Overuse Injuries of the Lower Extremities Associated with Marching, Jogging, and Running: A Review

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Lower extremity injuries associated with military training are a serious problem which may be preventable. These injuries have plagued military personnel for centuries, even millenia, and, despite mechanization and modern medical technology, these lower extremity disorders persist as a consequential problem for the Army. The seriousness of the problem is reflected by the high injury rates encountered during basic training, when over 25 per cent of male and nearly 60 per cent of all female recruits are afflicted.[2,13] The problem has been exacerbated by the increasing numbers of women being recruited, since during training they experience a much larger, overall incidence of injury than their male counterparts.[13,17]

These injuries are an important problem resulting in loss of manpower and training time, as well as increased cost of medical care. Time is lost reporting to sick call, on light duty, at bed rest, or in the hospital itself, depending on the severity of the injury. Further time may be lost during rehabilitation. During basic training, recycling of injured soldiers may be necessary and, in some instances, they must be discharged from the Service. If even a small portion of these injuries could be prevented, it could mean large benefits to the military both monetarily and in terms of troop productivity.

Incidence of Injury

Despite the apparent enormity of this problem, few reliable, comprehensive studies of lower extremity injuries in military populations are available. There are no controlled studies dealing with the prevention of lower extremity injuries, perhaps because the knowledge and technology to remedy them have been lacking. A review of available literature reveals only two substantial studies of the incidence of lower extremity injuries. One was a study of Army basic trainees published by Kowal[13] in 1980. The other was a prospective study of Marine basic trainees produced as a technical report by Bensel[2] in 1976. These studies, while illuminating the problem, are limited in scope which will be addressed in the following discussion.

The study of Army basic trainees reported by Kowal was carried out at Ft. Jackson, S.C. in 1978, and followed trainees who wore boots through one seven-week basic training cycle. The intent of this study was to focus on "exercise-related injuries and performance-limiting conditions" in female trainees.[13] Some comparative data were also collected on injuries among male counterparts of these females. The overall incidence of lower extremity injuries to females during the study period was 62 per cent (215 of 347) and for males 26 per cent (202 of 770). The average injury sustained by these women resulted in 13 days of lost training time (no data on time lost for males are available).

Bensel studied Marines undergoing basic training at the San Diego, Calif. Marine Recruiting Depot in 1975. This project was designed to determine whether use of tropical combat boots would reduce the incidence of lower extremity injuries normally experienced using the standard leather combat boot. This study encompassed one training cycle of 11 weeks. An overall incidence of injury of 37 per cent (325 of 879) was observed during this cycle. The average amount of time lost was only three days per injury. Parenthetically, wearing tropical combat boots was not found to be beneficial.[2]

Both of these studies, while suggestive, need amplification to delineate the true magnitude of the problem of lower extremity injuries in Army populations. Kowal's investigation was not monitored and really only focused on injuries to women, while Bensel's study focused only on men. Furthermore, this latter study was limited in scope, dealing only with injuries below the knee. Other studies, mostly on civilian runners, indicate that 20–40 per cent of all debilitating training injuries involve the knee[4,6,12,15,16] Therefore, this is an important anatomical site to include in any investigation of lower extremity training injuries. Also, neither study dealt with the injuries of seasoned soldiers. In spite of these limitations, these studies do provide a glimpse of the size and nature of the problem.

Because of the limited amount of data available on military populations it is necessary to extrapolate from other sources. Unfortunately, data from civilian populations regarding the incidence of injury secondary to weight bearing physical training are also scanty. The only recent published data on incidence of injuries suffered by civilian runners appeared in a popular running journal in 1977, and indicated that during the course of the preceding year nearly two out of three runners surveyed were injured.[11] In another large but retrospective study of injured distance runners (1,077 patients), published in 1980 by a podiatrist and an orthopaedist in the same popular journal, it was found that 48 per cent of those injured ran less than 20 miles per week.[15] It might be assumed from this information that, even in civilian populations of runners, most of whom are likely to wear "state-of-the-art" running shoes and who are not performing excessive training mileage, injuries still occur. Any further speculation must be made with caution.

