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Quadriceps contusions

West Point update*

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ABSTRACT

A 3 year study of 117 quadriceps contusions in West Point cadets was undertaken to document the effectiveness of a three-phased therapy program to return these young athletes to full activity with a normal knee range of motion and without recurrence of injury. The treatment protocol of this study was modeled after the 1973 West Point study of Jackson and Feagin with two major changes: 1) resting the injured leg in flexion (versus extension) and 2) emphasizing early flexion exercises (versus extension). Classification of contusions was based on knee range of motion at 12 to 24 hours after the injury (mild, >90°; moderate, 45° to 90°; severe, <45°). The average disability time was 13 days for mild, 19 days for moderate, and 21 days for severe contusions. Myositis ossificans developed in 9% of cadets and was associated with five risk factors (knee motion less than 120°, injury occurring during football, previous quadriceps injury, delay in treatment greater than 3 days, and ipsilateral knee effusion).

Quadriceps femoris contusion is defined as an external blow to the anterior, medial, or lateral thigh in the area of the muscle belly of the quadriceps femoris. This injury is associated with pain and swelling, a decreased range of knee motion, and occasionally a permanent palpable mass.

Between September 1969 and June 1970, a study was undertaken at the United States Military Academy concerning quadriceps femoris contusions.[9] A method of initial classification was outlined and a rationale for treatment and therapy developed. Following the therapy recommendations of that study, trainers and therapists noted that normal flexion was the slowest parameter to return, and this lack of normal range of motion prolonged disability even after pain resolved. Since 1983, acute quadriceps injuries at West Point have been treated using a modified protocol including having the patient rest with the injured leg flexed and using early passive pain-free motion, emphasizing flexion, in the mobilization phase of therapy. This contrasts with the protocol of the study by Jackson and Feagin[9] where the injured leg is in extension during rest and early restoration of full knee extension was emphasized, initiating flexion slowly.

The purpose of this review is to evaluate the effectiveness of this modified protocol for treatment of quadriceps femoris contusions in West Point cadets as measured by the number of days on limited duty, the incidence of myositis ossificans, postinjury subjective complaints, and functional performance on the Army fitness test and the West Point indoor obstacle course. In addition, those factors associated with myositis ossificans are outlined.

MATERIALS AND METHODS

A study of quadriceps femoris contusions in cadets at the United States Military Academy at West Point was initiated in June 1985 and continued for 3 full school years, through May 1988. During that period, 150 quadriceps femoris contusions occurred in 148 West Point cadets. This study consists of 117 contusions in 115 cadets (109 males and 6 females; age range, 17 to 23 years; average age, 19) who were available to be evaluated at least 6 months postinjury by questionnaire, physical examination, and roentgenogram of the thigh. Thirty-three contusions were eliminated, 20 because of graduation and 13 because of resignation from the Academy. No cadet left West Point as a result of a quadriceps contusion.

Classification of quadriceps contusions was determined

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by active knee range of motion at 12 to 24 hours after the injury, or whenever the cadet initially presented if later than 24 hours after the injury. Mild contusions had active knee motion greater than 90°, moderate contusions 45° to 90°, and severe contusions, less than 45°.

Cadet disability was measured as the number of days stated on the official cadet excusal slip for a quadriceps contusion, which coincides with successful completion of the therapy program and a return to full activity. Any West Point cadet unable to participate fully in all activities (military formations and training, physical education classes, and varsity, club, or intramural athletics) must obtain a cadet excusal form that lists the diagnosis and duration of limited activity. Each excusal is entered into a computerized injury record using a predetermined injury vocabulary agreed upon by all physicians, physician assistants, and therapists. Orthopaedic sick call is held Monday through Friday at 6:30 AM in the Cadet Health Center and 5:00 PM in the intramural and varsity training rooms. Injured outpatient cadets must attend physical therapy in lieu of extracurricular activities. Return to full activity requires a change or termination of the profile by the orthopaedic physician or physical therapist. This injury surveillance system is described to indicate that, although not impossible, it is difficult to avoid diagnosis and treatment as an injured cadet.

