Seasonal Variations in Injury Rates During US Army Basic Combat Training

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Objectives. Previous literature suggests that injury rates during physical activity may be higher in the summer than in the fall or winter, possibly due to the greater amount or intensity of physical activity in the summer. This study examined seasonal differences in injury incidence during US Army Basic Combat Training, where physical activity was similar at all times of the year.

Methods. Four independent groups of subjects (total \( n = 1543 \) men and \( 1025 \) women) were investigated, two training in the summer and two training in the fall. Injury data were obtained from a retrospective review of the subjects' medical records at the conclusion of the 8 week training program.

Results. For men, the corrected relative risk of suffering an injury or a time loss injury in the summer was, respectively, 2.0 [95% confidence interval (CI) = 1.7–2.4] and 2.5 (95% CI = 1.9–3.0) times higher than in the fall. For women, the corrected relative risk of suffering an injury or time-loss injury in the summer was, respectively, 1.4 (95% CI = 1.3–1.6) and 1.7 (95% CI = 1.5–2.0) times higher than in the fall. These risks were essentially unchanged after adjustment for subject physical characteristics (age, stature, body mass, body mass index) and physical fitness (push-ups, sit-ups and 2 mile run), indicating that the summer season was an injury risk factor independent of these variables. Linear correlations (r-values) between maximal daily temperature and injury incidence ranged from 0.92 to 0.97, indicating a strong relationship between these two variables.

Conclusions. These data suggest that injury incidence among physically active individuals is higher in the summer than in the fall and that environmental temperature may provide a partial explanation for this finding.

Keywords: temperature; physical fitness; training; military personnel

INTRODUCTION

Several studies have reported that injury rates may vary depending on the time of year (Baker et al., 1985; Koutedakis and Sharp, 1998; Phillips et al., 1998). One investigation of elite athletes (Koutedakis and Sharp, 1998) showed that injury rates were higher in the summer than at other times of the year. However, the competitive season was in the summer, suggesting that activity intensity was the mechanism of the higher injury rate. Another study of English rugby league players (Phillips et al., 1998) also showed a higher injury rate in the summer than in the winter. However, the year in which the summer data were collected involved a longer playing season, so that the total playing time (exposure) rather than the season may have been a primary factor. Mortality due to unintentional injury is higher in the summer than in the winter, possibly due to an increase in recreational activity (Baker et al., 1985).

US Army Basic Combat Training (BCT) is a reliable model in which to study seasonal variations in injury rates. BCT is conducted all year round, and individuals participating in BCT are required to...
perform and complete the same tasks regardless of the time of year. Living conditions in BCT are comparable for all trainees at all times of the year. Trainees reside in similar barracks, eat from the same menu in the mess hall, and receive the same opportunity for rest and sleep. There is little or no time for trainees to perform activity outside the training schedule. The program of instruction is well established and training personnel are required to carry out activities with little variation.

In a series of recently conducted studies (Knapik et al., 1998, 1999, 2001) we found great variations in injury rates during BCT. Plotting the data by time of year showed that injury incidence seemed to vary depending on the season in which the data were collected and, more specifically, with the environmental temperature. The purpose of the present study was to investigate these variations in activity-associated injury rates during different seasons of the year and to examine any potential associations with environmental temperatures.

**METHODS**

**Subjects**

Subjects were 1543 men and 1025 women participating in BCT at Ft Jackson, SC, from October 1997 to December 1998. There were four independent groups of subjects investigated, two groups training in the fall and two groups training in the summer. Table 1 shows the training dates and the number of subjects in each group. There were three different training battalions; subjects in groups 3 and 4 were separate cohorts in the same battalion, one cohort training in the summer, the other in the fall.

**Training activities**

BCT was 8 weeks in duration and involved a highly standardized set of physical exercise activities, military training operations and classroom instruction. One hour of exercise activity was conducted 4–6 times per week early in the morning. Exercise sessions alternated between ‘cardiovascular days’ and ‘muscle strength days’. Both days began with 10–15 min of muscle group stretching. Cardiorespiratory days involved distance runs and sprints, with some push-ups and sit-ups. Running distances were progressively increased from 0.5 miles to 3 miles during training to improve aerobic endurance. There were four or five running ‘ability groups’ comprising subjects of similar running speed. Muscle strength days involved many different types of push-ups and sit-ups in addition to a wide variety of calisthenic exercises, including inverted crawls, hops, high jumps, supine bicycles and other exercises.