Distribution of Injuries

As previously mentioned, published incidence of inju-

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ries suffered by runners and joggers is difficult to find. All the large civilian studies are retrospective compilations from the medical records of injured runners. They present only distributive data,[4,6,12,14,15] since the size of the running population in which they occur is not known. These studies are interesting because the distribution patterns among civilian runners and joggers are very similar to those of military trainees. Also, one of these retrospective studies by Brubaker and James[4] presents the only extensive account of training days lost and treatment modalities. It can be inferred from their tables that, of the 109 injuries discussed, a minimum of 1,764 training days (an average of 16 days per injury) were lost as a result. This suggests how potentially costly running injuries can be.

Significant Categories of Injuries

Over 50 specific injuries can be tabulated from the available literature.[6,12,14,15,17] However, five categories of injury account for more than 50 per cent of all injuries in both civilian and military populations (Table I). These injuries are:

1. Stress fracture
2. Knee problems
3. Achilles tendinitis
4. Ankle sprain
5. Plantar fasciitis.

The first two of these injuries are general and could be subcategorized. The other three are specific entities. Even if the general categories were further subdivided, only eight specific injuries would account for nearly the same percentages.

Given their frequency and debilitating nature, these five injuries should be clearly defined prior to, and accounted for, during any comprehensive study of lower extremity injuries. While none of these injuries is crippling or life threatening, without adequate rest (frequently two to eight weeks) and proper medical attention, each has the potential to limit performance and possibly become incapacitating.

Another malady, blisters, could be added to the above injury list, particularly in military populations. Many think of blisters as a trivial problem but, in Bensel's study,[2] one-third of all trainees suffered from them, and ten per cent of these went on to develop cellulitus, which was the most serious problem in her study and the only one requiring hospitalization. The military combat boot has been implicated in the causation of blisters, supposedly due to such factors as stiffness and poor fit.[1,2,7] For this reason, any investigation of lower extremity injuries in military populations or of military footwear would be well advised to account for this condition.

TABLE I

PER CENT OF TOTAL NUMBER OF LOWER EXTREMITY INJURIES ACCOUNTED FOR BY FIVE CATEGORIES OF OVERUSE INJURIES IN CIVILIAN AND MILITARY POPULATIONS

	Civilian				Military	
Study	Clement[6]	Pagliano[15]	Brubaker[4]	James[12]	Reinker[17]	Kowal[13] +
Injury						
Stress Fracture	6	9.1	16.4	6.0	11.3	34.0
Knee Problems	42	30.0	24.2	27.1	—	—
Chondromalacia/Patellofemoral Syndrome	(26)	(9.0)	(4.6)	(7.3)	8.3	10.0
Achilles Tendinitis	8	5.7	9.0	11.0	14.5	4.0
Ankle Sprain	—	3.8	4.5	—	6.2*	6.0
Plantar Fasciitis	5	14.1	1.8	7.0	13.3	—
Per Cent Total No. Accounted for	61.0	62.7	55.9	51.1	53.6	54.0
Avg. Per Cent Total	56.4					

—Denotes that this injury was not specifically accounted for (numerically)
( ) Denotes subset of larger category and per cent of total injuries
* Denotes unpublished data from same study
+ Kowal's data were for females only

Factors Influencing the Incidence of Injuries

The majority of injuries incurred as a result of weight bearing physical training fall into a general category commonly referred to as "overuse injuries." Multiple factors influence the development such injuries. Among these factors are the following:

1. Prior physical condition
2. Physical anomalies
3. Body weight
4. Previous injury
5. Gender
6. Training surface
7. Equipment—footwear
8. Training techniques.

The influence of some of the above categories is obvious. Individuals who begin training at a low level of fitness need to proceed cautiously. They are more predisposed to injury as they lack strength and, thereby, essential musculoskeletal support. They also fatigue more readily. Some physical anomalies such as flat feet (pes planus), high arched feet (pes cavus), bowed legs (tibia varum), and bunions (hallux valgus), among others, have been implicated as predisposing factors,[2,6,12] although clear associations in all have not been established. Bensel's study suggests that individuals with high arches are predisposed to injuries such as stress fractures.[2] Obesity has likewise been cited as an etiological factor in the development of overuse injuries in military trainees, particularly for stress fractures of the heel.[2,10] Higher injury rates are also likely to be associated with previous injuries, such as fractures, torn knee cartilages, and badly sprained ankles.

