163].

The hypothalamic–pituitary–adrenal axis, the central stress response system, becomes dysregulated with age. Geriatric dogs and cats may exhibit prolonged cortisol elevation in response to even minor stressors because of impaired negative feedback and altered receptor sensitivity [11,112,164]. Chronic cortisol elevation exacerbates muscle catabolism, insulin resistance, immunosuppression, and behavioral withdrawal—factors that collectively reduce resilience and healthspan [165].

https://doi.org/10.4142/jvs.25227

Indoor environments often lack adequate cognitive, sensory, and physical stimulation, especially in aging pets with mobility or sensory decline. Long hours alone, lack of routine, noise exposure (e.g., from household appliances or urban noise), and an absence of safe retreat areas contribute to chronic environmental stress [165,166]. Cats are susceptible to subtle environmental disruptions, such as rearranged furniture, unfamiliar scents, or the presence of household visitors [167,168]. McCoy et al. [169] highlighted the importance of social determinants of health in dogs, including neighborhood stability, economic status, and interactions with children and other animals. These psychosocial factors may play a critical role in shaping long-term health outcomes.

Research on pet thanatology is limited. Behavioral changes following the loss of a companion have been reported and are often theorized to reflect stress or grief responses, but direct physiological links to stress mechanisms have not been demonstrated [5,75]. Clinical signs may include changes in appetite, sleep disturbances, inappropriate elimination, excessive vocalization, aggression, or withdrawal—often misinterpreted as "just getting old" [5,75,170,171]. Repeated stress insults are associated with CDS, anxiety disorders, gastrointestinal disturbances, dermatologic flare-ups, and impaired immune surveillance [140,172,173]. Moreover, stress-induced gut dysbiosis can contribute to a feedforward loop of systemic inflammation and behavioral deterioration via the microbiota–gut–brain axis [140,174,175].

Recognizing the signs of stress in aging animals is critical. Common indicators include panting, pacing, lip licking, hiding, trembling, excessive grooming, or sudden behavioral changes [176-178]. Veterinarians should routinely inquire about household dynamics, daily routines, inter-animal conflicts, and owner stress because pet stress often mirrors caregiver stress levels [179,180]. Hair cortisol analysis has revealed long-term stress synchronization between dogs and their owners [12,180], suggesting that the emotional state of the owner can significantly influence the physiological stress levels of their pets.

Stress mitigation strategies include environmental enrichment (e.g., elevated perches, access to catios or other safe outdoor spaces, puzzle toys, and soft bedding), predictable daily routines (feeding, play, and toileting schedules), safe spaces and hiding areas, pheromone therapy (e.g., Feliway, Adaptil), sound masking or calming music, and behavioral therapy or anti-anxiety medications for refractory cases [181-187]. In cats, the use of scent-marking substrates, vertical territory, and solitary feeding spaces can reduce conflict and stress. For dogs, gentle handling, leash training in low-stimulation areas, and owner–pet interaction routines promote security and engagement [122,182,183,186].

The management of environmental and psychosocial stress must consider the owner's attitudes, consistency, and awareness. Stress education during senior pet wellness visits, including behavioral health screening, is crucial for supporting the emotional needs of aging pets [5,171,186,188,189]. Holistic approaches that integrate nutrition, pain management, and behavior modification can help reverse stress-induced frailty and enhance the quality of life in elderly animals [5,16,51,171,177,186,190,191].

Environmental pollutants and toxic exposures in aging pets

In addition to psychosocial stressors, chronic low-level exposure to environmental pollutants may accelerate aging and increase disease susceptibility in companion animals. Recent studies have shown that pets accumulate chemical residues from various sources, including

secondhand tobacco smoke, household pesticides, lawn chemicals, parasiticide treatments, and microplastics—all of which may burden the hepatic, renal, endocrine, and immune systems over time [192,193]. Recent human data have raised pesticide exposures associated with living in proximity to a golf course as a risk factor for neurological disease (Parkinson's disease) [194]. Although direct veterinary evidence is lacking, these findings raise concern, given that pets share environments with humans. Older pets with decreased detoxification and metabolic capacity are particularly vulnerable to these exposures [193]. For example, nicotine metabolites and the markers of oxidative stress were elevated in cats residing in smoking households, and pet dogs have been shown to carry pesticide biomarkers in urine samples at levels that mirror human exposure concerns [193]. Chronic exposure to tobacco smoke has also been linked to higher rates of lymphoma and oral squamous cell carcinoma in cats, and nasal cancers in dogs [195].

Emerging data indicate the presence of microplastics in canines and human tissues. In one study, microplastics were identified in dog testes, highlighting a risk of potential endocrine and reproductive disruption, which may be relevant to aging or geriatric declines [192]. Endocrine-disrupting chemicals, including polychlorinated biphenyls, polybrominated diphenyl ethers, and bisphenol A, have been epidemiologically linked to hyperthyroidism in cats [196,197], but the causality remains to be fully established. The bioaccumulation of such chemicals may affect the lifespan of cats because hyperthyroidism is a major cause of morbidity in middle-aged and elderly cats.

Veterinarians should take comprehensive environmental histories, covering exposure to tobacco smoke, pesticide/herbicide use, flea/tick and deworming products, and indoor air quality, as part of geriatric assessments. Although long-term veterinary-specific outcome data remain limited, extrapolation from human and wildlife toxicology underscores the importance of minimizing exposure to potentially bioaccumulative compounds, particularly in pets with reduced liver or kidney function. Owners should be counseled on the benefits of smoke-free environments, the judicious use of chemical pest control, and the potential risks of and steps to take to reduce microplastic ingestion in older animals.

Integrative and adjunctive therapies in geriatric veterinary care

As companion animals age, multimodal approaches that incorporate complementary and integrative veterinary medicine (IVM) have attracted increasing attention in managing chronic conditions, mobility limitations, and quality of life. IVM integrates evidence-based complementary therapies, including acupuncture, rehabilitation, laser therapy, manual therapies, herbal medicine, regenerative modalities such as stem cells and exosomes (membrane-bound extracellular vesicles released by cells, especially stem cells, that function as messengers to facilitate intercellular communication), and nutritional therapy, with conventional care, offering individualized, whole-animal support for aging pets [198-200].

Commonly used therapies in geriatric patients include acupuncture for pain and neurologic modulation, physical rehabilitation techniques such as underwater treadmill, neuromuscular electrical stimulation, and proprioceptive training, as well as photobiomodulation and ultrasound for musculoskeletal recovery [198-200]. Recent clinical data suggest that multimodal neurorehabilitation programs improve the outcomes in patients recovering from spinal injuries, while also delaying disease progression in degenerative conditions such as myelopathies [198-200].

https://doi.org/10.4142/jvs.25227

Regenerative therapies, including platelet-rich plasma, mesenchymal stem cells (MSCs), and exosome injections, are increasingly used in conjunction with rehabilitation or orthopedic care to promote tissue healing and reduce inflammation in osteoarthritic or injured joints [198-200].

Recent veterinary studies have shown that MSCs, derived from adipose tissue or bone marrow, can improve joint function and reduce pain in canine OA, with sustained benefits on mobility and the quality of life [201]. Case-based applications also indicate potential systemic effects, including the modulation of inflammatory cytokines and enhanced tissue repair in geriatric patients [198-200]. Exosome therapy, though still largely investigational, has shown promise in experimental models by delivering bioactive molecules that reduce oxidative stress, support chondrocyte survival, and stimulate endogenous repair pathways [201]. These findings suggest that stem cell and exosome-based therapies may target localized musculoskeletal disease and could serve as adjunctive anti-aging interventions, warranting further controlled clinical studies in companion animals.

Beyond musculoskeletal health, the use of health supplements (nutraceuticals) as a complementary strategy to support neurological function in aging companion animals has also been attracting increasing attention. One study reported that dietary supplementation with a brain protection blend containing arginine, antioxidants, B vitamins, and omega-3 fatty acids over a six-month period significantly improved performance on specific cognitive tasks in senior dogs [202]. Dewey et al. [203] reported that the administration of CogniCaps, an integrative nutraceutical blend, to dogs with cognitive dysfunction led to a 38% and 41% reduction in cognitive scores at 30 and 60 days, respectively, indicating substantial symptomatic improvement. Moreover, recent studies have shown that the co-administration of CoQ10 with low-dose EPA/DHA may enhance the mitochondrial function and benefit cognitive function in aging companion animals [204].

Although high-quality evidence continues to emerge, client demand and clinician experience support the thoughtful inclusion of these adjunctive modalities in geriatric care plans. Education, reassessment, and individualized treatment are essential to optimizing outcomes.

