Effects of early intensive postoperative physiotherapy on limb function after tibial plateau leveling osteotomy in dogs with deficiency of the cranial cruciate ligament

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Objective—To determine effects of early intensive postoperative physiotherapy on limb function in dogs after tibial plateau leveling osteotomy (TPLO) for deficiency of the cranial cruciate ligament (CCL).

Animals—8 adult dogs with CCL deficiency.

Procedure—After TPLO, dogs underwent a physiotherapy program 3 times/wk (physiotherapy group; n = 4) or a walking program (home-exercise group; 4). All dogs were evaluated before surgery, 1 and 10 days after surgery, and 3 and 6 weeks after surgery. Thigh circumference (TC), stifle joint flexion and extension range of motion (ROM), lameness, and weight-bearing scores were recorded.

Results—Before surgery, CCL-deficient limbs had significantly reduced TC and reduced flexion and extension ROMs, compared with values for the contralateral control limb. Six weeks after TPLO, the physiotherapy group had significantly better TC than the home-exercise group, with the difference no longer evident between the affected and nonaffected limbs. Extension and flexion ROMs were significantly greater in the physiotherapy group, compared with values for the home-exercise group, 3 and 6 weeks after surgery. Six weeks after surgery, the difference in flexion and extension ROMs was no longer evident between the affected and nonaffected limbs in the physiotherapy group. Both groups had improvements for lameness and weight-bearing scores over time, but no difference was found between the 2 groups.

Conclusions and Clinical Relevance—After TPLO in CCL-deficient dogs, early physiotherapy intervention should be considered as part of the postoperative management to prevent muscle atrophy, build muscle mass and strength, and increase stifle joint flexion and extension ROMs. (*Am J Vet Res* 2006;67:xxx–xxx)

Deficiency of the CCL is the most commonly diagnosed stifle injury in dogs.[1,2] It results in lameness, muscle atrophy, and ongoing poor limb function even after surgical correction.[3,4] There have been numerous studies investigating the benefits of various surgical procedures for CCL deficiency. However, only in a few studies[1,2,5,6] has attention been paid to the importance of postoperative rehabilitation because of the recent increased awareness and concern about the harmful effects of immobilization and the ongoing problems of atrophy, poor limb function, and development of osteoarthritis.[1,2,6-8]

After surgery for correction of CCL deficiency in humans, protocols of early intensive physiotherapy, including immediate weight bearing, can reduce muscle atrophy; restore ROM, strength, and function for the knee joint; and reduce the incidence of osteoarthritis without causing pain or compromise of the repair.[9-12] After surgery, joint biomechanics and proprioception are altered, and even a good surgical outcome may not equate to functional recovery or return of neuromuscular control of the limb.[13] Accelerated CCL rehabilitation protocols are now the standard, with up to 96% of knee surgeons in Australia routinely referring their patients for physiotherapy after CCL surgery. Exercises performed during weight bearing in humans or closed kinetic chain exercises in humans can help to restore proprioception and aid in rebuilding joint stability with a reduction in pain and more rapid return to function.[13-15]

Several authors[1,2,6] have documented the benefits of postoperative physiotherapy in the recovery of dogs after extracapsular surgery to stabilize the CCL. Various physiotherapeutic interventions have been investigated, including electrical stimulation,[6] massage,[1] passive ROM exercises,[1] leash walking,[1] swimming,[1,2] and treadmill exercise.[3] Benefits of physiotherapy over more typical restricted exercise include improvement in scores for lameness evaluation, larger TC, and reduced radiographic bony changes in 1 study[6]; improvements in limb function determined by force-plate analysis in another study[1]; and improvements in ROM of the stifle joint in a third study.[2] However, in each of those studies, interventions did not commence until 3 weeks after surgery and exercises were not performed by a physiotherapist.

The TPLO is a relatively new and innovative surgical treatment for CCL-deficient stifles.[5] To our knowledge, there have been no investigations of the

Received April 12, 2005.
Accepted July 11, 2005.
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The authors thank Allan Lisle for assistance with the statistical analysis.
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CCL	Cranial cruciate ligament
ROM	Range of motion
TC	Thigh circumference
TPLO	Tibial plateau leveling osteotomy
UWTM	Underwater treadmill
TPA	Tibial plateau slope angle

effects of physiotherapy after TPLO surgery for CCL-deficient dogs, although a rehabilitation program that includes UWTM exercise has been suggested[16] to allow exercise with reduced weight-bearing stresses while the osteotomy heals. Use of UWTM exercise in the rehabilitation of dogs is increasingly popular because of the ability to exercise dogs during weight bearing with reduced loading as a result of the buoyant force of the water.[17] Exercise on a UWTM can increase joint ROM when the water level is higher than the joint of interest.[18] In humans, aquatic therapy also often forms part of a rehabilitation program after CCL surgery. A study[19] comparing an aquatic exercise program versus a land based exercise program after CCL surgery found that those who exercised in water had less effusion and better function with no difference in TC improvements between the 2 groups.

Ongoing muscle atrophy after CCL surgery is a common problem in dogs.[3,4] In 1 study,[20] thigh muscle mass continued to decrease for up to 5 weeks after transection of the CCL and began to increase only at 10 weeks after CCL transection, despite immediate stabilization of the joint after CCL transection. Thus, it seems crucial to commence physiotherapy in this early postoperative period and continue it for at least 6 weeks.

