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Injury Reduction Effectiveness of Assigning Running Shoes Based on Plantar Shape in Marine Corps Basic Training

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Background: Shoe manufacturers market motion control, stability, and cushioned shoes for plantar shapes defined as low, normal, and high, respectively. This assignment procedure is presumed to reduce injuries by compensating for differences in running mechanics.

Hypothesis: Assigning running shoes based on plantar shape will not reduce injury risk in Marine Corps basic training.

Study Design: Randomized controlled clinical trial; Level of evidence, 1.

Methods: After foot examinations, Marine Corps recruits in an experimental group (E: 408 men, 314 women) were provided motion control, stability, or cushioned shoes for plantar shapes indicative of low, medium, or high arches, respectively. A control group (C: 432 men, 257 women) received a stability shoe regardless of plantar shape. Injuries during the 12 weeks of training were determined from outpatient visits obtained from the Defense Medical Surveillance System. Other known injury risk factors (eg, fitness, smoking, prior physical activity) were obtained from a questionnaire, existing databases, or the training units.

Results: Cox regression indicated little difference in injury risk between the E and C groups among men (hazard ratio [E/C] = 1.01; 95% confidence interval, 0.82-1.24) or women (hazard ratio [E/C] = 0.88; 95% confidence interval, 0.70-1.10).

Conclusion: This prospective study demonstrated that assigning shoes based on the shape of the plantar foot surface had little influence on injuries even after considering other injury risk factors.

Keywords: physical fitness; physical activity; tobacco use; prior injury; demographics; menstrual dysfunction

Injuries are a significant problem in the military and have a major effect on operational readiness because of medical costs, lost training time, and attrition associated with these injuries.[4-6] Historically, injuries have been shown to be the leading causes of disability, hospitalization, and outpatient visits in the military services.[5,8,28,29] In 2008, injuries and musculoskeletal conditions among members of active duty Armed Forces were responsible for 17 218 hospital admissions and over 2.7 million ambulatory visits.[19,20] Injury-related conditions account for limited duty rates of 40 to 120 days per 100 soldiers per month.[32] The occurrence of a training-related injury is associated with poor long-term military outcomes.[12,31] Previous studies have found varying injury incidence, but generally, about 25% of men and 45% of women will experience one or more injuries during the course of Marine Corps basic training.[1,2,7,24,27] The majority of overuse injuries involve the lower extremities and appear to come from physical fitness training activities, specifically running.[30]

When recruits first arrive for Marine Corps basic training, they are issued a new pair of running shoes. At the time the current study was conducted, these shoes were assigned based on the foot surface area contacting the floor (ie, the shape of the plantar surface) while standing. The

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plantar shape during static weightbearing was presumed to reflect foot arch height. Recruits judged to have high, low, and normal arches were assigned cushioned shoes, motion control shoes, or stability shoes, respectively. Shoe manufacturers market these 3 types of running shoes, and they are presumably designed to reduce injuries by compensating for differences in running mechanics. Cushioned shoes contain softer midsole material like ethyl vinyl acetate (EVA) that is thought to allow for greater shock absorption and permit more pronation for high-arched individuals who are assumed to impact the ground with high force and to underpronate. Motion control shoes are reputed to limit the excessive pronation experienced by lower arched individuals by using harder midsole materials (polyurethane) and other features that are specific to particular models. Stability shoes designed for normal-arched individuals are midway between motion control and cushioned type shoes, containing some motion control features and cushioning characteristics.[23]

We previously reported on studies conducted in US Army Basic Combat Training[16] and Air Force Basic Military Training[10] showing that assigning running shoes on the basis of plantar shape did not reduce the risk of training-related injuries. The major purpose of the present study was to determine whether injury risk could be reduced in Marine Corps basic training (MCBT) by assigning running shoes based on the static weightbearing plantar foot shape.

MATERIALS AND METHODS

Participants

Participants were volunteers from among male basic trainees at the Marine Corps Recruit Depot (MCRD), San Diego, California, and female basic trainees at the MCRD, Parris Island, South Carolina. Potential volunteers were briefed on the purposes and risks of the study, and those wishing to participate signed an informed consent statement. The research protocols were approved by the Institutional Review Board of the Naval Health Research Center, San Diego, California.

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. Recruits then removed their shoes and socks and mounted the acrylic platform of the light box device.[10,16] The device contained a mirror that reflected the underside of the trainee's foot. This provided a view of the footprint from above, showing how much of the foot was in contact with the acrylic surface. The participants were instructed to stand with equal weight on each foot, with their feet comfortably apart. The plantar surface area (footprint) was examined by trained evaluators who rated the plantar surface as either high arched, normal arched, or low arched, based on templates[23]: more area in contact with the acrylic surface in the middle third of the plantar surface indicated a low plantar shape, and less area in contact, a high plantar shape. In a subsample of cases (n = 66), 2 evaluators made independently recorded determinations of the plantar shape for the purposes of calculating between-rater reliability.