DISCUSSION

For centuries, epidemiologists have studied how the environment affects health and disease, a task becoming increasingly nuanced as the complexity of acute and chronic conditions in animals is recognized. Lifestyle modifications, combined with scientific advances, offer practical ways to promote healthy aging and enhance the quality of life in old age. Lifestyle factors play a central and multifaceted role in shaping health outcomes during aging in dogs and cats. The collective insights presented in this manuscript emphasize that aging is not a passive process, but rather a dynamic, modifiable trajectory that can be influenced by proactive, individualized interventions [205,206].

Key pillars such as targeted nutrition, body weight regulation, physical activity goals, gut microbiome modulation, stress reduction, environmental toxin minimization, and integrative medical strategies are essential for extending healthspan and preserving functional independence in aging pets [104,182,187,207-209]. Nevertheless, the current evidence base remains heterogeneous. Some interventions show modest or inconsistent

effects, and many studies lack replication. For example, enriched diets have shown cognitive benefits in some trials [35-40], but others found no effect after one year [75]. Similarly, although omega-3s and glucosamine are used widely for OA, the reviews provide mixed evidence [95-97]. Data on the gut microbiome and FMT are also preliminary, based on small studies with limited follow-up [155-158]. These gaps underscore the need for rigorous, long-term trials to confirm efficacy and safety [204,210].

Preventive care must begin before the overt signs of decline appear. For example, strategic dietary adaptations, early screening for body and muscle condition, and structured activity regimens can mitigate obesity and sarcopenia [104,182,187,207-209]. Likewise, microbiome health can be supported through fiber-rich diets and the judicious use of probiotics, while stress-related behavioral decline may be reversed through environmental enrichment and caregiver education [128,211-213]. Emerging concerns regarding pollutant exposure and chemical burden highlight the need for environmental awareness and long-term toxicity mitigation, particularly in pets with reduced detoxification capacity [205,206]. In addition to improving the health outcomes, preventive strategies may also be economically advantageous. In human medicine, health-economic evidence shows that preventive care generally provides good value and can even be cost-saving. A recent systematic review found that physical activity programs implemented before or in the early stages of cognitive impairment were cost-effective in reducing the future burden of dementia [210].

Similarly, in companion dogs, proactive care, including preventive healthcare measures such as vaccinations, parasite control, and regular veterinary examinations, are economically advantageous and effective in mitigating the disease risk. The American Veterinary Medical Association also emphasizes that the cost of preventive care is substantially lower than that of treating established conditions [208,214]. Beyond physical health, a broader body of research findings indicates that systematic desensitization, counter-conditioning, and positive reinforcement-based methods foster long-term behavioral stability and welfare gains. In contrast, punishment-based or purely reactive interventions are associated with a heightened risk of exacerbating problem behaviors [212,215-217]. Collectively, scientific and economic data show that proactive, reward-based approaches to canine care optimize welfare outcomes while reducing long-term costs. Caregiver burden is increasingly recognized in the management of aging pets, encompassing emotional stress, financial strain, and the challenge of adhering to complex care regimens. These burdens can significantly affect compliance and ultimately pet health outcomes [208,214].

Early preventive interventions may substantially delay the onset of age-associated morbidities in companion animals. Maintaining optimal body condition through tailored nutrition reduces risks of OA, diabetes, and cardiovascular disease [87,101]. Structured physical activity, adjusted for breed and health status, helps preserve lean mass and delay sarcopenia [102,104]. Environmental enrichment, including cognitive stimulation, social interaction, and stress reduction, supports cognitive function and overall well-being in aging pets [115,137]. Overall, these modifiable lifestyle factors emphasize the importance of preventive medicine as a cornerstone of healthspan extension in veterinary care. **Table 1** summarizes the key anti-aging strategies in veterinary practice.

These therapies contribute to symptomatic relief, an enhanced quality of life, and functional maintenance [49,104,201,209,218-220]. Importantly, the success of such strategies depends on veterinarians adopting a personalized, lifespan-oriented approach that integrates

Table 1. Key anti-aging strategies in veterinary practice

Domain	Example strategies	Expected benefits	References
Nutrition	Caloric moderation, balanced macronutrients, omega-3 fatty acids, antioxidants	Reduced obesity, improved metabolic health, and delayed chronic disease onset	[21,58,60,87]
Exercise	Low-impact aerobic and resistance training, rehabilitation	Preserved lean mass, reduced sarcopenia, joint protection	[101,102,104,115]
Environmental enrichment	Cognitive stimulation, social engagement, and multisensory stimulation	Delayed cognitive decline, reduced stress, enhanced welfare	[115,137,140]
Pharmacological adjuncts	Senolytics, rapamycin, metformin, mitochondrial protectants	Targeted modulation of aging pathways, potential lifespan extension	[14,58,149]

medical, behavioral, and environmental insights [207,208]. This review emphasizes the importance of considering environmental factors in future research on pet health, while acknowledging potential limitations, such as recall bias and non-representative sampling. Continued monitoring of canine and feline cohort may help clarify the long-term effects of environmental exposures, given the faster disease progression in dogs and cats compared to humans [205-206].

Future research should prioritize the development of robust biomarkers of biological aging to enableearly detection of frailty and monitoring of intervention efficacy [15,149]. Translational aging models that bridge human and veterinary geroscience will accelerate the discovery of interventions that are relevant across species [10,11]. Finally, individualized geriatric care plans that integrate genetic predispositions, lifestyle histories, and comorbidity profiles represent a promising path toward precision veterinary gerontology, ensuring that interventions are effective and personalized. Agraphical summary (**Fig. 1**) that integrates the major lifestyle factors highlighted in this review was developed to provide readers with a concise overview. The figure depicts how nutrition, physical activity, body weight regulation, gut microbiome modulation, stress reduction, environmental toxicant minimization, and integrative geriatric care collectively influence biological pathways and promote the extension of healthspan in aging dogs and cats.

In conclusion, veterinarians can shift from reactive treatment to healthspan optimization by embracing a holistic and proactive model of geriatric care centered on lifestyle medicine. This paradigm supports longer and more vibrant lives for companion animals, strengthening the human–animal bond especially during the critical final stages of life.

ACKNOWLEDGMENT

We are grateful to clinicians and caregivers who support aging dogs and cats through individualized, lifestyle-centered care. Their dedication continues to inspire the development of practical, evidence-based strategies that enhance the healthspan and well-being of geriatric pets.

SUPPLEMENTARY MATERIALS

Supplementary Fig. 1

Canine BCS chart based on a nine-point scale used for a clinical evaluation of the fat reserves in aging dogs [85-87].

Supplementary Fig. 2

Feline BCS chart using a nine-point scale. Illustrates underweight, ideal, and overweight categories with visual examples [85-87].

Supplementary Fig. 3

Canine MCS chart used to detect sarcopenia or cachexia in dogs through palpation and visual assessment [85-87].

Supplementary Fig. 4

Feline MCS chart categorizing muscle mass as normal, mild, moderate, or severe loss [85-87].

Supplementary Fig. 5

Bug's main cat gym at WTVC [117,118].

Supplementary Fig. 6

Bug's private cat gym and boarding suites at WTVC [117,118]. This quieter, light-filled gym is adjacent to individual glass-walled cat condos. It includes a modern cat exercise wheel, viewing platforms near a large picture window, and cozy enrichment toys—perfect for cats who prefer a more private yet stimulating environment.

