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Long-term quadriceps femoris functional deficits following intramedullary nailing of isolated tibial fractures

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Abstract This retrospective study assessed 5 male and 5 female patients, age 35.1±16 years, height 171.8±12 cm, and weight 75.5±18 kg (mean±SD) who were more than 1 year post isolated tibial fracture (18±6 months) and had been treated with an intramedullary tibial nail. Subjects completed a 12-question visual analog scale, a physical symptom and activity of daily living survey, and were also tested for bilateral isokinetic (60°/s) quadriceps femoris and hamstring strength. Knee pain during activity, stiffness, swelling, and buckling were the primary symptomatic complaints. Perceived functional task deficits were greatest for climbing or descending stairs, pivoting, squatting, and walking on uneven surfaces. Involved lower extremity knee extensor and flexor torque production deficits were 25% and 17%, respectively. Early rehabilitation focuses on maintaining adequate operative site bony fixation while providing controlled, progressive, and regular biomechanical loading to restore functionally competent tissue. Following adequate fracture healing, greater emphasis should be placed on lower extremity functional recovery including commonly performed activities of daily living and other functional tasks that are relevant to the patient's disability level. A cyclic rehabilitation program that progresses the weight-bearing environment to facilitate bone and soft tissue healing and neuromuscular re-education is proposed.

Résumé Étude rétrospective de 10 patients (5 hommes et 5 femmes) qui ont présenté une fracture isolée du tibia et qui ont été traités par un clou intra-médullaire. Les caractéristiques de ce groupe (moyenne±déviation standard) sont: délai depuis la fracture=18+6 mois, age=35.1+16 ans, taille=171.8+12 cm, et poids=75.5+18 kg. Les sujets ont rempli un questionnaire comprenant douze questions portant sur la description de l'amélioration de leurs symptômes et sur leurs vies quotidiennes. Des études ont également été entreprises afin de tester un isokinétisme bilatéral (60°/s) du quadriceps. Les principaux symptômes rapportés par les patients comprennent des douleurs du genou durant l'effort, ainsi qu une raideur, un gonflement et des phénomènes de ressaut. L'action de monter et de descendre un escalier, de pivoter, de s'accroupir et de marcher sur un terrain irrégulier s'avère comme les taches les plus difficiles à réaliser. Le déficit du moment de rotation en flexion et extension de l'extrémité basse du genou sont respectivement de 25% et 17%. Dans le futur, les preuves radiologiques et cliniques d'une cicatrisation adéquate de la fracture devront tenir compte de l'évaluation de la récupération fonctionnelle du membre inférieur. Un programme cyclique de rééducation est proposé.

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Introduction

Trafton [20] reported that intramedullary (IM) nailing of tibial fractures increased functional recovery rates, lessened the frequency of postoperative deformity and produced fewer complications than non-operative management methods. However, anterior knee pain from the IM nail is a common complaint [2, 13, 23] in about 50–70% of patients.

Insertion of an IM nail through the patellar tendon produces a greater incidence of anterior knee pain than para-tendonous nail insertion [16]. Tornetta et al. [19] reported a "safe zone" for intraarticular knee structures with IM nail placement 9.1±5 mm lateral to the midline of the tibial plateau and 3 mm lateral to the center of the tibial tubercle. Devitt et al. [5] reported increased articular contact pressure at the lateral facet of the patellofemoral joint by using a medial para-tendonous approach and at the medial facet when a patellar tendon piercing method of IM tibial nail insertion was used.

The proximity of IM tibial nail placement to articular tissues may adversely influence knee extensor mechanism function [11]. The patellar ligament transfers the locomotion and dynamic knee joint control stabilizing forces of the quadriceps femoris muscle group to the lower leg during function. Ligament neuroreceptors provide afferent signals that assist in modulating knee extensor contractility. Regardless of the precise operative approach, it is imperative that the surgeon places the IM nail in a manner that minimizes its likelihood for inhibiting knee extensor function.

The purpose of this retrospective study was to assess the quadriceps femoris and hamstring muscle group strength, symptomatic complaints and perceived functional capabilities during routine activities of daily living of patients who had undergone successful medial IM nailing for an isolated tibial fracture. A secondary purpose was to propose a progressive rehabilitation program designed to facilitate both bone and soft tissue healing by using functionally relevant tasks, thereby minimizing patient disability levels.