Following all foot measurements, participating recruits were randomized into 1 of 2 groups using an assignment order that was randomly generated by a statistical software program. Recruits assigned to the control (C) group received a stability shoe, the New Balance 767ST (Boston, Massachusetts), regardless of plantar shape. Recruits assigned to the experimental (E) group received a shoe based on the determined shape of the plantar surface of their foot. If the E-group recruit had a low arch, a motion control shoe, New Balance 587NV, was assigned. If the E-group recruit had a high arch, a cushion shoe, New Balance 881WG, was assigned. If the E-group recruit had a normal arch, a stability shoe was assigned, a New Balance 767ST. All participating recruits were asked their shoe size, and a shoe of this size was initially provided. If the shoe did not fit, different shoe sizes were tried until a proper fit was achieved.

Physical Characteristics, Physical Fitness, and Demographics

Additional data were obtained from an existing administrative data source routinely collected and maintained by the recruit training staff. These data included weight, height, and physical fitness test scores measured before the first day of recruit training. The recruits' weight and height were measured in socks, T-shirts, and shorts using a standard, calibrated mechanical physician's beam scale with a stadiometer.

The fitness test for the men consisted of 3 events: pull-ups, abdominal crunches, and a 1.5-mile run, conducted in that order. The fitness test for the women involved the same abdominal crunch and 1.5-mile run events that were performed by the men. However, instead of the pull-ups, women performed a flexed arm hang. Test events were administered by drill instructors using well-standardized procedures.

The Armed Forces Health Surveillance Center (AFHSC)[25] provided demographic data for the recruits from the Defense Manpower Data Center (DMDC). Recruit information obtained from the DMDC included date of birth, component (active Marine Corps or reserve Marine Corps), educational level, marital status, and race.

Marine Corps Recruit Training

United States Marine Corps recruit training consisted of 12 weeks of standardized military instruction for both male and female recruits. Men and women were trained by drill instructors of their own sex. Because of logistical and geographical reasons alone, the training schedules at the 2 training locations (ie, Parris Island and San Diego)

vary only in the training day in which events occur. The 12 weeks included 5 to 7 processing and forming days, and 70 training days, with no formal training conducted on Sundays. Running shoes were worn during processing and forming. There were about 40 miles of running during physical training in the 12 weeks.

Formal recruit training was divided into 3 phases of about 23 to 24 training days. Phase 1 used a progressive physical training program, which included general physical conditioning (14 sessions), pugil stick training (2 sessions), water survival skills training (4 days), and 5-km and 8-km conditioning marches (1 each). General physical conditioning exercises included running, calisthenics, obstacle courses, and circuit courses. There were 4 days when no physical training was scheduled. Running shoes and Marine Corps combat boots were alternated on the first 16 training days, but after that, running shoes were worn for 12 to 15 hours per week of physical training. Phase 1 also included classroom instruction on Marine Corps history, core values, leadership, ethics, first aid training, health and hygiene, personal appearance, and uniform instruction.

Phase 2 emphasized marksmanship fundamentals using the M-16A2 rifle and a final qualifying test. Physical activity included general physical conditioning (7 sessions), platoon drill, and 10-km and 12-km marches (1 each). Running shoes were worn for 8 to 10 hours per week of physical training. There were 9 days when no physical training was scheduled.

Phase 3 focused on a field training exercise (the Crucible), which took place over 54 hours, during training days 63 to 65. The first day of the exercise began with a 10-km march and ended with an 8-km night march. The last day finished with a 15-km march. Other physical training consisted of Basic Warrior Training (BWT, 4 sessions), general physical conditioning (4 sessions), platoon drills, and a motivation run the day before graduation. The BWT course was 2 one quarter miles with obstacles every quarter mile; one session was performed in running shoes. Running shoes were worn 8 to 10 hours per week in phase 3, and there were 6 days when no physical training was scheduled. The final few training days involved continued drill and ceremony, practice for graduation, and the graduation ceremony.

Attrition From Training

Some participants did not complete the entire 12-week basic training cycle, but their data were included for the time they remained in training, as described below. Reasons for attrition included discharge from the Marine Corps or reassignment to a new company (recycle). Discharges and recycles were obtained from a local data system maintained at MCRD San Diego or MCRD Parris Island.

Injury Outcome Measures

Injury outcome data were obtained from the AFHSC. The AFHSC systematically obtains data on ambulatory (outpatient) encounters that occur within military treatment facilities (MTFs) or outside MTFs but are paid for by the Department of Defense. The AFHSC provided visit dates and International Classification of Diseases, Version 9, Clinical Modification (ICD-9-CM) codes for all outpatient medical visits within the recruit training time frame for each recruit. The first 4 diagnoses for each visit were considered, although a single visit usually included only one diagnosis. Five injury indices were calculated: the Installation Injury Index (III), Modified Installation Injury Index (MIII), Training-Related Injury Index (TRII), Overuse Injury Index (OII), and Comprehensive Injury Index (CII). These indices include specific ICD-9 codes, as described previously.[13] The III has been used to compare overall injury rates (acute and overuse) among military posts and is reported on a monthly basis at the Armed Forces Health Surveillance Center Web site (http://afhsc.army.mil), where the ICD-9-CM codes are also provided. The MIII is similar to the III but captures a greater number of injuries than the III, including more overuse-type injuries. The TRII is limited to lower extremity overuse injuries and has been used to compare injury rates among Army basic training posts. The OII captures the subset of musculoskeletal injuries presumably resulting from cumulative microtrauma (overuse injuries) such as stress fractures, stress reactions, tendinitis, bursitis, fasciitis, arthralgia, neuropathy, radiculopathy, shin splints, synovitis, and musculoskeletal pain (not otherwise specified). The CII captures all ICD-9 codes related to injuries including overuse and traumatic.