REFERENCES

1. McKenzie BA. Comparative veterinary geroscience: mechanism of molecular, cellular, and tissue aging in humans, laboratory animal models, and companion dogs and cats. *Am J Vet Res*. 2022;83(6):ajvr.22.02.0027. PUBMED | CROSSREF
2. Landsberg GM, Nichol J, Araujo JA. Cognitive dysfunction syndrome: a disease of canine and feline brain aging. *Vet Clin North Am Small Anim Pract*. 2012;42(4):749-768. PUBMED | CROSSREF
3. Seals DR, Melov S. Translational geroscience: emphasizing function to achieve optimal longevity. *Aging (Albany NY)*. 2014;6(9):718-730. PUBMED | CROSSREF
4. Laflamme DP. Nutritional care for aging cats and dogs. *Vet Clin North Am Small Anim Pract*. 2012;42(4):769-791. PUBMED | CROSSREF
5. Landsberg G, Araujo JA. Behavior problems in geriatric pets. *Vet Clin North Am Small Anim Pract*. 2005;35(3):675-698. PUBMED | CROSSREF
6. Landsberg G, Madari A, Žilka N. *Canine and Feline Dementia: Molecular Basis, Diagnostics and Therapy*. Springer; 2017.
7. Horwitz DF, Mills DS. Behavior problems in the senior pet. In: Landsberg GM, Denenberg S, eds. *BSAVA Manual of Canine and Feline Behavioural Medicine*. BSAVA Library; 2009: p127-135.
8. Landsberg GM, Denenberg S, Araujo JA. Cognitive dysfunction in cats: a syndrome we used to dismiss as 'old age'. *J Feline Med Surg*. 2010;12(11):837-848. PUBMED | CROSSREF
9. Jiménez AG. A revisiting of "the hallmarks of aging" in domestic dogs: current status of the literature. *Geroscience*. 2024;46(1):241-255. PUBMED | CROSSREF
10. Somasundaram I, Jain SM, Blot-Chabaud M, Pathak S, Banerjee A, Rawat S, et al. Mitochondrial dysfunction and its association with age-related disorders. *Front Physiol*. 2024;15:1384966. PUBMED | CROSSREF
11. Guelfi G, Capaccia C, Tedeschi M, Bufalari A, Leonardi L, Cenci-Goga B, et al. Dog aging: a comprehensive review of molecular, cellular, and physiological processes. *Cells*. 2024;13(24):2101. PUBMED | CROSSREF
12. Dhaliwal R, Boynton E, Carrera-Justiz S, Cruise N, Gardner M, Huntingford J, et al. 2023 AAHA senior care guidelines for dogs and cats. *J Am Anim Hosp Assoc*. 2023;59(1):1-21. PUBMED | CROSSREF
13. Li Y, Tian X, Luo J, Bao T, Wang S, Wu X. Molecular mechanisms of aging and anti-aging strategies. *Cell Commun Signal*. 2024;22(1):285. PUBMED | CROSSREF
14. Joseph AM, Adhihetty PJ, Leeuwenburgh C. Beneficial effects of exercise on age-related mitochondrial dysfunction and oxidative stress in skeletal muscle. *J Physiol*. 2016;594(18):5105-5123. PUBMED | CROSSREF

15. Dewey CW. Poop for thought: can fecal microbiome transplantation improve cognitive function in aging dogs? *Open Vet J*. 2025;15(2):556-564. PUBMED | CROSSREF
16. Bermingham EN, Patterson KA, Shoveller AK, Fraser K, Butowski CF, Thomas DG. Nutritional needs and health outcomes of ageing cats and dogs: is it time for updated nutrient guidelines? *Anim Front*. 2024;14(3):5-16. PUBMED | CROSSREF
17. Laflamme D, Gunn-Moore D. Nutrition of aging cats. *Vet Clin North Am Small Anim Pract*. 2014;44(4):761-774. PUBMED | CROSSREF
18. Larsen JA, Farcas A. Nutrition of aging dogs. *Vet Clin North Am Small Anim Pract*. 2014;44(4):741-759. PUBMED | CROSSREF
19. Stockman J. Nutrition and aging in dogs and cats. *Adv Exp Med Biol*. 2024;1446:203-215. PUBMED | CROSSREF
20. Fascetti AJ, Delaney SJ, Larsen JA, Villaverde C. *Applied Veterinary Clinical Nutrition*. John Wiley & Sons; 2012.
21. Laflamme DP. Nutrition for aging cats and dogs and the importance of body condition. *Vet Clin North Am Small Anim Pract*. 2005;35(3):713-742. PUBMED | CROSSREF
22. Freeman LM. Cachexia and sarcopenia: emerging syndromes of importance in dogs and cats. *J Vet Intern Med*. 2012;26(1):3-17. PUBMED | CROSSREF
23. Laflamme DP. Understanding and managing obesity in dogs and cats. *Vet Clin North Am Small Anim Pract*. 2006;36(6):1283-1295. PUBMED | CROSSREF
24. Verbrugghe A, Hesta M. Cats and carbohydrates: the carnivore fantasy? *Vet Sci*. 2017;4(4):55. PUBMED | CROSSREF
25. Hoenig M. The cat as a model for human obesity and diabetes. *J Diabetes Sci Technol*. 2012;6(3):525-533. PUBMED | CROSSREF
26. German AJ. The growing problem of obesity in dogs and cats. *J Nutr*. 2006;136(7 Suppl):1940S-1946S. PUBMED | CROSSREF
27. Laflamme DP, Backus RC, Forrester SD, Hoenig M. Evidence does not support the controversy regarding carbohydrates in feline diets. *J Am Vet Med Assoc*. 2022;260(5):506-513. PUBMED | CROSSREF
28. Hand MS, Thatcher CD, Remillard RL, Roudebush P, Novotny BJ. *Small Animal Clinical Nutrition*. Mark Morris Institute; 2010.
29. Dobenecker B, Webel A, Reese S, Kienzle E. Effect of a high phosphorus diet on indicators of renal health in cats. *J Feline Med Surg*. 2018;20(4):339-343. PUBMED | CROSSREF
30. Ray M, Carney HC, Boynton B, Quimby J, Robertson S, St Denis K, et al. 2021 AAFP feline senior care guidelines. *J Feline Med Surg*. 2021;23(7):613-638. PUBMED | CROSSREF
31. Polzin DJ. Chronic kidney disease in small animals. *Vet Clin North Am Small Anim Pract*. 2011;41(1):15-30. PUBMED | CROSSREF
32. Elliott J, Barber PJ. Feline chronic renal failure: clinical findings in 80 cases diagnosed between 1992 and 1995. *J Small Anim Pract*. 1998;39(2):78-85. PUBMED | CROSSREF
33. Plantinga EA, Everts H, Kastelein AM, Beynen AC. Retrospective study of the survival of cats with acquired chronic renal insufficiency offered different commercial diets. *Vet Rec*. 2005;157(7):185-187. PUBMED | CROSSREF
34. Ross SJ, Osborne CA, Kirk CA, Lowry SR, Koehler LA, Polzin DJ. Clinical evaluation of dietary modification for treatment of spontaneous chronic kidney disease in cats. *J Am Vet Med Assoc*. 2006;229(6):949-957. PUBMED | CROSSREF
35. Pan Y, Landsberg G, Mougeot I, Kelly S, Xu H, Bhatnagar S, et al. Efficacy of a therapeutic diet on dogs with signs of cognitive dysfunction syndrome (CDS): a prospective double blinded placebo controlled clinical study. *Front Nutr*. 2018;5:127. PUBMED | CROSSREF
36. Cotman CW, Head E, Muggenburg BA, Zicker S, Milgram NW. Brain aging in the canine: a diet enriched in antioxidants reduces cognitive dysfunction. *Neurobiol Aging*. 2002;23(5):809-818. PUBMED | CROSSREF
37. Milgram NW, Head E, Zicker SC, Ikeda-Douglas C, Murphey H, Muggenberg BA, et al. Long-term treatment with antioxidants and a program of behavioral enrichment reduces age-dependent impairment in discrimination and reversal learning in beagle dogs. *Exp Gerontol*. 2004;39(5):753-765. PUBMED | CROSSREF
38. Kim SH, Hao J. Recent advances in diagnostic and therapeutic strategies for canine cognitive dysfunction. *Am J Vet Res*. 2025;86(8):ajvr.25.02.0053. PUBMED | CROSSREF
39. Milgram NW, Zicker SC, Head E, Muggenburg BA, Murphey H, Ikeda-Douglas CJ, et al. Dietary enrichment counteracts age-associated cognitive dysfunction in canines. *Neurobiol Aging*. 2002;23(5):737-745. PUBMED | CROSSREF
40. Pan Y, Larson B, Araujo JA, Lau W, de Rivera C, Santana R, et al. Dietary supplementation with medium-chain TAG has long-lasting cognition-enhancing effects in aged dogs. *Br J Nutr*. 2010;103(12):1746-1754. PUBMED | CROSSREF

