Advances in Small Animal Care 2 (2021) 1–10
ADVANCES IN SMALL ANIMAL CARE

Multifactorial Rehabilitation Planning in Companion Animals

Denis J. Marcellin-Little, DEDV[a,*], David Levine, PT, PhD, DPT, CCRP, FAPTA[b], Darryl L. Millis, MS, DVM[c]
[a]Veterinary Orthopedic Research Laboratory, School of Veterinary Medicine, University of California, 1285 Veterinary Medicine DR, VM3A rm 4206, Davis, CA 95616, USA; [b]Department of Physical Therapy, 615 McCallie Avenue, University of Tennessee at Chattanooga, Chattanooga, TN 37403, USA; [c]Department of Small Animal Clinical Sciences, University of Tennessee College of Veterinary Medicine, C247 VTH, 2407 River Drive, Knoxville, TN 37996, USA

KEYWORDS
• Physical rehabilitation • Patient profile • Owner characteristics • Ergonomics • Electrophysical modalities
• Manual therapy • Therapeutic exercise

KEY POINTS
- The design of a physical rehabilitation program is based on the medical condition and the anticipated progression of that condition, the profile of the patient, and the owner.
- The evaluation of the patient profile includes age, size, body condition, body conformation, demeanor, and anticipated role and activities.
- The evaluation of the owner profile includes their background knowledge, their ability and willingness to provide care, and their goals.
- The evaluation of the medical condition includes initial severity, impact on limb use and on locomotion, pain burden, chronicity, and anticipated progression.
- Physical rehabilitation programs rely on ergonomics, electrophysical modalities, manual therapy, and therapeutic exercise. Electrophysical modalities and manual therapy dominate therapy in the near term. Exercise dominates therapy in the midterm and long term.

INTRODUCTION

Physical rehabilitation focuses on the management of transient or permanent disability using ergonomics, electrophysical modalities, manual therapy, and therapeutic exercise. Rehabilitation programs may draw from some or all of these approaches. The selection of a rehabilitation program is a complex process that aims to maximize safety and efficacy, while streamlining the logistics and labor involved. Also, physical rehabilitation programs can be conducted as inpatient, outpatient, or at home. The purpose of this article is to describe the rehabilitation planning in companion animal rehabilitation, focusing on the relative importance of ergonomics, electrophysical modalities, manual therapy, and therapeutic exercise, and on the logistics of rehabilitation for situations that have resulted in disuse of musculoskeletal tissues and disability of the patient.

GENERAL FEATURES OF REHABILITATION PROGRAMS

Physical rehabilitation is planned based on the needs of the disabled patient. Rehabilitation patients may have sustained an injury, may have undergone surgery, or may have a chronic disease. Most patients have

*Corresponding author, *E-mail address:* djmarcel@ucdavis.edu

https://doi.org/10.1016/j.yasa.2021.06.001
2666-450X/21/

orthopedic or neurologic problems, some patients have systemic or chronic problems that interfere with their mobility or their ability to perform daily activities.

Rehabilitation can vary widely from inpatient care with multiple daily therapy sessions, outpatient care, home-based therapy, to intermittent oversight that relies on few interventions. The level of care in physical rehabilitation is generally based on patient or disease parameters: how severe the problem is, how rapidly it is progressing, and how debilitating it is (Table 1).

The severity of a problem influences rehabilitation planning; for example, a dog with patellar luxation may have unilateral or bilateral luxation that may be intermittent or constant. Unilateral, intermittent (grade 1 or 2) luxation can lead to skipping (intermittent and brief episodes of non–weight-bearing lameness). Surgery is likely to be relatively noninvasive. After surgery, the patient is likely to be weight-bearing and only have modest rehabilitation needs. By comparison, a dog with bilateral and permanent (grade 4) luxation may have such internal rotation of the tibia relative to the femur that the quadriceps femoris no longer extends the stifle joint and may act as a flexor of the stifle. Over time, the dog may lose stifle extension and quadriceps length, and may alter its posture by shifting weight forward. Surgery is likely to be invasive and may be staged or done bilaterally, and stifle joint extension is likely to remain limited immediately after surgery. The patient is likely to need extensive rehabilitation to regain stifle joint extension and recover proper limb use and posture.

The rate of progression of a problem influences rehabilitation planning. A femoral fracture in a skeletally immature dog or cat carries a risk of quadriceps contracture that has been reported to be as high as 16% in 1 study of 28 cats with a femoral fracture [1]. Quadriceps contractures are challenging to manage when discovered promptly and are irreversible if left untreated for a few weeks. The potential rapid progression of a distal femoral fracture toward quadriceps contracture warrants frequent examination (daily, in the immediate postoperative period), combined with rehabilitation (protection from postoperative trauma, promotion of limb use, and stretching). Although most orthopedic problems do not progress as rapidly as a contracture of the quadriceps femoris muscle (approximately 2–3 weeks from onset to irreversible contracture), most orthopedic problems increase in impact and complexity when left untreated.