Data Analysis

Data were compiled and analyzed using SPSS version 16.0.1 (Chicago, Illinois). Age was calculated from the date of birth in the DMDC data to the date of the informed consent briefing. Body mass index (BMI) was calculated as weight/height×height (kg/m^2).[11]

The E and C groups were compared on attrition, age, physical characteristics, physical fitness, demographic characteristics, and the questionnaire variables. For continuous measures, group comparisons were performed using an independent sample t test; for discrete, nominal, and ordinal variables, comparisons were made using the χ^2 statistic. Between-rater reliability of plantar foot shape determination was made with the κ coefficient.

Person-time injury incidence rates (injured subjects/1000 person-days) for all injury indices were calculated as ([recruits with $\geq$1 injury by index]/[total recruit time in basic training]) $\times$ 1000. Comparisons between the E and C groups were made using a χ^2 for person-time.[9]

Cox regression (survival analysis) was used to examine group differences in time to first injury, examining the OII, TRII, and CII. The number of days in training was the time scale. Univariate Cox regression involved group (E or C) as the only independent variable. The C group was defined as the reference group (hazard ratio = 1.00), and simple contrasts were made between the C and E groups. Multivariate Cox regression included any variable that differed between the groups in the χ^2 or t test analyses ($P < .10$). For each Cox regression analysis, once a recruit had an

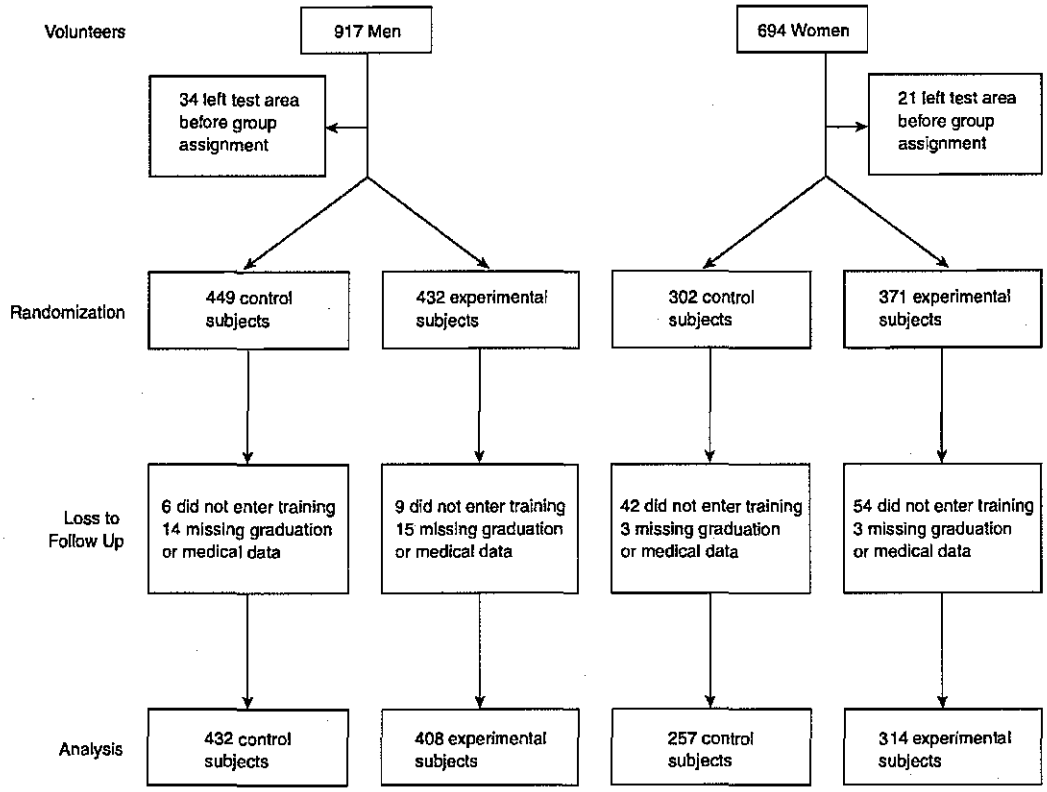

Figure 1. Flow of volunteers through study.

injury, his or her contribution to time in MCBT was terminated. Those who withdrew from MCBT had their times censored (ie, end of time at risk) at the day they left training.