With the current interest in rehabilitation of dogs after CCL surgery and the increased use of the TPLO procedure for CCL deficiency, it seems timely to investigate the effects of physiotherapy after TPLO. Analysis of evidence from studies[9-12] in humans suggests that commencing rehabilitation early after knee surgery and including weight-bearing exercise are crucial for reducing muscle atrophy and restoring ROM, strength, and function of the joint with less pain. Therefore, the objective of the study reported here was to investigate the effects of an early intensive postoperative physiotherapy program (including UWTM exercise) and a home-exercise program on limb function after TPLO surgery for CCL deficiency in dogs.

Materials and Methods

Animals—All adult dogs referred to the Animal Surgery Centre for examination and requiring a TPLO between April 2004 and July 2004 were considered for inclusion in the study. Criteria for inclusion included unilateral CCL deficiency, lack of any other neurologic or orthopedic injuries or disease, body weight between 20 and 40 kg, and body condition score between 5 and 7 (scale of 1 to 9, with 1 being emaciated and 9 being grossly obese).[21] Before surgery, all owners were offered the opportunity for their dogs to receive postoperative physiotherapy at our facility,[a] with attendance required 3 times/wk. Dogs were then assigned to 1 of 2 treatment groups (postoperative physiotherapy group or home-exercise group) on the basis of the owners' decision to bring their dogs to the center 3 times/wk. Thus, random allocation was not performed, but because this was a clinical trial, we wanted to reflect the situation typically encountered in practice.

Data collection—Before surgery, dogs underwent orthopedic, radiographic, and physiotherapy examinations. Data were collected for each dog, including signalment (body weight, condition score, breed, sex, and age), limb affected, and duration of lameness.

A routine orthopedic examination was performed on all dogs by the same surgeon (CAP) as part of the initial consultation. Caudocranial and mediolateral radiographic views of the stifle were obtained by the surgeon to determine the TPA and evidence of any other condition. Radiography was repeated immediately after surgery and 6 weeks after surgery to evaluate the TPA, plate and screw position, and bony healing. Dogs that had a unilaterally deficient CCL and whose owners elected that they should undergo a TPLO were then subjected to physiotherapy examination.

All physiotherapy examinations were performed by the same investigator (MLM), who was aware of the treatment group for each dog. Measurements were recorded for all dogs before surgery, at time of discharge on the first day after surgery, at day 10 after surgery (day of suture removal), and at the end of weeks 3 and 6 after surgery.

A score (maximum of 5) was assigned for lameness, willingness to bear weight on the affected limb while standing, and willingness to lift the contralateral limb **(Appendix 1)**. Flexion and extension ROMs of the stifle joint were measured in triplicate by use of a single standard 18-cm full-circle plastic universal goniometer. Measurements were made for each limb with the dogs awake and positioned in lateral recumbency. The axis of the goniometer was placed over the lateral aspect of the stifle joint axis. The femoral arm was aligned with the greater trochanter and the tibial arm with the lateral malleolus. End of ROM was determined when the limb could not be moved any further or when the dog flinched, vocalized, or pulled the limb away. Presurgical measurements were obtained without shaving the limb; measurements obtained after surgery were obtained on shaved limbs.

Measurement of TC—The TC was measured at the midpoint on the long axis of the femur. Length of the femur was measured by use of a single standard 30-cm plastic ruler at the point half the distance between the greater trochanter and the lateral femoral condyle. The TC was measured by use of a single standard plastic nonstretchable metric tape; measurements were obtained in triplicate with the dogs positioned in lateral recumbency, and the tape measure was placed around the limb. Mean of the 3 TC values was calculated and recorded.

Surgical procedure—A TPLO was performed on the affected limb of each dog by the same surgeon (CAP), who was licensed to perform the procedure. The surgery was performed as described elsewhere.[22] Joint arthrotomy and meniscectomy or meniscal release were performed at the discretion of the surgeon on the basis of the surgeon's clinical assessment. The limbs were not bandaged after surgery.

Meloxicam (0.2 mg/kg, IV) was administered approximately 30 minutes before surgery, and each dog was administered morphine as an epidural (0.2 mg/kg) before surgery. After surgery, dogs were administered morphine (0.3 mg/kg, IM, q 4 h for 24 hours) as an analgesic; dogs were hospitalized overnight. Dogs were discharged to their owners on the day after surgery; meloxicam (0.1 mg/kg, PO, q 24 h) was routinely administered by the owners for approximately 5 to 10 days after surgery.

Physiotherapy treatment—Within the first 2 hours after surgery, an ice pack consisting of crushed ice in a plastic bag was wrapped in a clean wet towel and placed around the operated stifle joint for 20 minutes. Then, flexion and extension passive ROMs were performed on the operated stifle for 30 repetitions. On the first day after surgery, dogs were placed on a short leash and allowed to ambulate outside to defecate and urinate. A sling was used to provide support when a dog appeared unsteady.

