MILITARY MEDICINE, 173, 3:278, 2008

Risk Factors for Training Injuries among British Army Recruits

Sam D. Blacker, BSc; David M. Wilkinson, PhD*; James L.J. Bilzon, PhD†; Mark P. Rayson, PhD**

ABSTRACT This study aimed to identify risk factors for training injuries resulting in referral to a remedial instructor (RI) or medical discharge (MD) among British Army recruits undertaking initial training. Physical performance and anthropometric data for 11,937 male and 1,480 female recruits were examined as potential risk factors for RI referral and MD, using Cox regression. There was a trend showing that female recruits' MD rates were higher than male recruits' rates ($p = 0.096$), and RI referral rates were significantly greater for women than for men ($p = 0.041$). The independent risk factors for MD were 2.4-km run time, ethnicity, and Army training regiment attended ($p < 0.001$), and those for RI referral were 2.4-km run time, ethnicity, Army training regiment attended, and body mass index ($p < 0.001$). Gender was not an independent risk factor for injury, suggesting that lower levels of aerobic fitness are the primary cause of the greater incidence of injury among female recruits during British Army initial training.

INTRODUCTION

Although risk factors for the development of training injuries have been investigated in detail during U.S.,[1–9] Australian,[10,11] and Norwegian[12,13] military training, there are no previously published studies identifying risk factors for injury during current British Army initial training courses. Previously identified risk factors for injury during various military training programs include aerobic fitness,[4,5,10,12–16] gender,[2,15,16] age,[3,6,12] ethnicity,[6] smoking,[1,5,6,13,17,18] physical activity and exercise before starting training,[5,13,17] previous injury before the start of training,[18] muscular endurance and strength,[4,5,16] flexibility,[5] and anthropometric measures.[2,3,12,16] These risk factors differ between military training programs and are specific to the populations investigated because of differences in recruit characteristics, training regimens, and environmental factors.

British Army initial training, which is attended by all potential soldiers except for infantry and junior recruits, consists of a 12-week training program, the common military syllabus (recruits) [CMS(R)], and is currently undertaken at three Army training regiments (ATRs). The course teaches military skills through classroom and practical lessons and improves recruits' physical fitness through a progressive, structured, physical training program.

The most recent analysis of training injuries during British Army initial training courses found high rates of overuse injuries (2.4% for men and 11.1% for women).[15] Training injuries can result in the loss of training time, causing reductions in physical fitness and specific skills training, which may result in recruits being put back in training or, in cases of severe injury, discharged from the military. This is of high personal cost to individual recruits and financial cost to the military. The aim of this investigation was to quantify injury rates and to identify risk factors for the development of training injuries (all acute and overuse injuries diagnosed by trained medical staff members) that resulted in referral to a remedial instructor (RI) or medical discharge (MD) among British Army recruits undertaking CMS(R).

METHODS

Subjects

Subjects consisted of 13,417 recruits (11,937 male recruits and 1,480 female recruits) who started CMS(R) after January 1, 2003, and completed training before March 1, 2005. Subject characteristics are presented in Table I. Ethics approval was obtained from the School of Sport and Exercise Sciences ethics committee at the University of Birmingham. Subject data were obtained through retrospective analysis of training and medical records. Recruits' names and military numbers were removed to ensure subject anonymity; therefore, written informed consent could not be obtained from individual subjects. Permission to access recruits' training and medical records was granted by Occupational Medicine, Headquarters Army Training and Recruiting Agency.

Data Collection

Data describing recruits' physical characteristics and fitness and strength test results were extracted from the Training, Administration, and Financial Management Information System, which records data on all recruits who enter British Army training. The data set was produced by selecting recruits from the database who had undertaken training at all ATRs that conduct CMS(R), that is, ATR Pirbright, ATR Lichfield, and ATR Winchester. The summary data for each parameter are shown in Table I. Physical characteristics (age, height, body mass, body mass index [BMI], and body fat percentage) were recorded and physical selection testing was conducted by military physical training instructors at one of four recruit selection centers, before the beginning of military training.

*Optimal Performance, Bristol, BS8 1BA, United Kingdom.

†Department of Occupational Medicine, Headquarters Army Recruiting Training and Division, Wiltshire, SN9 6BE, United Kingdom.

This manuscript was received for review in May 2007. The revised manuscript was accepted for publication in December 2007.