RESULTS

Participants, Attrition, and Reliability

In total, 917 men and 694 women volunteered for the study. Not considered in the analyses were recruits who left the testing area without receiving a group assignment (due to externally imposed time constraints), those not entering basic training, those who did not have a graduation date in administrative records, and/or those whose data were not obtained from the AFHSC. The final cohort consisted of 840 men and 571 women. The initial volunteers and loss of participants by group is shown in Figure 1.

Among the men, 15.3% in the C group and 11.5% in the E group withdrew from training ($P = .11$). Among the women, 12.1% of the C group and 11.5% of the E group withdrew from training ($P = .83$). The κ coefficient comparing 2 raters on the plantar surface evaluations was 0.91 for the right foot and 0.91 for the left foot (n = 66), suggesting strong agreement and high comparative quality beyond chance alone.[26]

Comparisons of C and E Groups

Sample sizes shown in the tables below can be different depending on the completeness of the data. This occurred because not all participants had complete measurements on all variables: a recruit may not have provided a response on the questionnaire or the AFHSC or the training unit may not have had some specific information.

Appendix 1 (available in the online version of this article at http://ajs.sagepub.com/supplemental/) compares group differences in age, physical characteristics, fitness scores, and the questionnaire items with continuous numeric responses. Group differences in age and the physical characteristics were small for both men and women. With regard to physical fitness, C-group men performed more pull-ups and crunches compared with the E-group men, but fitness differences were small between the C- and E-group women. None of the questionnaire items in Appendix 1 differed significantly between the C- and E-group men or women.

Appendix 2 (available in the online version of this article at http://ajs.sagepub.com/supplemental/) shows group comparisons on the demographic variables and the questionnaire items with ordinal, nominal, and discrete responses. The distribution of participants was similar for the C and E groups on the demographic variables for both men and women. On the questionnaire items, the E-group men had more recruits reporting that they had

TABLE 1
Comparison of Injury Incidence Rates Between Experimental (E) and Control (C) Groups[a]

	Men				Women			
	Injury Incidence Rate (injuries/1000 person-days)				Injury Incidence Rate (injuries/1000 person-days)			
Injury Index	C (n = 432)	E (n = 408)	Rate Ratio-C/E (95% CI)	*P* Value[b]	C (n = 257)	E (n = 314)	Rate Ratio-C/E (95% CI)	*P* Value[b]
Installation	5.14	5.40	0.95 (0.77-1.19)	.70	5.43	4.57	1.19 (0.91-1.55)	.24
Modified Installation	5.24	5.40	0.97 (0.78-1.21)	.79	5.90	4.59	1.20 (0.93-1.56)	.19
Overuse	4.14	4.06	1.02 (0.79-1.31)	.89	3.29	2.80	1.18 (0.83-1.66)	.41
Training-Related	3.56	3.63	0.98 (0.75-1.28)	.88	1.49	2.03	1.18 (0.79-1.77)	.48
Comprehensive	5.72	5.76	0.99 (0.80-1.22)	.95	6.00	4.96	1.21 (0.94-1.57)	.16

[a]CI, confidence interval.
[b]χ^2 statistic for person-time.[9]

TABLE 2
Injury Risk in the Control (C) and Experimental (E) Groups (Cox Regression)[a]

		Men (Univariate Analysis)		Women (Univariate Analysis)		Men (Multivariate Analysis)[b]	
Injury Index	Group	Hazard Ratio-C/E (95% CI)	*P* Value	Hazard Ratio-C/E (95% CI)	*P* Value	Hazard Ratio-C/E (95% CI)	*P* Value
Overuse	Control	1.00	—	1.00	—	1.00	—
	Experimental	0.99 (0.76-1.27)	.96	0.84 (0.59-1.19)	.32	1.03 (0.80-1.34)	.81
Training-Related	Control	1.00	—	1.00	—	1.00	—
	Experimental	1.04 (0.80-1.36)	.77	0.84 (0.56-1.26)	.39	1.07 (0.81-1.41)	.65
Comprehensive	Control	1.00	—	1.00	—	1.00	—
	Experimental	1.01 (0.82-1.24)	.94	0.88 (0.70-1.10)	.15	1.06 (0.85-1.32)	.62

[a]CI, confidence interval.
[b]Includes pull-up performance, crunch performance, cigarette smoking, and prior lower limb injury.

smoked 100 cigarettes in their lifetime and more recruits reporting a prior lower limb injury. The E- and C-group women were similarly distributed on the questionnaire responses.

Injuries, Injury Rates, and Injury Risk

The 10 most common ICD-9-CM codes for the men were the following (in order of high to lower frequency): 726.69 (enthesopathy of knee), 848.8 (other sprains/strains), 845.00 (sprains/strains of ankle and foot), 844.9 (sprains/strains of knee and leg), 717.9 (internal derangement of knee), 919 (superficial injury of other, multiple, and unspecified sites), 847.9 (sprains and sprains of unspecified back sites), 719.46 (pain in lower leg), 840.9 (sprain/strain of shoulder and upper arm), and 843.9 (sprain/strain of hip and thigh). The 10 most common ICD-9-CM codes for the women were the following (in order of high to lower frequency): 729.5 (pain in limb), 919 (superficial injury of other, multiple, and unspecified sites), 719.46 (pain in lower leg), 719.45 (pain in pelvic region and thigh), 845.00 (sprains/strains of ankle and foot), 719.47 (pain in ankle and foot), 719.41 (pain in shoulder region), 848.9 (sprains/strains, unspecified site), 919 (superficial injury of other, multiple, and unspecified sites), and 728.71 (plantar fascial fibromatosis).

