Effect on Injuries of Assigning Shoes Based on Foot Shape in Air Force Basic Training

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Background: This study examined whether assigning running shoes based on the shape of the bottom of the foot (plantar surface) influenced injury risk in Air Force Basic Military Training (BMT) and examined risk factors for injury in BMT.

Methods: Data were collected from BMT recruits during 2007; analysis took place during 2008. After foot examinations, recruits were randomly consigned to either an experimental group (E, n=1042 men, 375 women) or a control group (C, n=913 men, 346 women). Experimental group recruits were assigned motion control, stability, or cushioned shoes for plantar shapes indicative of low, medium, or high arches, respectively. Control group recruits received a stability shoe regardless of plantar shape. Injuries during BMT were determined from outpatient visits provided from the Defense Medical Surveillance System. Other injury risk factors (fitness, smoking, physical activity, prior injury, menstrual history, and demographics) were obtained from a questionnaire, existing databases, or BMT units.

Results: Multivariate Cox regression controlling for other risk factors showed little difference in injury risk between the groups among men (hazard ratio [E/C]=1.11, 95% CI=0.89–1.38) or women (hazard ratio [E/C]=1.20, 95% CI= 0.90–1.60). Independent injury risk factors among both men and women included low aerobic fitness and cigarette smoking.

Conclusions: This prospective study demonstrated that assigning running shoes based on the shape of the plantar surface had little influence on injury risk in BMT even after controlling for other injury risk factors.

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Introduction

Running shoe companies, popular running magazines, and other publications[1–6] suggest that the shape of the bottom of the foot (plantar surface) can be used as an indication of medial longitudinal foot arch height and foot flexibility, and that plantar shape can be used to select appropriate types of running shoes. Shoe manufacturers market three classes of running shoes designed for individuals with high, normal, and low arches: cushioned, stability, and motion control, respectively. These shoes are hypothesized to reduce injuries by compensating for presumed differences in running mechanics.[6]

The practice in the U.S. Air Force (USAF) has been to provide a single running shoe to recruits entering basic military training (BMT). However, in U.S. Army and U.S. Marine Corps basic training, new recruits have been assigned running shoes based on their plantar shapes, as recommended by the shoe companies and running magazines. This occurred despite the fact that there was insufficient evidence in the scientific literature to determine whether this strategy had any effect on injury rates.[7] The Military Training Task Force of the Defense Safety Oversight Council commissioned a study of this issue to see if the prescription

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technique should be adopted in USAF BMT. A parallel study was conducted in U.S. Army Basic Combat Training.[8] The major purpose of this paper is to report on the results of the evaluation, which was to determine whether or not injury risk could be reduced in USAF BMT by assigning running shoes based on plantar shape. A secondary purpose is to examine injury rates and injury risk factors in BMT as no previous study has done this.

Methods

Subjects

The subjects were men and women involved in BMT at Lackland Air Force Base, Texas, from March through June 2007. On entry to BMT, recruits were briefed on the purposes and risks of the study. Those wishing to participate signed an informed consent statement, which, along with the research protocol, had been approved by the institutional review board of Wilford Hall Medical Center at Lackland Air Force Base, Texas.

Study Design

This was a randomized controlled study spanning 4 months during 2007. Study participants were randomly assigned to either an experimental (E) or a control (C) group, based on order of arrival for testing. Experimental group subjects were provided a motion control, stability, or cushioned running shoe based on their plantar foot shape. Control group subjects received a standard stability running shoe regardless of the shape of their plantar surface.

Initial Testing Procedures

Immediately after informed consent was obtained, volunteers were administered a questionnaire that asked about tobacco use, physical activity, injury history, and (for women) menstrual history. To determine the shape of the plantar surface, the barefoot volunteers in both groups mounted the acrylic platform of a device with a mirror that reflected the underside of the trainee's foot.[9] This provided a view of the footprint, showing the amount of the foot in contact with the acrylic surface. The subjects were instructed to stand with equal weight on each foot and feet comfortably apart. The area encompassed by the footprint was examined by two testers, sitting side by side. The testers independently judged whether the plantar surface was high arched, normal arched, or low arched, based on templates:[6] More area in the middle third of the plantar surface indicated a low plantar shape and less area a high plantar shape. If the assessments of the two raters differed, they discussed the assessment and reached a consensus.

Running Shoe Assignments

Subjects in the control group received a New Balance 498 shoe regardless of plantar shape. Experimental group subjects with plantar shapes indicative of low arches received a New Balance 587 (motion-control shoe); those with plantar shapes indicative of high arches received a New Balance 755 (cushioned shoe). Experimental group subjects with plantar shapes indicative of normal arches received a New Balance 498 (stability shoe). If, for an experimental-group subject, the plantar shapes differed for the right and left foot, the raters considered the degree of difference and selected the closest plantar shape. For example, a subject with a plantar shape indicative of a moderately high left foot arch and a plantar shape indicative of a normal right foot arch would be assigned a stability shoe, since the left foot arch was not judged extremely high.

Physical Fitness Assessments

Within 2 to 4 days of arrival in their training units, recruits took the physical fitness assessment test, which was repeated in the 5th week of training. The test consisted of three events: a 1-minute maximal effort push-up event, a 1-minute maximal effort abdominal crunch event, and a 1.5-mile run for time, conducted in that order. The three fitness assessment events were administered by military training instructors using standardized procedures.[10]

Physical Characteristics

The subjects' heights, weights, and abdominal circumferences were measured on the same day that they were initially tested and received their shoes. A three-dimensional body scanner (Human Solutions, Kaiserslautern, Germany) incorporated a force platform to measure weight and a laser to measure height. Abdominal circumference was measured during the initial physical fitness assessment with an anthropometric tape. The tape was placed parallel to the floor at the level of the iliac crest, and the measurement was made at the end of a normal expiration. Height and abdominal circumference were obtained only on entry to BMT but weight was obtained on entry and at Week 5 of BMT.