The sport and mechanism of injury were recorded, as well as any previous similar injury and whether a sympathetic knee effusion developed after the injury. A previous quadriceps injury was defined as any recent or past external blow to the anterior thigh that caused pain and was associated with a limp and loss of knee motion. A previous injury could have occurred prior to entrance to West Point or in a cadet who had not sought medical treatment. A sympathetic knee effusion was swelling that developed in the ipsilateral knee after the contusion when there was no evidence of ligamentous or intraarticular injury.

Final evaluation included any subjective complaints, measurement of range of motion, and performances on the Army's physical fitness test (including a 2 mile run) and the West Point indoor obstacle course. Myositis ossificans was determined by comparison of radiographs at the time of injury and at a minimum of 6 months later.

Inpatient and outpatient physical therapy treatment protocols are described in Tables 1 and 2. Hospitalization was offered or recommended to cadets who presented with knee flexion less than 90° or if there was a suspicion of a significant injury. This therapy protocol is a goal-orientated, individualized, three-phased program that allows each patient to progress at their own pain-free rate. The purpose of Phase I is to limit hemorrhage; Phase II, the restoration of motion; and Phase III, functional rehabilitation. All patients were advised to avoid those exercises in therapy that caused any increased pain. In addition, patients that returned to contact sports, especially football, were to wear a football girdle with an extra-thick thigh pad for 3 to 6 months.

RESULTS

Of the 117 quadriceps contusions, 71 were classified as mild, 38 as moderate, and 8 as severe. Followup ranged from 6 to 42 months with an average of 20 months. The participation of cadets in at-risk sports, the distribution and injury rates by sport, and the mechanism of injury are listed in Tables 3 and 4. The greatest number of injuries occurred in tackle football, but the percentage of injuries were higher in rugby and karate/judo.

Average disability was 13 days for mild contusions (range, 2 to 42), 19 days for moderate (range, 7 to 60), and 21 days for severe (range, 7 to 35). Comparison with the study by Jackson and Feagin[9] shows that the disability was slightly longer for mild contusions in this study (13 versus 7 days), but significantly shorter for moderate (19 versus 56 days) and severe (21 versus 72 days) contusions.

Hospitalization was part of the initial treatment in 28 cadets (5 mild, 18 moderate, 5 severe). The average hospital stay was 3 days (range, 1 to 10). Only one cadet remained hospitalized longer than 4 days and he stayed 10 days. He presented in clinic on a Monday (2 days after a Saturday varsity football game injury) with 50° of knee motion and unable to bear weight on the extremity. Treatment with a continuous passive motion machine was started within 12 hours of admission in 25 of the 28 hospitalized cadets. The other three cadets had their leg elevated with the hip and knee flexed and used well-leg and gravity-assisted passive motion. Well-leg and gravity-assisted motion is performed with the patient sitting on a therapy table that is high enough to keep the feet from reaching the floor. The patient then hooks the foot of his uninjured leg behind the ankle of the injured leg and lifts it, allowing gravity to flex the injured knee. Compared to cadets treated as outpatients, hospitalization and the use of continuous passive motion did not result in a significant difference in disability days for mild, moderate, or severe contusions.

A return to full activity with normal knee range of motion was attained by all cadets. Preinjury and postinjury activity levels were determined subjectively by questionnaire and objectively by scores on the Army fitness test and the West Point indoor obstacle course. Subjectively, five cadets complained of residual symptoms at least 6 months postinjury. Two cadets reported weakness evidenced by having to work harder to attain the same speed in running, two complained of problems with endurance, and one complained of numbness in the area of his quadriceps contusion after running 5 miles. None of the cadets with subjective residual symptoms had developed myositis ossificans. Objectively, all cadets were able to match or exceed their preinjury scores on the Army fitness test and the West Point indoor obstacle course. No cadet sustained a reinjury after completing this treatment protocol.