Some factors listed as influencing injury rates are more complicated. Gender, for instance, probably influences injury rates for a number of reasons. As noted previously, women suffer a much greater percentage of lower extremity problems than men, particularly during military basic training. This may reflect a lesser degree of conditioning than their male counterparts on entering the Service. They have a higher percentage of body fat and less lean body mass (muscle). Also, female anatomic characteristics, such as wider pelvis and femoral anteversion have also been suggested as contributing to the likelihood of injury. Other parameters undoubtedly contribute to the higher incidence of injury among women, but their discussion would require more space than the scope of this paper will permit.

Training surfaces are another complex variable affecting training injuries. Many people insist that the safest surface is grass or dirt. But, in a recent booklet, Brody[3] presents a more enlightened view:

> The running surface is important. A soft, level surface—such as a dirt path—is ideal, but most people run on whatever surface is most convenient. Running on concrete sidewalks and up and down curbs exaggerates shock transmitted to the legs, feet and back; an asphalt road, on the other hand, provides more cushioning. Grassy surfaces are irregular, and sand is unstable. A sloping or banked surface such as a beach or shoulder of a road forces the foot on the higher part of the slope to pronate excessively, which puts additional stress on the tendons and ligaments of the lower extremity.

Most surfaces have their own peculiar disadvantages. Running on uneven, unpredictable surfaces, like grass (golf courses and parade fields included) or poorly groomed dirt trails or tracks, can accentuate the problems of anatomic malalignment, muscular weakness, and improper footwear. Because it provides a relatively smooth, stable, running surface and is in abundant supply, asphalt may be considered an adequate medium to train on, especially if shock absorbent footwear is worn.

For the remainder of this discussion of the variables influencing the incidence of training injuries, the focus will be on two factors, footwear and training techniques. The reason for this emphasis is twofold. One, these are among the most commonly implicated factors. Secondly and perhaps more importantly, they are probably the most amenable to manipulation for the purpose of preventing injuries.

Footwear

In regard to footwear, the combat boot has historically been blamed for such military training maladies as march (stress) fractures, Achilles tendinitis, and blisters.[1,2,7,17,19] In recent years, there has been a growing advocacy for the use of running shoes for physical training by many military units. This advocacy has aroused a considerable amount of controversy and debate throughout the Army, with some commanders countering that, since the soldier fights in the boot, he should train in the boot. Thus far, neither side has provided any conclusive evidence in its favor. The primary rationale for switching to a shoe for running is: (1) the alarmingly high incidence of lower extremity injuries in boots; and (2) the suspicion that injury rates could be reduced while aerobic fitness and morale would be enhanced.

It is probably no coincidence that the increasing interest by some Army commanders parallels the availability of "good" running shoes over the last six years. It is commonly felt that these new shoes are better than those previously available in terms of injury preventive characteristics. Furthermore, some feel that it is logical to assume that these new shoes are also better than the combat boot in this regard, and that shoes therefore merit consideration as a standard issue item of military physical training gear.

Addressing the issue of footwear and injuries, Cavanagh[9] of the Pennsylvania State Univ. Biomechanics Laboratory recently stated:

> Unfortunately, it is not as scientific as I would hope, because there is so much we don't know about injury prevention and shoe design. And part of the reason for this is because there have been no really well controlled studies where you try four or five different shoes under controlled conditions on large populations.

There likewise, have been no controlled studies published comparing the incidence of injury in boots versus shoes. Cavanagh[5] suggests that the military would be an ideal place to conduct an epidemiological study of footwear. Despite the lack of confirmatory evidence from large field studies, it is commonly felt in civilian circles that one can actually shop for shoes with specific injury preventive characteristics.

Regarding the problem of combat boots and military training injuries, various elements of the Army have felt strongly enough to issue policies such as the following:

> Running for endurance during organized physical training should be performed wearing soft, cushioned soled foot gear designed to allow mobility of the foot and ankle as well as dampen the impact forces on the ankle and knee joints (memorandum, US 7th Army, 1978).