At the time of discharge from the hospital, written instructions and a description of exercises were provided to each owner. Owners also received training in the exercise techniques by the physiotherapist (MLM). Instructions included that the owners should ensure their dog was kept restricted inside the house or a small room for the first 6 weeks after surgery; dogs were not to have unsupervised exercise; no running, jumping, or climbing of stairs was allowed; and dogs were to be assisted when getting into and out of a vehicle. Each owner was given a logbook to record information on a daily basis; the logbooks were reviewed at each physiotherapy session.

A progressive program of physiotherapy was initiated, including massage of the thigh muscles, passive ROM of the stifle joint, functional weight-bearing exercises, use of icepacks, and controlled walking on a leash from weeks 1 to 6 after surgery (**Appendix 2**). The dogs returned to the facility[a] for physiotherapy 3 times/wk for 6 weeks. At each physiotherapy session, the physiotherapist performed one of the exercise sessions for that day. Exercise techniques used by the owners were monitored by the physiotherapist, and additional training was provided to the owners when necessary. At the end of each week, exercises for the following week were demonstrated to the owners, who then practiced performing them. After suture removal on day 10 after surgery, progressive UWTM exercise was completed at each physiotherapy session in place of walking on a leash for that day.

The UWTM[b] was 1.2 m wide × 2 m long. The tank had glass panels on each side so that ambulation could be viewed at all times. Water in the tank was maintained in accordance with standards set by the Victorian Health Department,[23] with free chlorine of 2 to 3 mg/kg, pH of 7.6 to 7.8, total alkalinity of 150 to 200 mg/kg, and calcium hardness of 60 to 100 mg/kg. Water temperature was maintained at 32°C. The tank was filled to the level of the greater trochanter, as described elsewhere.[24]

The first session in the UWTM was also used for the acclimation process. Speed of the UWTM belt was determined for each dog at each session. The selected speed allowed each dog to maintain a comfortable walking pace. It differed slightly among dogs but was always within the range of 14 to 20 m/min for the duration of the study. During the sessions, the UWTM belt was periodically stopped and the dogs were allowed to rest in the water-filled tank; the dogs were allowed to move freely around the tank during the rest periods.

Home-exercise treatment—At the time of discharge from the hospital, owners of dogs in the home-exercise group were provided with the same instructions given to owners of the physiotherapy group (ie, dogs were restricted inside the house or to a small room for the first 6 weeks after surgery; no unsupervised exercise; no running, jumping, or climbing of stairs; and dogs were to be assisted when getting into and out of a vehicle). Instructions for a walking program, identical to the walking program for the physiotherapy group, were provided. The walking program during the first week after surgery consisted of 5 minutes of controlled walking on a leash twice daily plus allowing the dogs to ambulate on a leash to defecate or urinate. The amount of walking time was increased by 5 min/walk each week up to a maximum of 30 minutes of walking on a leash twice daily by week 6 after surgery. No other exercises were instituted. Dogs returned for suture removal and physiotherapy examination on day 10 after surgery, and subsequent physiotherapy examinations were conducted at the end of weeks 3 and 6 after surgery. Each owner was given a logbook to record information on a daily basis; the logbooks were reviewed at each physiotherapy examination.

Statistical analysis—Flexion and extension ROMs and TC for physiotherapy and home-exercise groups were evaluated by use of a repeated-measures ANOVA,[c] with post hoc analysis when significant group-by-time interactions were found. Scores for lameness, willingness to bear weight on the affected limb, and willingness to lift the contralateral limb were analyzed by use of nonparametric tests (Kruskal-Wallis test).[c] Student *t* tests were used to compare differences for TC and flexion and extension ROMs of the stifle joint between affected and nonaffected limbs before surgery and at 6 weeks after surgery. The same tests were used to compare duration of lameness, body weight, age, and body condition score before surgery and TPA before and after surgery in the affected limbs. Values of $P < 0.05$ were considered significant.

Results

Dogs—Eight dogs met the criteria for inclusion in the study, with 4 dogs in each treatment group. The physiotherapy group comprised 3 females and 1 male (1 each of Rottweiler, Siberian Husky, Labrador Retriever, and Golden Retriever). The home-exercise group comprised 2 females and 2 males (1 each of American Staffordshire Terrier, Labrador Retriever, German Short-Haired Pointer, and Bull Terrier crossbred dog). In each of the physiotherapy and home-exercise groups, 1 dog had a caudal medial menisecto-

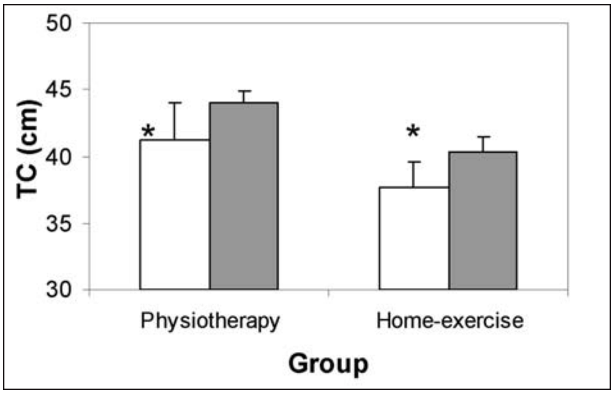

Figure 1—Mean ± SEM TC before surgery for the affected (white bars) and nonaffected contralateral (gray bars) limbs of dogs undergoing a TPLO for CCL deficiency and subsequently included in a physiotherapy treatment or home-exercise treatment. *Within a treatment group, value differs significantly ($P < 0.001$) from value for the nonaffected limbs.

