0363-5465/80/0804-0265$02.00/0
THE AMERICAN JOURNAL OF SPORTS MEDICINE, Vol. 8, No. 4


# Nature and causes of injuries in women resulting from an endurance training program*

DENNIS M. KOWAL,† Ph.D., *Washington, D.C.*

*From the Health and Performance Division, United States Army Research Institute of Environmental Medicine, Natick, Massachusetts*

## ABSTRACT

**Women entering the Army are exposed to considerable physical stress due to the intense physical training program encountered. At the beginning of a basic training cycle, a prospective study was initiated to identify exercise-related injuries and performance-limiting conditions that resulted from an 8-week physical training program and to identify some of the factors that may contribute to their occurrence. Four hundred women recruits (age 18 to 29 years) participated in the study. All had passed an initial physical examination and were without any limiting disabilities. An initial assessment of physical fitness was accomplished to determine the current status of body composition, strength of the major muscle groups (e.g., legs, trunk, arms, and upper torso), aerobic capacity, previous athletic history, self-perception of physical fitness, and psychosomatic predisposition. The training and conditioning program (1 hr daily, five to six times a week) involved a series of standard warm-up calisthenics and stretching exercises followed by a run, beginning at ¾ mile at a 10 min per mile pace and increasing to 2 miles at 9½ min per mile by the end of training. Extensive road marches and military training activities were also included. At the end of training, a self-report injury questionnaire was used to collect injury data. These data were documented with the records from the unit dispensary and data provided by the installation physical therapy, orthopaedic, and podiatry clinics. Fifty-four percent (215) of the women sustained some reportable injury. These injuries resulted in an average training time loss of 13 days. Forty-one percent of these injuries prevented participation in all activity, 31% resulted in only limited participation. Early training "overuse syndrome" accounted for 42% (92) of the reported injuries. Significant injuries were: tibial stress fracture (45), chondromalacia of the patella (21), hip or neck of femur stress fracture (20), sprains (12), Achilles tendinitis (10), calcaneous or metatarsal stress fracture (8), and fascial and anterior compartment strains (6). The injury data were correlated with prior-fitness measures. The results indicated that a major cause of injury in women can be attributed to the lack of prior conditioning, greater body weight and fat percent, and limited leg strength. These factors, coupled with some inherent physiologic characteristics of women (i.e., wide pelvis, less strength, and greater joint flexibility), probably contributed to the increased risk of injury in these women. It is concluded that susceptibility to these potential orthopaedic and medical conditions can be identified before the beginning of training and minimized through proper remedial activity before a strenuous physical training program is initiated.**

With the rising recruitment of women into the armed forces, data are needed on their response to physical training and the physical differences that may limit their performance capacity. Although insights have been gained regarding the beneficial effects of physical training on the stamina, muscular strength, and endurance of both men and women in the armed forces,[1-3] little information is available concerning the *risk of injury* involved in exposing previously sedentary women to a rigorous physical training program.

In the past, it has been extremely difficult to study the incidence and distribution of injuries in normal young women because of the relatively small number participating in stren-

* Presented at the Fifth Annual Meeting of the American Orthopaedic Society for Sports Medicine, Innisbrook, Florida, July 9 to 12, 1979. The views of the author do not purport to reflect the position of the Department of the Army or the Department of Defense. (Para. 4-3, AR 360-5).

† Present address: Psychology-Psychiatry Service, Walter Reed Army Medical Center, Washington, D.C. 20012

uous physical activity and the self-selected nature (athletes) of those who do.[4-7] However, this has changed with the rising interest and participation of women in the whole spectrum of sport activities. The purpose of this prospective research was to (1) determine the incidence and nature of injuries in a female population as a result of a rigorous supervised endurance training program and (2) identify the predisposing factors that may be related to their occurrence.

## METHODS

We followed a group of 400 women recruits, age 18 to 29 years old (average age 21), through a complete 8-week basic training cycle (January 15 to March 12, 1978). (See Table 1 for other descriptive characteristics.) A complete medical history was available, and they were given a complete physical examination before training began. An initial assessment of physical work capacity also was accomplished. This assessment included the determination of body composition by using skinfold estimation and the equation of Durnin and Wormseley,[8] strength of the major muscle groups (legs, trunk, arms, and upper torso), aerobic capacity ($VO_2$ max),[9] psychosomatic predisposition by using the Health Opinion Survey,[10] activity history (previous athletic participation), and self-perception of fitness level compared to other women of comparable age.