TABLE I. Subject Characteristics and Physical Test Scores

Variable	Combined	Male Recruits	Female Recruits	p for Difference
No.	13,417	11,937	1,480	
Age (years)	20.5 ± 3.2	20.5 ± 3.2	20.4 ± 3.2	
Height (cm)	175 ± 8	176 ± 7	164 ± 6	<0.001
Mass (kg)	70 ± 10	71 ± 9	61 ± 7	<0.001
BMI (kg/m^2)	23 ± 2	23 ± 2	23 ± 2	<0.001
Body fat (%)	16 ± 6	14 ± 5	25 ± 6	<0.001
SAE (seconds)	208 ± 45	216 ± 37	148 ± 55	<0.001
BES (kg)	95 ± 18	98 ± 16	70 ± 11	<0.001
DLS (kg)	59 ± 11	61 ± 10	45 ± 8	<0.001
Heaves (no.)	6 ± 4	7 ± 4	1 ± 2	<0.001
SLS (kg)	117 ± 26	121 ± 24	84 ± 15	<0.001
MSFT time (seconds)	521 ± 95	538 ± 85	393 ± 70	<0.001
2.4-km run time (seconds)	631 ± 66	618 ± 54	740 ± 50	<0.001

Values are mean ± SD.

The 2.4-km run time was measured when recruits completed a standardized, 2.4-km, outdoor course. The multistage fitness test (MSFT) was conducted in a gymnasium; subjects were required to run 20-m shuttles continuously, at progressively increasing speeds, until they were unable to complete three consecutive shuttles. The durations of the tests were taken as the test scores.

Heaves were performed by hanging from a wooden beam with hands shoulder-width apart and the beam grasped in an underhand grip. From the start position (arms straight), the participants performed as many pull-ups as possible, by raising their chins above the bar and then returning to the start position. The score was recorded as the number of complete pull-ups achieved without rest.

Static arm endurance (SAE) was measured as subjects held a 4-kg ammunition box in their hands at waist height, close to the body, with elbows flexed at 90° and knees slightly bent. Subjects were required to hold the ammunition box in position for as long as possible (for a maximum of 4 minutes). The test duration was recorded as the test score.

Back extension strength (BES) was measured by using an isometric dynamometer (Lafayette Instruments, Loughborough, United Kingdom). A strap was placed around the subject's shoulders and connected to the dynamometer's strain gauge. While standing in an upright position, subjects were instructed to perform an isometric contraction by pushing back and exerting maximal force over a 3-second period, using their back extensors. The best result of two trials was recorded.

For measurement of static lift strength (SLS), subjects were instructed to stand on a base plate with their feet approximately shoulder-width apart, looking forward with straight arms and using an overhand grip to grasp a bar attached to a strain gauge via a 38-cm chain. After a practice at 50% of maximal effort, subjects completed two maximal isometric lifts by pulling up on the bar from the start position. The maximal force exerted during the two tests was recorded.

Dynamic lift strength (DLS) was assessed with a dynamometer (Lafayette Instruments). Subjects held the lifting bar with arms straight and an over-grasp grip, with feet flat, knees bent, and back straight with the head up. The aim of the test was to assess the maximal weight that could be lifted from the start position (dependent on subject height) to a height of 1.45 m. The start weight for women was 20 kg, which increased in 2.5-kg increments, and that for men was 30 kg, which increased in 5-kg increments (subjects could opt for 2.5-kg increments when they were near their maximal limit). The maximal weight lifted safely was recorded as the test score.

Injuries resulting in MD or RI referral were diagnosed by trained medical staff members and included all injuries sustained because of training (acute or overuse) but excluded all nontraining-related injuries. MD data were extracted from a database maintained by Occupational Medicine, Headquarters Army Training and Recruiting Agency. RI referral data were extracted from a database maintained by RIs at each of the ATRs, in which they recorded visits by injured recruits. The details from the databases were merged by using Microsoft Access 2002 for Windows (Microsoft, Redmond, Washington) and were cleaned by hand to create a data set for analyses of the incidence of and risk factors for MD and RI referral.

To take into account subject attrition during training, the injury rates were expressed as person-time injury incidence rates. These rates were calculated by dividing the number of recruits with one or more injuries (numerator) by the total number of days in training (denominator); to obtain values for people injured per 100 person-days, this number was multiplied by 100.[5] The total number of days in training included data for all recruits, regardless of whether they were injured, were discharged, or completed training.