Table 1 shows the person-time injury incidence rates for the various injury indices and compares the rates in the C and E groups. The incidence rates for the C and E groups were similar for both men and women for all of the indices.

Table 2 shows the results of the Cox regressions. Univariate analyses showed that for both men and women, there was little difference in OII, TRII, or CII risk between the groups. Because the 2 groups of men differed on pull-ups, crunches, smoking, and prior lower limb injury, a multivariate Cox regression was performed including these measures as covariates with the group factor. The hazard ratios for the men changed little when these covariates were included in a multivariate Cox regression.

Table 3 shows Cox regressions comparing CII risk between groups with high and low plantar shapes who wore different shoe types. Among the men and women with either low or high plantar shapes, injury risk was similar regardless of shoe type.

TABLE 3
Comparison of Recruits With Low and High Plantar Shapes Wearing Different Shoe Types (Comprehensive Injury Index)[a]

		Men			Women		
Plantar Shape	Shoe Comparison	n	Hazard Ratio-E/C (95% CI)	*P* Value	n	Hazard Ratio-E/C (95% CI)	*P* Value
Low	Motion control/stability	62	0.91 (0.40-2.07)	.82	57	0.74 (0.31-1.76)	.49
High	Cushion/stability	79	1.05 (0.53-2.10)	.89	105	1.11 (0.62-2.00)	.72

[a]E, experimental group; C, control group; CI, confidence interval.

TABLE 4
Running Shoes Used in the Marine Corps, Air Force, and Army Physical Training Footwear Studies

	Experimental Group Shoes			
Service	*Motion Control Shoe*	Stability Shoe	Cushion Shoe	Control Group Stability Shoe
Marine Corps	New Balance 587	New Balance 767	New Balance 881	New Balance 767
Air Force	New Balance 587	New Balance 498	New Balance 755	New Balance 498
Army	Asics Gel Foundation 7	Asics Gel 1120	Asics Gel Cumulus	New Balance 767
	Brooks Addiction 7	Asics Gel 2120	Brooks Radius 6	
	Saucony Grid Stabil 6	Brooks Adrenaline GTS6	Nike Air Pegasus	
	New Balance 857[a]	Brooks Adrenaline GTS7	Saucony Grid Trigon 4	
		Nike Structure Triax	New Balance 644	
		Nike Air Max Moto[a]	New Balance 755	
		Saucony Grid Omni 5		
		New Balance 717		
		New Balance 767		

[a]For 2 shoes, the Army classification differed from those of the Runner's World and the manufacturer. One shoe was the New Balance 857, which the Army classification listed as a motion control shoe but Runner's World and the manufacturer listed as a stability shoe; the other was the Nike Air Max Moto, listed in the Army classification as a stability shoe but by Runner's World and the manufacturer as a cushioned shoe.

DISCUSSION

The present study demonstrated that assigning running shoes on the basis of the shape of plantar foot surface did not reduce injury risk in MCBT. Men and women who wore the shoe assigned based on their plantar shape had similar injury risk when compared with those who received a standard stability shoe regardless of foot type.

The results of the current study can be compared with the results of similar Army[16] and Air Force[10] basic training investigations, which also examined the effectiveness of assigning shoes based on plantar shape. These studies were designed to be complementary, but there were some important differences. Similarities among the 3 studies included (1) tracking participants in the same medical surveillance system, (2) calculating injury incidence rates in an identical manner, (3) an identical lifestyle questionnaire, and (4) the same randomized prospective design with the C group receiving a single stability shoe and an E group receiving a shoe based on plantar shape. Major differences among the Services' studies had to do with the brands and models of the shoes provided and the nature of the training environment. Table 4 shows the shoes used in the Marine Corps, Air Force, and Army investigations. The C-group participants in the Marine Corps and Army studies received the same stability-type shoe, but C-group participants in the Air Force investigation received another type of stability shoe. The E-group participants in the Marine Corps and Air Force study received only 1 of 3 shoes, one for each foot type; E participants in the Army study could select from 19 different shoes, as long as the shoe they chose had been designated as appropriate for their plantar shape. There are also differences in the Marine Corps, Air Force, and Army basic training programs of instruction and length of training (12, 6, and 9 weeks, respectively).