The most common complication in orthopedic patients is the onset of limb disuse resulting from sustained chronic pain most often caused by a partial failure of fixation, low-grade infection, or joint subluxation or instability. In most instances, limb disuse progresses over a period of 2 months to severe muscle atrophy, potential loss of joint motion, and local hyperesthesia. The physical rehabilitation examination should evaluate early limb disuse of musculoskeletal tissues and pain. This evaluation may be performed as early as the day after injury or surgery in some situations (such as a distal femoral physeal fracture in a puppy), or 10 to 14 days after injury or surgery in less critical

TABLE 1
Risks and Impact of Common Problems Managed Using Physical Rehabilitation

Problem	Risks	Impact
Fracture		
Long bone fracture	Potential high-energy injury	Tissue trauma, muscle damage
Articular fracture	Joint surface and capsule damage	Loss of joint motion, osteoarthritis
Cranial cruciate ligament injury	Chronicity, bilateral injury	Limb disuse, osteoarthritis
Patellar luxation	Loss of quadriceps extensor function	Loss of stifle joint motion, disuse
Femoral head ostectomy	Chronic joint instability	Loss of hip extension, limb disuse
Osteoarthritis	Inflammation, capsular fibrosis	Loss of joint motion, limb disuse
Disc herniation	Loss of motor function, deep pain	Loss of muscle mass (lower motor neuron), loss of mobility
Degenerative myelopathy	Progressive loss of motor function	Progressive loss of mobility
Fibrocartilaginous embolism	Loss of motor function, deep pain	Loss of muscle mass (lower motor neuron), loss of mobility

situations (such as after a tibial plateau leveling osteotomy in a patient with a chronic cruciate ligament rupture). Although patients with acute or rapidly developing conditions may be re-evaluated daily in some situations, patients with slowly progressive chronic problems are reevaluated less frequently.

The physical rehabilitation examination of neurologic conditions follows a pattern similar to orthopedic physical rehabilitation: patients with acute neurologic problems and rapidly evolving problems are evaluated immediately and often daily, and patients with slowly progressive problems are evaluated less often. Acute and rapidly evolving problems include the early postoperative period after intervertebral disc herniation, fibrocartilaginous embolic myelopathy, and spinal cord myelomyelacia. Slowly progressive problems include disc protrusion, the long-term recovery after intervertebral disc herniation, and degenerative myelopathy.

The level of disability resulting from injury or disease impacts rehabilitation needs. There is no standard or global measure of impairment or disability in companion animals for many conditions. Impairment includes being nonambulatory or being unable to perform daily activities (also described as activities of daily living). Large nonambulatory dogs are a major management burden for most owners, warranting a more comprehensive rehabilitation plan, and potentially requiring inpatient care. Severe impairment includes the loss of limb use (often described as limb disuse). Orthopedic problems that result in an initial loss of ambulation include pelvic and long bone fractures affecting multiple limbs. In the presence of cofactors or comorbidities, some dogs with joint pain or joint instability in multiple limbs may become nonambulatory. Some examples include large or overweight dogs with bilateral cranial cruciate ligament rupture or severe patellar luxation, or elbow joint osteoarthritis and pain secondary to elbow dysplasia. Severe impairment can include a partial loss of mobility that interferes with daily activities. For example, a dog may need to climb a set of stairs to go indoors and may be unable to do so as a consequence of chronic pain or loss of strength. Severe impairment may also include a loss of ability to posture to urinate or defecate, or a loss of ability to eat and drink. As described elsewhere in this article, limb disuse most often results from sustained chronic pain resulting from a biological problem (infection, loss of joint motion) or a mechanical problem (failure of fixation, joint instability). For working dogs and some sporting dogs, being unable to work or engage in sporting activity creates a major hardship for handlers or owners and might be construed as major disability. Fortunately, the majority of orthopedic and neurologic problems warranting physical rehabilitation are not associated with major impairment.

MUSCULOSKELETAL TISSUE ATROPHY RESULTING FROM DISUSE

The consequences of the severity of the problem, the progression of the problem, and how debilitating the problem is all affect the magnitude and severity of atrophy of musculoskeletal tissues. Muscle, cartilage, ligaments, tendons, and bone all undergo atrophy as a result of disuse or disability. In addition, fibrosis of tissues, especially joint capsule and muscle, must be considered when planning a rehabilitation program to improve the function of patients. Depending on the length of time atrophy is allowed to occur, or the severity of tissue atrophy, changes may be reversible or permanent. These factors have been reviewed previously [2,3]. Although the primary focus of rehabilitation is directed to the main tissues that are affected, such as a fractured bone or tendon repair, knowledge of the timing and magnitude of atrophy or the other tissues is key to preventing or reversing deleterious changes. As a general rule, muscles are among the first tissues to undergo atrophy, usually within 7 to 10 days of injury or after surgery, and are often the most noticed. For example, after acute rupture of a cranial cruciate ligament, muscle mass may decrease by one-third in the affected limb within 4 to 6 weeks if no rehabilitation is performed [4]. Recovery of muscle mass is more gradual over the course of several months, and attention should be paid to aerobic and strengthening exercises to restore more normal function. Neurogenic muscle atrophy as a result of lower motor neuron conditions is more severe and rapid and is generally permanent if neurologic function is not restored [5]. Cartilage atrophy also occurs with limb disuse, including decreased cartilage matrix and cartilage thickness and stiffness [6,7]. The restoration of cartilage function is possible, but the therapists should use caution when implementing a rehabilitation program to avoid continued deleterious changes that may occur from loading the joints too rapidly or with too much intensity early in the rehabilitation period [8]. Tendons lose strength and stiffness over several weeks and return to strength and stiffness generally occurs over several months with appropriate, gradually increased loading stresses [9]. The bulk of ligaments respond similarly to tendons regarding disuse and rehabilitation. However, the insertion site of ligaments on bones responds