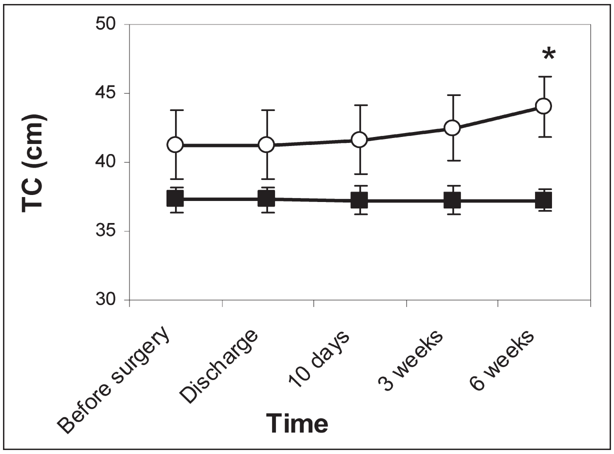

Figure 2—Mean ± SEM TC for the affected limbs of dogs in the physiotherapy (open circles) and home-exercise (solid squares) groups over time. Measurements were obtained before surgery, on the day dogs were discharged to the owners (1 day after surgery), and 10 days and 3 and 6 weeks after surgery. *Within a time point, values differ significantly ($P < 0.05$) between treatment groups.

my, whereas the other 3 dogs in each group did not have an arthrotomy or meniscal surgery.

Differences between the groups were not detected for duration of lameness, body weight, age, or body condition score before surgery or TPA before or after surgery. Mean ± SD duration of lameness for the physiotherapy group was 21 ± 7 weeks, compared with 17 ± 11 weeks for the home-exercise group. Mean body weight for the physiotherapy group was 31.0 ± 5.0 kg, compared with 28.0 ± 0.5 kg for the home-exercise group. Mean age for the physiotherapy group was 5.0 ± 1.4 years, compared with 5.8 ± 2.6 years for the home-exercise group. Mean body condition score for the physiotherapy group was 5.25 ± 1.50, compared with 5.75 ± 2.60 for the home-exercise group. Mean TPA before surgery for the physiotherapy group was 27.5 ± 6.6°, compared with 28.5 ± 0.6° for the home-exercise group. Mean TPA after surgery for the physiotherapy group was 5.2 ± 1.5°, compared with 5.0 ± 0.8° for the home-exercise group. The desired TPA after a TPLO is 5°.[24] None of the dogs had radiographic evidence of complications associated with the surgery.

Values for TC—The TC measurements in each dog were always within a range of 0.5 cm. Before surgery, TC was significantly ($P < 0.001$) less in the affected limbs of dogs in both groups, compared with TC for the

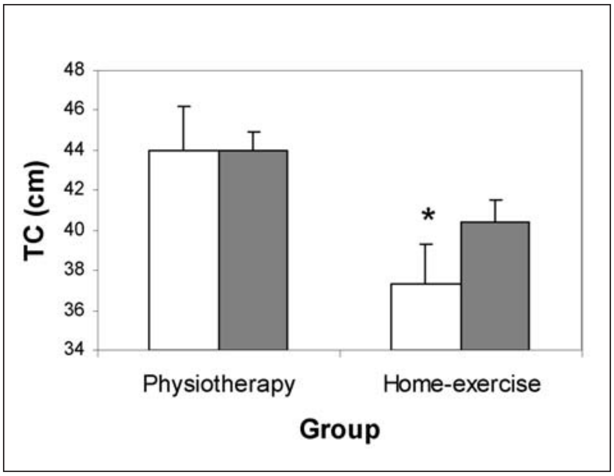

Figure 3—Mean ± SEM TC of the affected (white bars) and nonaffected contralateral (gray bars) limbs of dogs in the physiotherapy and home-exercise groups at various time points before and up to 6 weeks after surgery. *See* Figure 1 for remainder of key.

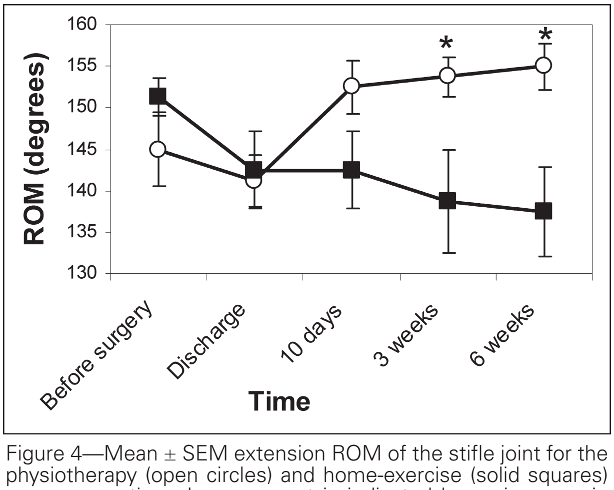

Figure 4—Mean ± SEM extension ROM of the stifle joint for the physiotherapy (open circles) and home-exercise (solid squares) groups over time. Improvement is indicated by an increase in ROM measurement. *See* Figure 2 for remainder of key.