41. Rand JS, Fleeman LM, Farrow HA, Appleton DJ, Lederer R. Canine and feline diabetes mellitus: nature or nurture? *J Nutr*. 2004;134(8 Suppl):2072S-2080S. PUBMED | CROSSREF
42. German AJ. Outcomes of weight management in obese pet dogs: what can we do better? *Proc Nutr Soc*. 2016;75(3):398-404. PUBMED | CROSSREF
43. Kealy RD, Lawler DF, Ballam JM, Mantz SL, Biery DN, Greeley EH, et al. Effects of diet restriction on life span and age-related changes in dogs. *J Am Vet Med Assoc*. 2002;220(9):1315-1320. PUBMED | CROSSREF
44. Loftus JP, Wakshlag JJ. Canine and feline obesity: a review of pathophysiology, epidemiology, and clinical management. *Vet Med (Auckl)*. 2014;6:49-60. PUBMED | CROSSREF
45. Moreau M, Troncy E, Del Castillo JR, Bédard C, Gauvin D, Lussier B. Effects of feeding a high omega-3 fatty acids diet in dogs with naturally occurring osteoarthritis. *J Anim Physiol Anim Nutr (Berl)*. 2013;97(5):830-837. PUBMED | CROSSREF
46. McCarthy G, O'Donovan J, Jones B, McAllister H, Seed M, Mooney C. Randomised double-blind, positive-controlled trial to assess the efficacy of glucosamine/chondroitin sulfate for the treatment of dogs with osteoarthritis. *Vet J*. 2007;174(1):54-61. PUBMED | CROSSREF
47. Marshall WG, Hazewinkel HA, Mullen D, De Meyer G, Baert K, Carmichael S. The effect of weight loss on lameness in obese dogs with osteoarthritis. *Vet Res Commun*. 2010;34(3):241-253. PUBMED | CROSSREF
48. German AJ, Holden SL, Wiseman-Orr ML, Reid J, Nolan AM, Biourge V, et al. Quality of life is reduced in obese dogs but improves after successful weight loss. *Vet J*. 2012;192(3):428-434. PUBMED | CROSSREF
49. Roush JK, Cross AR, Renberg WC, Dodd CE, Sixby KA, Fritsch DA, et al. Evaluation of the effects of dietary supplementation with fish oil omega-3 fatty acids on weight bearing in dogs with osteoarthritis. *J Am Vet Med Assoc*. 2010;236(1):67-73. PUBMED | CROSSREF
50. Cline MG, Burns KM, Coe JB, Downing R, Durzi T, Murphy M, et al. 2021 AAHA nutrition and weight management guidelines for dogs and cats. *J Am Anim Hosp Assoc*. 2021;57(4):153-178. PUBMED | CROSSREF
51. Chan D. *Nutritional Management of Hospitalized Small Animals*. John Wiley & Sons; 2015.
52. Rollins AW, Murphy M. Nutritional assessment in the cat: practical recommendations for better medical care. *J Feline Med Surg*. 2019;21(5):442-448. PUBMED | CROSSREF
53. Stockman J, Fascetti AJ, Kass PH, Larsen JA. Evaluation of recipes of home-prepared maintenance diets for dogs. *J Am Vet Med Assoc*. 2013;242(11):1500-1505. PUBMED | CROSSREF
54. Wilson SA, Villaverde C, Fascetti AJ, Larsen JA. Evaluation of the nutritional adequacy of recipes for home-prepared maintenance diets for cats. *J Am Vet Med Assoc*. 2019;254(10):1172-1179. PUBMED | CROSSREF
55. Villaverde C, Chandler M. Commercial vs homemade cat diets: what you need to know. *J Feline Med Surg*. 2022;24(5):415-428. PUBMED | CROSSREF
56. Hayes KC. Nutritional problems in cats: taurine deficiency and vitamin A excess. *Can Vet J*. 1982;23(1):2-5. PUBMED
57. Mellanby RJ, Mee AP, Berry JL, Herrtage ME. Hypercalcaemia in two dogs caused by excessive dietary supplementation of vitamin D. *J Small Anim Pract*. 2005;46(7):334-338. PUBMED | CROSSREF
58. Xiong Y, Li X, Liu J, Luo P, Zhang H, Zhou H, et al. Omega-3 PUFAs slow organ aging through promoting energy metabolism. *Pharmacol Res*. 2024;208:107384. PUBMED | CROSSREF
59. Kennedy DO. B Vitamins and the brain: mechanisms, dose and efficacy--a review. *Nutrients*. 2016;8(2):68. PUBMED | CROSSREF
60. Alhasaniah AH. l-Carnitine: nutrition, pathology, and health benefits. *Saudi J Biol Sci*. 2023;30(2):103555. PUBMED | CROSSREF
61. Singh P, Gollapalli K, Mangiola S, Schranner D, Yusuf MA, Chamoli M, et al. Taurine deficiency as a driver of aging. *Science*. 2023;380(6649):eabn9257. PUBMED | CROSSREF
62. Barrs VR, Gunew M, Foster SF, Beatty JA, Malik R. Prevalence of autosomal dominant polycystic kidney disease in Persian cats and related-breeds in Sydney and Brisbane. *Aust Vet J*. 2001;79(4):257-259. PUBMED | CROSSREF
63. Lederer R, Rand JS, Hughes IP, Latter M, Wattle O. Pancreatic histopathology of diabetic Burmese and non-Burmese cats. 22nd American College of Veterinary Internal Medicine Forum; 2004 Jun 9-12; Minneapolis, MN. Hoboken, NJ: Wiley; 2004.
64. Hotea I, Sirbu C, Plotuna AM, Tîrziu E, Badea C, Berbecea A, et al. Integrating (nutri-)metabolomics into the one health tendency-the key for personalized medicine advancement. *Metabolites*. 2023;13(7):800. PUBMED | CROSSREF
65. Haq ZU, Saleem A, Khan AA, Dar MA, Ganaie AM, Beigh YA, et al. Nutrigenomics in livestock sector and its human-animal interface-a review. *Vet Anim Sci*. 2022;17:100262. PUBMED | CROSSREF
66. Salt C, Morris PJ, Wilson D, Lund EM, German AJ. Association between life span and body condition in neutered client-owned dogs. *J Vet Intern Med*. 2019;33(1):89-99. PUBMED | CROSSREF

67. Montoya M, Péron F, Hookey T, Morrison J, German AJ, Gaillard V, et al. Overweight and obese body condition in ~4.9 million dogs and ~1.3 million cats seen at primary practices across the USA: prevalences by life stage from early growth to senior. *Prev Vet Med*. 2025;235:106398. PUBMED | CROSSREF

68. Laflamme DP. Companion animals symposium: obesity in dogs and cats: what is wrong with being fat? *J Anim Sci*. 2012;90(5):1653-1662. PUBMED | CROSSREF

69. Kivimäki M, Frank P, Pentti J, Xu X, Vahtera J, Ervasti J, et al. Obesity and risk of diseases associated with hallmarks of cellular ageing: a multicohort study. *Lancet Healthy Longev*. 2024;5(7):e454-e463. PUBMED | CROSSREF

70. Creevy KE, Akey JM, Kaeberlein M, Promislow DEL, Barnett B, Benton B, et al. An open science study of ageing in companion dogs. *Nature*. 2022;602(7895):51-57. PUBMED | CROSSREF

71. Radin MJ, Sharkey LC, Holycross BJ. Adipokines: a review of biological and analytical principles and an update in dogs, cats, and horses. *Vet Clin Pathol*. 2009;38(2):136-156. PUBMED | CROSSREF

72. German AJ, Ryan VH, German AC, Wood IS, Trayhurn P. Obesity, its associated disorders and the role of inflammatory adipokines in companion animals. *Vet J*. 2010;185(1):4-9. PUBMED | CROSSREF

73. Schmid SM, Hoffman JM, Prescott J, Ernst H, Promislow DEL, et al.; Dog Aging Project Consortium The companion dog as a model for inflammaging: a cross-sectional pilot study. *Geroscience*. 2024;46(6):5395-5407. PUBMED | CROSSREF

74. McKenzie B, Peloquin M, Graves JL, Chen F, Tovar A, Carttar TA, et al. Changes in insulin, adiponectin and lipid concentrations with age are associated with frailty and reduced quality of life in dogs. *Sci Rep*. 2025;15(1):5380. PUBMED | CROSSREF

75. Chapagain D, Wallis LJ, Range F, Affenzeller N, Serra J, Virányi Z. Behavioural and cognitive changes in aged pet dogs: no effects of an enriched diet and lifelong training. *PLoS One*. 2020;15(9):e0238517. PUBMED | CROSSREF

76. Saavedra C, Pérez C, Oyarzún C, Torres-Arévalo Á. Overweight and obesity in domestic cats: epidemiological risk factors and associated pathologies. *J Feline Med Surg*. 2024;26(11):1098612x241285519. PUBMED | CROSSREF

77. Clark M, Hoenig M. Feline comorbidities: pathophysiology and management of the obese diabetic cat. *J Feline Med Surg*. 2021;23(7):639-648. PUBMED | CROSSREF

78. Patra S, McMillan CJ, Snead ER, Warren AL, Cosford K, Chelikani PK. Feline diabetes is associated with deficits in markers of insulin signaling in peripheral tissues. *Int J Mol Sci*. 2024;25(23):13195. PUBMED | CROSSREF