much more slowly, primarily because of bone loss and because recovery of bone mineral content and density at the insertion sites is slow. In some instances, the ligament–bone junction may take a year or more to recover [10]. Bone is usually the slowest tissue to respond to decreased loading stresses and recovery. Bone atrophy generally takes 2 weeks to begin after injury or disuse, atrophy may continue for several weeks after loading of the bone occurs, and it may take months to regain lost bone mineral content [4]. If bone atrophy lasts for months, such as in a patient with deep pain negative intervertebral disc herniation patient, loss of bone mineral may be permanent, even if function is restored [11].

SELECTING MANAGEMENT OPTIONS DURING PHYSICAL REHABILITATION

Physical rehabilitation relies on 5 categories of actions and interventions: the rehabilitation assessment, electrophysical modalities, manual therapy, ergonomics, and therapeutic exercise. The rehabilitation assessment is done in all patients and is the basis for the selection of the 4 types of interventions (Fig. 1).

Electrophysical modalities include cold and heat, sensory and motor electrical stimulation, and energy such as ultrasound, electromagnetic field, acoustic shockwaves, and photons delivered to tissues. Manual therapy includes passive range of motion, massage, stretching, and joint mobilization. Ergonomics includes the use of specific resting and ambulation surfaces, external coaptation, and ambulation assistance. Therapeutic exercises are all forms of activity used to achieve specific therapeutic purposes such as strengthening, stretching, enhancing balance, and proprioception. Many rehabilitation plans draw from these 4 categories of therapy; however, because time and resources are most often limited, programs emphasize aspects of therapy over others based on therapeutic needs (Table 2). Also, clinicians have a responsibility to streamline and simplify therapy as much as possible to minimize the burden of care on the patient and owners, to maximize compliance, and to minimize cost. Electrophysical modalities are most often selected in the short term after injury or surgery to manage pain and inflammation. Manual therapy is used to stretch (improve range of motion) and is also used to decrease edema and provide pain relief via massage. Ergonomics is used to protect patients and to assist with the delivery of electrophysical modalities and therapeutic exercises. Exercise is key to preserving or recovering strength and mobility. The emphasis shifts over time, generally from electrophysical modalities in the short term, to manual therapy in the midterm, and to therapeutic exercise in the long term. The therapy plan informs who should be delivering therapy, where it should occur and how often it should take place.

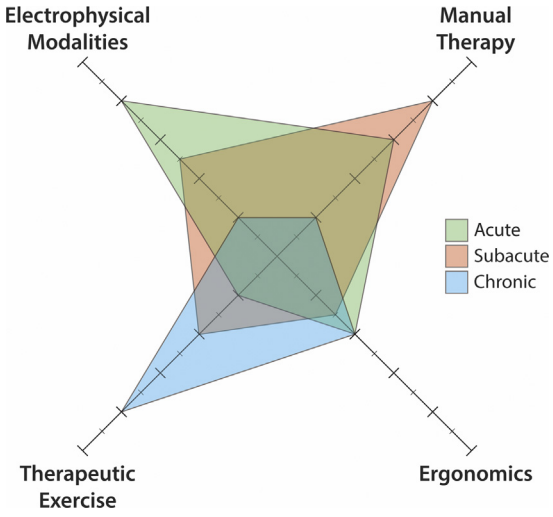

FIG. 1 The use of electrophysical modalities, manual therapy, ergonomics, and therapeutic exercise during physical rehabilitation varies over time. As an example, when considering physical rehabilitation at 3 stages of recovery after stabilization of a cranial cruciate injury, a shift in emphasis over time is visible from electrophysical modalities in the acute phase (*green*), to manual therapy in the midterm (*red*), and to therapeutic exercise in the long term (*blue*).

PROACTIVE AND RETROACTIVE FORMS OF PHYSICAL REHABILITATION

Physical rehabilitation can occur in preparation for an activity, including work or sport (conditioning), can occur proactively after an injury or surgery, or can occur retroactively when recovery after an injury or surgery is suboptimal.

Conditioning is the most proactive form of therapy. It relies on the principles of specificity and overload [12]. According to the specificity principle, activities during conditioning should match the type of activities a dog is being conditioned to do. According to the overload principle, activities should fatigue muscles to trigger metabolic changes that will enhance future performance. Conditioning takes place in the absence of injury and at a rate that ensures an increase in performance without the onset of injury. The conditioning rate varies based on the type of activity and the trainer or owner objectives and priorities.