Patients and methods

Patients

Five male and five female patients (age 35.1±16 years, height 171.8±12 cm, weight 75.5±18 kg) who were more than 1 year post-isolated closed or grade I open transverse or spiral mid-shaft tibial fracture (18±6 months) and treated with an IM tibial nail (medial insertion, tourniquet at 300 mm Hg for 40±10 min) participated in this study. Surgery had been performed between 24 and 48 h following trauma for all subjects. Subjects sustained their injury either from a motor vehicle accident (n=6), falling from a height (n=2) or while playing soccer (n=2). The patients had been released by their treatment physician following clinical and radiographic evidence of tibial fracture union and were ambulating independently without an assistive device at the time of participating in the study. All the subjects provided informed consent prior to participating in the study.

Survey instrument

Subjects completed a 12-question visual analog scale (VAS) survey, which had been adapted from that reported by Flandry et al. [7]. Questions related to functionally demanding tasks such as running, jumping, and cutting were removed from our analysis, as we did not consider them relevant to our subject population. Items related to subject perceptions of physical symptoms (knee pain, swelling, buckling, catching, and stiffness) and functional capability (rising from a chair, walking on level ground, walking on uneven ground, pivoting, climbing or descending stairs, and squatting) were included. Descriptors (ranked 1–10) were employed, which denoted progressively increasing symptomatic complaints or perceived functional deficits. Subjects were individually instructed in the VAS question format prior to completing the survey.

Isokinetic testing

Subjects were tested for concentric isokinetic knee flexion and extension torque/bodyweight at 60°/s. The dynamometer was calibrated prior to data collection (Biodex Operations/Applications Manual, Biodex Corporation, Shirley, N.Y., USA). All the subjects were familiar with the testing procedure and followed a uniform protocol. Verbal encouragement was provided to facilitate a maximal volitional effort. Stabilization was standardized according to the manufacturer's guidelines. Three submaximal warm-up repetitions were performed immediately prior to testing. Subjects performed 5 maximal volitional effort repetitions during isokinetic testing with each lower extremity. The contralateral lower extremity was always tested prior to testing the involved lower extremity, following the manufacturer's protocol.

Results

Subject symptomatic complaints (Fig. 1) and perceived functional task deficiencies during routine activities of daily living (Fig. 2) results are presented. Symptomatic