Statistical Analyses

Survival analysis (Cox regression analysis) was used to examine differences in time to both RI referral and MD,[19] by using SPSS 11.0 for Windows (SPSS, Chicago, Illinois). Statistical significance was set a priori at $p < 0.05$. A "time to event" category was produced for both MD and RI referral. Censored cases represented recruits who completed training

TABLE II. Individual Risk factors for MD during CMS(R)

Quintile	Low/High	Minimum to Maximum	*n*	MD Rate (people injured per 100 person-days)	HR (95% CI)	*p* for Difference
Age (years)						
1	Youngest	16.16–17.69	2,679	0.025	1.00	
2		17.70–18.69	2,675	0.015	0.80 (0.51–1.23)	
3		18.70–20.27	2,692	0.023	1.17 (0.80–1.71)	
4		20.28–23.20	2,687	0.019	0.93 (0.62–1.39)	
5	Oldest	23.21–35.39	2,686	0.017	0.77 (0.52–1.16)	
Height (cm)						
1	Shortest	1.43–1.68	2,187	0.027	1.00	
2		1.69–1.72	1,864	0.015	0.69 (0.42–1.14)	
3		1.73–1.76	2,436	0.018	0.86 (0.56–1.33)	
4		1.77–1.81	2,228	0.016	0.93 (0.58–1.47)	
5	Tallest	1.82–2.03	2,602	0.019	1.05 (0.69–1.60)	
Mass (kg)						
1	Lightest	43–60	2,315	0.028	1.00	
2		61–66	2,816	0.014	0.67 (0.44–1.04)	
3		67–71	2,552	0.019	1.06 (0.71–1.60)	
4		72–77	2,391	0.017	0.94 (0.61–1.46)	
5	Heaviest	78–111	2,798	0.022	1.17 (0.79–1.71)	
BMI (kg/m^2)						
1	Lowest	17–20	2,479	0.021	1.00	
2		21	1,835	0.023	1.17 (0.75–1.28)	
3		22	2,057	0.018	1.12 (0.70–1.78)	
4		23–24	3,424	0.016	0.95 (0.62–1.44)	
5	Highest	25–28	3,624	0.022	1.20 (0.82–1.77)	
Body fat (%)						
1	Lowest	1–9	1,998	0.024	1.00	
2		10–12	2,889	0.014	0.72 (0.45–1.14)	
3		13–15	2,560	0.018	0.89 (0.56–1.39)	
4		16–20	3,256	0.015	0.65 (0.42–1.01)	
5	Highest	21–45	2,708	0.029	1.02 (0.69–1.51)	
2.4-km run time (seconds)						
1	Fastest	442–575	2,664	0.008	1.00	
2		576–605	2,661	0.010	1.07 (0.57–2.01)	
3		606–636	2,665	0.019	1.95 (1.11–3.43)	<0.05
4		637–684	2,719	0.023	2.12 (1.22–3.68)	<0.001
5	Slowest	685–840	2,688	0.036	2.34 (1.38–3.97)	<0.001
MSFT time (seconds)						
1	Shortest	165–442	1,420	0.035	1.00	
2		443–496	1,370	0.028	0.97 (0.62–1.51)	
3		497–548	1,570	0.021	0.98 (0.61–1.59)	
4		549–599	1,418	0.013	0.73 (0.40–1.32)	
5	Longest	600–1,296	1,520	0.008	0.47 (0.24–0.95)	<0.05
SAE (seconds)						
1	Shortest	16–167	1,442	0.028	1.00	
2		168–219	1,405	0.022	1.04 (0.62–1.73)	
3		220–239	303	0.042	2.05 (1.04–4.04)	<0.05
4		240	2,036	0.016	0.97 (0.58–1.61)	
5	Longest	240	2,036	0.018	0.98 (0.60–1.59)	
BES (kg)						
1	Lowest	9–78	2,492	0.030	1.00	
2		79–89	2,736	0.022	1.05 (0.73–1.51)	
3		90–98	2,600	0.017	0.89 (0.59–1.35)	
4		99–108	2,711	0.013	0.66 (0.42–1.02)	
5	Highest	109–170	2,876	0.016	0.90 (0.60–1.34)	
DLS (kg)						
1	Lowest	3–54	2,265	0.030	1.00	
2		55	2,002	0.021	1.00 (0.65–1.52)	
3		55	2,000	0.012	0.67 (0.40–1.11)	
4		55	4,259	0.016	0.80 (0.55–1.14)	
5	Highest	68–100	2,889	0.020	0.99 (0.67–1.45)	