TABLE 2
Use of Various Aspects of Physical Rehabilitation to Achieve Specific Medical Goals

Therapeutic Purpose	Electrophysical Modalities	Manual therapy	Ergonomics	Exercise
Prevent or eliminate edema	+++	+++	++	+
Prevent or alleviate pain	+++	++	+	+
Preserve or recover joint motion	-	++	-	++
Preserve or recover muscle strength	-	-	+	+++
Preserve or recover mobility	-	-	++	+++

Key: +++, primary and predictably efficacious therapeutic option; ++, efficacious therapeutic option; +, secondary and possibly efficacious option; -, minor or indirect benefits.

Proactive physical rehabilitation follows an injury or surgery and includes therapeutic steps that are implemented during recovery and in the absence of complications. Proactive physical rehabilitation usually is divided into 3 phases, starting with the acute phase, which focuses on minimizing pain, decreasing inflammation, and promoting the onset of limb use, therefore decreasing the likelihood of the onset of limb disuse. The acute phase usually lasts 7 to 14 days.

The subacute phase of proactive physical rehabilitation focuses on increasing limb use and joint motion. It lasts 2 to 4 weeks. The chronic phase focuses on completing healing and recovering muscle mass. It may last 1 to 3 months. Proactive physical rehabilitation is based on regular visits that ensure the appropriate transition from one phase to the next. It provides the opportunity to educate owners regarding recovery and enhances the safety of that recovery.

Retroactive physical rehabilitation is used to address the failure to recover from an injury or surgery. It is generally implemented to manage limb disuse, that is, to recover limb use, recover the loss of muscle mass, or recover joint motion. Retroactive rehabilitation requires a more complex assessment of the cause of limb disuse. Mechanical factors and pain may contribute to the need for retroactive rehabilitation. The pain patterns, which are more complex in patients with limb disuse owing to local amplification of pain perception, regional and central sensitization, hyperalgesia, and allodynia are analyzed. The impairment in strength (loss of muscle mass) and joint motion are evaluated. Pain is treated first. A specific set of activities is developed that ensures appropriate limb use when standing, walking, and trotting. Parameters explored include the type of constraint (harness type, leash length, the position of the handler relative to the dog during exercise), the type of activity (intensity, duration, frequency), and the exercise environment (location, ground surface). Retroactive physical rehabilitation is more complex and less predictably successful than proactive physical rehabilitation.

Logistics of Physical Rehabilitation

For acute care, physical rehabilitation is often done daily as an inpatient or an outpatient. In subacute care, physical rehabilitation is often offered as outpatient care, 1 to 3 times per week. For chronic care, physical rehabilitation visits often occur weekly or every other week. The frequency of physical rehabilitation visits is increased when patients have severe problems, including the loss of locomotion, limb disuse, and severe sustained pain. Frequency is also increased when managing rapidly evolving problems, such as a loss of joint motion in a skeletally immature patient. The frequency of physical rehabilitation is also increased when a dog is not meeting progress milestones at anticipated time points and when owners are unable or unwilling to participate in rehabilitation care, but are seeking rehabilitation. It may be most effective to hospitalize a patient who needs daily rehabilitation care or whose transportation to and from home is challenging.

MEDICAL CONDITIONS

Several aspects of medical problems greatly impact rehabilitation planning, including the anticipated duration, the anticipated pain, and the anticipated impact.

The duration of medical conditions warranting rehabilitation varies widely from brief and transient to permanent. Problems with brief duration include acute orthopedic injury such as low-energy fractures, acute joint luxations, or acute tendon ruptures. Relatively

young patients undergoing uncomplicated tibial plateau leveling (to manage a cranial cruciate ligament injury) or undergoing a total hip replacement also fit in this category [13]. Neurologic patients with acute disc herniation who have motor function after surgery also fit in this category. For those patients, pain and inflammation can be managed with relatively few interventions, for example, with cold therapy and passive range of motion but without the need for more labor-intensive electrophysical modalities such as therapeutic ultrasound or transcutaneous electrical stimulation. Pain and inflammation are expected to subside substantially within 1 week, and limb use and mobility are expected to return within a few days. In the subacute rehabilitation period, joint motion is unlikely to be impacted significantly, and therefore a focus on stretching is unnecessary. In the chronic rehabilitation period, the dog may look and feel normal; however, their musculoskeletal tissues are relatively weak and are still undergoing remodeling. The exercise program restricts high-impact activity to avoid excessive stress on healing tissues while promoting low-impact activities that prevent muscle atrophy and promote normal limb use, a normal posture, and a normal gait. Because many owners and dogs are unfamiliar with control, educating owners to balance dog control and activity restriction on the one hand, and the promotion of low-impact activity on the other hand, is often challenging. Overall, physical rehabilitation for focal and transient problems is predictably successful and should be affordable to most owners, owing to its relative simplicity. Alternatively, chronic problems warranting physical rehabilitation can affect patients in the long term or may result in permanent deficits in function. These chronic problems may include slowly progressive conditions resulting in pain and inflammation, or neurologic compromise. Problems such as severe osteoarthritis affecting multiple limbs, long-term joint subluxation or luxation, musculoskeletal tissue fibrosis with loss of joint motion, permanent or progressive neurologic compromise, fracture nonunions, chronic low-grade musculoskeletal tissue infection, loose total joint components, and some forms of neoplasia fit in this category. Because the objective of rehabilitation shifts from curing to managing the patient (optimizing quality of life, preserving mobility), the presence of long-term or permanent disability greatly influences the physical rehabilitation plan.