While edicts such as the above have been issued, there has been no confirmation through experimental studies that one shoe is better than another, or that shoes are better than boots (for running) in terms of injury prevention. But, there is quantitative evidence from the Pennsylvania State Univ. Biomechanics Laboratory comparing some qualities of shoes and boots felt to be essential for injury prevention.[8] Their data indicate that, in the areas of impact protection, flexibility, and energy retrieval, all boots presently in use by the Army were inferior to all running shoes (five types) investigated in all three categories.

These findings are not surprising, since the combat boot was designed primarily to provide protection to the foot and ankle for a variety of surfaces and activities, not specifically for physical training. It is commonly believed that adequate footwear for running should exhibit the following characteristics:

1. Shock absorption (impact properties)
2. Flexibility
3. A stable heel counter
4. Supportive insole.

As stated previously, the combat boot is measurably inferior in at least the first two qualities listed above. It also lacks a supportive insole. On these grounds alone, the boot must be viewed as inadequate for running by the standards set forth by civilian practitioners and investigators of sports medicine and biomechanics. It might be pointed out that the Marines presently wear running shoes to perform physical training during basic training. Although no conclusive epidemiological evidence is available, current information suggests that, if military endurance (aerobic) training is to be conducted in "adequate" footwear, some modification of the boot is necessary, especially in basic training, or this type of exercise should be done in a properly designed shoe.

In considering a shoe for physical training, especially if substantial amounts of running are involved, not just any athletic shoe will suffice. Brody[3] warns:

> Wearing poorly constructed running shoes or inappropriate shoes, such as sneakers, can also contribute to injury, as they do not provide the cushioning or stability needed to protect the foot and leg from the repetitive shocks of running.

The relationship between footwear and injury is a complex one which is only beginning to be defined.

Training Techniques

Another factor deserving further attention is training techniques. In discussing injuries to runners, James[12] states "that about 60 per cent of these problems are associated with a training error." Common errors include increasing intensity, duration, or frequency of training too rapidly.[3,6,12,16] Even in trained distance runners, injuries tend to be associated with sudden increases in mileage or "speed work".

As with footwear, there is very little substantive information regarding the impact of training techniques on overuse injuries. One of the few studies on this subject was published by Pollock,[16] in 1977. In this investigation, he examined the effect of frequency and duration of training on the incidence of injury in novice runners. In relation to frequency, Pollock found that, among subjects who were trained over a 20-week period at 85–90 per cent maximal heart rate for 30 minutes per session, those training five days per week suffered a 39 per cent incidence of injury, as compared with 12 per cent and zero per cent in those training three days and one day per week, respectively. Aerobic achievement was felt to be comparable in the three- and five-day per week groups.

To address the effect of duration of training sessions on injury rates, subjects trained for 20 weeks, at 85–90 per cent of maximal heart rate three days per week, but the duration of each session was varied. The results showed that individuals training 45 minutes per session, three times per week, experienced a 54 per cent incidence of injury, as compared with a 24 per cent and 22 per cent incidence, respectively, for the 30- and 15-minute per session groups. In these studies, an injury was defined as a training-related condition that prevented a subject from running for a minimum of one week. Aerobic fitness gains were similar for the 30- and 45- minute groups, but significantly less for the 15-minute group. The implications of this study for the conditioning of untrained subjects seem obvious: limiting the frequency and duration of training can be expected to reduce injury rates, while sacrificing little in terms of training effect.

The only evidence available on the impact of training methods on overuse injuries in military populations pertains to stress fractures. Even in this instance, the information is only speculative and not conclusive. Scully[18] reports success in decreasing the incidence of stress fractures in basic trainees at Ft. Knox in 1974 and at Ft. Bliss in 1979–1980, by prohibiting running and marching during the third week of the basic training cycle. Worthen and Yanklowitz,[19] at Ft. Leonard Wood, similarly felt that they could significantly reduce the number of stress fractures in basic trainees by separating physical training and drill and ceremony sessions by eight hours, and by prohibiting physical training episodes of greater than two hours duration during the first three weeks of basic training. The importance of these military studies of stress fractures is that they suggest that modifications of training techniques may help reduce the high incidence of some overuse injuries in military trainees.