79. Bennett D, Zainal Ariffin SM, Johnston P. Osteoarthritis in the cat: 1. how common is it and how easy to recognise? *J Feline Med Surg*. 2012;14(1):65-75. PUBMED | CROSSREF

80. Bishop G, Cooney K, Cox S, Downing R, Mitchener K, Shanan A, et al. 2016 AAHA/IAAHPC end-of-life care guidelines. *J Am Anim Hosp Assoc*. 2016;52(6):341-356. PUBMED | CROSSREF

81. Partington C, Hodgkiss-Geere H, Woods GRT, Dukes-McEwan J, Flanagan J, Biourge V, et al. The effect of obesity and subsequent weight reduction on cardiac structure and function in dogs. *BMC Vet Res*. 2022;18(1):351. PUBMED | CROSSREF

82. Tropf M, Nelson OL, Lee PM, Weng HY. Cardiac and metabolic variables in obese dogs. *J Vet Intern Med*. 2017;31(4):1000-1007. PUBMED | CROSSREF

83. Sordo L, Gunn-Moore DA. Cognitive dysfunction in cats: update on neuropathological and behavioural changes plus clinical management. *Vet Rec*. 2021;188(1):e3. PUBMED | CROSSREF

84. Belotta AF, Teixeira CR, Padovani CR, Rahal SC, Mayer MN, Mamprim MJ. Sonographic evaluation of liver hemodynamic indices in overweight and obese dogs. *J Vet Intern Med*. 2018;32(1):181-187. PUBMED | CROSSREF

85. Freeman L, Becvarova I, Cave N, MacKay C, Nguyen P, Rama B, et al. WSAVA nutritional assessment guidelines. *Compend Contin Educ Vet*. 2011;33(8):E1-E9. PUBMED

86. Christie KM, Barnhard JA, Otto CM, Mallikarjun A, Wilson C, Levine D, et al. Interobserver variability of assessing body condition scores and muscle condition scores in a population of 43 active working explosive detection dogs. *Front Vet Sci*. 2024;11:1431855. PUBMED | CROSSREF

87. Freeman LM. Cachexia and sarcopenia in companion animals: an under-utilized natural animal model of human disease. *JCSM Rapid Commun*. 2018;1(2):1-17. CROSSREF

88. Mawby DI, Bartges JW, d'Avignon A, Laflamme DP, Moyers TD, Cottrell T. Comparison of various methods for estimating body fat in dogs. *J Am Anim Hosp Assoc*. 2004;40(2):109-114. PUBMED | CROSSREF

89. Bjornvad CR, Nielsen DH, Armstrong PJ, McEvoy F, Hoelmkjaer KM, Jensen KS, et al. Evaluation of a nine-point body condition scoring system in physically inactive pet cats. *Am J Vet Res*. 2011;72(4):433-437. PUBMED | CROSSREF

90. Laflamme DP. Development and validation of a body condition score system for dogs. *Canine Pract.* 1997;22:10-15.
91. Downes MJ, Devitt C, Downes MT, More SJ. Understanding the context for pet cat and dog feeding and exercising behaviour among pet owners in Ireland: a qualitative study. *Ir Vet J.* 2017;70(1):29. PUBMED | CROSSREF
92. Alexander JE, Colyer A, Morris PJ. The effect of reducing energy density, via the addition of water to dry diet, on body weight and activity in dogs. *J Nutr Sci.* 2017;6:e42. PUBMED | CROSSREF
93. Phungviwatnikul T, Lee AH, Belchik SE, Suchodolski JS, Swanson KS. Weight loss and high-protein, high-fiber diet consumption impact blood metabolite profiles, body composition, voluntary physical activity, fecal microbiota, and fecal metabolites of adult dogs. *J Anim Sci.* 2022;100(2):skab379. PUBMED | CROSSREF
94. Brooks D, Churchill J, Fein K, Linder D, Michel KE, Tudor K, et al. 2014 AAHA weight management guidelines for dogs and cats. *J Am Anim Hosp Assoc.* 2014;50(1):1-11. PUBMED | CROSSREF
95. Corbee RJ, Barnier MM, van de Lest CH, Hazewinkel HA. The effect of dietary long-chain omega-3 fatty acid supplementation on owner's perception of behaviour and locomotion in cats with naturally occurring osteoarthritis. *J Anim Physiol Anim Nutr (Berl).* 2013;97(5):846-853. PUBMED | CROSSREF
96. Barbeau-Grégoire M, Otis C, Cournoyer A, Moreau M, Lussier B, Troncy E. A 2022 systematic review and meta-analysis of enriched therapeutic diets and nutraceuticals in canine and feline osteoarthritis. *Int J Mol Sci.* 2022;23(18):10384. PUBMED | CROSSREF
97. Bhathal A, Spryszak M, Louizos C, Frankel G. Glucosamine and chondroitin use in canines for osteoarthritis: a review. *Open Vet J.* 2017;7(1):36-49. PUBMED | CROSSREF
98. Churchill J, Ward E. Communicating with pet owners about obesity: roles of the veterinary health care team. *Vet Clin North Am Small Anim Pract.* 2016;46(5):899-911. PUBMED | CROSSREF
99. Linder D, Mueller M. Pet obesity management: beyond nutrition. *Vet Clin North Am Small Anim Pract.* 2014;44(4):789-806. PUBMED | CROSSREF
100. Prochaska JO, Velicer WF. The transtheoretical model of health behavior change. *Am J Health Promot.* 1997;12(1):38-48. PUBMED | CROSSREF
101. Gaesser GA, Hall SE, Angadi SS, Poole DC, Racette SB. Increasing the health span: unique role for exercise. *J Appl Physiol.* 2025;138(6):1285-1308. PUBMED | CROSSREF
102. Lu X, Chen Y, Shi Y, Shi Y, Su X, Chen P, et al. Exercise and exerkines: Mechanisms and roles in anti-aging and disease prevention. *Exp Gerontol.* 2025;200:112685. PUBMED | CROSSREF
103. Gomes-Osman J, Cabral DF, Morris TP, McInerney K, Cahalin LP, Rundek T, et al. Exercise for cognitive brain health in aging: a systematic review for an evaluation of dose. *Neurol Clin Pract.* 2018;8(3):257-265. PUBMED | CROSSREF
104. McKenzie BA, Chen FL. Assessment and management of declining physical function in aging dogs. *Top Companion Anim Med.* 2022;51:100732. PUBMED | CROSSREF
105. Lund EM, Armstrong PJ, Kirk CA, Kolar LM, Klausner JS. Health status and population characteristics of dogs and cats examined at private veterinary practices in the United States. *J Am Vet Med Assoc.* 1999;214(9):1336-1341. PUBMED | CROSSREF
106. Bland IM, Guthrie-Jones A, Taylor RD, Hill J. Dog obesity: owner attitudes and behaviour. *Prev Vet Med.* 2009;92(4):333-340. PUBMED | CROSSREF
107. Siwak CT, Murphey HL, Muggenburg BA, Milgram NW. Age-dependent decline in locomotor activity in dogs is environment specific. *Physiol Behav.* 2002;75(1-2):65-70. PUBMED | CROSSREF
108. Davies M. Geriatric screening in first opinion practice - results from 45 dogs. *J Small Anim Pract.* 2012;53(9):507-513. PUBMED | CROSSREF
109. German AJ, Holden SL, Morris PJ, Biourge V. Long-term follow-up after weight management in obese dogs: the role of diet in preventing regain. *Vet J.* 2012;192(1):65-70. PUBMED | CROSSREF
110. Bray EE, Raichlen DA, Forsyth KK, Promislow DEL, Alexander GE, MacLean EL, et al. Associations between physical activity and cognitive dysfunction in older companion dogs: results from the Dog Aging Project. *Geroscience.* 2023;45(2):645-661. PUBMED | CROSSREF
111. Studzinski CM, Araujo JA, Milgram NW. The canine model of human cognitive aging and dementia: pharmacological validity of the model for assessment of human cognitive-enhancing drugs. *Prog Neuropsychopharmacol Biol Psychiatry.* 2005;29(3):489-498. PUBMED | CROSSREF
112. Head E, Rofina J, Zicker S. Oxidative stress, aging, and central nervous system disease in the canine model of human brain aging. *Vet Clin North Am Small Anim Pract.* 2008;38(1):167-178. PUBMED | CROSSREF
113. Mondino A, Khan M, Case B, Giovagnoli S, Thomson A, Lascelles BDX, et al. Activity patterns are associated with fractional lifespan, memory, and gait speed in aged dogs. *Sci Rep.* 2023;13(1):2588. PUBMED | CROSSREF

114. Cimino Brown D. What can we learn from osteoarthritis pain in companion animals? *Clin Exp Rheumatol*. 2017;35 Suppl 107(5):53-58. PUBMED

115. Hanks J, Levine D, Bockstahler B. Physical agent modalities in physical therapy and rehabilitation of small animals. *Vet Clin North Am Small Anim Pract*. 2015;45(1):29-44. PUBMED | CROSSREF

116. Drum MG, Marcellin-Little DJ, Davis MS. Principles and applications of therapeutic exercises for small animals. *Vet Clin North Am Small Anim Pract*. 2015;45(1):73-90. PUBMED | CROSSREF

117. Bobst K. 1 Veterinarian, 1 Cat, Countless Adventures [Internet]. Adventure Cats. Published [2017]. Updated [2017]. Accessed [Aug 3, 2025]. https://www.adventurecats.org/cat-tales/one-veterinarian-one-cat-countless-adventures

118. West Towne Veterinary Center. Cat Boarding at West Towne Veterinary Center [Internet]. West Towne Veterinary Center. Published [2025]. Updated [2025]. Accessed [Aug 3, 2025]. https://www.westtownevet.com

119. Levine D, Millis DL, Marcellin-Little DJ, Taylor R. Rehabilitation and physical therapy. *Vet Clin North Am Small Anim Pract*. 2005;35(6):1247-1517.