Demographics

The Army Medical Surveillance Activity (now the Armed Forces Health Surveillance Center) provided demographic data for study subjects from the Defense Medical Surveillance System (DMSS). The DMSS regularly and systematically incorporates into their systems demographic data from the Defense Manpower Data Center. Information obtained from the DMSS for study subjects included date of birth, component (active, Reserve, National Guard), educational level, marital status, and race.

Injury Outcomes

In addition to demographic data, the DMSS regularly incorporates data on ambulatory (outpatient) encounters that occur within military treatment facilities, as well as those that occur outside the medical treatment facilities but are paid for by the Department of Defense. The DMSS provided visit dates and codes from the ICD-9-CM for all outpatient medical visits within the BMT timeframe for each subject. The first four diagnoses for each visit were considered, although a single visit usually resulted in only one diagnosis. Five injury indices were calculated: the Installation Injury Index, the Modified Installation Injury Index, the Overuse Injury Index, the Training Injury Index , and the Comprehensive Injury Index (CII). All indices include specific ICD-9-CM codes, as described previously.[11]

The Installation Injury Index has been used to compare injury rates among different military posts and is reported on a monthly basis at the Armed Forces Health Surveillance Center website (afhsc.army.mil/) where the specific ICD-9-CM codes are also provided. The Modified Installation Injury Index is similar to the Installation Injury Index but captures a greater number of overuse-type injuries (i.e., those resulting from cumulative microtrauma). The Overuse Injury Index specifically captures the subset of both upper and lower body overuse-type musculoskeletal injuries and includes such diagnoses as stress fractures, stress reactions, tendonitis, bursitis, fasciitis, arthralgia, neuropathy, radiculopathy, shin splints, synovitis, and strains. The Training Injury Index is limited to lower extremity– overuse injuries and has been used to compare injury rates among basic training posts. The Comprehensive Injury Index captures all ICD-9-CM codes related to injuries, both traumatic and overuse.

Attrition

Some subjects did not complete the entire 6-week BMT cycle with their initially assigned unit, but in most cases their data could be included for the time they remained in training, as described below. Reasons for attrition included discharge from the air force or reassignment to a new unit (recycle). Discharges and recycles were obtained from a local data system maintained at Lackland AFB.

Data Analyses

The data from this study were analyzed during 2008. Age was calculated from the date of birth to the date of the informed consent briefing. BMI was calculated as weight/height^2.[12] Between-rater reliability on the plantar shape determination was determined with Cohen's kappa coefficient. A two-way mixed model, repeated-measures ANOVA was used to compare the groups on physical characteristics and fitness measures before and after BMT (groups × test period ANOVA, repeated measures on the test period). Comparisons between the groups on the questionnaire and demographic variables were performed using the chi-square statistic.

For all five injury indices, person-time injury incidence rates (injured subjects/1000 person-days) were calculated as:

$$(\text{Subjects with } \geq 1 \text{ injury}) \div (\text{total subject time in BMT} \times 1000).$$

The total time in BMT was 43 days for subjects who completed BMT and fewer for those who left before the completion of training. Comparisons between the groups were made using a chi-square for person-time.[13]

Cox regression was used to examine the associations between potential risk factors (including group) and time to first injury in the Comprehensive Injury Index. For each analysis, once a subject had an injury his or her contribution to time in BMT was terminated. Those who attrited from training were censored (i.e., end of time at risk) at the day they left the unit. All potential risk factors were entered into the regression model as categorical variables. Some interval and ordinal variables were combined to increase statistical power. Continuous variables (except age) were converted to four equal-sized groups based on the distribution of the scores. Age was partitioned into three groups (17–19, 20–24, ≥25 years). For all Cox regressions, simple contrasts were used, comparing the hazard at a baseline level of a variable (defined with a hazard ratio (HR) of 1.00) to other levels of the same categorical variable. Univariate Cox regressions established the association between time to first injury and levels of each potential risk factor in isolation. Multivariate Cox regressions established the effect of multiple risk factors (including group) on injury risk and identified the independent risk factors. Potential risk factors were included in the multivariate model if they achieved $p<0.10$ in the univariate analyses.[14]

Results

Subjects and Attrition

Study volunteers included 2167 men and 854 women. Of this group, 113 (60 men and 53 women) did not enter BMT for medical or administrative reasons and were not considered in further analyses. There were 206 subjects (128 men, 78 women) who did not complete training with the unit to which they were originally assigned (recycles). The recycle database did not have the day the subject was reassigned, so the time at risk could not be determined; these subjects were not considered in subsequent analyses. Thus, the final cohort considered for analysis consisted of 1979 men and 723 women. Among the men, 8.9% in the experimental group and 8.2% in the control group attrited from training ($p=0.58$). Among the women, 16.0% of the experimental group and 11.3% of the control group attrited from training ($p=0.07$). The kappa coefficients quantifying the degree of agreement between the two raters on the plantar surface determinations were 0.98 for both the right and the left foot.

Not all subjects had complete measurements on all variables. This occurred primarily because the data were not available in the DMSS databases, subjects did not provide a response on the questionnaire, or the training unit did not have the information. Personnel in the clothing issue section imposed time constraints so that some subjects could not complete the entire initial testing battery. Therefore, the tables indicate the sample size for each variable.

Changes in Physical Characteristics and Fitness During BMT

Table 1 compares group differences and changes in physical characteristics and fitness scores from the start to the end of training. Only subjects with complete data at the start (pre) and end (post) of BMT could be considered in the analysis as both values were required for repeated-measures ANOVA. There was no main effect of group or group × test period interaction on any of the measures. However, pre- to post-BMT changes did show significant main effects: there were significant losses in body weight and BMI and significant performance increases in all the fitness measures. The average height (±standard deviation) of the experimental- and control-group men was 70±3 inches and 70±3 inches (p=0.27); corresponding values for women were 65±3 inches and 65±3 inches (p=0.47).