(Continued)

TABLE II. (*Continued*)

Quintile	Low/High	Minimum to Maximum	*n*	MD Rate (people injured per 100 person-days)	HR (95% CI)	*p* for Difference
SLS (kg)						
1	Lowest	12–95	2,610	0.030	1.00	
2		96–109	2,638	0.016	0.74 (0.49–1.11)	
3		110–121	2,651	0.020	1.00 (0.68–1.47)	
4		122–136	2,761	0.018	0.89 (0.60–1.31)	
5	Highest	137–250	2,755	0.014	0.77 (0.50–1.18)	
Heaves (no.)						
1	Lowest	0–1	2,159	0.030	1.00	
2		2–4	2,530	0.019	1.01 (0.67–1.52)	
3		5–6	2,228	0.023	1.27 (0.85–1.89)	
4		7–9	3,134	0.020	0.97 (0.67–1.42)	
5	Highest	10–30	3,364	0.010	0.56 (0.35–0.87)	<0.05
Gender						
Male recruits			11,937	0.018	1.00	
Female recruits			1,480	0.033	1.06 (0.77–1.47)	
Ethnicity						
Caucasian			10,877	0.023	1.00	
Other			2,467	0.006	0.27 (0.16–0.46)	<0.001
ATR						
Lichfield			2,906	0.030	1.00	
Pirbright			7,265	0.017	0.49 (0.36–0.67)	<0.001
Winchester			3,246	0.016	0.40 (0.27–0.58)	<0.001
Recruit selection center						
Pirbright			4,882	0.016	1.00	
Lichfield			3,812	0.021	1.36 (0.97–1.90)	
Glencorse			4,480	0.022	1.28 (0.93–1.77)	
Unknown			243	0.020	1.39 (0.51–3.81)	

or left training early without injury, and events were recorded for recruits who sustained an injury requiring either RI treatment (first presentation for repeated visits) or MD. Mean differences in physical characteristics were compared by using independent *t* tests.

To examine associations between potential injury risk factors and RI referral or MD, continuous variables were converted into categorical variables by separating them into five groups (quintiles) with approximately equal numbers of recruits. Analyses of individual potential risk factors were then performed to compare the time to RI referral or MD between various categorical groups or quintiles (levels) for each potential risk factor (Table II). Each level of the potential risk factor was compared with a reference level (except for the reference level itself) to obtain the hazard ratio (HR), with 95% confidence interval (CI).[19] Significant individual risk factors for RI referral and MD were then used as covariates to identify independent risk factors, by using a backward elimination procedure that removed variables that did not contribute significantly ($p > 0.05$) to explaining the risk of RI referral or MD.[19]

RESULTS

The overall rate of MD was 0.02 people injured per 100 person-days ($n = 221$; training time, 1,120,803 days), and the overall rate of RI referral was 0.07 people injured per 100 person-days ($n = 752$; training time, 1,021,970 days). The rate of MD for women was 0.03 people injured per 100 person-days ($n = 48$; training time, 143,671 days), and that for men was 0.02 people injured per 100 person-days ($n = 173$; training time, 977,132 days; $p = 0.096$). The rate of RI referral for women was 0.17 people injured per 100 person-days ($n = 202$; training time, 116,712 days), and that for men was 0.06 people injured per 100 person-days ($n = 550$; training time, 905,258 days; $p = 0.041$). The anatomical site associated with the greatest rates of both MD and RI referral was the lower limbs (81% and 55% of all MDs and RI referrals, respectively). The other injury sites resulting in MD were the back and neck (13%), upper limbs (4%), and other anatomical sites (2%); those for RI referral were the back and neck (10%), upper limbs (5%), and other anatomical sites (30%).

Table II shows the independent risk factors for MD. The significant risk factors were 2.4-km run time, MSFT time, SAE time, number of heaves, ethnicity, and ATR attended ($p < 0.05$). Table III shows the independent risk factors for RI referral. The significant risk factors were age, height, body mass, BMI, 2.4-km run time, MSFT time, SAE time, BES, DLS, SLS, heaves, gender, ethnicity, ATR attended, and recruit selection center attended ($p < 0.05$).