120. Levine D. *Rehabilitation and Physical Therapy, an Issue of Veterinary Clinics of North America: Small Animal Practice*. Elsevier Health Sciences; 2014.

121. Case LP. *Canine and Feline Behavior and Training: a Complete Guide to Understanding Our Two Best Friends*. Delmar Cengage Learning; 2010.

122. Herron ME, Buffington CA. Environmental enrichment for indoor cats: implementing enrichment. *Compend Contin Educ Vet*. 2012;34(1):E3. PUBMED

123. Buffington CA. External and internal influences on disease risk in cats. *J Am Vet Med Assoc*. 2002;220(7):994-1002. PUBMED | CROSSREF

124. Mitchell CM, Davy BM, Hulver MW, Neilson AP, Bennett BJ, Davy KP. Does exercise alter gut microbial composition? a systematic review. *Med Sci Sports Exerc*. 2019;51(1):160-167. PUBMED | CROSSREF

125. Suchodolski JS. Intestinal microbiota of dogs and cats: a bigger world than we thought. *Vet Clin North Am Small Anim Pract*. 2011;41(2):261-272. PUBMED | CROSSREF

126. Masuoka H, Shimada K, Kiyosue-Yasuda T, Kiyosue M, Oishi Y, Kimura S, et al. Transition of the intestinal microbiota of dogs with age. *Biosci Microbiota Food Health*. 2017;36(1):27-31. PUBMED | CROSSREF

127. Shah H, Trivedi M, Gurjar T, Sahoo DK, Jergens AE, Yadav VK, et al. Decoding the gut microbiome in companion animals: impacts and innovations. *Microorganisms*. 2024;12(9):1831. PUBMED | CROSSREF

128. Barko PC, McMichael MA, Swanson KS, Williams DA. The gastrointestinal microbiome: a review. *J Vet Intern Med*. 2018;32(1):9-25. PUBMED | CROSSREF

129. Fernández-Pinteño A, Pilla R, Manteca X, Suchodolski J, Torre C, Salas-Mani A. Age-associated changes in intestinal health biomarkers in dogs. *Front Vet Sci*. 2023;10:1213287. PUBMED | CROSSREF

130. Bhosle A, Jackson MI, Walsh AM, Franzosa EA, Badri DV, Huttenhower C. Response of the gut microbiome and metabolome to dietary fiber in healthy dogs. *mSystems*. 2025;10:e0045224. PUBMED | CROSSREF

131. Pilla R, Suchodolski JS. The role of the canine gut microbiome and metabolome in health and gastrointestinal disease. *Front Vet Sci*. 2020;6:498. PUBMED | CROSSREF

132. Han Y, Wang B, Gao H, He C, Hua R, Liang C, et al. Vagus nerve and underlying impact on the gut microbiota-brain axis in behavior and neurodegenerative diseases. *J Inflamm Res*. 2022;15:6213-6230. PUBMED | CROSSREF

133. Silva YP, Bernardi A, Frozza RL. The role of short-chain fatty acids from gut microbiota in gut-brain communication. *Front Endocrinol (Lausanne)*. 2020;11:25. PUBMED | CROSSREF

134. O'Riordan KJ, Collins MK, Moloney GM, Knox EG, Aburto MR, Fülling C, et al. Short chain fatty acids: microbial metabolites for gut-brain axis signalling. *Mol Cell Endocrinol*. 2022;546:111572. PUBMED | CROSSREF

135. Cao Q, Shen M, Li R, Liu Y, Zeng Z, Zhou J, et al. Elucidating the specific mechanisms of the gut-brain axis: the short-chain fatty acids-microglia pathway. *J Neuroinflammation*. 2025;22(1):133. PUBMED | CROSSREF

136. Ramadan YN, Alqifari SF, Alshehri K, Alhowiti A, Mirghani H, Alrasheed T, et al. Microbiome gut-brain-axis: impact on brain development and mental health. *Mol Neurobiol*. 2025;62(8):10813-10833. PUBMED | CROSSREF

137. Head E, Nukala VN, Fenoglio KA, Muggenburg BA, Cotman CW, Sullivan PG. Effects of age, dietary, and behavioral enrichment on brain mitochondria in a canine model of human aging. *Exp Neurol*. 2009;220(1):171-176. PUBMED | CROSSREF

138. Hall JA, Picton RA, Finneran PS, Bird KE, Skinner MM, Jewell DE, et al. Dietary antioxidants and behavioral enrichment enhance neutrophil phagocytosis in geriatric Beagles. *Vet Immunol Immunopathol*. 2006;113(1-2):224-233. PUBMED | CROSSREF

139. Roudebush P, Zicker SC, Cotman CW, Milgram NW, Muggenburg BA, Head E. Nutritional management of brain aging in dogs. *J Am Vet Med Assoc*. 2005;227(5):722-728. PUBMED | CROSSREF

140. Cryan JF, Dinan TG. Mind-altering microorganisms: the impact of the gut microbiota on brain and behaviour. *Nat Rev Neurosci*. 2012;13(10):701-712. PUBMED | CROSSREF

141. O'Riordan KJ, Moloney GM, Keane L, Clarke G, Cryan JF. The gut microbiota-immune-brain axis: therapeutic implications. *Cell Rep Med*. 2025;6(3):101982. PUBMED | CROSSREF

142. Kubinyi E, Bel Rhali S, Sándor S, Szabó A, Felföldi T. Gut microbiome composition is associated with age and memory performance in pet dogs. *Animals (Basel)*. 2020;10(9):1488. PUBMED | CROSSREF

143. Jameson KG, Kazmi SA, Ohara TE, Son C, Yu KB, Mazdeyasnan D, et al. Select microbial metabolites in the small intestinal lumen regulate vagal activity via receptor-mediated signaling. *iScience*. 2024;28(2):111699. PUBMED | CROSSREF

144. Lu S, Zhao Q, Guan Y, Sun Z, Li W, Guo S, et al. The communication mechanism of the gut-brain axis and its effect on central nervous system diseases: a systematic review. *Biomed Pharmacother*. 2024;178:117207. PUBMED | CROSSREF

145. Fock E, Parnova R. Mechanisms of blood-brain barrier protection by microbiota-derived short-chain fatty acids. *Cells*. 2023;12(4):12. PUBMED | CROSSREF

146. Pellowe SD, Zhang A, Bignell DRD, Peña-Castillo L, Walsh CJ. Gut microbiota composition is related to anxiety and aggression scores in companion dogs. *Sci Rep*. 2025;15(1):24336. PUBMED | CROSSREF

147. Xiong RG, Li J, Cheng J, Zhou DD, Wu SX, Huang SY, et al. The role of gut microbiota in anxiety, depression, and other mental disorders as well as the protective effects of dietary components. *Nutrients*. 2023;15(14):3258. PUBMED | CROSSREF

148. Sacoor C, Marugg JD, Lima NR, Empadinhas N, Montezinho L. Gut-brain axis impact on canine anxiety disorders: new challenges for behavioral veterinary medicine. *Vet Med Int*. 2024;2024(1):2856759. PUBMED | CROSSREF

149. Kim H, Chae Y, Cho JH, Song M, Kwak J, Doo H, et al. Understanding the diversity and roles of the canine gut microbiome. *J Anim Sci Biotechnol*. 2025;16(1):95. PUBMED | CROSSREF

150. Garcia-Mazcorro JF, Lanerie DJ, Dowd SE, Paddock CG, Grützner N, Steiner JM, et al. Effect of a multi-species synbiotic formulation on fecal bacterial microbiota of healthy cats and dogs as evaluated by pyrosequencing. *FEMS Microbiol Ecol*. 2011;78(3):542-554. PUBMED | CROSSREF

151. Zhu M, Huang Y, Wang Z, Jin Z, Cao J, Zhong Q, et al. Fecal microbiota transplantation attenuates frailty via gut-muscle axis in old mice. *Aging Dis*. 2024;16(2):1180-1198. PUBMED | CROSSREF

152. Winston JA, Suchodolski JS, Gaschen F, Busch K, Marsilio S, Costa MC, et al. Clinical guidelines for fecal microbiota transplantation in companion animals. *Adv Small Anim Care*. 2024;5(1):79-107. CROSSREF

153. Sugimoto K, Kozuka T, Harada S, Harada T. Clinical outcomes of azodyl administration in three dogs with chronic kidney disease. *Intern J Appl Res Vet Med*. 2020;18(2):120-130.