Comparison of Groups on Questionnaire and Demographic Variables

Table 2 shows a comparison of the two groups on the questionnaire and demographic variables. The distribution of scores on these variables differed little between

Table 1. Group comparisons on initial and final physical characteristics and fitness test scores

	Experimental		Control		*p*-values[a]		
	n	**Mean ±SD**	***n***	**Mean ±SD**	**Group**	**Test period**	**Group × test period**
Men							
Initial weight	787	168±22	697	166±23	0.17	<0.01	0.65
Final weight (lb)		161±18		160±18			
Initial BMI	787	24.4±2.7	697	24.2±2.7	0.12	<0.01	0.69
Final BMI (kg/m^2)		23.4±2.0		23.2±2.0			
Initial push-up	814	37±13	717	37±13	0.60	<0.01	0.35
Final push-ups (reps)		53±9		54±9			
Initial crunches	814	37±11	717	37±10	0.44	<0.01	0.14
Final crunches (reps)		56±7		56±7			
Initial 1.5-mile run	789	12.7±1.7	696	12.7±1.8	0.47	<0.01	0.78
Final 1.5-mile run (min)		11.5±1.3		11.5±1.9			
Women							
Initial weight	295	138±17	290	138±20	0.68	<0.01	0.45
Final weight (lb)		134±15		135±17			
Initial BMI	295	23.3±2.6	290	23.3±2.6	0.51	<0.01	0.35
Final BMI (kg/m^2)		22.7±1.9		22.7±1.9			
Initial push-up	291	16±9	283	16±11	0.68	<0.01	0.68
Final push-ups (reps)		33±7		33±9			
Initial crunches	291	26±10	284	26±11	0.74	<0.01	0.36
Final crunches (reps)		52±6		51±9			
Initial 1.5-mile run	295	16.3±2.3	288	16.4±2.5	0.86	<0.01	0.90
Final 1.5-mile run (min)		14.1±1.7		14.1±1.9			

[a]Two-way repeated measures analysis of variance

Table 2. Comparison of groups on questionnaire variables and demographics

		Men			Women		
Variable	**Level of variable**	**E (%)**	**C (%)**	***p*-value[a]**	**E (%)**	**C (%)**	***p*-value[a]**
Smoked cigarettes in last 30 days	No	72.4	74.6	0.34	78.6	76.8	0.63
	Yes	27.6	25.4		21.4	23.2	
Cigarettes per day in last 30 days	None	71.8	74.7	0.12	78.9	78.0	0.44
	1–9	18.4	14.5		10.9	14.0	
	≥10	9.7	10.8		10.2	8.0	
Self-rating of physical activity	Much less active	4.9	5.0	0.26	7.5	8.5	0.44
	Less active	16.9	18.3		27.5	24.0	
	About the same	36.4	32.2		34.7	35.4	
	More active	29.4	33.8		22.6	25.6	
	Much more active	12.4	10.8		7.5	6.5	
Frequency of exercise or sports	≤1 time/week	15.9	15.6	0.15	20.8	22.1	0.67
	2–4 times/week	59.2	54.9		60.4	56.6	
	≥5 times/week	25.0	29.5		18.9	21.3	
Frequency run/jog before BMT	≤1 time/week	39.7	37.2	0.32	42.6	40.2	0.34
	2–4 times/week	50.1	50.3		45.3	50.8	
	≥5 times/week	10.2	12.5		12.1	8.9	
Length of time run/jog before BMT	≤1 month	39.7	37.2	0.32	42.6	40.2	0.34
	2–6 months	50.1	50.3		45.3	50.8	
	≥7 months	10.2	12.5		12.1	8.9	
Prior lower limb injury	No	79.9	79.8	0.97	79.2	78.4	0.83
	Yes	20.1	20.2		20.8	21.6	
Component	Active Air Force	80.8	82.0	0.63	76.3	77.3	0.70
	National Guard	14.8	13.3		14.0	14.8	
	Air Force Reserve	4.4	4.7		9.6	7.9	
Educational level	<High school graduate	0.7	0.7	0.32	0.9	1.2	0.93
	High school graduate	91.6	93.8		90.9	91.5	
	Some college/graduate	5.0	3.7		6.7	5.7	
	Unknown	2.7	1.8		1.5	1.5	
Race	White	76.4	79.8	0.02	69.9	70.4	0.99
	Black	16.8	11.8		19.6	19.6	
	Asian	4.2	5.2		5.8	5.7	
	Other	2.4	3.1		4.7	4.2	
	Unknown	0.3	0.1		0.0	0.0	
Marital status	Single, never married	87.2	89.1	0.34	80.7	83.4	0.32
	Married	12.6	10.6		17.5	16.0	
	Other	0.2	0.3		1.8	0.6	
Menstrual periods in last year	0				6.4	2.4	0.15
	1–9				11.3	11.2	
	10–12				78.5	81.2	
	≥13				3.8	5.2	

[a]Chi-square statistic
BMT, Air Force Basic Military Training; C, control; E, experimental; HS, high school

the two groups. For the variable *race*, the experimental-group men had more black recruits than the control-group men. The abdominal circumference (mean±SD) of the control-group men was 32.8±3.1 inches, and that of the experimental-group men 32.8±3.0 inches (p=0.96). The abdominal circumference (mean±SD) of the control-group women was 30.7±3.4 inches, and that of the experimental-group women 30.9±3.2 (p=0.59) inches. The height (mean±SD) of the control-group men was 69.6±2.7 inches, while that of the experimental-group men 69.6±2.7 inches (p=0.94). The height (mean±SD) of the control-group women was 64.8±2.7 inches, and that of the experimental-group women 69.5±2.7 inches (p=0.20).