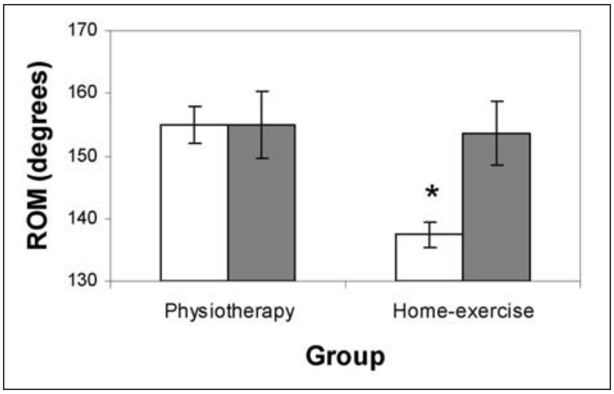

Figure 5—Mean ± SEM extension ROM of the stifle joint for the affected (white bars) and nonaffected contralateral (gray bars) limbs of dogs in the physiotherapy and home-exercise groups at 6 weeks after surgery. *See* Figure 1 for remainder of key.

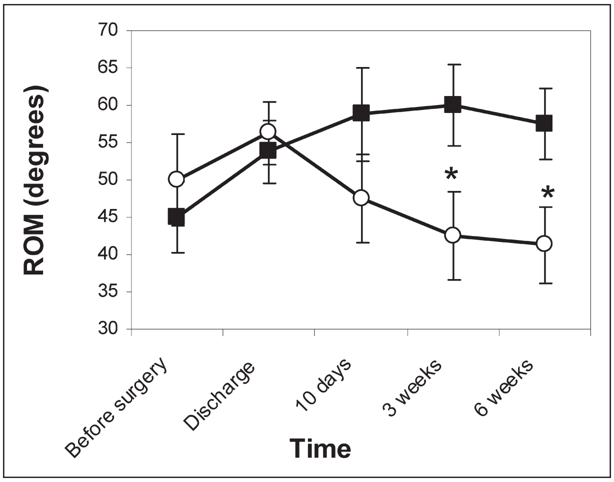

Figure 6—Mean ± SEM flexion ROM of the stifle joint for the physiotherapy (open circles) and home-exercise (solid squares) groups over time. Improvement is indicated by a decrease in ROM measurement. *See* Figure 2 for remainder of key.

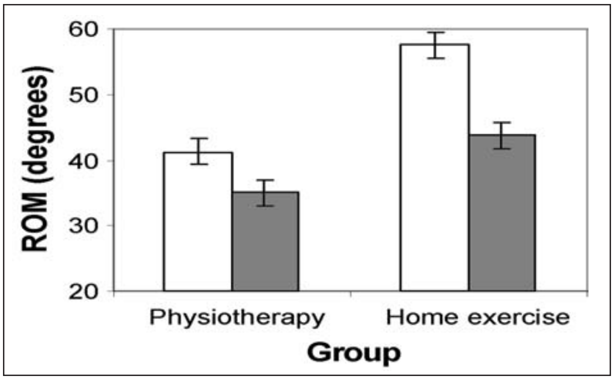

Figure 7—Mean ± SEM flexion ROM of the stifle joint for the affected (white bars) and nonaffected contralateral (gray bars) limbs of dogs in the physiotherapy and home-exercise groups at 6 weeks after surgery. Values for limbs in the home-exercise group differed but not significantly ($P = 0.06$).

Table 1—Mean ± SD scores for lameness, willingness to bear weight on the affected limb while standing, and willingness to lift the contralateral limb for the physiotherapy and home-exercise groups (4 dogs/group) before surgery; on the day of discharge from the hospital (ie, the day after surgery); and on day 10 and weeks 3 and 6 after surgery.

Time	Lameness		Willingness to bear weight on affected limb while standing		Willingness to lift the contralateral limb	
	Physiotherapy	Home-exercise	Physiotherapy	Home-exercise	Physiotherapy	Home-exercise
Before surgery	2.75 ± 0.5	2.5 ± 0.58	2.75 ± 0.5	2.5 ± 0.54	3.0 ± 0.82	3.0 ± 0.0
Day of discharge	3.5 ± 0.58	3.75 ± 0.5	3.5 ± 1.0	3.75 ± 0.67	4.75 ± 0.5	4.25 ± 0.5
Day 10	2.75 ± 0.5	2.75 ± 0.5	2.75 ± 0.5	2.5 ± 0.54	4.25 ± 0.5	3.5 ± 0.58
Week 3	2.5 ± 0.58	2.25 ± 0.5	2.5 ± 0.58	2.25 ± 0.54	3.25 ± 0.96	3.5 ± 0.58
Week 6	2.0 ± 0.82	2.0 ± 0.0	2.0 ± 0.0	2.0 ± 0.36	2.25 ± 0.96	2.5 ± 0.58

Variables were scored on a scale of 0 to 5 (lameness) or 1 to 5 (willingness to bear weight on affected limb while standing and willingness to lift the contralateral limb).