Myositis ossificans developed in 11 of the 117 quadriceps contusions (9%); 3 of 71 mild contusions (4%); 7 of 38 moderate contusions (18%); and 1 of 8 severe contusions (13%). In the three mild contusions in which myositis ossificans developed, the initial range of motion was between 90° and 120°. No cadet with a knee range of motion >120° at initial evaluation developed myositis ossificans. Compared to those cadets treated as outpatients, hospitalization

TABLE 1
Inpatient quadriceps contusion therapy

	Phase I	Phase II
Purpose	Limit hemorrhage.	Restoration of **pain-free** motion.
Modalities	Rest: bed rest; ice: ice pack applied to injured area; compression: thigh-length support hose and Ace wrap entire thigh; elevation: hip and knee flexed to tolerance.	Continuous passive motion; well-leg gravity-assisted motion; supine and prone active knee flexion; isometric quadriceps contraction; ice, crutch ambulation, Ace wrap.
Advance to next phase when:	Comfortable; **pain-free** at rest; stabilized thigh girth.	**Pain-free** passive range of motion 0°–90°; good quadriceps control; crutch ambulation with patient weightbearing to tolerance and negotiating steps.
		Continue Phase II as outpatient. See Table 3.

TABLE 2
Outpatient quadriceps contusion therapy[a]

	Phase I	Phase II	Phase III
Purpose	Limit hemorrhage	Restoration of **pain-free** motion.	Functional rehabilitation—strength and endurance.
Modalities	Rest: weightbearing to tolerance, crutch ambulation if limp present; ice: ice massage for 10 min; cold pack/cool whirlpool for 20 min; compression: Ace wrap entire thigh (occasional use: long-leg support hose, confirm taping); elevation: in class and in barracks, hip and knee flexed to tolerance; isometric quadriceps contracture <10 reps.	Ice or cool whirlpool, 15–20 min; isometric quadriceps exercises, 15–20 min; supine and prone active flexion; well-leg gravity-assisted motion; static cycle: minimum resistance; discard: 1) crutches when range of motion >90°, no limp, good quadriceps control, and **pain-free**, with flexed weightbearing gait; 2) Ace, when thigh girth reduced to equivalent of uninjured thigh.	**Always pain-free.** Static cycle with increasing resistance; Cybex; swim; walk; jog (pool and surface); run.
Advance to next phase when:	Comfortable; **pain-free** at rest; stabilized thigh girth.	>120° **pain-free** active knee motion; equal thigh girth bilaterally.	Full active range of motion; full squat; **pain-free** all activities; wear thigh girdle with thick pad 3 to 6 months for all contact sports.

[a] Mild and moderate treat daily/severe treat twice daily.

TABLE 3
Participation in sports and number of quadriceps contusions by sport

Sport	No. of cadets participating each year	No. of contusions occurring during 3 years	Injury rate per year (%)
Rugby	100	14	4.7
Karate/judo	100	7	2.3
Football	1000	47	1.6
Soccer	500	12	0.8
Hockey	50	1	0.7
Lacrosse	600	11	0.6
Team handball	475	4	0.3
Baseball	610	3	0.2
Wrestling	1000	2	0.07
Other (military training, misc.)	4500	16	0.3

TABLE 4
Quadriceps contusions by mechanism

Mechanism	No.
Kneed	48
Helmet	31
Shoulder	12
Direct blow	8
Object	6
Ground contact	5
Kicked	2
Other	5

and the use of continuous passive motion did not result in a significant difference in the development of myositis ossificans for mild, moderate, or severe contusions. As stated above, all cadets, including those who developed myositis ossificans, returned to full activity with a normal range of motion. No cadet with myositis ossificans had any residual symptoms and no surgery was performed in patients with myositis ossificans.

Five risk factors were identified as being associated with

the occurrence of myositis ossificans. Of the 11 cadets who developed myositis ossificans: 1) all 11 had a knee range of motion <120° at classification, 2) 8 were injured in football, 3) 7 had a history of a previous quadriceps injury, 4) 6 developed a sympathetic knee effusion, and 5) 4 delayed their treatment ≥3 days. Not every one of these risk factors was significant by itself, but cadets who developed myositis ossificans averaged a total of 3.3 risk factors, compared to 1.6 for those who did not.