Primary Analyses of Injury Outcomes

Table 3 shows the person-time injury incidence rates for the various injury indices and compares the rates in the groups. For both men and women, injury rates are slightly higher in experimental group.

Table 4 shows the univariate Cox regression examining the association between time to first injury and the injury risk factors, including group. Among the men, injury risk was about the same for the groups. Higher injury risk among the men was associated with low performance on push-ups, crunches, or the 1.5-mile run; cigarette smoking; active duty status; black race; and “other” marital status (primarily divorced or separated). Men in the middle quartile of BMI or abdominal circumference tended to have lower risk than men with lower BMI or abdominal circumference. Among the women, the experimental group tended to have higher injury risk than the control group. Higher injury risk was also associated with higher BMI, greater abdominal circumference, slower run time, cigarette smoking, less frequent running or jogging before BMT, fewer months of running or jogging before BMT, lower educational level, white race (compared with Asian descent), “other” race (compared with whites), and being married.

Table 5 shows the results of the backward-stepping multivariate Cox regression with group membership forced into the model. Subjects with complete data on all the variables included 1268 men (65% of the male sample) and 454 women (53% of the female sample). Among the men, injury risk was similar in the experimental and control groups. Injury risk was independently associated with slower run times and smoking cigarettes in the 30 days before BMT. Among the women, injury risk was about the same for the experimental and control groups. Injury risk was independently associated with slower run times, smoking cigarettes in the 30 days before BMT, less time running or jogging prior to BMT, and marriage.

Table 3. Comparison of injury incidence rates between the experimental and control groups

Index	Men				Women			
	Injury incidence rate (injuries/1000 person-days)		Rate ratio-E/C (95% CI)	*p*-value[a]	Injury incidence rate (injuries/1000 person-days)		Rate ratio-E/C (95% CI)	*p*-value[a]
	E	C			E	C		
Installation Injury Index	5.54	4.99	1.11 (0.92, 1.35)	0.29	10.14	8.27	1.22 (0.96, 1.56)	0.11
Modified Installation Injury Index	5.91	5.39	1.10 (0.92, 1.32)	0.33	10.55	8.93	1.18 (0.93, 1.49)	0.17
Overuse Injury Index	5.86	5.25	1.12 (0.93, 1.35)	0.25	10.55	8.50	1.24 (0.98, 1.58)	0.08
Training-Related Injury Index	4.62	3.94	1.17 (0.95, 1.45)	0.14	8.41	6.68	1.26 (0.96, 1.65)	0.09
Comprehensive Injury Index	7.04	6.43	1.09 (0.92, 1.30)	0.30	12.96	10.89	1.19 (0.96, 1.47)	0.11

[a]Chi-square statistic for person-time[13]
C, control; E, experimental

Table 4. Injury hazard ratios for various potential injury risk factors (univariate Cox regression)

	Men				Women			
Variable	**Level of variable**	***n***	**Hazard ratio (95% CI)**	***p*-value**	**Level of variable**	***n***	**Hazard ratio (95% CI)**	***p*-value**
Shoe prescription group	Experimental	1042	1.09 (0.92, 1.29)	0.31	Experimental	373	1.23 (1.00, 1.53)	0.06
	Control	913	1.00	—	Control	345	1.00	—
Age (years)	18–19	446	1.00	—	18–19	154	1.00	—
	20–24	1271	1.11 (0.90, 1.38)	0.32	20–24	442	1.12 (0.85, 1.47)	0.42
	≥25	160	1.29 (0.94, 1.81)	0.12	≥25	80	1.09 (0.73, 1.62)	0.67
Height (inches)	60.0–67.0	376	0.87 (0.66, 1.16)	0.34	57.0–62.5	160	1.04 (0.76, 1.44)	0.80
	67.5–69.5	477	0.99 (0.77, 1.28)	0.94	63.0–64.5	165	1.04 (0.75, 1.43)	0.82
	70.0–71.5	486	1.04 (0.80, 1.34)	0.78	65.0–66.5	195	1.25 (0.93, 1.69)	0.14
	72.0–81.0	396	1.00	—	67.0–73.0	167	1.00	—
Weight (pounds)	96–151	448	1.00	—	90–124	174	1.00	—
	152–168	440	0.94 (0.73, 1.21)	0.61	125–137	177	1.01 (0.74, 1.37)	0.96
	169–183	432	0.83 (0.64, 1.08)	0.17	138–152	167	1.00 (0.73, 1.36)	0.99
	184–254	418	1.02 (0.79, 1.31)	0.89	153–202	167	1.21 (0.89, 1.65)	0.22
Body mass index (kg/m^2)	14.72–22.28	432	1.49 (1.09, 2.04)	0.01	16.47–21.29	172	1.04 (0.76, 1.43)	0.79
	22.29–24.63	432	1.00	—	21.30–23.24	170	1.00	—
	25.64–26.39	432	0.97 (0.69, 1.37)	0.88	23.25–25.67	172	1.01 (0.73, 1.38)	0.97
	26.40–35.44	430	1.19 (0.86, 1.66)	0.30	25.68–30.24	172	1.35 (1.00, 1.83)	0.05
Abdominal circumference (inches)	22.0–30.5	433	1.00	—	23.0–28.2	168	1.00	—
	30.6–32.9	452	1.02 (0.79, 1.30)	0.90	28.3–30.6	175	1.03 (0.75, 1.42)	0.86
	33.0–35.1	431	0.77 (0.59, 1.01)	0.06	30.7–32.9	163	1.17 (0.85, 1.60)	0.34
	35.2–41.5	416	1.01 (0.78, 1.30)	0.95	33.0–45.2	168	1.30 (0.95, 1.77)	0.10
Push-ups (repetitions)	0–28	455	1.49 (1.14, 1.93)	<0.01	0–7	175	1.26 (0.92, 1.71)	0.15
	29–36	449	1.05 (0.80, 1.39)	0.72	8–14	175	0.92 (0.67, 1.26)	0.60
	37–45	440	1.04 (0.78, 1.37)	0.81	15–21	183	0.88 (0.64, 1.21)	0.45
	46–94	385	1.00	—	22–101	151	1.00	—
Crunches (repetitions)	0–30	459	1.52 (1.18, 1.97)	<0.01	0–19	180	1.14 (0.84, 1.54)	0.41
	31–36	417	1.17 (0.89, 1.55)	0.25	20–26	172	0.88 (0.64, 1.21)	0.43
	37–44	432	1.13 (0.86, 1.48)	0.40	27–32	165	1.05 (0.77, 1.43)	0.77
	45–75	421	1.00	—	33–62	167	1.00	—
1.5-mile run (minutes)	8.33–11.53	432	1.00	—	9.67–14.92	173	1.00	—
	11.54–12.63	432	0.95 (0.72, 1.26)	0.73	14.93–16.50	174	0.98 (0.70, 1.35)	0.88
	12.64–13.97	422	1.34 (1.03, 1.74)	0.03	16.51–18.23	164	1.28 (0.93, 1.75)	0.13
	13.98–20.53	427	1.47 (1.13, 1.90)	<0.01	18.24–31.40 minutes	169	1.62 (1.19, 2.21)	<0.01
Smoked cigarettes in last 30 days	No	1064	1.00	—	No	400	1.00	—
	Yes	386	1.41 (1.14, 1.74)	<0.01	Yes	114	1.30 (0.97, 1.74)	0.08
Cigarettes per day in last 30 days	None	1060	1.00	—	None	404	1.00	—
	1–9	241	1.29 (1.00, 1.67)	0.05	1–9	64	1.50 (1.05, 2.15)	0.03
	≥10	149	1.47 (1.09, 1.99)	<0.01	≥10	46	1.49 (0.98, 2.27)	0.09
Self-rating physical activity	Much less active	70	1.11 (0.67, 1.85)	0.69	Much less active	40	1.20 (0.63, 2.30)	0.57
	Somewhat less active	251	0.93 (0.64, 1.35)	0.70	Somewhat less active	131	1.09 (0.64, 1.84)	0.76
	About the same	491	1.04 (0.75, 1.44)	0.81	About the same	178	1.22 (0.74, 2.03)	0.44
	Somewhat more active	453	0.80 (0.57, 1.13)	0.21	Somewhat more active	123	0.90 (0.53, 1.55)	0.71
	Much more active	167	1.00	—	Much more active	37	1.00	—