nonaffected limbs (**Figure 1**). Analysis of TC between groups over time revealed a significant ($P < 0.001$) group-by-time interaction. Post hoc analysis revealed no difference before surgery, at time of discharge to the owners, or on day 10 or 3 weeks after surgery. However, at 6 weeks after surgery, TC for the physiotherapy group was significantly larger, compared with TC for the home-exercise group (**Figure 2**). The TC for the physiotherapy group increased by a mean ± SD of 2.75 ± 0.96 cm, compared with a reduction of 0.5 ± 0.28 cm for the home-exercise group over time. At 6 weeks after surgery, TC of the affected limbs for the home-exercise group still was significantly smaller, compared with TC of the nonaffected limbs for the home-exercise group, whereas for the physiotherapy group, TC of the affected limbs was not significantly different from TC for the unaffected limbs (**Figure 3**).

Values for ROM—The ROM measurements in each dog were always within a range of 5°. Before surgery, ROMs of the stifle joint were reduced in the affected limbs in both groups, for extension ($P < 0.05$) and flexion ($P = 0.06$), compared with values for the nonaffected limbs. Analysis of extension ROM between groups over time revealed a significant ($P < 0.001$) group-by-time interaction. Post hoc analysis revealed no significant difference before surgery, on the day of discharge to the owners, or on day 10 after surgery. However, 3 and 6 weeks after surgery, extension ROM for the physiotherapy group was significantly greater, compared with extension ROM for the home-exercise group (**Figure 4**). Affected limbs for the physiotherapy group improved extension ROM by a mean ± SD of 10.0 ± 4.08°, whereas affected limbs for the home-exercise group became stiffer and lost a mean of 13.75 ± 6.4°. At 6 weeks after surgery, extension ROM of the affected limbs for the home-exercise group still remained significantly less than that for the nonaffected limbs, whereas for the physiotherapy group, extension ROM of the affected limbs had returned to values similar to those for the contralateral unaffected limbs (**Figure 5**).

Similarly, analysis of flexion ROM between groups over time revealed a significant ($P < 0.001$) group-by-time interaction. Post hoc analysis revealed no significant difference before surgery, on the day of discharge to the owners, or on day 10 after surgery. At 3 and 6 weeks after surgery, the change in flexion ROM for the physiotherapy group was significantly greater, compared with the change in flexion ROM for the home-exercise group (**Figure 6**). Affected limbs for the physiotherapy group had an improvement in flexion ROM of a mean ± SD of 8.8 ± 10.3°, whereas affected limbs for the home-exercise group became stiffer and lost a mean of 12.5 ± 9.4°. At 6 weeks after surgery, flexion ROM of the affected limbs for the home-exercise group remained lower than the flexion ROM for the nonaffected limbs, but the values did not differ significantly ($P = 0.06$). At 6 weeks after surgery for the physiotherapy group, flexion ROM in the affected limbs was similar to the flexion ROM for the unaffected limbs (**Figure 7**).

Lameness and weight bearing—Scores for lameness, willingness to bear weight on the affected limb, and willingness to lift the contralateral limb did not differ significantly between the physiotherapy and home-exercise groups before surgery (**Table 1**). At 6 weeks after surgery, both groups had improvement as indicated by lower scores for each of the 3 measures, but no significant difference was evident between the 2 groups.

Discussion

Analysis of results of the study reported here revealed that early intensive physiotherapy after a TPLO for CCL deficiency in dogs was more successful in increasing TC and flexion and extension ROMs of the stifle joint, compared with results for a home-exercise program. No differences were found between treatment groups for lameness scores, willingness to bear weight on the affected limb, or willingness to lift the contralateral limb.

Before surgery, affected limbs had smaller TC measurements, which was expected, with all dogs being lame for several weeks before surgery. During the 6-week study period, TC of dogs in the physiotherapy group increased significantly, whereas TC of the home-exercise group decreased. These findings are important because after stabilization surgery for CCL deficiency, thigh muscle mass typically continues to decrease until 5 weeks after surgery, with only a slight increase by 10 weeks after surgery.[20] In another study,[6] dogs involved in a rehabilitation program of electrical muscle stimulation after CCL surgery had greater TC measurements, compared with values for dogs confined to cages. However, evaluation of data revealed that TC continued to decrease until 9 weeks after surgery for both groups in that study. Analysis of results of the study reported here indicated that a program of early intensive physiotherapy commencing on the day of surgery prevented muscle atrophy and increased TC measurements to values similar to those for the nonaffected limbs by 6 weeks after TPLO.

In humans, the degree of muscle atrophy is proportional to strength of the quadriceps muscle during isokinetic testing.[25] Because it is difficult to assess strength in dogs, it seems plausible that improvements in TC indicate that strength of the thigh muscles has also improved. Atrophy of thigh muscles in humans after CCL surgery results in delayed return to function and ongoing pain.[9] Prevention of atrophy and restoration of muscle strength are essential for restoring the knee to normal function and preventing reinjury.[11] Therefore, commencing a program of intensive physiotherapy on the first day after a TPLO in dogs may hasten restoration of function and reduce discomfort by preventing atrophy and increasing muscle strength.