These women participated in an integrated (male and female) endurance training and conditioning program for 1 hr per day, five to six times a week that involved a series of standard warm-up calisthenics including situps, pushups, side straddle hop, leg overs, and modified knee bends. These exercises preceded each training session and progressed from 6 to 12 repetitions per session over the course of the training program. Running began with ¾ miles a day at a 10 min per mile pace and increased to 2 miles in 18:30 min by the end of the 8-week training period. The training program also involved extensive marching and other activities germane to military training.‡

For the purposes of this study, an injury was defined as any disability that was incurred during or as a result of physical training-conditioning which required attention from the medical facility. Only 327 of the 400 women were available for evaluation after the training period; 20 other women were followed up because they had sustained injuries which required them to be hospitalized. The remaining 53 women were administratively discharged or unavailable for testing; no information was available on them.

The injury data were gathered through the use of a self-report medical disposition questionnaire given to the women after training. These data were supplemented with records from the dispensary, consultation reports, and radiographic data provided by the installation's physical therapy, orthopaedic, and podiatry clinics.

A discriminant function analysis was performed using injury during training as the criterion variable and using the variables gathered during initial assessment as predictors.

‡ The training program is outlined in the *Drill Sergeant Guide for Pre-Baseline Physical Training*. Fort Benning, Georgia, Dated December 20, 1977.

TABLE 1

Comparison of selected parameters for injured vs. uninjured women prior to participation in 8 weeks of physical training

| | Injured | Uninjured |
|---|---|---|
| Variables | $n = 195$ | $n = 132$ |
| Body weight (kg) | 59.2 ± 7.3 | 59.3 ± 6.8 |
| Height (cm) | 162.3 ± 6.8 | 162.5 ± 6.3 |
| Body fat (%) | 28.4 ± 4.9 | 27.7 ± 4.4[a] |
| Static strength of leg extensors | | |
| Leg strength (kg of force) | 91.2 ± 32 | 95.7 ± 28[a] |
| $VO_2$ max (ml/kg min) | 37.9 ± 4.6 | 36.2 ± 3.3 |
| Previous athletic participation (1 very inactive-5 very active) | 3.18 ± 0.9 | 3.25 ± 0.8 |
| Physical fitness compared to other women (1 poor to 5 superior) | 2.82 ± 0.7 | 2.90 ± 0.5 |
| HOS[b] score (psychosomatic predisposition) | 31.3 ± 6.6 | 30.3 ± 5.5 |

[a] $P \leq 0.05$.

[b] HOS, Health Opinion Survey[10].

## RESULTS

The self-report questionnaire data indicated that 54% (215 of 347) of the women had sustained some sort of injury requiring medical attention over the 8 weeks of training. The incidence as tabulated from the questionnaire is presented in Table 2. (It should be noted that the incidence of injury in women compared unfavorably with the incidence reported for men undergoing the same training (26% or 202 of 770.) These injuries resulted in an average loss of 13 training days during the basic training cycle, 41% (80) of the injuries prevented participation in all physical activity (major profile), and 31% (61) resulted in limited participation (minor profile). Table 3 presents a summary of the specific diagnoses and structural involvement of these injuries as documented by the hospital consultation sheets and radiographic evidence. The majority were either overuse syndrome or stress fractures.

Injuries usually resulted from a combination of (1) continued hard training after onset of symptoms, (2) inherent structural weakness, or (3) biomechanical anomaly. Tibial and femoral stress fractures accounted for one-third of all of the injuries identified and represented the most serious sequelae of this endurance training program. Figure 1 presents stress fracture data as a function of the onset of symptoms during the 8-week training cycle. The incidence of tibial stress fractures increased during February and dropped off in March. The hip-femoral stress fractures increased throughout training and reached the maximum during the last 2 weeks of training.