154. Rishniw M, Wynn SG. Azodyl, a synbiotic, fails to alter azotemia in cats with chronic kidney disease when sprinkled onto food. *J Feline Med Surg*. 2011;13(6):405-409. PUBMED | CROSSREF

155. Toresson L, Spillmann T, Pilla R, Ludvigsson U, Hellgren J, Olmedal G, et al. Clinical effects of faecal microbiota transplantation as adjunctive therapy in dogs with chronic enteropathies-a retrospective case series of 41 dogs. *Vet Sci*. 2023;10(4):271. PUBMED | CROSSREF

156. Vecchiato CG, Sabetti MC, Sung CH, Sportelli F, Delsante C, Pinna C, et al. Effect of faecal microbial transplantation on clinical outcome, faecal microbiota and metabolome in dogs with chronic enteropathy refractory to diet. *Sci Rep*. 2025;15(1):11957. PUBMED | CROSSREF

157. Brugnoli F, Simionati B, Patuzzi I, Lombardi A, Giron MC, Savarino E, et al. A protocol for fecal microbiota transplantation using freeze-dried capsules: dosage and outcomes in 171 dogs with chronic enteropathy. *Pets*. 2025;2(2):16. CROSSREF

158. Ryu MO, Lee SY, Kim SH, Youn HY, Seo KW. Fecal microbiota transplantation via commercial oral capsules for chronic enteropathies in dogs and cats. *J Vet Clin*. 2024;41(3):150-156. CROSSREF

159. Suchodolski JS. Analysis of the gut microbiome in dogs and cats. *Vet Clin Pathol*. 2022;50 Suppl 1(Suppl 1):6-17. PUBMED | CROSSREF

160. Swanson KS, Carter RA, Yount TP, Aretz J, Buff PR. Nutritional sustainability of pet foods. *Adv Nutr*. 2013;4(2):141-150. PUBMED | CROSSREF

161. Li Q, Lauber CL, Czarnecki-Maulden G, Pan Y, Hannah SS. Effects of the dietary protein and carbohydrate ratio on gut microbiomes in dogs of different body conditions. *mBio*. 2017;8(1):e01703-16. PUBMED | CROSSREF

162. Lagoumintzis G, Afratis NA, Patrinos GP. Editorial: nutrigenomics and personalized nutrition: advancing basic, clinical, and translational research. *Front Nutr*. 2024;11:1435475. PUBMED | CROSSREF

163. Polsky LR, Rentscher KE, Carroll JE. Stress-induced biological aging: a review and guide for research priorities. *Brain Behav Immun*. 2022;104:97-109. PUBMED | CROSSREF

164. Liu H, Lin J, Lin W. Cognitive mechanisms and neurological foundations of companion animals' role in enhancing human psychological well-being. *Front Psychol*. 2024;15:1354220. PUBMED | CROSSREF

165. Sapolsky RM. Glucocorticoids, stress, and their adverse neurological effects: relevance to aging. *Exp Gerontol*. 1999;34(6):721-732. PUBMED | CROSSREF

166. Salonen M, Mikkola S, Niskanen JE, Hakanen E, Sulkama S, Puurunen J, et al. Breed, age, and social environment are associated with personality traits in dogs. *iScience*. 2023;26(5):106691. PUBMED | CROSSREF

167. Buffington CAT, Bain M. Stress and feline health. *Vet Clin North Am Small Anim Pract*. 2020;50(4):653-662. PUBMED | CROSSREF

168. Ellis S, Sparkes AH. *ISFM Guide to Feline Stress and Health: Managing Negative Emotions to Improve Feline Health and Well-Being*. International Cat Care; 2016.

169. McCoy BM, Brassington L, Jin K, Dolby GA, Shrager S, Collins D, et al. Social determinants of health and disease in companion dogs: a cohort study from the Dog Aging Project. *Evol Med Public Health*. 2023;11(1):187-201. PUBMED | CROSSREF

170. Pankratz K. Integrating Behavior Services Into Veterinary Practice [Internet]. Merck. Published [2024]. Updated [2024]. Accessed [May 5, 2025]. https://www.msdvetmanual.com/behavior/behavioral-medicine-introduction/integrating-behavior-services-into-veterinary-practice

171. Landsberg GM, Deporter T, Araujo JA. Clinical signs and management of anxiety, sleeplessness, and cognitive dysfunction in the senior pet. *Vet Clin North Am Small Anim Pract*. 2011;41(3):565-590. PUBMED | CROSSREF

172. Dinan TG, Cryan JF. The impact of gut microbiota on brain and behaviour: implications for psychiatry. *Curr Opin Clin Nutr Metab Care*. 2015;18(6):552-558. PUBMED | CROSSREF

173. Lilly ML, Siracusa C. Skin disease and behavior changes in the cat. *Vet Clin North Am Small Anim Pract*. 2024;54(1):135-151. PUBMED | CROSSREF

174. He Y, Wang K, Su N, Yuan C, Zhang N, Hu X, et al. Microbiota-gut-brain axis in health and neurological disease: Interactions between gut microbiota and the nervous system. *J Cell Mol Med*. 2024;28(18):e70099. PUBMED | CROSSREF

175. Schächtle MA, Rosshart SP. The microbiota-gut-brain axis in health and disease and its implications for translational research. *Front Cell Neurosci*. 2021;15:698172. PUBMED | CROSSREF

176. Tucak P. Manual of clinical behavioral medicine for dogs and cats by KL Overall. Elsevier Mosby Publishing, St Louis, 2013. 812 pages. Price: A$79.95. ISBN 9780323008907. *Aust Vet J*. 2014;92(7):234. CROSSREF

177. Overall KL. Behavior problems of the dog and cat, Landsberg G., Hunthausen W., Ackerman L., 3rd ed., Saunders, Elsevier (2013), 472 pp.; $99.95 (paperback), ISBN: 9780702043352. *Vet J*. 2014;200(2):e5. CROSSREF

178. Manteca X, Camps T, Amat M, García-Morato C. Stress and behavior problems. World Small Animal Veterinary Association Congress Proceedings; 2016 Sep 27-30; Cartagena, Colombia. [place unknown: publisher unknown]; 2016.

179. Custance D, Mayer J. Empathic-like responding by domestic dogs (Canis familiaris) to distress in humans: an exploratory study. *Anim Cogn*. 2012;15(5):851-859. PUBMED | CROSSREF

180. Sundman AS, Van Poucke E, Svensson Holm AC, Faresjö Å, Theodorsson E, Jensen P, et al. Long-term stress levels are synchronized in dogs and their owners. *Sci Rep*. 2019;9(1):7391. PUBMED | CROSSREF

181. Grigg EK, Chou J, Parker E, Gatesy-Davis A, Clarkson ST, Hart LA. Stress-related behaviors in companion dogs exposed to common household noises, and owners' interpretations of their dogs' behaviors. *Front Vet Sci*. 2021;8:760845. PUBMED | CROSSREF

182. Ellis SL. Environmental enrichment: practical strategies for improving feline welfare. *J Feline Med Surg*. 2009;11(11):901-912. PUBMED | CROSSREF

183. Houser B, Vitale KR. Increasing shelter cat welfare through enrichment: a review. *Appl Anim Behav Sci*. 2022;248:105585. CROSSREF

184. Hermiston C, Montrose VT, Taylor S. The effects of dog-appeasing pheromone spray upon canine vocalizations and stress-related behaviors in a rescue shelter. *J Vet Behav*. 2018;26:11-16. CROSSREF

185. Kim YM, Lee JK, Abd el-aty AM, Hwang SH, Lee JH, Lee SM. Efficacy of dog-appeasing pheromone (DAP) for ameliorating separation-related behavioral signs in hospitalized dogs. *Can Vet J*. 2010;51(4):380-384. PUBMED

186. Overall KL. *Manual of Clinical Behavioral Medicine for Dogs and Cats*. Mosby; 2013.

187. Herron ME, Buffington CA. Environmental enrichment for indoor cats. *Compend Contin Educ Vet*. 2010;32(12):E4. PUBMED

188. Stella J, Croney C, Buffington T. Effects of stressors on the behavior and physiology of domestic cats. *Appl Anim Behav Sci*. 2013;143(2-4):157-163. PUBMED | CROSSREF

189. Stella JL, Buffington CAT. Pain and sickness behaviors. In: Stelow E, ed. *Clinical Handbook of Feline Behavior Medicine*. John Wiley & Sons; 2022: p103-128.