The method of TC measurement used to provide an indication of muscle atrophy was chosen on the basis that it is relatively simple and regularly performed in clinical practice. Comparison of several methods for measuring increases in muscle mass, including TC measurement, body weight, net thigh girth, and quadriceps and biceps femoris thickness via B-mode ultrasonography, reveals that ultrasonography is the most sensitive method for detecting early changes; however, results of ultrasonography are comparable with TC measurements.[26] Because measurement of TC is simple and can be quickly performed in a clinical setting without the need for dogs to be sedated or anesthetized, it appears to be an appropriate test for detection of change in muscle mass in dogs.

When examining the data for ROM, it is important to mention that as flexion ROM of the stifle joint improves, the angle between the femoral and tibial shafts is reduced; hence, an improvement in flexion is seen as a smaller value. As extension ROM of the stifle joint improves, the angle becomes larger and improvement in ROM is seen as a larger value. Analysis of results of the study reported here indicated that flexion and extension ROMs of the stifle joint revealed improvement soon after surgery with early intensive physiotherapy and continued to increase to values similar to those for the unaffected limb by 6 weeks after surgery. This finding is important because it has been reported that when improvements in ROM of the stifle joint are not evident within the first 2 weeks after CCL surgery, the likelihood for return of normal ROM is reduced.[8] In another study,[6] a program of electrical muscle stimulation was compared with cage confinement to determine the effects on ROM of the stifle joint after extracapsular CCL stabilization surgery in dogs. Although there was no difference evident between the 2 groups over time, ROM of the stifle joint continued to deteriorate after surgery and did not reveal improvement until week 7 after surgery. However, rehabilitation was not commenced until 3 weeks after surgery.

Early improvements in ROM of the knee after cruciate surgery in humans can result in more rapid and more complete return to function, reduction of ongoing pain, and prevention of reinjury without a compromise of stability.[9,12] Thus, it appears that early intensive physiotherapy after a TPLO prevents deterioration of ROM of the stifle joint but also allows early return to normal ROM, which leads to a more rapid return to function.

The physiotherapy program described here consisted of several exercises; thus, the contribution of each exercise to improvements in ROM cannot be precisely determined. Increases in ROM of the stifle joint have been reported for dogs performing aquatic therapy.[2,18] Investigation of swimming exercise after CCL stabilization surgery revealed increases in flexion of the stifle joint without excessive forces being placed through the limb.[1] Although regaining full ROM for flexion and extension is desirable, restricted extension of the stifle joint is particularly detrimental to function because full extension of the stifle joint is required for normal walking, trotting, and running.[7] Investigation of dogs walking on an UWTM with the water level higher than the stifle revealed increased flexion and near-normal extension of the stifle joint.[18] Thus, it would appear that UWTM exercise is superior to swimming for increasing total joint ROM.

The contribution of UWTM exercise to improvements in TC in the study reported here is unclear. In a study[19] in humans in which investigators compared aquatic rehabilitation and land-based exercises after CCL surgery, both groups had an equal increase in TC with no difference found between the 2 groups. It is possible that exercising in a reduced-loading environment contributed to the increases seen in TC in the physiotherapy group of our study. Although a combination of physiotherapy treatments including UWTM is usually performed and prescribed for home-based exercise programs, investigation of the effects of specific exercises on TC and ROM is warranted.

Scores for lameness, willingness to bear weight on the affected limb, and willingness to lift the contralateral limb improved for all dogs during the 6-week study period, but we did not detect differences between the physiotherapy and home-exercise groups. It is possible that 6 weeks was an insufficient amount of time to detect functional changes between the 2 groups because no dog in either group had a score < 2/5 for any measure at the end of the study. Similar measures have been used to determine the effects of electrical stimulation on limb function after extracapsular CCL surgery in dogs.[6] Analysis of results for that study revealed significantly lower scores for lameness and weight bearing in the treatment group; however, because numeric scores were not provided for those dogs, it is not evident whether the dogs returned to normal function in either group at the conclusion of that study.

After TPLO, dogs often continue to be lame for several months as a result of altered biomechanics of the stifle joint.[16] Dogs in 1 study[5] continued to be graded lame (score of 2/5) at 8 weeks after surgery and had lameness scores of 1/5 at 18 weeks after a TPLO. Therefore, it may be that lameness scores are not suitable early indicators of improvement after a TPLO. It is also possible that the grading system may not have been sufficiently sensitive to detect changes between the groups. A grading system with a larger scale may have allowed us to detect differences between the groups. Alternatively, kinematic video analysis of gait may have been useful in establishing subtle differences between the groups.

It has been suggested[5,6,27] that force-plate analysis may be a more objective measure of limb function after CCL stabilization surgery. However, force-plate data have not been used for comparison with any other measures[28] and do not correlate with functional measures[6] or lameness scores.[5] In humans, more functional measures, such as ROM, TC, and several strength and weight-bearing tests (including hopping, jumping, and running), are more frequently used to measure the effects of therapy.[11,12,25] Additional investigation of the correlation of force-plate data with functional measures in dogs is required.