(continued on next page)

Table 4. Injury hazard ratios for various potential injury risk factors (univariate Cox regression) *(continued)*

	Men				Women			
Variable	Level of variable	*n*	Hazard ratio (95% CI)	*p*-value	Level of variable	*n*	Hazard ratio (95% CI)	*p*-value
Frequency exercise or sports before BMT (per week)	≤1	223	0.85 (0.61, 1.18)	0.33	≤1	109	1.24 (0.83, 1.86)	0.30
	2–4	818	1.01 (0.80, 1.27)	0.93	2–4	297	1.24 (0.88, 1.75)	0.22
	≥5	391	1.00	—	≥5	101	1.00	—
Frequency running/jogging before BMT (per week)	≤1	431	1.01 (0.72, 1.41)	0.96	≤1	168	1.71 (1.03, 2.84)	0.04
	2–4	806	1.14 (0.84, 1.55)	0.40	2–4	291	1.43 (0.87, 2.33)	0.16
	≥5	196	1.00	—	≥5	50	1.00	—
Length of time running/jogging before BMT (months)	≤1	547	1.19 (0.84, 1.68)	0.34	≤1	210	1.57 (0.96, 2.56)	0.07
	2–6	719	1.14 (0.81, 1.60)	0.47	2–6	244	1.64 (1.01, 2.65)	0.05
	≥7	164	1.00	—	≥7	55	1.00	—
Prior lower limb injury	No	1142	1.00	—	No	403	1.00	—
	Yes	287	1.01 (0.80, 1.30)	0.89	Yes	109	0.99 (0.72, 1.35)	0.93
Menstrual periods in last year					0	23	1.32 (0.74, 2.36)	0.36
					1–9	58	1.07 (0.72, 1.58)	0.74
					10–12	409	1.00	—
					≥13	23	0.85 (0.44, 1.66)	0.64
Component	Active Air Force	1526	1.00	—	Active Air Force	518	1.00	—
	National Guard	84	0.79 (0.50, 1.24)	0.30	National Guard	59	1.11 (0.76, 1.62)	0.59
	Air Force Reserve	262	0.77 (0.59, 1.01)	0.06	Air Force Reserve	97	1.18 (0.87, 1.60)	0.29
Educational level	<High school graduate	13	0.25 (0.04, 1.77)	0.16	<High school graduate	7	2.10 (0.94, 4.72)	0.07
	High school graduate	1735	1.00	—	High school graduate	614	1.00	—
	Some college/graduate	82	0.89 (0.57, 1.39)	0.61	Some college/graduate	43	0.93 (0.60, 1.48)	0.79
	Unknown	42	0.77 (0.40, 1.49)	0.43	Unknown	10	0.83 (0.60, 1.48)	0.70
Race	White	1457	1.00	—	White	472	1.00	—
	Black	272	1.24 (0.98, 1.56)	0.07	Black	133	1.20 (0.92, 1.58)	0.18
	Asian	88	0.75 (0.47, 1.20)	0.23	Asian	39	0.60 (0.33, 1.06)	0.08
	Other	51	0.76 (0.42, 1.39)	0.38	Other	30	1.67 (1.07, 2.67)	0.03
	Unknown	4	1.00 (0.14, 7.14)	0.99	Unknown	0	—	—
Marital status	Single, never married	1649	1.00	—	Single, never married	553	1.00	—
	Married	218	1.07 (0.82, 1.39)	0.64	Married	113	1.31 (1.00, 1.73)	0.05
	Other	5	3.04 (0.98, 9.46)	0.06	Other	8	1.50 (0.62, 3.63)	0.37

BMT, Air Force Basic Military Training

Because of the large number of subjects excluded from the multivariate analyses, analyses were conducted to compare those included with those excluded. As shown in Table 6, differences between these two groups were very small for the variables retained in the backward-stepping multivariate Cox regression.