Further Research Needed

More detailed and specific recommendations will have to await the results of further investigations of the impact of footwear and training techniques on overuse injuries. Major questions remaining to be answered are:

1. What impact (if any) does footwear have on the incidence of lower extremity injuries?
2. What impact does alteration of training methods have on the incidence of injury?
3. What are the incidences of lower extremity injuries in military populations?
4. How much time is lost due to these injuries?
5. What are the differences of injury rates in males and females?
6. What factors account for these differences between males and females?
7. Are these injuries more reflective of physiological fatigue or mechanical stresses to the lower extremities?

Summary

While no extensive definitive studies have been done, the available literature suggests that overuse injuries are a significant problem for the military. Several approaches to this problem are suggested. These include progressive increases in weight-bearing physical training, taking into account initial fitness levels, and wearing adequately supportive footwear, such as a well designed running shoe. Adequately supportive, lightweight footwear may be even more crucial during the early phases of training, while the foundations of strength and stamina are being established. Alternate days of running or marching during the early phases of physical training to insure adequate physiologic recovery would also seem advisable. This is important because, without adequate recovery, training effects will be diminished while the risk of injury will increase.

Furthermore, it seems clear that women are more likely to be injured than men. Whether the large discrepancy in injuries between males and females is secondary to inherent anatomic and physiologic differences or some other factor, such as a lower level of initial fitness, is not yet established. For this reason, no special remedial program can be prescribed for women at this time, except to initiate physical training at modest levels and then gradually increase.

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Book Reviews

Real-Time Ultrasonography, Vol. 10. Clinics in Diagnostic Ultrasound. Ed. by Fred Winsberg, M.D., Prof., Dept. of Diagnostic Radiology, McGill Univ. Faculty of Medicine, Montreal, Quebec, Canada, and Peter L. Cooperberg, M.D., Churchill-Livingstone, Inc., New York, 1982, 321 pp., 226 illus., $27.00.

The multi-volume series of Clinics in Diagnostic Ultrasound, published under the direction of an Editorial Board made up of recognized authorities in the field, is a creditable effort to keep pace with a rapidly advancing and dynamic technology. Each volume provides an opportunity to review recent progress limited to a specific topic, and attempts to bridge the gap between the textbook and current journals, thus enabling those involved with this form of imaging to have quicker access to the most modern state-of-the-art.

Real-time ultrasound, the subject of the tenth volume of the series, is analogous to fluoroscopy of diagnostic roentgenology. It has been known approximately for the past 15 years, has been used rather extensively in obstetrics for about seven years, and has undergone in the past three years sophisticated improvements in instrumentation. As a result, the indications for its use have been greatly extended. Ultrasonography has been done principally by static B-mode scanners because of the feeling that resolution is better with this method. However, the improved instrumentation of real-time ultrasound now yields resolution considered to be equal to that of the static scanners. Furthermore, the great number of contributions to the recent literature relative to real-time imaging point to its increasingly more frequent use and to a greater degree of confidence in its application.

The term "real-time" has been borrowed from the language of the computer world. It refers to the ability of the instrument to produce images of a moving organ at a rapid rate, and to permit the operator to manipulate the image as it is observed. The advantages claimed for this form of imaging are speed, flexibility, and diagnostic utility.

The contents of the book consist of 14 chapters prepared by 18 contributors. The format generally follows an anatomical classification after accounts of historical background and instrumentation. Excellent descriptions are given of the use of ultrasonography in the abdomen generally, emergencies involving abdominal structures due to trauma, the acute abdomen, the gallbladder and biliary tract, the bowel, and the carotid arteries. Also included are discussions of the thyroid, parathyroid, and salivary glands, eye and orbit, breast, scrotum, early pregnancy, fetal abnormalities, and biopsy techniques. Illustrations of good quality demonstrate most of the conditions described, and an appendix of five case studies at the end of the book is included to test the reader. The editors have presented an excellent overview of the current knowledge in ultrasound imaging.

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(*Continued on page 792*)