Table IV shows the results of the multivariate Cox regression analysis for MD. The independent risk factors for MD during CMS(R) were 2.4-km run time, ethnicity, and ATR attended. The HR showed that recruits' risk of injury increased with greater 2.4-km run times; recruits in the slowest run quintile had 2.61 times the risk of MD, compared with

TABLE III. Individual Risk Factors for RI Referral during CMS(R)

Quintile	Low/High	Minimum to Maximum	*n*	RI Referral Rate (people injured per 100 person-days)	HR (95% CI)	*p* for Difference
Age (years)						
1	Youngest	16.16–17.69	2,679	0.088	1.00	
2		17.70–18.69	2,675	0.070	0.79 (0.63–0.99)	<0.05
3		18.70–20.27	2,692	0.077	0.87 (0.70–1.08)	
4		20.28–23.20	2,687	0.068	0.78 (0.63–0.98)	<0.05
5	Oldest	23.21–35.39	2,686	0.066	0.76 (0.61–0.95)	<0.05
Height (cm)						
1	Shortest	1.43–1.68	2,187	0.108	1.00	
2		1.69–1.72	1,864	0.063	0.58 (0.45–0.75)	<0.001
3		1.73–1.76	2,436	0.055	0.50 (0.39–0.64)	<0.001
4		1.77–1.81	2,228	0.058	0.53 (0.41–0.68)	<0.001
5	Tallest	1.82–2.03	2,602	0.057	0.52 (0.41–0.66)	<0.001
Body mass (kg)						
1	Lightest	43–60	2,315	0.114	1.00	
2		61–66	2,816	0.069	0.61 (0.49–0.75)	<0.001
3		67–71	2,552	0.059	0.51 (0.41–0.65)	<0.001
4		72–77	2,391	0.066	0.53 (0.46–0.72)	<0.001
5	Heaviest	78–111	2,798	0.063	0.52 (0.44–0.69)	<0.001
BMI (kg/m^2)						
1	Lowest	17–20	2,479	0.093	1.00	
2		21	1,835	0.074	0.79 (0.62–1.01)	
3		22	2,057	0.069	0.74 (0.58–0.95)	<0.05
4		23–24	3,424	0.063	0.69 (0.55–0.85)	<0.001
5	Highest	25–28	3,624	0.073	0.78 (0.64–0.96)	<0.05
Body fat (%)						
1	Lowest	1–9	1,998	0.071	1.00	
2		10–12	2,889	0.063	0.89 (0.69–1.15)	
3		13–15	2,560	0.065	0.92 (0.71–1.19)	
4		16–20	3,256	0.057	0.81 (0.63–1.04)	<0.05
5	Highest	21–45	2,708	0.115	1.65 (1.31–2.07)	<0.001
2.4-km run time (seconds)						
1	Fastest	442–575	2,664	0.025	1.00	
2		576–605	2,661	0.041	1.66 (1.18–2.34)	<0.001
3		606–636	2,665	0.061	2.44 (1.76–3.37)	<0.001
4		637–684	2,719	0.089	3.56 (2.61–4.85)	<0.001
5	Slowest	685–840	2,688	0.154	6.25 (4.66–8.39)	<0.001
MSFT time (seconds)						
1	Shortest	165–442	1,420	0.160	1.00	
2		443–496	1,370	0.097	0.63 (0.47–0.76)	<0.001
3		497–548	1,570	0.070	0.43 (0.33–0.55)	<0.001
4		549–599	1,418	0.053	0.33 (0.24–0.44)	<0.001
5	Longest	600–1,296	1,520	0.033	0.20 (0.14–0.29)	<0.001
SAE (seconds)						
1	Shortest	16–167	1,442	0.140	1.00	
2		168–219	1,405	0.071	0.50 (0.38–0.66)	<0.001
3		220–239	303	0.110	0.77 (0.50–1.17)	
4		240	2,036	0.060	0.42 (0.33–0.55)	<0.001
5	Longest	240	2,036	0.066	0.47 (0.37–0.60)	<0.001
BES (kg)						
1	Lowest	9–78	2,492	0.132	1.00	
2		79–89	2,736	0.077	0.57 (0.47–0.70)	<0.001
3		90–98	2,600	0.052	0.38 (0.31–0.48)	<0.001
4		99–108	2,711	0.062	0.46 (0.38–0.58)	<0.001
5	Highest	109–170	2,876	0.050	0.37 (0.30–0.47)	<0.001
DLS (kg)						
1	Lowest	3–54	2,265	0.137	1.00	
2		55	2,002	0.072	0.52 (0.42–0.66)	<0.001
3		55	2,000	0.050	0.37 (0.28–0.47)	<0.001
4		55	4,259	0.063	0.45 (0.38–0.55)	<0.001
5	Highest	68–100	2,889	0.057	0.41 (0.33–0.51)	<0.001