Secondary Analyses of Injury Outcomes

Table 7 shows a univariate Cox regression examining injury risk for the three plantar foot shapes for the groups independently. Among the control-group men (stability shoe), there was little difference in injury risk by plantar shape. Among the experimental-group men, there was higher injury risk among individuals with plantar shapes indicative of a low arch who wore the motion-control shoe compared with individuals with plantar shapes indicative of a normal arch who wore the stability shoe. Men and women with plantar shapes indicative of a high arch had injury risk similar to that of their counterparts with normal plantar shapes.

Table 8 shows univariate Cox regressions comparing injury risk between groups with high and low plantar

Table 5. Injury hazard ratios for study variables (multivariate Cox regression)

Variable	Level of variable	*n*	Hazard ratio (95% CI)	*p*-value
Men				
Shoe prescription group	Experimental	658	1.11 (0.89, 1.38)	0.35
	Control	610	1.00	—
1.5-mile run (minutes)	8.33–11.53	330	1.00	—
	11.54–12.63	305	0.92 (0.66, 1.29)	0.64
	12.64–13.97	310	1.33 (0.97, 1.80)	0.07
	13.98–20.53	323	1.42 (1.05, 1.93)	0.02
Smoked cigarettes in past 30 days	No	929	1.00	—
	Yes	339	1.28 (1.01, 1.61)	0.04
Women				
Shoe prescription group	Experimental	234	1.20 (0.90, 1.60)	0.14
	Control	220	1.00	—
1.5-mile run (minutes)	9.67–14.92	126	1.00	—
	14.93–16.50	119	1.09 (0.74, 1.62)	0.66
	16.51–18.23	99	1.09 (0.72, 1.66)	0.67
	18.24–31.40	110	1.81 (1.22, 2.67)	<0.01
Smoked cigarettes in past 30 days	No	359	1.00	—
	Yes	95	1.33 (0.96, 1.79)	0.10
Length of time running/jogging before BMT (months)	≤1	180	1.25 (0.72, 2.17)	0.58
	2–6	225	1.55 (0.92, 2.61)	0.10
	≥7	49	1.00	—
Marital status[a]	Single	378	1.00	—
	Married	76	1.44 (1.03, 2.02)	0.03

[a]None of the “other” marital status women were included in this analysis because only two subjects in this category had complete data on other variables.
BMT, Air Force Basic Military Training

shapes who wore different shoe types. Among the men with low plantar shapes, injury risk was somewhat elevated among the experimental-group men who wore the motion-control shoe compared with the control-group men who wore the stability shoe, but the women with low plantar shape had similar injury risk regardless of shoe type. Among the men with high plantar shape, injury risk was similar regardless of the shoe type, but among the women with high plantar shape, injury risk was somewhat elevated among the experimental-group women who wore the cushioned shoe compared with the control-group women who wore the stability shoe.

Discussion

The present study demonstrated that assigning running shoes based on the shape of plantar surface did not reduce injury risk in Air Force BMT. In fact, men and women who wore shoes presumably designed for their foot type tended to have a slightly higher injury incidence rate and a higher injury risk in the univariate Cox regression. Injury risk in the assigned shoe group remained slightly higher in the multivariate model that controlled for other significant injury risk factors.

The results of the current study can be compared with the results of a similar army investigation[9] because the two studies were designed to be complementary; however, there were some important differences. Similarities in the two studies included (1) tracking of subjects in the same medical surveillance system, (2) calculation of injury indices in an identical manner, and (3) the same randomized design with a control group receiving a single stability shoe and an experimental group receiving a

Table 6. Comparison of subjects included and not included in the multivariate Cox regression

Variable	Included in multivariate analyses		Not included in multivariate analyses		*p*-value[a]
Men					
1.5-mile run	*n*=1268	Mean±SD	*n*=444	Mean±SD	0.48
		12.9±1.8 min		12.9±1.8 min	
Smoked cigarettes in past 30 days	*n*=1268	Proportion	*n*=386	Proportion	0.80
		28%		26%	
Women					
1.5-mile run	*n*=454	Mean±SD	*n*=226	Mean±SD	0.10
		16.6±2.7 min		16.9±2.6 min	
Smoked cigarettes in past 30 days	*n*=454	Proportion	*n*=60	Proportion	0.47
		21%		25%	
Marital status	*n*=454	Proportion	*n*=55	Proportion	0.82
Single		83%		83%	
Married		17%		18%	
Length of time running/jogging before BMT (months)	*n*=454	Proportion	*n*=212	Proportion	0.94
≤1		40%		42%	
2–6		50%		47%	
≥7		11%		11%	

[a]Chi-square statistics for proportions, t-test for continuous variable
BMT, Air Force Basic Military Training

shoe based on plantar shape. Differences between the studies had to do with (1) the brands and models of the shoes and (2) the nature of the training environment. Control group subjects in the current air force study received a New Balance 498, while control-group subjects in the army study received a New Balance 767ST. Experimental group subjects in the current air force study received only one of only three shoes, one for each foot type. Experimental-group subjects in the army study could select from 19 different shoes, as long as the shoe they selected had been designated as appropriate for their plantar shape. There were also differences in the army and air force basic training instructional programs and length of training (6 versus 9 weeks). Despite these differences, the results generally concur. Injury risk was slightly elevated in the group that received a shoe based on plantar shape (experimental group) when compared with the group that received a stability shoe regardless of plantar shape (control group). Multivariate injury hazard ratios (experimental/control) were very similar in the two studies.