DISCUSSION

It has been almost 20 years since the first study was undertaken on quadriceps contusion at the United States Military Academy.[9] Recommendations from that study were followed closely. Trainers, physical therapists, and physicians continue to emphasize the importance of early detection, treatment, and patient education for this injury. Successful education of cadets is evidenced by the referral of a fourth class cadet (freshman) by an upper class cadet who himself had suffered a quadriceps contusion.

The muscles of the anterior thigh lie in contact with bone throughout the length of the thigh and thus are especially vulnerable to external compressive forces. Blunt trauma causes transmission of force through the fluid compartment of all muscles but damage usually occurs only in the layer next to bone.[19] Muscle damage can be minor with swollen cellular components that repair by collagen turnover. Major muscle injury is associated with capillary damage, hemorrhage, and fiber disruption.[1] This latter injury process has been studied in a sheep model demonstrating an acute inflammatory response, clearing of necrotic debris, invasion by fibroblasts and macrophages, and finally formation of a matrix of inelastic, noncontractile connective tissue.[19] Heterotopic bone formed within this reaction scar in 17% of the sheep thighs. This bone resulted from metaplastic ossification. Considering this theoretical and experimental work, the object of any therapy is to limit swelling and hemorrhage, minimize the amount of scar formation, and preserve bioelasticity, contractility, and strength of the injured and uninjured muscle tissue.[3,5]

The treatment protocol for quadriceps contusions at the military academy at West Point is a three-phased program fashioned after the protocol of the 1973 study by Jackson and Feagin. The purpose of treatment in Phase I is to limit hemorrhage. Rest, ice, compression, and elevation are used, usually for 24 hours or less in mild contusions and for 48 hours in moderate and severe contusions. When the patient is pain-free at rest and the thigh girth has stabilized, he advances to Phase II, the restoration of motion phase. Ice or cool whirlpool is continued, well-leg and gravity-assisted motion and active flexion and extension exercises are initiated. Weightbearing as tolerated is allowed, and crutches are discarded when there is greater than 90° of motion, no limp, and good quadriceps control. The patient advances to Phase III (functional rehabilitation) when there is 120° of pain-free active knee motion. Participation in noncontact sports is allowed. When full strength, motion, and endurance are achieved, contact sports can be resumed. A football thigh girdle with a thigh pad is worn for 3 to 6 months for contact sports. If at any time during any phase of treatment there is an increase in pain or loss of motion, the patient regresses to the prior phase.

There are differences between the present treatment protocol in use for quadriceps contusions at West Point and the protocol of almost 20 years ago. In the past, immobilization in extension and limited early motion in the mobilization phase was recommended.[9] However, because of the observations of trainers and therapists that the lack of normal flexion prolonged disability, two phases of therapy were modified. In the immobilization phase, rest with the knee and hip flexed to pain tolerance was substituted for extension. In the mobilization phase, pain-free passive knee motion with emphasis on flexion was substituted for an early emphasis on extension and slow initiation of flexion. Immobilization with the hip and knee in flexion along with thigh compression gently increases tension, limiting the extent of the intramuscular hematoma. In addition, this position allows drainage of the edematous fluid from the region. Early pain-free passive motion establishes normal tissue planes, maintains uninjured muscle fiber excursion, and pumps excessive detritous from the soft tissue. This immobilization and early motion should encourage any immature intramuscular scar to form at maximal muscle fiber length and avoid becoming a check rein to knee flexion.

The use of the continuous passive motion machine provided a convenient, adjustable frame for hip and knee flexion in the immobilization phase and a gentle passive exerciser during the mobilization phase of hospitalized patients. In three patients hospitalized during a shortage of continuous passive motion machines, positioning the leg with the hip and knee in flexion on an adjustable bed and using well-leg and gravity-assisted motion proved effective. Cadets that were not hospitalized were instructed to rest as much as possible in the barracks with their knee and hip flexed, supported by pillows or cushions.