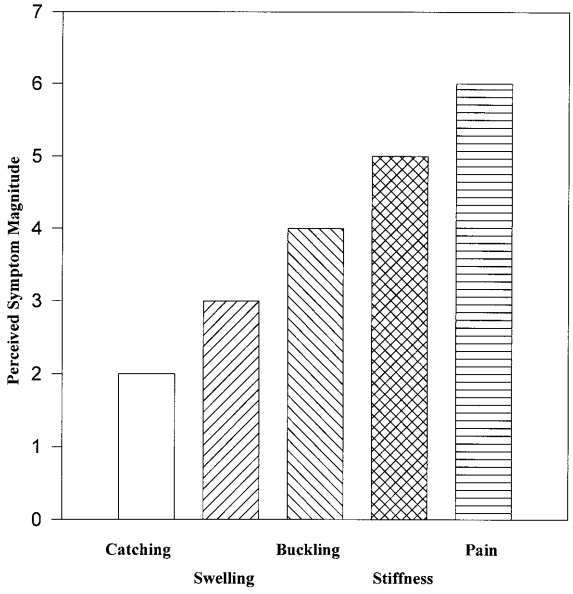

Fig. 1 Patient symptomatic complaints

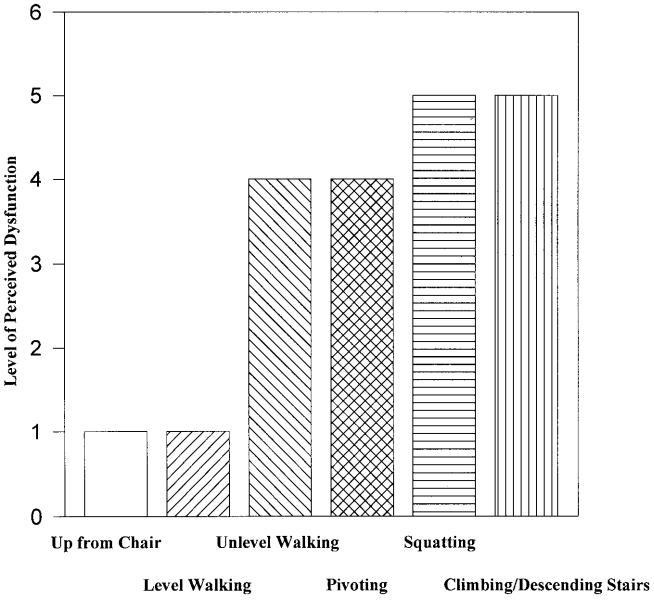

Fig. 2 Patient perceived functional task deficits

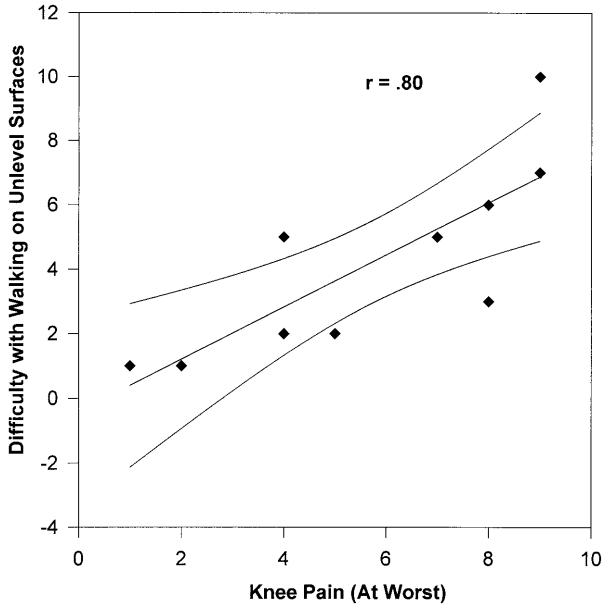

Fig. 3 Pearson product moment correlation for knee pain and uneven walking (±95% confidence interval).

complaints were greatest for knee pain at its worst, stiffness and buckling. Perceived functional task capability deficiencies were greatest for climbing/descending stairs, pivoting, squatting and walking on uneven surfaces. Mean concentric isokinetic testing revealed knee extensor torque of 107.1±48 Nm and 134.3±45 Nm at the involved and contralateral lower extremities, respectively. Mean concentric isokinetic testing revealed knee flexor torque of 61.4±32 Nm and 72.6±31 Nm at the involved and contralateral lower extremities, respectively. Concentric isokinetic testing revealed knee extensor torque/bodyweight of 1.54±8 Nm/kg for the involved lower extremity and 1.93±.7 Nm/kg for the contralateral lower extremity. Involved lower extremity knee flexor torque/bodyweight was 86±4 Nm/kg, while the contralateral lower extremity knee flexor torque/bodyweight was 1.03±4 Nm/kg. Mean concentric involved lower extremity knee extensor torque/bodyweight deficits compared to the contralateral lower extremity were 25±18% (range 5 to 60%). Mean concentric involved lower extremity knee flexor torque/bodyweight deficits compared to the contralateral lower extremity were 17±16% (range 0 to 45%). Post-hoc Pearson product moment correlational analysis revealed that knee pain at its worst and difficulty with walking on uneven surfaces were directly related (r=0.80) (Fig. 3).

Discussion

Despite successful fracture healing and return to unrestricted activities of daily living, subject symptomatic complaints, perceived functional deficits during routine activities of daily living, and functionally significant isokinetic knee extensor and flexor strength deficits were evident at more than 1 year following tibial nailing. Perceived functional deficits were greatest during stair climbing or descending. Knee pain and stiffness were the most troublesome symptom complaints.

The likelihood of a patient regaining optimal function following tibial fracture treatment with an IM nail is enhanced when the nail is positioned in a manner that minimizes knee extensor mechanism trauma. Rehabilitation following a tibial fracture treated with an IM nail should focus on enhancing operative site bony stability with controlled and regular progressive loading to restore functionally competent tissue [22]. The rehabilitation progression proposed in Table 1 is designed to optimize functional recovery.