A discriminant function analysis was used to identify the underlying variables that contributed to the prediction of injury. We found that body composition, muscular strength of the legs, previous athletic participation, self-perception of fitness and psychosomatic predisposition were correlated with injury (Table 4). The discriminant analysis resulted in a linear combination of the variables that maximally differentiated between the two groups. For the present data (Table 4), the discriminant function is 0.507 physical fitness + 0.683 weight minus 0.662 leg strength minus 0.552% body fat. However,

TABLE 2

Self-report of the incidence of injuries sustained by men and women during basic training

| Type of injury | Women (215) | | Men (202) | | % difference (W-M) |
|---|---|---|---|---|---|
| | *n* | % | *n* | % | |
| Fracture (break) | 8 | 3 | 4 | 2 | 1 |
| Stress fracture | 45 | 21 | 9 | 4 | 17 |
| Joint problems | 30 | 14 | 47 | 24 | −10 |
| Foot problems | 28 | 12 | 54 | 27 | −15 |
| Tendon inflammations | 67 | 31 | 23 | 12 | 19 |
| Muscle strain | 27 | 12 | 26 | 13 | −1 |
| Other | 10 | 4 | 39 | 20 | −16 |

TABLE 3

Diagnosed injury sustained by women during basic training ($n$ = 215)

| Structure | No. | % |
|---|---|---|
| Overuse syndrome (leg soreness, lowered general energy level, clumsiness, and poor coordination) | 92 | 43 |
| Tibial stress fracture | 45 | 21 |
| Chondromalacia of patella | 21 | 10 |
| Hip or neck or femur stress fracture | 20 | 9 |
| Ankle sprain | 12 | 6 |
| Achilles tendinitis | 10 | 4 |
| Calcaneus stress fracture | 6 | 3 |
| Anterior compartment and fascial strain | 6 | 3 |
| Metatarsal stress fracture | 2 | 1 |

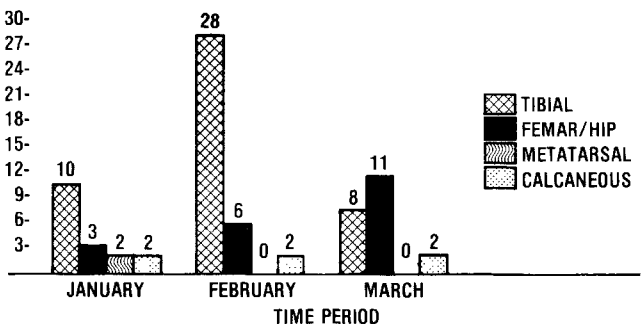


Fig. 1. *Number of stress fractures as a function of onset of symptoms during training period.*

only 55% of the cases could be correctly classified. Table 5 presents a breakdown of the different degree of injury (major, minor, overuse) within the group of injured women. As can be seen, the variables of percent of body fat and leg strength are both significantly different across the group and correspond to the previous comparison of injured vs. uninjured women.

## DISCUSSION

The data presented document that weight, percent of body fat, and limited leg strength were related to the increased incidence of injury in women during training and may have attributed to lack of prior fitness or conditioning. With the assessment techniques described in this paper, it may be possible to identify women "at risk" for orthopaedic injury before training.

There are several physiologic factors reported in the literature[12] which are generally considered to predispose women to these injuries. The elasticity in the connective tissue, which allows women to be more flexible, may also make them more vulnerable to ligament or joint injury. Women's biomechanics and wide pelvis appear to contribute to the increased risk of injury to the hip and the outer aspect of the knee, leg, and foot because of the varus tilt. This is further aggravated by the apparent lack of heel stability inherent in the Army boot used by the women during basic training. Although the standard Army boot has proved quite satisfactory for men during basic training, women report that the heel width is too great even in the narrow sizes used by them. The resulting heel instability

TABLE 4

Discriminant analysis of factors contributing to classification of individuals who were injured or uninjured

| | % Predicted | |
|---|---|---|
| Actual group | Injured | Uninjured |
| Injured 195 | 52.9 | 47.1 |
| Uninjured 132 | 41.1 | 58.9 |