Although the ideal situation would be to use a continuous passive motion machine and hospitalize every patient with a quadriceps contusion, we realize that is not practical, economically feasible, or even allowable by today's standards. In the environment at the military academy at West Point, the only effective means of complete bed rest is hospitalization; cadets in the barracks are required to be at all formations and go to the mess hall for meals. The points to be emphasized are not whether hospitalization and continuous passive motion machines are used, but that rest and elevation in flexion and early gentle exercise emphasizing flexion are used. In a civilian setting, elevation in bed with the hip and knee flexed and well-leg and gravity-assisted motion are certainly acceptable. Home use of a continuous passive motion machine may also be an alternative.

Disability in cadets undergoing this modified rehabilitation program compares favorably with the results of Jackson and Feagin.[9] The slightly longer disability in the mild group

indicates our reluctance to allow cadets to rush into activities and an adherence to the goal-oriented, individualized therapy program. The significantly shorter disability for moderate and severe contusions documents the effectiveness of the changes made in the modified therapy program.

The overall incidence of myositis ossificans after a quadriceps contusion in our population was 9%. This, too, compares favorably with the 20% reported by Jackson and Feagin,[9] the 17% reported by Rothwell[15] in humans, and the 17% reported by Walton and Rothwell[19] in sheep. Our 17% incidence of myositis ossificans in moderate and severe contusions compares very favorably with the 72% incidence reported for subjects with moderate and severe contusions in the 1973 West Point study by Jackson and Feagin. They did not diagnose myositis ossificans in any mild contusion, but serial roentgenograms were not made for cadets with mild contusions. We took roentgenograms of all quadriceps contusions at least 6 months postinjury and found myositis ossificans in 4% of mild contusions. In the mild contusions that developed myositis ossificans, the knee range of motion was between 90° and 120° at initial evaluation. Myositis ossificans did not develop in any cadet who had a range of motion at least 120°. This may indicate the difference of a minor injury (>120°), with only intracellular changes, from a major injury (<120°), with capillary rupture, hemorrhage, and muscle fiber disruption.

The development of myositis ossificans is a multifactorial problem.[4,6-8,12] Induction of local and distant bone-forming elements have been studied in the laboratory.[19,21] The data from our study and other studies[9,10,15,17,22] appear to identify several risk factors for myositis ossificans. Of the five identified risk factors (range of motion less than 120°, injury secondary to football, a history of a previous quadriceps injury, delay in treatment greater than 72 hours, and ipsilateral knee effusion), cadets in our study that did not develop myositis ossificans averaged 1.6 risk factors (range, 0 to 4), while patients who developed myositis ossificans averaged 3.3 risk factors (range, 2 to 5). Hospitalization and the use of continuous passive motion did not statistically effect the rate of occurrence of myositis ossificans.

We did not use aspiration, injectible or oral medications, femoral nerve blocks, or radiation therapy in the treatment of quadriceps contusions even though these appear to decrease the incidence of myositis ossificans.[16,18,20] In our population, the side effects and risks of these treatments must be weighed against the apparent benign course of quadriceps contusions and myositis ossificans.

The differential diagnosis of quadriceps contusions must eliminate muscle rupture and arterial bleeding.[14] An acute compartment syndrome, although unusual in the thigh, can occur. If the thigh becomes tense because of excessive swelling and severe pain continues at rest or with mild passive stretching, intramuscular compartment pressure measurements are necessary. Sensory deficit is not a reliable indicator of a compartment syndrome in the thigh. The femoral nerve terminal branches in the anterior compartment need not be involved clinically in a compartment syndrome.[11] If swelling is severe and thigh girth has not stabilized by 24 to 48 hours, an arteriogram should be considered. We did not have to use arteriograms or measure compartment pressures in the evaluation or treatment of any quadriceps contusion in this study since all of the subjects experienced decrease in pain and stabilized thigh girth.