Both animal [21] and human [4, 12] studies have identified early progressive weight bearing as essential to increasing bone mineral density and fracture healing. Dynamic loads from the impact forces of hop or jump training may be more effective than walking or running

Table 1 Cyclic progressive function rehabilitation program proposal. *ARP* Active rest phase, *PRP* progressive function phase (weight bearing, impact, non-cardinal plane movements, pace or cadence, uneven surfaces and stairs, varying surface stiffness)

Post-operative week	Walking	Progressive multiple plane stepping and lunges	Hop-jog-run progression	Agility maneuvers	Aquatic therapy	Low impact general conditioning or neuromuscular re-education	Pulsed electromagnetic field or low intensity ultrasound therapy
0–2	PFP					PFP	PFP
3	ARP				ARP	ARP	ARP
4–6	PFP					PFP	
7	ARP				ARP	ARP	ARP
8–10	PFP	PFP				PFP	
11	ARP				ARP	ARP	ARP
12–14		PFP					
15					ARP	ARP	
16–18		PFP	PFP	PFP			
19					ARP	ARP	
20–22			PFP	PFP			
23					ARP	ARP	
24–26			PFP	PFP			

[17, 21]. Scully and Besterman [18] reported that training sessions separated by a 1-week period of active rest helped prevent tibial stress fractures among military recruits. By allowing an active rest phase during the third training week, subtle soft tissue and bone irritation was decreased and stress fracture incidence was reduced 3-fold compared to a control group that followed traditional training principles [18]. Our proposal uses this "cyclic training" concept at regular 3- to 4-week intervals to enhance bone and soft tissue accommodation and remodeling to the stresses of the progressive rehabilitation program.

During active rest phases, pulsed electromagnetic field and ultrasound modalities may further facilitate tibial fracture healing [1, 10]. Aquatic therapy provides relatively safe, low impact functional exercise during the active rest phases [14, 15]. Although aquatic therapy has been listed in the active rest phase, progressive activities performed below the tissue irritation threshold may be performed throughout the entire program.

Neuromuscular inhibition commonly occurs at the quadriceps femoris and gastrocnemius muscles following knee joint injury, prolonged lower extremity immobilization, knee extensor mechanism or lower leg trauma, and limited weight bearing during ambulation [15]. In addition to progressive weight-bearing activities, neuromuscular electrical stimulation and biofeedback associated with volitional muscle activation can safely achieve "neuromuscular re-education" while maintaining or increasing muscular girth and local bone mineral density [15, 17]. Low impact general conditioning activities during the active rest phases can improve cardiovascular exercise capacity, muscular fatigue resistance and strength. Weight training is an excellent method of increasing overall bone mineral density [17].

Following sufficient evidence of bony healing and lower extremity neuromuscular recovery, the program focuses more on tasks performed in non-cardinal movement planes [3] to promote functionally relevant tissue healing [22]. Progressively increased weight bearing, impact force loading, and pace or cadence should be applied to functional tasks performed on surfaces of varying stiffness or friction [6], on stairs, and on uneven surfaces. Appropriate neuromuscular responses to sudden perturbations during these tasks is also essential to ensure adequate fall prevention capability.

The therapist's role changes as the rehabilitation program progresses. During initial sessions (0–3 weeks) and during each active rest phase, treatment frequency may be 3–4 days per week to achieve full weight bearing. Between 4 and 15 weeks following surgery the therapist gradually assumes more of the consultant role. During the latter part of this phase it is essential that the patient understands that discomfort or other signs and symptoms in the vicinity of the fracture site and/or at the knee or ankle suggests a need for activity modification and communicates these observations to the therapist. Compliance with therapist recommendations for program modification is essential.

By progressing the patient through functionally relevant exercise and activity challenges that strategically alter the weight-bearing environment [8], the ultimate disability level should be minimized. Greenwood [9] stated that the most important outcome for patients with tibial fractures was whether they had pain or disability, not solely whether or not the fracture had healed. Even with successful fracture healing, the long-term knee pain associated with IM nailing predisposes many patients to functional deficiencies during many routine activities of daily living. Greater emphasis should be placed on the regular physical therapy evaluation of individualized lower extremity functional recovery regarding both commonly performed activities of daily living and related vocational, recreational or athletic tasks that influence the patient's disability level.

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