The pain burden on rehabilitation patients varies widely and has a profound impact on rehabilitation planning. It is, therefore, critically important to evaluate pain in rehabilitation patients. A mild pain experience treated without delay can often be managed with a nonsteroidal anti-inflammatory drug combined with rest, without extensive use of electrophysical modalities and manual therapy. In contrast, the treatment of severe acute or postoperative pain and the treatment of sustained chronic pain must be more comprehensive, multifocal, and integrated with the pharmacologic pain management. Whenever possible, the cause of sustained chronic pain should be identified and eliminated. Subjectively, sustained chronic pain is particularly likely in a patient with neoplasia and failure of fixation after the stabilization of a fracture. Sustained chronic pain happens in a subset of patients with joint disease such as cruciate ligament injury, patellar luxation, or elbow and hip dysplasia. Sustained chronic pain also occurs after surgery for these and other conditions, and seems to be more likely when surgery addresses the problem only partially. As an example, a femoral head ostectomy can lead to severe limb disuse possibly because of the addition of acute pain (from surgery) on chronic pain (from hip dysplasia), and possibly because the pseudoarthrosis resulting from the removal of the femoral head has physical limitations, such as lack of stability under load, restriction of motion, or chronic inflammation.

The anticipated impact of a medical problem on limb use and mobility has a major impact on physical rehabilitation planning. Limb use is likely to be compromised in patients with problems affecting joint motion, including loss of joint motion or an excess of joint motion. Subjectively, the loss of joint motion is more detrimental to limb use than excess joint motion. Loss of joint motion can be primary developmental or secondary. Primary loss of motion can be neurologic or orthopedic (Fig. 2) [14]. A mild loss of motion generally has no negative impact on limb use. For example, with hip dysplasia, a modest loss of hip extension is likely. That loss has no clear detrimental impact on limb use [15]. Loss of joint motion has a profound impact when the loss is severe. For example, a loss of carpal extension of 50° precludes the use of a forelimb [14,16]. Loss of joint motion also has a profound impact when severe pain is perceived at the end of joint motion, such as in some dogs with severe patellar luxation or partial tear of the cranial cruciate ligament.

Evaluation of full joint motion and the response to full joint motion are therefore key aspects of the rehabilitation assessment [17]. Joint motion may be evaluated subjectively during palpation. When abnormal motion is detected, it can be measured objectively using goniometry or photography [18]. Excess motion is most often the consequence of joint laxity or luxation. The most common developmental joint luxation is hip