Despite the differences in the Marine Corps, Air Force,[10] and Army[16] studies, the results generally concurred in showing that assigning running shoes based on plantar shape had little influence on injury risk during basic training. Hazard ratio comparisons for the 3 studies are shown in Table 5. To more fully examine injury risk when shoes were assigned based on plantar shape, meta-analysis was performed. The meta-analysis method was a general variance-based technique that employed univariate hazard ratios and confidence intervals from each study to produce a summary hazard ratio (SHR) and summary 95% confidence interval (S95% CI) that reflected the

TABLE 5
Meta-Analysis of Studies Examining if Injury Risk Can be Reduced by Assigning Shoe Based on Plantar Shape (Comprehensive Injury Index)[a]

	Men		Women	
Service	Hazard Ratio-E/C (95% CI)	Summary Hazard Ratio-E/C (S95% CI)	Hazard Ratio-E/C (95% CI)	Summary Hazard Ratio-E/C (S95% CI)
Marine Corps	1.01 (0.82-1.24)	1.04 (0.94-1.14)	0.88 (0.70-1.10)	1.05 (0.95-1.18)
Air Force	1.09 (0.92-1.29)		1.23 (1.00-1.53)	
Army	1.02 (0.89-1.17)		1.06 (0.90-1.24)	

[a]E, experimental group; C, control group; 95% CI, 95% confidence interval; S95% CI, summary 95% confidence interval.

TABLE 6
Meta-Analysis of Recruits With Low and High Plantar Shapes Wearing Different Shoe Types (Comprehensive Injury Index)[a]

			Men		Women	
Service	Plantar Shape	Shoe Comparison	Hazard Ratio-E/C (95% CI)	Summary Hazard Ratio-E/C (S95% CI)	Hazard Ratio-E/C (95% CI)	Summary Hazard Ratio-E/C (S95% CI)
Marine Corps	Low	Motion control/stability	0.91 (0.40-2.07)	Low: 1.13 (0.85-1.51)	0.74 (0.31-1.76)	Low: 1.11 (0.75-1.65)
	High	Cushion/stability	1.05 (0.53-2.10)	High: 1.19 (0.93-1.52)	1.11 (0.62-2.00)	High: 1.12 (0.85-1.48)
Air Force	Low	Motion control/stability	1.33 (0.80-2.21)		0.95 (0.47-1.93)	
	High	Cushion/stability	1.01 (0.66-1.55)		1.41 (0.77-2.58)	
Army	Low	Motion control/stability	1.08 (0.73-1.60)		1.48 (0.83-2.63)	
	High	Cushion/stability	1.36 (0.97-1.91)		1.04 (0.72-1.49)	

[a]E, experimental group; C, control group; 95% CI, 95% confidence interval; S95% CI, summary 95% confidence interval.

combined results of all the studies.[22] As shown in Table 5, the SHRs indicated that there was little difference in injury risk between the C and E groups for men or women. Said another way, there was little difference in injury risk if the subjects received a stability shoe (C group) or received a shoe based on plantar surface (E group) after combining the results of the Marine Corps, Air Force, and Army studies.

As noted earlier, 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.[17,18,21,33] If injury risk could be reduced by assigning running shoes based on plantar shape, that reduced risk might be best seen by comparing E and C groups with low or high plantar shapes. This is because the low plantar-shape E group wore motion control shoes designed by shoe companies for their foot type, but the low plantar-shape C group wore stability shoes designed for another foot type. Likewise, the high plantar-shape E group wore cushioned shoes designed by shoe companies for their plantar shape, but high plantar-shape C group participants wore stability shoes designed for another foot type. Table 6 shows these comparisons in the Marine Corps, Army, and Air Force studies for men and women separately. Again, meta-analysis employing a general variance-based technique was used to combine the results of the 3 studies, and the SHR and S95% CI indicated the combined results.[22] Contrary to expectation, SHRs in Table 6 indicated that injury risk was modestly elevated in the E group after combining the Marine Corps, Air Force, and Army studies.

Despite the general concurrence among the Marine Corps, Air Force,[10] and Army[15] investigations, these studies are not in accord with a previous Army study[14] that showed a postwide decrease in serious injuries at Fort Drum, New York, after initiation of a running shoe prescription program. Methodological differences between the Fort Drum project and the current Marine Corps study are similar to those previously outlined in the Air Force and Army investigations.[10,15] The current Marine Corps study involved a prescription based only on plantar shape; the Fort Drum project involved a prescription based on an evaluation of foot arch height and foot flexibility. The current Marine Corps study involved a population of recruits in a situation where there was assurance that the correct shoe was given to the recruit and worn during training. The Fort Drum project involved soldiers who were given the shoe prescription, but there was little follow-up to determine whether they had actually purchased and/or worn the recommended shoe. In fact, a survey involving a convenience sample of 122 Fort Drum soldiers (of an average 9752 estimated to be on post) found that only 11% self-reported that they had followed the shoe prescription advice. The current Marine Corps study involved

a prospective shoe prescription involving 2 randomly assigned groups (C and E) training side by side in a standardized program with follow-up for any injury occurring during the period. The Fort Drum project 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 project, and these were discussed at length in the report on that study.[14] The major potential bias was a change in the medical surveillance system used to track injuries, which was discovered after investigating the time point when injuries dramatically decreased. In summary, the advantages of the current Marine Corps study were that it (1) involved a randomized prospective design manipulating only one variable (running shoe prescription based on plantar shape), (2) provided considerably better knowledge about the shoes worn, and (3) involved a more controlled training environment. Men and women in the current Marine Corps study trained in separate locations (San Diego, California, and Parris Island, South Carolina); however, the male and female data were analyzed separately, ensuring that gender-specific C and E groups were in the same training environment.