Table 7. Injury hazard ratios by group and plantar foot shape (univariate Cox regression)

Subjects	Shoe type	Plantar foot shape	Men			Women		
			n	Hazard ratio (95% CI)	*p*-value	*n*	Hazard ratio (95% CI)	*p*-value
Control subjects only	Stability	Low	79	1.09 (0.70, 1.70)	0.69	23	1.50 (0.83, 2.72)	0.18
	Stability	Normal	714	1.00	—	280	1.00	—
	Stability	High	119	1.11 (0.77, 1.59)	0.59	41	0.84 (0.50, 1.40)	0.50
Experimental subjects only	Motion control	Low	134	1.39 (1.02, 1.43)	0.04	37	1.16 (0.74, 1.84)	0.52
	Stability	Normal	726	1.00	—	272	1.00	—
	Cushioned	High	181	1.06 (0.76, 1.43)	0.73	64	0.95 (0.64, 1.41)	0.79

Table 8. Comparison of recruits with low and high plantar shapes wearing different shoe types

Plantar shape	Shoe comparison	Men			Women		
		n	Hazard ratio–E/C (95% CI)	*p*-value	*n*	Hazard ratio–E/C (95% CI)	*p*-value
Low	Motion control/stability	213	1.33 (0.80, 2.21)	0.27	60	0.95 (0.47, 1.93)	0.88
High	Cushioned/stability	300	1.01 (0.66, 1.55)	0.97	105	1.41 (0.77, 2.58)	0.27

Motion-control shoes are designed for low-arched individuals to presumably control for excessive pronation; cushioned shoes are designed for high-arched individuals to presumably provide cushioning to reduce ground impact forces and to allow for more foot pronation.[15–18] If injury risk could be reduced by assigning running shoes based on plantar shape, that reduced risk might be best seen by comparing subjects with the same plantar shapes who wore different shoe types. That is, comparing low plantar–shaped subjects who wore motion-control shoes with those who wore stability shoes, and comparing high plantar–shape subjects who wore cushioned shoes with those who wore stability shoes. Contrary to expectation, comparing subjects in this manner indicated that injury risk was similar or slightly elevated in the group wearing the shoe presumably designed for their plantar shape (Table 8). This indicated that even with the extreme foot types, assigning running shoes based on plantar surface did not reduce injury risk. Again, these results concur with the complementary army study[9] testing the assignment effectiveness.

Despite the general concurrence between the army[9] and air force investigations, these studies are not in accord with a previous study[19] that showed an installation-wide decrease in serious injuries at Fort Drum, New York, after initiation of a running shoe–prescription program. There were methodologic differences between the Fort Drum project and the current air force study. The current study involved a prescription based only on plantar shape; the Fort Drum study involved a prescription based on an evaluation of foot arch height and foot flexibility. The current study involved a population of recruits in a situation where there was assurance that the correct shoe was obtained and worn. The Fort Drum study involved soldiers who were given the shoe prescription, but there was little follow-up to determine whether they had actually purchased and worn the recommended shoe. In fact, a survey involving a convenience sample of 122 Fort Drum soldiers (out of an average 9752 estimated to be on post) found that only 11% had followed the shoe prescription advice.

The current study involved a prospective shoe prescription involving two groups training side by side in a standardized 6-week program with follow-up for any injury occurring during the period. The Fort Drum study involved a retrospective examination of medical visits to a physical therapy clinic before and after the shoe program was initiated. A number of temporal factors were potential confounders in the Fort Drum study, and these were discussed at length in the report on that study.[19] The major potential confounder was the change in the medical surveillance system used to track injuries, which occurred at the exact point when injuries began to decrease. Thus, the current study involved manipulation of only one variable (running shoe prescription based on plantar shape), provided considerably better knowledge about the shoes worn, and involved a more controlled training environment.

Injury Rates in BMT

A secondary purpose of this study was to examine injury rates and injury risk factors in air force BMT. Table 9 compares injury incidence and injury rates in the current study with that of a previous air force study in which the data were collected about 13 years earlier.[20] In the previous study,[20] injuries were obtained from the Sports Med-

Table 9. Comparison of injury incidence and injury rate in current study and previous Air Force Basic Training study[20]

Study	Year data collected	Gender	*n*	Injury incidence (%)	Injury rate (injured airmen/month)
Snedecor et al.[20]	1994–1995	Men	8660	16.8	11.2
		Women	5250	37.8	25.2
Current[a]	2007	Men	1979	27.6	18.4
		Women	723	46.9	31.3

[a]Injury index is the Comprehensive Injury Index.

icine and Research Team (SMART) System, a surveillance system that tracked outpatient encounters. Injuries were broadly defined and included medical visits for both overuse- and traumatic-type injuries. Examination of injuries included in the SMART system indicated that they were similar to those included in the Comprehensive Injury Index. Thus, the CII was the injury index chosen for comparison with the earlier study. Table 9 shows that the injury rate for men was 1.64 times higher and the injury rate for women was 1.24 times higher in the current study compared with the earlier study.

The higher injury rates in the current study could be at least partially due to changes that have occurred in the BMT program of instruction since 1999 in response to changing world conditions. Since 1999 recruits have spent more time training on field security, developing fighting positions, checkpoint operations, road marching, confidence courses, M-16 rifle, and cover and concealment. Recruits spend more time in the field. A 2-day perimeter defense exercise ("Scorpion's Nest") has recently been developed and is designed to simulate defense of a fixed airfield in hostile territory. Activities during this exercise include patrolling, defense against infiltration, and area operations under simulated attacks.[21–24] Besides changes in the program of instruction, the air force also replaced the cycle ergometer test with the current 1.5-mile running test in 2004. It can be assumed that this has increased the emphasis on running during BMT. Longer running distance has been shown to be associated with a higher incidence of injury in both military[25,26] and civilian[27–30] environments.