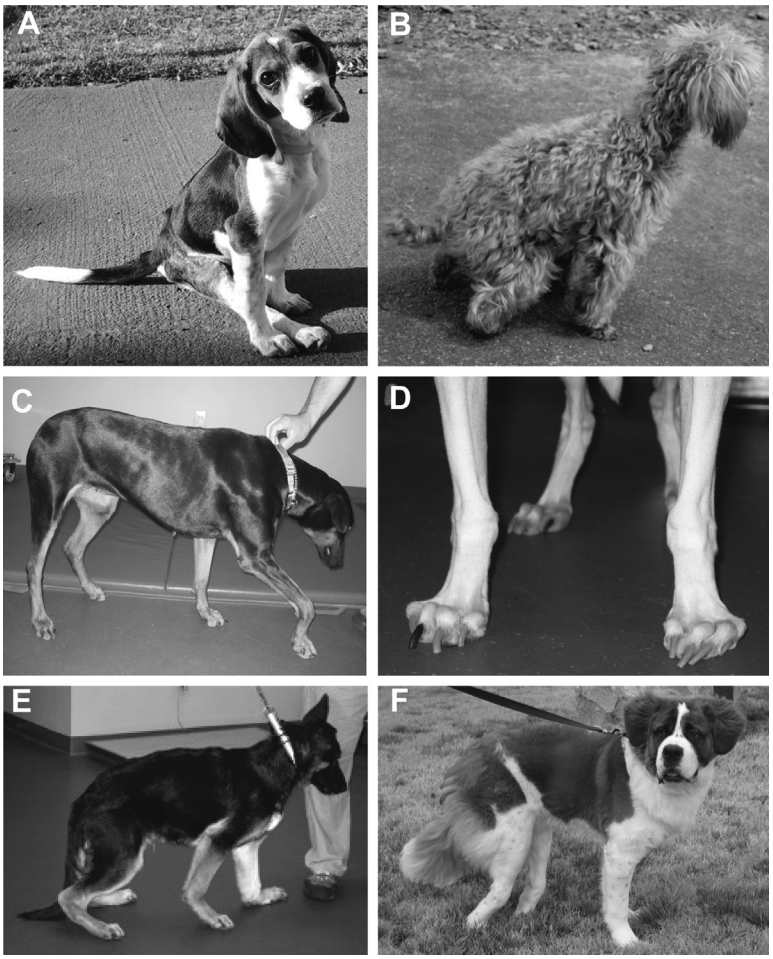

FIG. 2 Loss of joint motion can affect all joints and has a profound impact on physical rehabilitation of dogs. Subjectively, the stifle joint is most vulnerable, as seen in a young Beagle after a bite to the thigh region (loss of flexion, **A**) or a Miniature Poodle with bilateral grade 4 patellar luxation (loss of extension, **B**). Loss of motion can also occur in the carpus, as seen a young Doberman with a developmental loss of extension associated with a lack of length in the flexor carpi ulnaris muscle (**C**) or in a Whippet with a lack of digit extension, resulting from a lack of length in the digital flexor muscles (**D**). Excess motion also impacts physical rehabilitation. Subjectively, the carpus and tarsus are most vulnerable to excess joint motion compared with other major joints. A young German Shepherd has lax carpi (**E**) and a young Saint Bernard has hyperextended tarsi as a consequence of hip dysplasia (**F**).

luxation secondary to excessive hip laxity. Other developmental joint luxations include shoulder luxation, most often medially, in small dogs. Elbow luxation or, more specifically, lateral or caudolateral luxation of the radial head relative to the humerus may be seen in young dogs. Often, these dogs have a large, heavy body and are chondrodystrophic (Bulldogs). In the tarsus, hyperextension can result from a cranial weight shift present in large dogs with severe hip pain. The tarsus become more and more extended over time and that excessive extension interferes with limb use. Large dogs with angular deformities of the distal portion of the femur can have intertarsal rotational subluxation, where the pes rotates externally in relation to the tarsus. Mobility also has a major impact on rehabilitation. Baseline mobility may be compromised owing to chronic joint disease (osteoarthritis) affecting multiple limbs, excess weight, a large size, or systemic or neurologic problems. Postinjury mobility may be compromised by a loss of limb use, particularly when multiple limbs are affected. Common causes of loss of mobility include intervertebral disc herniation, pelvic