In conclusion, this prospective study demonstrated that assigning running shoes based on the static weightbearing plantar foot surface shape had little influence on injury risk during MCBT, even after controlling for other injury risk factors. The findings are strengthened by the similar results in Air Force and Army basic training studies and the meta-analysis reported above. If the goal is injury prevention, it is not necessary to provide running shoes to Marine Corps recruits based on a visual inspection of the static weightbearing plantar shape. This assignment procedure was no more protective against injury than issuing a single stability shoe regardless of plantar shape. It is still recommended that recruits receive a new shoe on entry to recruit training because older shoes have previously been shown to be associated with increased injury risk.[3]

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Appendix 1. Group Comparisons of Age, Physical Characteristics, Fitness Scores and Numeric Questionnaire Items

Variable Category	Variable	Men					Women				
		C		E		p-value[a]	C		E		p-value[a]
		N	Mean ±SD	n	Mean ±SD		n	Mean ±SD	n	Mean ±SD	
Age	Age (yr)	415	20.6±2.2	393	20.7±2.2	0.57	256	19.2±2.0	312	19.1±2.0	0.41
Physical Characteristics	Height (cm)	394	177±7	377	176±7	0.38	232	163±7	281	162±7	0.12
	Weight (kg)	394	77.6±12.3	376	76.7±12.3	0.23	257	59.9±7.7	313	59.4±7.3	0.40
	BMI (kg/m^2)	394	24.9±3.4	376	24.6±3.5	0.38	232	22.5±2.3	281	22.6±2.4	0.90
Physical Fitness	Pull-Ups (reps)	401	8±5	381	9±5	<0.01	NA[b]				
	Flexed Arm Hang (sec)	NA[b]					254	45±17	313	45±17	0.60
	Crunches (reps)	401	62±17	381	65±18	<0.01	255	66±19	313	67±20	0.67
	1.5-Mile Run (min)	401	11.3±1.1	381	11.2±1.1	0.16	255	13.9±1.2	313	13.8±1.2	0.43
Questionnaire Items	Age Started Smoking (years)[c]	254	16±3	258	16±2	0.45	106	15±2	114	15±3	0.70
	Smoking in Last 30 Days[c] (days)	151	15±11	149	13±11	0.17	60	17±11	70	20±11	0.13
	Cigarettes in Last 30 Days[c] (n/day)	147	8±13	155	7±7	0.27	60	6±6	71	7±7	0.56
	Quit Smoking (months)[d]	41	13±16	56	15±17	0.49	33	17±14	20	14±15	0.51
	Age at Menarche (years)	NA[b]					257	12±1	314	13±1	0.19
	Menstrual Cycles (n/year)						257	11±2	314	11±3	0.23

a. Independent sample t-test
b. Not applicable
c. Only subjects who reported smoking included
d. Only subjects who reported that they had quit smoking were included

Appendix 2. Group Comparisons on Demographics and Ordinal, Nominal, and Discrete Questionnaire Variables