Injury Risk Factors

The present study is the first to examine risk factors for injuries in USAF BMT. A number of risk factors previously identified in army and marine basic training were also established here. Higher injury risk was associated with lower aerobic fitness, as found in studies of army and marine basic training,[9,31–42] and cigarette smoking, as found in army studies.[9,35,43–45] Lower levels of muscular endurance (push-ups and crunches) were also associated with injury among the men; muscular endurance trends were similar among women, although they did not reach statistical significance. Previous army and marine studies have also found lower muscular endurance to be associated with higher injury rates.[9,35,43]

In the current study, there tended to be a bimodal relationship between BMI and injury risk among the men: those having both high and low BMI were at increased risk compared with the middle BMI group. Some army studies also report bimodal relationships among male recruits,[9,32] but others have shown no relationship[35,43] or increased risk with higher BMI.[46] In contrast with the men, women with high BMI were at elevated risk compared with those in the middle BMI group, but the low BMI group differed little from the middle BMI group. A similar trend was reported in one army recruit study;[35] in other female recruit studies, bimodal relationships have been reported;[31,32,47] and in another study women in the lowest decile of BMI tended to be at higher injury risk.[9] BMI has been increasing in army recruits over the last 30 years,[9,48] but the weight gain that accounts for most of the change in BMI (height has changed little) appears to be about evenly distributed between fat and fat-free mass.[48,49] The relationship between BMI and injury in basic training is likely to be complex because individuals can have a high BMI either because of higher body fat or because of higher fat-free mass. If high BMI reflects a larger percentage of body fat relative to height, injury risk might be elevated because the additional fat burden would both (1) increase the intensity of physical activity[50] leading to more rapid fatigue and (2) impose additional repetitive stress on the musculoskeletal system. However, body fat has not shown a consistent relationship with injuries in Army Basic Combat Training.[31,32,35] In contrast to high BMI, low BMI may reflect a paucity of either fat, fat-free mass, or both. Low BMI may make recruits more susceptible to injury if they lack the muscle mass or strength in the supportive structures (ligaments, bones) required to perform certain physical tasks and overexert or overuse the available muscle mass or supportive structures. As various studies, including the current one, have demonstrated that both high and low BMI were associated with injury in basic training,[9,31,32,46,47] a bimodal relationship is most plausible and could probably be demonstrated with larger sample sizes.

Four items on the questionnaire asked about physical activity prior to BMT. Among the men, none of the responses to these questions was associated with injury. This differs sharply from other studies of army and marine recruits, all of which have shown that higher levels of pre-basic training physical activity reduced injury risk in training.[9,32,35,38,40,42,43,51,52] BMT at the air force may be less intense than that of army and marine basic training, and prior physical training on the part of the men may be less associated with injury for this reason. On the other hand, women who had performed more running/jogging or had been running/jogging for a long time before BMT tended to be at lower injury risk. In BMT, subjects perform weight-bearing physical activity primarily in the form of standing (in formation), marching, walking, and running. It seems reasonable that a higher frequency of weight-bearing physical training prior to BMT would result in less susceptibility to injury, especially for women, who have lower fitness levels than men, on average.[49] Physical activity has several favorable influences on the body. When of the proper intensity, frequency, and duration, physical activity can increase aerobic fitness, muscle strength, connective tissue strength, and general health, as well as reducing body fat.[53–60] These and other factors may contribute to reducing susceptibility to injury.[61]

Men who were of "other" marital status (divorced, widowed, or separated) tended to have a higher injury rate than single men. Only five men were in the "other" category, and normally this would advise caution in interpreting this association. However, the complimentary army running shoe study[9] also found that men of "other" marital status were at higher injury risk than those who were single and had never been married. Among the women, those who were married had higher injury risk than single women, and marital status was an independent risk factor for injury in the multivariate model. Married female army recruits have been shown to have higher injury risk in two previous basic training investigations.[9,34] In contrast with the findings here, civilian studies have generally shown that married individuals experience a **lower** injury rate than unmarried individuals, usually attributed to greater risk-taking behavior on the part of the unmarried individuals.[62–64] However, in BMT this is not likely to be the case: because all individuals perform the same activities, a single individual can take little additional risks. It may be that married individuals who receive emotional and physical support from their partners lack this support in BMT, as contact with spouses and children is extremely limited. It is also possible that married women may experience more stress in BMT due to family-care pressures, and this manifests itself in a higher injury rate mediated by factors like distraction, lack of attention, or other problems.

Limitations

This study evaluated injuries as the outcome measure. There other issues such as shoe comfort and shoe wear that were not evaluated and might be important considerations. Also, only three shoes were evaluated in the present study, although the previously discussed army study[9] evaluated 19 different shoes using techniques similar to the present investigation.

Conclusion

This prospective study demonstrated that assigning running shoes based on the static, weight-bearing, plantar foot surface shape had little influence on injury risk in BMT, even after controlling for other injury risk factors. There was little difference in injury rates among those who were assigned a different type of shoe (motion control, stability, or cushioned) based on plantar foot shape and those who received a stability shoe regardless of plantar foot shape. If the goal is injury prevention, it is not necessary to assign running shoes to BMT recruits based on a visual inspection of the static, weight-bearing plantar shape. This study underscores the importance of carefully evaluating injury prevention measures that are widely accepted but that have not been previously tested. It is still recommended that recruits receive a new shoe on entry to BMT, as older shoes have previously been shown to be associated with increased injury risk.[51]

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