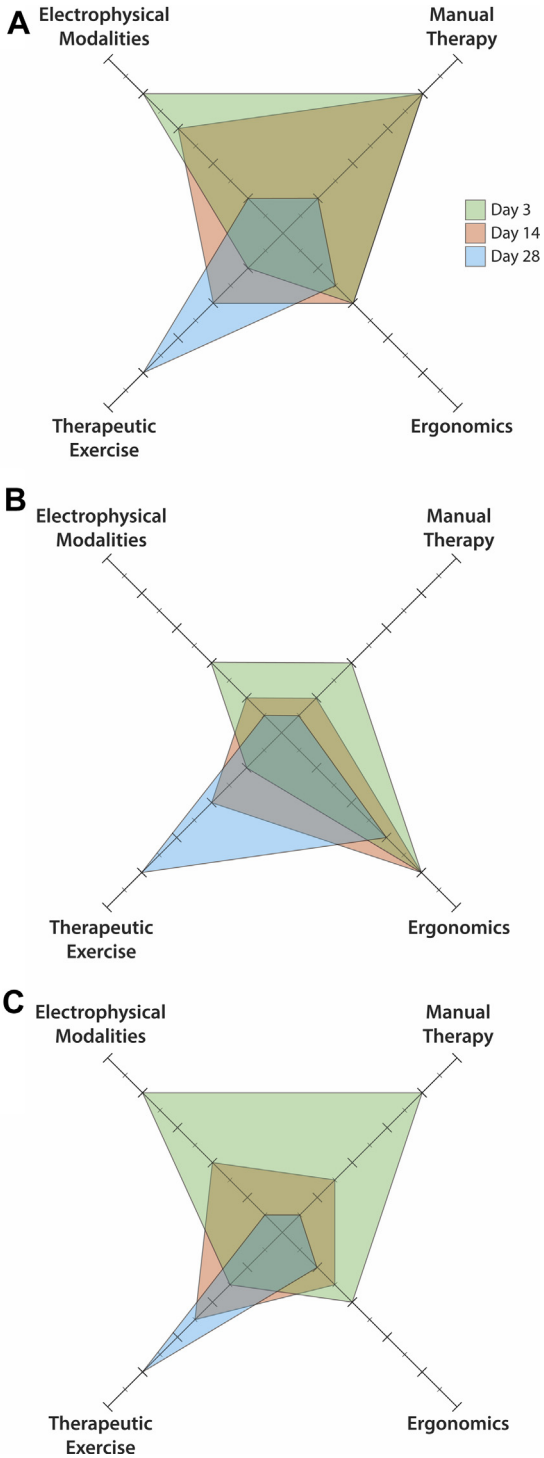

FIG. 3 Care algorithms representing the reliance on the 4 key aspects of rehabilitation: electrophysical modalities, manual therapy, therapeutic exercise, and ergonomics over time for various patients commonly receiving physical rehabilitation. For a patient undergoing surgery to stabilize a cranial cruciate ligament-deficient stifle joint (**A**), the initial emphasis of care (at day 3, acute phase, green shaded area) would be placed on electrophysical modalities (cold, therapeutic ultrasound, TENS, photobiomodulation) and manual therapy (passive range of motion, massage). At day 14 (subacute phase, red shaded area), the emphasis would shift to manual therapy (stretching) and therapeutic exercise. At day 28 (chronic phase, blue shaded area) the emphasis would shift further to therapeutic exercise. For a dog recovering from surgery to manage herniation on an intervertebral disc (**B**), the emphasis of care would initially be placed on ergonomics (eg, nursing care, ambulation assistance) with some care involving electrophysical modalities and manual therapy. At day 14, the emphasis on ergonomics would remain, with an increase of emphasis toward therapeutic exercise. At day 28, the emphasis would shift to therapeutic exercise while continuing the focus on ergonomics (ambulation assistance). For a dog recovering from surgery to manage a fracture (**C**), the initial emphasis of care would be on electrophysical modalities (cold, TENS, therapeutic ultrasound) and manual therapy (passive range of motion and massage). That emphasis would shift progressively to exercise at days 14 and 28.

fractures or bilateral long bone fractures, and bilateral cranial cruciate ligament injury, the latter in dogs with a baseline compromise in mobility. The loss of muscle mass, in the absence of chronic pain, may not lead to limb disuse or to the loss of mobility.

PATIENT PROFILE

Physical rehabilitation planning is influenced by the patient's profile, including age, size, conformation, and anticipated functions and activities. Skeletally immature dogs are high-risk patients because young dogs undergo rapid growth and rapid tissue turnover. Although healing in growing dogs is rapid, limb disuse, loss of joint motion, and tissue loss also have a rapid onset. Bone loss can develop rapidly as a consequence of limb disuse or joint immobilization. Mechanically, bone and fracture repairs are fragile relative to bone and fracture repairs in adult dogs, potentially incentivizing clinicians to protect repairs with a bandage or splint. However, bandages and splints carry a high risk of complications in growing dogs. Growing dogs have an exaggerated connective tissue response to injury, relative to adult dogs. That response may lead to fibrosis of the joint capsule, adhesions between tissue planes, and to the invasion of limb compartments, including muscles, with rapidly maturing fibrous

tissue. Muscle and joint laxity (carpal hypertension, flaccid digits) can occur after a brief period of limb disuse. Growing dogs tend to have excitable personalities, making the control of their activity and the delivery of nursing and rehabilitation care more challenging. Owners and therapists may have difficulties with manual therapy and therapeutic exercises because of growing dogs' brief attention span and low obedience level. In addition, growing dogs can possibly be at indirect risk because owners may subconsciously think that youth positively impacts the likelihood of rapid and complete healing, when experience suggests that growing dogs have a higher complication rate than adult dogs after injury or surgery [19]. It is also possible that the bond between owners and growing dogs may not be as strong as the bond with adult dogs who may be more likely to be considered long-term family members; this factor may result in less attention to rehabilitation of younger dogs performed by the owner. Geriatric patients are also at risk because of the greater likelihood of orthopedic comorbidities and possibly a lack of drive during recovery.

Patient size influences the physical rehabilitation plan. Small patients are at an increased risk of fracture, such as of the radius, and other injuries. Subjectively, small patients are also at risk of limb disuse, possibly because they can ambulate effectively on 3 legs. The demeanor of small patients can complicate the planning of a therapeutic program. Very large dogs also present challenges in physical rehabilitation. They are at risk of becoming nonambulatory and they are difficult to manage, often requiring the efforts of several people. Their large size also complicates the planning of a therapeutic exercise program. Overweight dogs also have complicated physical rehabilitation plans because overweight and obese dogs are at risk of becoming nonambulatory and require therapeutic exercise tailored to their mobility and fitness. Dogs with chondrodystrophic conformation also need oversight during rehabilitation because of potential comorbidities (upper airway syndrome, limb deformity, elbow joint subluxation, patellar luxation). The patient's demeanor influences physical rehabilitation. Poorly socialized or aggressive dogs may be best suited for hands-off rehabilitation based mostly on therapeutic exercise provided by the owner, whereas shy dogs may be best suited for hand-on rehabilitation with manual therapy.

OWNERSHIP PROFILE

The ownership profile impacts physical rehabilitation. Owners have variable background knowledge in medical problems, physical restrictions and risks, commitment to recovery, and ability to engage in hands-on (massage, passive range of motion, cold therapy, stretching) and hands-off (therapeutic exercise) activities. Also, an owner's intent for their dog to engage in work or sporting activities varies widely. Finally, an owner's ability and willingness to incur the costs of care vary widely. The rehabilitation clinician adapts care, including the type of care (inpatient, outpatient, or home-based therapy) and visit frequency and duration to the level of owner involvement, abilities and expectations.