Military training activities were divided into three phases. All phases included prolonged standing in formation and non-tactical hikes (road marches) of varying length and from field training sites. The first phase (2 weeks in length) involved introductory classroom lessons in military customs and courtesies, physical fitness, nutrition, first aid, wearing of the uniform, rifle maintenance, manual of arms and communication procedures. Major physical training events included a high rappelling tower, introductory tactical road march (hiking with pack and equipment), bayonet training, drill and ceremony, and obstacle courses. The second phase (3 weeks in length) emphasized weapons training (basic rifle marksmanship, machine gun, grenade launcher, Claymore mine). Major physical events included continued bayonet training (including pugil-stick training), nuclear, biological and chemical defense training, hand-to-hand combat, tactical road marches, and continued drill and ceremony training. The third phase (3 weeks in length) involved combat maneuvers, live fires exercises, tactical road marches and a 3 day field training exercise. For the field training exercise, the subjects trained on common military skills and were tested on proficiency. Major physical activities included the hand grenade qualification range, individual tactical training, obstacle courses and live fire exercises.

**Physical characteristics and physical fitness**

Physical characteristics were obtained from subjects’ physical examination generally taken ~1–2 weeks before entering basic training. Data included gender, stature, body mass, and date of birth (for age calculation). Body mass index was calculated as body mass/stature² (Knapik et al., 1983).

Physical fitness data were obtained from the Army Physical Fitness Test administered 1–3 days after arrival at the training battalion. The test involved three events—push-ups, sit-ups and a 2 mile run—administered in that order. The push-ups and sit-ups were the maximum number that could be completed in two separate 2 min periods. For the 2 mile run, time to
Temperature data

Average daily maximal and minimal dry bulb temperatures were obtained from data provided by the National Climatic Data Center (Asheville, NC). Data for the Columbia SC airport was obtained (14 miles from Ft Jackson). Daily maximal and minimal dry bulb temperatures were averaged for the inclusive dates of each of the four BCT cycles (groups 1–4).

Injury data

Injury data were obtained from a retrospective review of the subjects’ medical records at the conclusion of each training cycle. For each visit to a medical care provider the following information was collected: date of visit, diagnosis, body part injured, disposition and any days of limited duty. An injury was defined as an event (presumably an energy exchange) that resulted in physical damage to the body (Haddon, 1973) and for which the subject visited a medical care provider. Time-loss injuries were those for which the medical care provider prescribed one or more days of limited duty. Injuries were sub-categorized into overuse (long-term energy exchanges resulting in cumulative microtrauma) or traumatic (sudden energy exchanges resulting in sudden, overload trauma) types. Overuse injuries included diagnoses such as stress fractures, stress reactions, tendinitis, bursitis, fasciitis, overuse syndromes, strains and musculoskeletal pain (not otherwise specified). Traumatic injuries included diagnoses such as sprains, dislocations, fractures, blisters, abrasions, lacerations and contusions. Environmental injuries (heat injuries, cold injuries and animal bites) were not included in the analysis (i.e. only traumatic and overuse injuries were considered). Environmental injuries made up no more than 3% of the total number of injuries.

Six injury categories were developed. These included all injuries, all overuse injuries, all traumatic injuries, time-loss injuries, time-loss overuse injuries and time-loss traumatic injuries. These categories were not mutually exclusive since any subject experiencing a particular category of injury was included in that category. Thus, a single subject experiencing a time-loss overuse and a time-loss traumatic injury would be included in all categories.

Data analysis

Cumulative injury incidence over the 8 week period was calculated as the number of trainees with one or more injuries (numerator) divided by the total number of trainees (denominator) and expressed as a percent. To examine differences in cumulative incidence of all injuries between the four groups, the Pearson $\chi^2$ was used to test the hypothesis of no difference. After comparing all four groups, the two groups training in the summer were combined (groups 1 and 4) and the two groups training in the fall were combined (groups 2 and 3). Cumulative injury incidence was then compared between these two groups using $\chi^2$ statistics.

A one-way analysis of variance was used to test the hypothesis of no difference in physical characteristics and fitness measures between the four groups. Since these analyses revealed group differences, logistic regression was used to determine the odds of injury during the summer compared with the fall, while adjusting for the physical characteristics and fitness measures. A ‘dummy variable’ (season) was developed with groups 1 and 4 representing the fall and groups 2 and 3 representing the summer. Separate regression analyses were performed for each injury category and gender (12 analyses total). Confidence intervals were calculated from the estimated regression coefficients and their standard errors (Hosmer and Lemeshow, 1989). Because odds ratios tend to overestimate the relative risk when the outcome of interest (i.e. injuries) is high in the study population, a correction was applied and the approximate relative risk calculated (Zhang and Yu, 1998).