Several authors[1,5] have acknowledged the difficulties in investigating limb function in dogs with naturally occurring CCL deficiencies because of the inherent number of variables that must be controlled for. In the study reported here, we controlled for age, weight, body condition score, duration of lameness, and TPA. We did not control for meniscal injury or menisectomy at time of surgery. Release of the medial meniscus during a TPLO procedure is controversial. Complications associated with TPLO are not related to whether a meniscal release is performed.[3] We are not aware of any studies conducted to determine the long-term effect of meniscal release versus no release after TPLO; therefore, the effects on results of the study reported here are unknown. We also did not account for the degree of degenerative joint disease in the stifle joints. Subjective grading systems for degenerative joint disease have been used in another study[6] with a combination of radiographic and postmortem examinations and may have been a helpful addition to our study.

We were also not able to control the conditions for each dog at home. Written instructions for owners and a logbook were provided in an effort to reduce variability between groups. In a further effort to reduce variability between groups of dogs, assessment, regular reassessment, prescription of exercises, and monitoring and correction of technique were performed by a physiotherapist experienced in the management of humans and dogs undergoing CCL surgery.

In human[28] and veterinary medicine, there is a lack of quality large-scale randomized controlled trials with long-term follow-up monitoring that assessed the effects of various postoperative rehabilitation programs after cruciate surgery. There is certainly a need for additional research in the postoperative management of CCL deficiency in dogs. However, before undertaking a study of this proportion, determination of the rehabilitation protocol needs to be established. The study reported here outlined a protocol that provided early benefits for TC and ROM and is suggested as a starting point for future studies.

The study reported here revealed that early intensive physiotherapy induces functional improvement in ROM of the stifle joint and an increase in TC in dogs undergoing a TPLO. Positive results of this study, in contrast to results for other studies, highlight the need for early intervention as well as an intensive program prescribed and closely monitored by a physiotherapist.

a. Animal Surgery Centre, Mt Waverley, Victoria, Australia.
b. Dogs In Motion underwater treadmill, Doveton, Victoria, Australia.
c. SAS, version 9, SAS Institute Inc, Cary, NC.

Appendix 1

Scoring system used for physiotherapy examination.

Variable	Grade	Description
Lameness assessed at a walk	0	No lameness detected at a walk.
	1	Intermittent lameness at a walk with some steps that are fully weight bearing.
	2	Always uses affected limb at a walk with slight lameness detected. Always uses affected limb but partial weight bearing and obviously lameness.
	3	Intermittent non–weight-bearing lame ness at a walk.
	4	Non–weight-bearing lameness at a walk.
	5	
Weight bearing while standing	1	Typical weight bearing on limbs while standing; bears weight evenly on both pelvic limbs.
	2	Stands on foot of affected limb at all times but more weight on unaffected limb.
	3	Stands on foot of affected limb most of the time but with minimal weight bearing.
	4	Touches toes of affected limb to ground with rare or no weight bearing.
	5	No weight bearing on affected limb while standing.
Willingness to lift contralateral limb	1	Readily accepts contralateral limb being lifted and bears weight fully on affected limb.
	2	Offers resistance to lifting of the contralateral limb but bears full weight on the affected limb for . 30 seconds.
	3	Offers moderate resistance to lifting of the contralateral limb and cannot stand for 30 seconds without flexing stifle or hopping. Offers resistance to lifting of the con tralateral limb and tries to sit or move away in , 10 seconds.
	4	Will not allow lifting of the contralateral limb or sits immediately.
	5	

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Appendix 2

Exercise regimen for dogs in the home-exercise group.

	Time after surgery (wk)					
Treatment	**1**	**2**	**3**	**4**	**5**	**6**
Massage (min)*	5	5	5	5	5	5
Stifle flexion and extension (repetitions)*	30	30	30	30	30	30
Icepack (min)*	15	—	—	—	—	—
Sitting to standing (repetitions)*	—	5	10	15	15	20
Weight shifting (min)*	—	1	2	—	—	—
3-legged standing (s; 10 repetitions)*	—	—	—	3	5	10
Leash walking (min)†	5	10	15	20	25	30
Figure 8s (repetition)	—	—	—	—	10	10
Steps (repetitions)†	—	—	—	—	10	20
UWTM (No. of sets X min)‡	—	3 × 3	2 × 5	2 × 7	1 × 15	1 × 20

* Each of these exercises was completed 3 times/d. †Each of these was performed 2 times/d. ‡Represents the number of sets per session times the number of minutes per set.

Massage = Massage of cranial and caudal thigh muscles. Stifle flexion and extension = Passive ROM exercises performed with dog in lateral recumbency. Icepack = Application of an ice pack wrapped in a wet towel to the stifle region. Sitting to standing = Voice command or treat used to induce dog to shift from a sitting to standing position. Weight shifting = With the dog in a standing position, pushing on the pelvis to shift the weight to the side of the affected limb. 3-Legged standing = Lifting the contralateral pelvic limb to force the dog to stand on the remaining 3 limbs. Leash walking = Dog walked on a leash at a walking pace. Figure 8s = Performed with the dog on a leash and walked in a figure-8 pattern around 2 objects placed 2 m apart. Steps = Dog on a leash walked up and down a step with a height of 120 mm. UWTM = Dogs walked on an UWTM. — = Not performed.