CARE ALGORITHMS

The development of a rehabilitation program is based on the intent of the clinician to incorporate various aspects of physical rehabilitation: electrophysical modalities, manual therapy, therapeutic exercise, and ergonomics (Fig. 3). Reliance on electrophysical modalities and manual therapy is initially high. Reliance on therapeutic exercise is initially modest and increases overtime to become the dominant form of therapy. Reliance on ergonomics is often biphasic: initially high in trauma and in neurologic patients and high over the long term in patients with chronic and progressive diseases.

CLINICS CARE POINTS

- Physical rehabilitation programs are particularly critical when managing patients with severe conditions that interfere with limb use and mobility, that carry a heavy pain burden, and that have a rapid progression.
- Physical rehabilitation programs are particularly important in patients with profiles that are associated with an increased complication rate, such as very small and very large dogs, skeletally immature and geriatric dogs, dogs with a heavy body condition, and chondrodystrophic dogs.
- Physical rehabilitation is simpler and more predictably efficacious when implemented proactively, when chronicity is minimal, and before the onset of complications.

ACKNOWLEDGMENTS

The authors thank Chrisoula Toupadakis Skouritakis, PhD, for assistance with illustrations.

DISCLOSURE

The authors report no conflict of interest.

REFERENCES

[1] Fries CL, Binnington AG, Cockshutt JR. Quadriceps contracture in four cats: a complication of internal fixation of femoral fractures. Vet Comp Orthop Traumatol 1988;1:38–43.

[2] Kirkby Shaw K, Alvarez L, Foster SA, et al. Fundamental principles of rehabilitation and musculoskeletal tissue healing. Vet Surg 2020;49:22–32.

[3] Millis DL. Responses of musculoskeletal tissues to disuse and remobilization. In: Millis DL, Levine D, editors. Canine rehabilitation and physical therapy. Philadelphia, PA: Saunders; 2014. p. 92–153.

[4] Francis DA, Millis DL, Head LL. Bone and lean tissue changes following cranial cruciate ligament transection and stifle stabilization. J Am Anim Hosp Assoc 2006; 42:127–35.

[5] Gordon T, Mao J. Muscle atrophy and procedures for training after spinal cord injury. Phys Ther 1994;74: 50–60.

[6] Palmoski M, Perricone E, Brandt KD. Development and reversal of a proteoglycan aggregation defect in normal canine knee cartilage after immobilization. Arthritis Rheum 1979;22:508–17.

[7] McDonough AL. Effects of immobilization and exercise on articular cartilage-a review of literature. J Orthop Sports Phys Ther 1981;3:2–5.

[8] Palmoski MJ, Brandt KD. Running inhibits the reversal of atrophic changes in canine knee cartilage after removal of a leg cast. Arthritis Rheum 1981;24:1329–37.

[9] Yasuda K, Hayashi K. Changes in biomechanical properties of tendons and ligaments from joint disuse. Osteoarthr Cartil 1999;7:122–9.

[10] Noyes FR. Functional properties of knee ligaments and alterations induced by immobilization: a correlative biomechanical and histological study in primates. Clin Orthop Relat Res 1977;210–42.

[11] Jortikka MO, Inkinen RI, Tammi MI, et al. Immobilisation causes longlasting matrix changes both in the immobilised and contralateral joint cartilage. Ann Rheum Dis 1997;56:255–61.

[12] Marcellin-Little DJ, Levine D, Taylor R. Rehabilitation and conditioning of sporting dogs. Vet Clin North Am Small Anim Pract 2005;35:1427–39.

[13] Marcellin-Little DJ, Doyle ND, Pyke JF. Physical rehabilitation after total joint arthroplasty in companion animals. Vet Clin North Am Small Anim Pract 2015;45: 145–65.

[14] Marcellin-Little DJ, Levine D. Principles and application of range of motion and stretching in companion animals. Vet Clin North Am Small Anim Pract 2015;45: 57–72.

[15] Greene LM, Marcellin-Little DJ, Lascelles BD. Associations among exercise duration, lameness severity, and hip joint range of motion in Labrador Retrievers with hip dysplasia. J Am Vet Med Assoc 2013;242:1528–33.

[16] Kwan TW, Marcellin-Little DJ, Harrysson OL. Correction of biapical radial deformities by use of bi-level hinged circular external fixation and distraction osteogenesis in 13 dogs. Vet Surg 2014;43:316–29.

[17] Levine D, Millis DL, Marcellin-Little DJ. Introduction to veterinary physical rehabilitation. Vet Clin North Am Small Anim Pract 2005;35:1247–54, vii.

[18] Jaegger G, Marcellin-Little DJ, Levine D. Reliability of goniometry in Labrador Retrievers. Am J Vet Res 2002; 63:979–86.

[19] Bardet JF. Quadriceps contracture and fracture disease. Vet Clin North Am Small Anim Pract 1987;17:957–73.