% of cases correctly classified, 55.16

Summary of table variables

| Step no. | Variable entered | Approximate F | Rao's V-test | DF | Level of significance |
|---|---|---|---|---|---|
| 1 | Physical fitness | 2.56 | 2.56 | 1/295 | 0.10 |
| 2 | Leg strength | 1.97 | 3.97 | 2/294 | 0.13 |
| 3 | Weight | 1.55 | 4.70 | 3/293 | 0.19 |
| 4 | Body fat (%) | 1.67 | 6.74 | 4/292 | 0.15 |

TABLE 5

Comparison of pretraining parameters for the levels of injury sustained by women during 8 weeks of physical training ($n$ = 215)

| Variables | Major injury ($n$ = 80) | Minor injury ($n$ = 66) | Overuse syndrome ($n$ = 64) |
|---|---|---|---|
| Body weight (kg) | 59.7 ± 7.4 | 58.0 ± 6.9 | 59.8 ± 7.6 |
| Height (cm) | 162.1 ± 6.9 | 161.3 ± 6.7 | 163.6 ± 6.9 |
| Body fat (%) | 29.5 ± 4.4 | 28.3 ± 5.3 | 27.4 ± 4.9[a] |
| Static strength of leg extensors (kg of force) | 93.5 ± 3.2 | 92.9 ± 3.2 | 103.1 ± 3.3[a] |
| Previous athletic participation (1 very inactive-5 very active) | 3.18 ± 0.7 | 3.19 ± 0.9 | 3.20 ± 0.8 |
| Physical fitness compared to other women (1 poor to 5 superior) | 1.85 ± 0.5 | 1.91 ± 0.4 | 2.10 ± 0.5 |
| HOS[b] score (psychosomatic predisposition) | 30.9 ± 6.7 | 31.6 ± 6.4 | 31.3 ± 6.7 |

[a] $P \leq 0.05$.

[b] HOS, Health Opinion Survey.

surely aggravates existent ankle weakness or foot disorder. Likewise, since women are smaller in structure, the 30-inch step, the very basis of the military drill and ceremony, is often an aggravating factor in the incidence of stress fractures and overuse syndromes. Another factor contributing to injuries in women may be their inability to differentiate between "pushing themselves" beyond the pain threshold and exposing themselves to undue risk of injury. It is evident from the data that many of the symptoms of overuse which occurred early in the training program culminated in injury later on, having been neglected or considered inconsequential initially. Likewise, returning to training before the symptoms had fully disappeared was courting disaster later in training.

A major factor in the development of injuries in this sample is believed to be the rapid onset of training which did not allow for a progressive exposure to stress and the development of tolerance. The more sedentary and unconditioned women were exposed to a greater risk of injury to the lower extremities when they were put under this physical stress. Initially, the bones attempt to become stronger by remodeling their internal architecture in response to the chronic physical demand. In doing so, they actually become weaker in the area of mechanical stress, and continued training during this period may have led to injury. The second phase of this remodeling involves actual deposition and hypertrophy of the bone along the lines of stress. However, during the lag time between these two phases, the bone is also more susceptible to fracture.[13] If training had been staged progressively, some of these injuries might have been avoided.

Stress fractures have been widely studied in men[7] because they can potentially prevent an individual from performing his normal duties for a prolonged period of time. However, with the increasing number of women participating in various physical activities, the occurrence of stress fracture has risen dramatically.[6] These findings were supported by another source of morbidity data (*in Health in the Army*, January 1979, pp 52–53. Health Services Command, Fort Sam Houston, Texas) which reported that during basic training women had greater than twice the rate of fractures as that reported for men (19.6 per 1,000 compared to 9.4 per 1,000 for women and men, respectively). With regard to the causes of stress fractures, the results of Gilbert and Johnson[11] apply equally well to women as to men. The stress fractures are related to body structure and are found to be more common among overweight recruits and those with little exercise experience. However, the majority of the fractures in men reported by Gilbert and Johnson[11] were fractures of the metatarsals and os calcis, i.e., "march fracture," whereas in the present study we found only eight cases of these types of stress fractures in women. The majority of those found in women recruits were tibial and femoral fractures. A large number of cases of symptomatic chondromalcia of the patella were also reported.

Although the conventional statistical criterion for significance was not achieved, it must be kept in mind that in this case the increased probability of a Type I error ($P \geq 0.15$) still provides for a substantial improvement (over no information at all) regarding an individual's susceptibility to injury.