To examine relationships between maximal daily temperature and injury incidence, Pearson product-moment correlation coefficients were calculated and linear regression equations developed.

RESULTS

Figures 1 and 2 depict the cumulative incidence of all injuries in the men and women, respectively. The two groups tested in the summer months (groups 2 and 3) did not differ in the incidence of all injuries ($P = 0.66$ for men, $P = 0.71$ for women) or incidence of time-loss injury ($P = 0.75$ for men, $P = 0.98$ for women). The single battalion tested in both the summer and fall (groups 3 and 4) had a lower injury incidence in the fall than in the summer (all injury incidence: $P < 0.01$ for men, $P = 0.02$ for women; time-loss injury incidence: $P < 0.01$ for both men and
When the two groups tested in the fall (groups 1 and 4) were compared, time-loss injury incidence was similar ($P = 0.22$ for men, $P = 0.39$ for women); however, group 1 had a lower incidence of all injuries ($P = 0.02$ for men, $P < 0.01$ for women).

Table 2 shows the cumulative injury incidence and relative injury risk in the summer and fall. Compared with groups training in the fall, groups training in the summer had a higher risk of all injuries, all overuse injuries, all traumatic injuries, time-loss injuries and time-loss overuse injuries. Women training in the summer had a higher risk of time-loss traumatic injuries but men did not.

Table 3 compares the physical characteristics and physical fitness of the four groups. Among the men, there were statistically significant differences between groups for age, body mass index, push-ups, sit-ups and 2 mile run times. Among the women, there were statistically significant differences between groups for age, stature, push-ups, sit-ups and 2 mile run times.

Logistic regression was used to examine the influence of season on injury incidence while controlling for the group differences in physical characteristics and physical fitness. Table 4 shows the adjusted odds ratios and the corrected relative risk from the multivariate analysis. The results were very similar to the
univariate (uncorrected) analysis, indicating that the adjustment had little influence on the risk ratio. Relative risks of injury in all injury categories were still higher in the summer than in the fall, except for time-loss traumatic injuries in the men. The overall goodness of fit $\chi^2$ statistic exceeded a probability of 0.05 for all 12 models in Table 4.

Table 5 shows the average daily maximal and minimal temperatures during the four BCT cycles. Summer temperatures exceeded fall temperatures by 10–18°C. Figure 3 shows the association between average daily maximal temperature and injury incidence among the men. The graphs demonstrate a linear relationship with a correlation ($r$-value) of 0.97 for all injuries and 0.92 for time-loss injuries. The regression equation for all injuries was $y = 1.29x - 6.69$, with a standard error of estimate (SEE) of 2.20. The equation for time-loss injuries was $y = 1.07x - 8.58$, with an SEE of 3.40. In these equations, $y$ is injury incidence (%) and $x$ is the average daily maximal dry bulb temperature (°C).

Figure 4 shows the association between average daily maximal temperature and injury incidence among the women. The correlations were 0.95 for all injuries and 0.94 for time-loss injuries. The regression equations were $y = 1.35x + 18.23$ (SEE = 3.21)
Table 5. Daily maximal and minimal temperatures during the study periods (temperature values are mean ± SD)

<table>
<thead>
<tr>
<th>Group</th>
<th>Daily maximal temperature (°C)</th>
<th>Daily minimum temperature (°C)</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16.2 ± 1.7</td>
<td>4.3 ± 0.9</td>
<td>24 Oct–17 Dec 1997</td>
</tr>
<tr>
<td>2</td>
<td>33.1 ± 2.3</td>
<td>20.2 ± 1.8</td>
<td>8 May–1 Jul 1998</td>
</tr>
<tr>
<td>3</td>
<td>34.2 ± 1.9</td>
<td>21.3 ± 1.4</td>
<td>15 May–9 Jul 1998</td>
</tr>
<tr>
<td>4</td>
<td>23.6 ± 2.5</td>
<td>10.5 ± 2.1</td>
<td>2 Oct–26 Nov 1998</td>
</tr>
</tbody>
</table>

Fig. 4. Association of all injuries with average maximum temperature among women.