Variable Category	Variable	Sample Sizes	Response Category	Men			Women		
				C(%)	E(%)	p-value[a]	C(%)	E(%)	p-value[a]
Demographics	Component	Men C=432 Men E=408 Women C=257 Women E=314	Active Marine Corps Marine Corps Reserves	87.0 13.0	89.7 10.3	0.23	82.9 17.1	82.8 17.2	0.98
	Educational Level	Men C=432 Men E=408 Women C=257 Women E=314	High School Graduate Some College or Graduate Unknown	94.0 5.3 0.7	95.6 3.9 0.5	0.58	94.9 1.6 3.5	97.7 1.3 1.0	0.11
	Race	Men C=432 Men E=408 Women C=257 Women E=314	White Hispanic Black Other Unknown	73.8 14.4 4.4 4.4 3.0	77.0 12.0 3.9 5.1 2.0	0.66	79.0 2.3 12.8 5.1 0.8	78.3 2.2 15.6 2.9 1.0	0.63
	Marital Status	Men C=432 Men E=408 Women C=257 Women E=314	Single Married Other[b]	94.2 5.6 0.2	92.6 6.1 1.2	0.22	95.7 4.3 0.0	97.1 2.5 0.3	0.35
Questionnaire Items	Shoe Type Prior to Basic Training	Men C=415 Men E=395 Women C=253 Women E=311	Boots Dress Running Heels ≤ 1 inch[b] Heels ≥ 1 inch[b] Sandals Other Unsure	18.8 4.8 57.6 0.0 0.0 2.2 11.3 5.3	22.5 5.3 55.2 0.0 0.0 2.0 10.6 4.3	0.82	1.2 2.0 1.2 1.6 61.7 28.1 2.4 2.0	3.2 2.3 1.3 3.9 56.6 25.4 6.1 1.3	0.14
	Smoked 100 Cigarettes in Lifetime	Men C=431 Men E=403 Women C=256 Women E=313	No Yes	64.7 35.3	57.3 42.7	0.03	74.6 25.4	77.6 22.4	0.40
	Self Rating of Physical Activity	Men C=422 Men E=407 Women C=257 Women E=314	Much less than average Somewhat less than average About the same Somewhat more active Much more active	4.5 18.0 30.6 36.3 10.7	3.4 15.5 31.0 38.1 12.0	0.75	2.7 12.1 33.5 42.4 9.3	1.9 13.1 30.6 42.7 11.8	0.79
	Frequency of Exercise or Sports Last 2 Months	Men C=425 Men E=408 Women C=257 Women E=314	Never < 1 time/week 1 time/week 2 times/week 3 times/week 4 times/week 5 times/week 6 times/week ≥ 7 times/week	2.8 8.5 6.1 20.5 24.5 15.3 12.2 6.0 3.5	2.9 5.9 9.1 20.6 24.0 15.4 11.5 5.6 4.9	0.68	0.8 4.3 7.8 19. 5 22.2 19.5 16.3 5.8 3.9	0.6 4.1 8.9 20.7 25.5 17.8 10.5 7.0 4.8	0.71
	Frequency of Running or Jogging Last 2 Months	Men C=427 Men E=407 Women C=257 Women E=314	Never < 1 time/week 1 time/week 2 times/week 3 times/week 4 times/week	3.7 7.5 11.0 20.1 26.0 16.2	4.2 8.6 11.5 19.9 23.1 16.2	0.99	0.8 8.6 12.1 24.1 22.6 15.6	0.6 7.3 12.4 27.1 23.2 16.2	0.97

Variable Category	Variable	Sample Sizes	Response Category	Men			Women		
				C(%)	E(%)	p-value[a]	C(%)	E(%)	p-value[a]
			5 times/week	9.1	9.1		10.1	8.3	
			6 times/week	3.5	4.7		3.9	3.5	
			≥ 7 times/week	2.8	2.7		2.3	1.3	
	Length of Time Ran or Jogged Prior to Basic Training	Men C=430 Men E=406 Women C=257 Women E=314	Did not run or jog	6.3	8.6		3.9	14.4	
			≤ 1 month	38.6	34.2		14.4	17.8	
			2 months	20.9	24.4		17.9	14.3	
			3 months	15.6	12.6	0.11	10.9	13.4	0.52
			4–6 months	6.7	10.8		18.7	19.7	
			7–11 months	4.0	3.4		12.1	8.6	
			≥ 12 months	7.9	5.9		22.2	21.0	
	Frequency of Exercise with Weights Prior to Basic Training	Men C=431 Men E=408 Women C=257 Women E=314	Never	14.2	20.8		22.2	22.3	
			< 1 time/week	12.3	10.3		8.6	16.9	
			1 time/week	9.5	7.1		16.7	12.7	
			2 times/week	19.5	22.1		19.1	16.6	
			3 times/week	17.9	16.7	0.22	16.3	13.7	0.24
			4 times/week	11.1	8.1		8.9	8.9	
			5 times/week	7.7	7.1		4.3	4.5	
			6 times/week	4.6	4.2		1.6	1.9	
			≥ 7 times/week	3.2	3.7		2.3	2.5	
	Length of Time Performing Weight Training ≥ 2 Times/Week	Men C=429 Men E=404 Women C=257 Women E=314	No training	29.4	34.2		44.4	46.8	
			≤ 1 month	23.3	22.5		17.1	17.8	
			2 months	19.3	14.6		12.5	10.8	
			3 months	11.4	9.7	0.29	4.3	5.4	0.95
			4–6 months	8.9	8.7		10.1	8.0	
			7–11 months	2.3	2.2		3.9	3.8	
			≥ 12 months	5.4	8.2		7.8	7.3	
	Had a Prior Lower Limb Injury	Men C=430 Men E=407 Women C=257 Women E=314	No	90.2	86.2	0.07	76.7	79.3	0.45
			Yes	9.8	13.8		23.3	20.7	
	Did Lower Limb Injury Prevent You from Doing Normal Physical Activity	Men C=429 Men E=406 Women C=257 Women E=313	No injury	90.4	86.5		76.7	79.6	
			No	4.2	4.7	0.13	5.8	5.1	0.71
			Yes	5.4	8.9		17.5	15.3	
	Gone ≥ 6 Months without Menstrual Cycle	Women C=257 Women E=314	Never had a Period	NA[b]			7.4	7.6	
			No				90.7	87.3	0.14
			Yes				1.9	5.1	
	Used Birth Control in Past 12 Months	Women C=257 Women E=314	No				64.6	67.5	0.46
			Yes				35.4	32.5	

a. Chi-square statistic
b. Not applicable