After monitoring training programs of 3 days a week or less,[5] we have deduced that training over 3 days per week results in a significant increase in the injury rate for previously sedentary women. However, the program that maintained a 3 day per week schedule with 1 day of rest in between, or at least 1 day of activities that did not involve continual pounding on the legs, had a salutary effect on the incidence of injury in these individuals. A soft running surface or shoes designed to absorb the shock of running on hard surfaces would be beneficial in reducing injuries still further.

There can be little doubt that disorders of the lower extremities for the woman recruit, like those in men, are costly in terms of medical care and utilization, recruit training time lost, hospitalization, and other duty restriction. The solution to the problem is not clear-cut because of the multidimensional nature of the problem. Preventive programs such as thorough preenlistment screening, that include an assessment of the factors discussed in this paper (e.g., prior physical activity, leg strength, body composition, and weight), would provide a means of identifying individuals at risk of injury and allow for appropriate action. This could be in the form of remedial physical training and toughening programs, orthotics, and proper breaking in of footwear. Personnel must be aware of signs and symptoms of overuse syndrome. Early identification and treatment of overuse symptoms are necessary to reduce further the incidence of lower extremity injuries in all recruits during training, especially in women because of their increased susceptibility to injury.

## ACKNOWLEDGMENTS

I would like to express my appreciation for assistance in data collection to Dr. M. Kish, Podiatry Service, and LTC S. Ozburn, Physical Therapy Service, Moncrief Army Hospital, Ft. Jackson, South Carolina, and to L. Kundla and D. Caruso for statistical assistance and manuscript preparation. I have incorporated into this manuscript the suggestions made by Arthur J. Pearl, M.D., the discussant of the paper at the Fifth Annual Meeting of the American Orthopaedic Society for Sports Medicine, Innisbrook, Florida, July 9 to 12, 1979. I gratefully acknowledge his contributions. Lottie Applewhite, M.S., Technical Publications Editor, Letterman Army Institute of Research, Presidio of San Francisco, California, offered a number of editorial suggestions while the manuscript was in preparation.

## REFERENCES

1. Kowal DM, Patton JF, Vogel JA: Psychological states and aerobic fitness of male and female recruits before and after basic training. *Aviat Space Environ Med 49:* 603–606, 1978
2. Kowal DM, Vogel JA, Peterson J: Comparison of strength and endurance training on aerobic power in young women. *Med Sci Sports 9:* 10–11, 1977
3. Daniels WL, Kowal DM, Vogel JA, et al: Physiological effects of a military training program on males and females. *Aviat Space Environ Med 50:* 562–566, 1979
4. Pollock ML, Gettman LR, Milesis CA, et al: Effects of frequency and duration of training on attrition and incidence of injury. *Med Sci Sports 9:* 31–36, 1977
5. Tomasi LF, Peterson JA, Pettit G, et al: Women's response to Army training. *Physcian Sportsmed 5:* 32–37, 1977
6. Eisenberg I, Allen WC: Injuries in a women's varsity athletic program. *Physician Sportsmed 6:* 112–120, 1978

7. Lanham RH: Stress fractures in military personnel. *J Am Podiatry Assoc 53:* 192–195, 1963
8. Durnin JV, Wormesley JW: Body fat assessed from total body density and its estimation from skinfold thickness. *Br J Nutr 32:* 77–92, 1974
9. Kowal DM, Vogel JA, Patton J, et al: Evaluation and requirements for fitness upon entry into the Army. *In Proceedings of the Symposium on Physical Fitness.* NATO Report DS/DR, 1978
10. McCarroll JA, Kowal DM, Phair PW: The health opinion survey: An exploration of its possible uses in a population of military recruits. *Milit Med* (in press)
11. Gilbert RS, Johnson HA: Stress fractures in military recruits. A review of twelve years experience. *Milit Med 131:* 716–721, 1966
12. Goldsmith NF: Bone mineral in the radius and vertebral asteoporosis in an insured population. *J Bone Joint Surg 55A:* 1276, 1976
13. Provost RA, Morris JM: Fatigue fractures of the femoral shaft. *J Bone Joint Surg 57A:* 487, 1969