DISCUSSION

The present study indicates that the incidence of injury in BCT was higher in the summer than in the fall. This is not due to a higher incidence of heat injuries, since we specifically excluded these from our analyses. Even after adjustment for physical characteristics and physical fitness, there was still a greater likelihood of injury in the summer, indicating that the summer season was an injury risk factor independent of these variables. The seasonal variations appeared to be due, at least in part, to variations in environmental temperature, since injury incidence was strongly associated with average maximum daily temperature in a dose-related manner.

Seasonal variations in sports injuries have been reported in two previous studies (Koutedakis and Sharp, 1998; Phillips et al., 1998), and these studies found higher injury incidence in the summer, consistent with our findings. However, these older studies are confounded by factors other than the season of the year. One investigation (Koutedakis and Sharp, 1998), of elite male athletes in seven different sports, found that injury incidence increased from 9% in October–February, to 19% in March–May and to 32% in June–August. This trend was identical for women. However, the competitive season was in the summer and thus competition, rather than the summer season per se, may have influenced injury incidence. Another study involved rugby players (Phillips et al., 1998). The athletes played back-to-back athletic seasons in the winter and summer. This had not been done in previous years, suggesting that the additional playing exposure, rather than the season, may have caused the higher injury rates. Besides sport injury studies, surveillance data also indicate that unintentional injury deaths peak in the summer compared with other seasons of the year. This is possibly due to increased exposure to physical activity, since drowning, electrical charges, motorcycling and bicycling account for most of the increase (Baker et al., 1985).

While we found a higher injury incident among basic trainees in the summer, it is not likely that this was due to increased activity intensity (Koutedakis and Sharp, 1998) or increased exposure (Baker et al., 1985; Phillips et al., 1998). Military trainers told us (and we observed) that activities performed by the subjects were identical during each BCT training cycle, regardless of the season. However, the summer probably had more rest breaks during training because of higher temperatures; efforts were made to start the training day earlier; and more daylight time was available for training. The fall had temperatures that were more comfortable and less daylight time to train, probably resulting in fewer rest breaks.

The relationship between average daily maximal temperature and injury incidence is intriguing, and examining the physiological influences of heat suggests that the association may be biologically plausible. Exercise in hot environments results in dehydration, increased perceived exertion, movement of blood from the muscles to the skin (for evaporative cooling) and higher rectal (core) temperature (Sawka and Wenger, 1988; Galloway and Maughan, 1995). Compared with a cooler environment, these factors place more stress on the cardiovascular system, increasing heart rate and cardiac output (Sawka and Wenger, 1988; Hargreaves et al., 1996) and leading to more rapid fatigue (Galloway and Maughan, 1995; Febbraio et al., 1996). Exercise in the heat also leads to increased muscle glycogenolysis, increased liver glucose output and lactate accumulation (Young et al., 1985; Febbraio et al., 1994; Hargreaves et al., 1996).

Heat-induced cardiovascular and metabolic stress may make injuries more likely. Reduced muscle blood flow to the musculoskeletal system may exacerbate minor injuries due to a reduction in substrates and blood flow (tissue ischemia). One study found that increasing muscle temperature from 25 to 35°C increased by half the amount of eccentric exercise-induced muscle injury (measured as a reduction in isometric force and morphologic damage) (Zebra et al., 1990). Muscle tissue damage impairs muscle...
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Glycogen repletion (O’Reilly et al., 1987), which could make fatigue more rapid in subsequent bouts of activity. In addition, fatigue induced by the heat (Galloway and Maughan, 1995; Febbraio et al., 1996) may lead to traumatic or overuse injuries because of changes in gait during prolonged activity (Elliot and Ackland, 1981; Frykman et al., 1994; Candau et al., 1998). Fatigue reduces the ability of the muscle to absorb eccentric force (Mair et al., 1996). This may result in a more prolonged eccentric lengthening of the muscle (Mair et al., 1996), resulting in (i) more exercise-induced muscle damage; (ii) muscle strain injury; or (iii) transfer of forces to other body structures (e.g. ligaments, bones, bursa) and subsequent overuse or traumatic injury to these structures. Isolated rabbit muscles are more likely to tear at 40°C than at 25°C (Noonan et al., 1993), and temperatures of 40°C have been documented in human muscle (Saltin and Hermansen, 1966). Finally, systematic dehydration-related decrements have been reported in the performance of mental tasks with high demands on attention (Gopinathan et al., 1988). This could influence injury rates by diverting attention away from injury-threatening events. It should be stated that there is no direct evidence that these hypothetical mechanisms are related to injury incidence, but the relationships are plausible and appropriate for further study.