190. Freeman LM, Chandler ML, Hamper BA, Weeth LP. Current knowledge about the risks and benefits of raw meat-based diets for dogs and cats. *J Am Vet Med Assoc*. 2013;243(11):1549-1558. PUBMED | CROSSREF

191. Główny D, Sowińska N, Cieślak A, Gogulski M, Konieczny K, Szumacher-Strabel M. Raw diets for dogs and cats: potential health benefits and threats. *Pol J Vet Sci*. 2024;27(1):151-159. PUBMED | CROSSREF

192. Hu CJ, Garcia MA, Nihart A, Liu R, Yin L, Adolphi N, et al. Microplastic presence in dog and human testis and its potential association with sperm count and weights of testis and epididymis. *Toxicol Sci*. 2024;200(2):235-240. PUBMED | CROSSREF

193. National Academies of Sciences, Engineering, and Medicine; Division on Earth and Life Studies; Standing Committee on the Use of Emerging Science for Environmental Health Decisions; Health and Medicine Division; Board on Health Care Services; Forum on Aging, Disability, and Independence; National Cancer Policy Forum. *Companion Animals as Sentinels for Predicting Environmental Exposure Effects on Aging and Cancer Susceptibility in Humans: Proceedings of a Workshop*. National Academies Press; 2022.

194. Krzyzanowski B, Mullan AF, Dorsey ER, Chirag SS, Turcano P, Camerucci E, et al. Proximity to golf courses and risk of Parkinson disease. *JAMA Netw Open*. 2025;8(5):e259198. PUBMED | CROSSREF

195. Campbell M. Health effects of secondhand smoke on pets. In: Greenhalgh EM, Scollo MM, Winstanley MH, eds. *Tobacco in Australia: Facts and Issues*. Cancer Council Victoria; 2019.

196. Pocar P, Grieco V, Aidos L, Borromeo V. Endocrine-disrupting chemicals and their effects in pet dogs and cats: an overview. *Animals (Basel)*. 2023;13(3):378. PUBMED | CROSSREF

197. Walter KM, Lin YP, Kass PH, Puschner B. Association of polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) with hyperthyroidism in domestic felines, sentinels for thyroid hormone disruption. *BMC Vet Res*. 2017;13(1):120. PUBMED | CROSSREF

198. Memon MA, Xie H. *Integrative Veterinary Medicine*. 1st ed. John Wiley & Sons; 2023.

199. Robinson NG. Overview of Integrative Veterinary Medicine [Internet]. Merck. Published [2022]. Updated [2024]. Accessed [Jun 13, 2025]. https://www.merckvetmanual.com/therapeutics/integrative-complementary-and-alternative-veterinary-medicine/overview-of-integrative-veterinary-medicine

200. McFaddin LP. *Integrative Medicine in Veterinary Practice*. Wiley-Blackwell; 2024.

201. Brondeel C, Pauwelyn G, de Bakker E, Saunders J, Samoy Y, Spaas JH. Mesenchymal stem cell therapy in canine osteoarthritis research:"experientia docet"(experience will teach us). *Front Vet Sci*. 2021;8:668881. PUBMED | CROSSREF

202. Pan Y, Kennedy AD, Jönsson TJ, Milgram NW. Cognitive enhancement in old dogs from dietary supplementation with a nutrient blend containing arginine, antioxidants, B vitamins and fish oil. *Br J Nutr*. 2018;119(3):349-358. PUBMED | CROSSREF

203. Dewey CW, Rishniw M, Sakovitch K, Hollenbeck J. Oral administration of an integrative supplement (CogniCaps®) improves cognitive scores in aging dogs with canine cognitive dysfunction for at least two months: an open-label investigation in 10 dogs. *Open Vet J*. 2023;13(2):188-192. PUBMED | CROSSREF

204. Blanchard T, Eppe J, Mugnier A, Delfour F, Meynadier A. Enhancing cognitive functions in aged dogs and cats: a systematic review of enriched diets and nutraceuticals. *Geroscience*. 2025;47(3):2925-2947. PUBMED | CROSSREF

205. Hegedus C, Andronie L, Uiuiu P, Jurco E, Lazar EA, Popescu S. Pets, genuine tools of environmental pollutant detection. *Animals (Basel)*. 2023;13(18):2923. PUBMED | CROSSREF

206. Sumner RN, Harris IT, Van der Mescht M, Byers A, England GCW, Lea RG. The dog as a sentinel species for environmental effects on human fertility. *Reproduction*. 2020;159(6):R265-R276. PUBMED | CROSSREF

207. Quimby J, Gowland S, Carney HC, DePorter T, Plummer P, Westropp J. 2021 AAHA/AAFP feline life stage guidelines. *J Feline Med Surg*. 2021;23(3):211-233. PUBMED | CROSSREF

208. Creevy KE, Grady J, Little SE, Moore GE, Strickler BG, Thompson S, et al. 2019 AAHA canine life stage guidelines. *J Am Anim Hosp Assoc*. 2019;55(6):267-290. PUBMED | CROSSREF

209. Frye C, Carr BJ, Lenfest M, Miller A. Canine geriatric rehabilitation: considerations and strategies for assessment, functional scoring, and follow up. *Front Vet Sci*. 2022;9:842458. PUBMED | CROSSREF

210. Li W, Kim KR, Zhang D, Liu B, Dengler-Crish CM, Wen M, et al. Cost-effectiveness of physical activity interventions for prevention and management of cognitive decline and dementia-a systematic review. *Alzheimers Res Ther*. 2023;15(1):159. PUBMED | CROSSREF

211. Wernimont SM, Radosevich J, Jackson MI, Ephraim E, Badri DV, MacLeay JM, et al. The effects of nutrition on the gastrointestinal microbiome of cats and dogs: impact on health and disease. *Front Microbiol*. 2020;11:1266. PUBMED | CROSSREF

212. Ellis SL, Rodan I, Carney HC, Heath S, Rochlitz I, Shearburn LD, et al. AAFP and ISFM feline environmental needs guidelines. *J Feline Med Surg*. 2013;15(3):219-230. PUBMED | CROSSREF

213. Pilla R, Suchodolski JS. The gut microbiome of dogs and cats, and the influence of diet. *Vet Clin North Am Small Anim Pract*. 2021;51(3):605-621. PUBMED | CROSSREF

214. American Veterinary Medical Association. *Preventive Pet Healthcare*. American Veterinary Medical Association; 2025.

215. Vieira de Castro AC, Fuchs D, Morello GM, Pastur S, de Sousa L, Olsson IAS. Does training method matter? Evidence for the negative impact of aversive-based methods on companion dog welfare. *PLoS One*. 2020;15(12):e0225023. PUBMED | CROSSREF

216. Herron ME, Shofer FS, Reisner IR. Survey of the use and outcome of confrontational and non-confrontational training methods in client-owned dogs showing undesired behaviors. *Appl Anim Behav Sci*. 2009;117(1-2):47-54. CROSSREF

217. Hiby E, Rooney N, Bradshaw J. Dog training methods: their use, effectiveness and interaction with behavior and welfare. *Anim Welf*. 2004;13(1):63-69. CROSSREF

218. Hochman L. Photobiomodulation therapy in veterinary medicine: a review. *Top Companion Anim Med*. 2018;33(3):83-88. PUBMED | CROSSREF

219. Alves JC, Santos A, Jorge P, Carreira LM. A randomized double-blinded controlled trial on the effects of photobiomodulation therapy in dogs with osteoarthritis. *Am J Vet Res*. 2022;83(8):ajvr.22.03.0036. PUBMED | CROSSREF

220. Lenox CE, Bauer JE. Potential adverse effects of omega-3 fatty acids in dogs and cats. *J Vet Intern Med*. 2013;27(2):217-226. PUBMED | CROSSREF