The differential diagnoses for myositis ossificans include periosteal osteosarcoma, parosteal osteosarcoma, and synovial sarcoma. In addition, myositis ossificans must also be differentiated from such benign conditions as osteochondroma, posttraumatic periostitis, and osteomyelitis. Radiographically, a myositis ossificans lesion can have a stalked connection to the underlying femur, have a broad periosteal attachment, or be separated by a radiolucent zone of soft tissue.[9,13] Microscopically, the periphery of myositis ossificans lesions is laminar bone while the central portion is much less mature.[2] A combination of clinical history and roentgenograms will normally allow adequate differentiation of myositis ossificans from these other lesions.

CONCLUSIONS

This 3 year study of 117 quadriceps contusions in cadets at the United States Military Academy at West Point indicates that the present treatment protocol for quadriceps contusions is effective in returning these young athletes to full activity with a normal range of knee motion and without recurrence of injury. The average disability time was 13 days for mild contusions (knee motion <90° at 12 to 24 hours after injury), 19 days for moderate contusions (45° to 90°), and 21 days for severe contusions (<45°). The principles of a three-phased therapy program presented by Jackson and Feagin (rest, mobilization, and restrengthening) are still used today. However, the use of immobilization with the hip and knee flexed to pain tolerance and an early restoration of flexion are introduced as effective modifications to the therapy recommendations of Jackson and Feagin (immobilization in extension and slow initiation of flexion). The potential for developing myositis ossificans should be suspected in anyone sustaining a quadriceps contusion who presents with active knee range of motion less than 120°. Other risk factors for the development for myositis ossificans are a delay in treatment greater than 3 days, a football injury, a previous history of a quadriceps injury, and the development of an ipsilateral knee effusion.

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DISCUSSION

Douglas W. Jackson, MD, *Long Beach, California:* Any time I review a paper from West Point it brings back many warm memories. I think that one of the criticisms that was always raised in the studies I did there, and should be considered, is that it is a select population and we have to extrapolate their experiences to a civilian population. We are caring for athletes in an environment that expects cost-effective outcomes. Our patients have asked us to give them quality care but also to take some consideration of cost. A passive motion machine in our area rents for $25.00 to $75.00 a day. Over the past 15 years I have not hospitalized anyone following a quadriceps contusion and have managed them as outpatients. I think, if you have a high-level athlete with a severe injury, hospitalization is a consideration. I do not obtain follow-up radiographs if their clinical course goes as expected.

I do not have any criticisms with the authors' treatment or results. I would just like to pose one question to them. The literature has had several articles recently on increased compartment pressure following trauma to the quadriceps: What do they think their resting position (flexion to pain limitation) does to the pressure in the compartment? If it increases the pressure, may there be more damage to muscle cells?

COMMENTARY

Robert C. Meisterling, MD, *Stillwater, Minnesota:* The authors have presented a method of converting a potentially disabling athletic injury into a relatively minor episode. Their emphasis on early knee flexion and quadriceps rehabilitation appears to be the key to their treatment protocol. It has been our experience that limiting the hematoma formation at the time of injury can effectively eliminate the disability in all but the most severe contusions and I think that their method of managing this hematoma once it has been established is certainly a worthwhile effort and probably accounts for their improved results over those of Jackson and others. I would like to ask the authors if they have attempted immediate treatment of these thigh bruises by compression and encouraging maximum knee flexion to prevent hematoma formation.

Authors' Reply: We fully realize that our "ideal" situation at West Point is very different from a civilian setting and that it is not practical or economically feasible to use continuous passive motion machines and hospitalization for every patient with a quadriceps contusion. We would reemphasize that the points to be remembered are not whether hospitalization and continuous passive motion machines are used, but that rest, compression, elevation with the hip and knee flexed, and gentle early exercises stressing flexion are important. Flexion to pain limitation should increase pressure in the anterior thigh compartment helping to limit hematoma formation, but not enough to damage the muscles any more than they have been already. Our reason for obtaining follow-up radiographs in all cadets was to document the true incidence of myositis ossificans following all grades of quadriceps contusions and represents an ideal setting rather than a practical or necessary one.