The proximity of different training units to the areas in which they perform field training must be considered as a possible confounding factor in the present study. Trainees were frequently required to walk out to training areas. The distances differed by as much as a mile for the different units. While this distance is not great, walking out and back several times a week could result in the accumulation of a considerable distance over the 8 week period, increasing the likelihood of overuse injuries due to the cumulative stress imposed. However, Battalion 3 (see Table 1) was tested in both the summer (group 3) and fall (group 4), and marched the same distance in both seasons. Injury incidence was still higher in the summer group.

Another possible confounding factor was a major change in the number of training events required to complete BCT and the emphasis put on these events early in our investigation. Shortly before our testing of group 1, changes were made in the BCT graduation requirements. The number of events required for graduation increased from four to 12. These events had been performed in previous BCT cycles, but participation in and successful completion of the events became mandatory. Special efforts were made by training personnel in group 1 to inform trainees that they must complete these events and failure to do so for any reason (including illness or injury) would not be acceptable. Due to this special emphasis, it is possible that trainees delayed medical care for (presumably minor) medical problems so as not to miss the required training, thereby lowering the injury incidence measured. This may account for the somewhat lower injury incidence in group 1. As time went on, the training personnel noted that most trainees were able to complete the requirements and, although trainees were still informed of the requirement, it was not emphasized to the same extent.

A number of studies have indicated that stature, body mass index, age and physical fitness can influence injury risk in BCT (Gardner et al., 1988; Jones et al., 1993a,b; Westphal et al., 1995; Knapik et al., 1998, 2001). Because of this, we specifically examined these variables within the four groups we tested. Our analysis indicated small but statistically significant differences between the four groups. Because of this, we used logistic regression to examine the effects of seasonality on injury rates while controlling for these variables. The results indicated that the corrected risk of injury in the summer was still higher than in the fall even when these variables were considered.

Several guidelines have been suggested to determine causation in epidemiological research (Gordis, 1996; Robertson, 1998). These guidelines were applied to assess the association between maximal daily temperature and injuries in the present study. The first guideline relates to the strength of the association, and, in this study, the association between injury and temperature appears to be relatively strong. The correlations between maximal temperature and injury risk ranged from 0.92 to 0.97, and the adjusted relative risk of injury in the summer was still 2.7, depending on gender and injury category. Another criterion for causality is a dose–response relationship. In this study, such a relationship was demonstrated since higher temperatures were systematically associated with higher injury incidence (Figs 3 and 4). A third criterion for causation is the ability to replicate findings, which we were able to do: lower injury incidence was found with lower temperature in two groups of subjects and higher injury incidence was found with higher temperature in two other subject groups. A fourth criterion is biological plausibility and this has been argued above. A fifth criterion is that a reduction in exposure reduces risk and we were able to show that lower maximal temperatures reduced injury risk.

On the other hand, some of the other guidelines for causal relationships (Gordis, 1996; Robertson, 1998) were not as strongly supported. One of these guidelines is a close temporal relationship between the variables. To demonstrate more strongly a temporal relationship it would be necessary to show that temperature increases are usually followed by an increase in injuries over a longer period than that allowed in this study. There may also be an inter-
action between temperature and different types or intensities of activities that cannot be addressed with the broad study design used here. Another guideline not fully supported is the consideration of alternative explanations. We have ruled out some of these in the discussion above, but we cannot totally disregard the effect of other changes in the training environment since the study was conducted over a 15 month period. A final guideline is the consistency of the findings with previous knowledge. This cannot be determined since no previous study has clearly demonstrated an association between temperature and overall injury incidence. Other studies (Baker et al., 1985; Koutedakis and Sharp, 1998; Phillips et al., 1998), conducted in warmer and cooler times of the year, have not reported temperatures and are confounded by other factors. Thus, while the present study meets many of the causal guidelines, others are not well met and future investigation is warranted.

Injury risk factors have been categorized as intrinsic if they involve personal characteristics of the participant (e.g. age, gender or physical fitness) or extrinsic if they involve factors external to the participant (e.g. equipment, ground conditions, type of activity) (VanMechelen et al., 1992). The present study suggests that the summer season may be an extrinsic injury risk factor and injury incidence may be associated with average daily maximal temperature in a dose-related manner.

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