(*Continued*)

TABLE III. (*Continued*)

Quintile	Low/High	Minimum to Maximum	*n*	RI Referral Rate (people injured per 100 person-days)	HR (95% CI)	*p* for Difference
SLS (kg)						
1	Lowest	12–95	2,610	0.124	1.00	
2		96–109	2,638	0.077	0.61 (0.50–0.75)	<0.001
3		110–121	2,651	0.060	0.48 (0.39–0.60)	<0.001
4		122–136	2,761	0.061	0.48 (0.39–0.60)	<0.001
5	Highest	137–250	2,755	0.048	0.38 (0.30–0.48)	<0.001
Heaves (no.)						
1	Lowest	0–1	2,159	0.141	1.00	
2		2–4	2,530	0.081	0.56 (0.46–0.69)	<0.001
3		5–6	2,228	0.063	0.44 (0.35–0.55)	<0.001
4		7–9	3,134	0.061	0.43 (0.35–0.52)	<0.001
5	Highest	10–30	3,364	0.044	0.30 (0.24–0.38)	<0.001
			2,744	0.070	1.01 (0.80–1.29)	
Gender						
Male recruits			11,937	0.061	1.00	
Female recruits			1,480	0.173	2.91 (2.48–3.43)	<0.001
Ethnicity						
Caucasian			10,877	0.079	1.00	
Other			2,467	0.051	0.67 (0.55–0.82)	<0.001
ATR						
Lichfield			2,906	0.087	1.00	
Pirbright			7,265	0.060	0.71 (0.59–0.85)	<0.001
Winchester			3,246	0.091	1.07 (0.88–1.30)	
Recruit selection center						
Pirbright			4,882	0.065	1.00	
Lichfield			3,812	0.065	0.99 (0.82–1.19)	
Glencorse			4,480	0.089	1.33 (1.13–1.58)	<0.001
Unknown			243	0.109	1.64 (1.03–2.61)	<0.05

TABLE IV. Independent Model of Risk Factors for MD during CMS(R)

Quintile	Low/High	Minimum to Maximum	*n*	MD Rate (people injured per 100 person-days)	HR (95% CI)	*p* for Difference
2.4-km run time (seconds)						
1	Fastest	442–575	2,664	0.008	1.00	
2		576–605	2,661	0.010	1.02 (0.54–1.94)	
3		606–636	2,665	0.019	1.98 (1.13–3.48)	<0.05
4		637–684	2,719	0.023	2.12 (1.22–3.69)	<0.001
5	Slowest	685–840	2,688	0.036	2.61 (1.53–4.44)	<0.001
Ethnicity						
Caucasian			10,877	0.023	1.000	
Other			2,467	0.006	0.26 (0.15–0.46)	<0.001
ATR						
Lichfield			2,906	0.030	1.000	
Pirbright			7,265	0.017	0.57 (0.42–0.78)	<0.001
Winchester			3,246	0.016	0.37 (0.26–0.55)	<0.001

those in the fastest run quintile ($p < 0.001$). Recruits of all ethnicities other than Caucasian had 0.26 times the risk of MD, compared with Caucasian recruits ($p < 0.001$), and all recruits training at ATR Lichfield had a significantly greater risk of injury, compared with those training at ATR Pirbright and ATR Winchester ($p < 0.001$). There were no significant interaction effects between variables in the model.

Table V shows the results of the multivariate Cox regression analysis for RI referral. The independent risk factors for RI referral during CMS(R) were 2.4-km run time, BMI, ethnicity, and ATR attended. Recruits' risk of RI referral increased steadily with run times and was 6.64 times greater for the lowest quintile (the slowest runners), compared with the highest quintile (the fastest runners) ($p < 0.001$). Recruits with BMI values of >23 kg/m^2 had a significantly lower risk of RI referral, compared with the reference group (BMI of 17–20 kg/m^2; $p < 0.001$). Recruits of ethnicities other than Caucasian had 0.72 times the risk of injury, compared with their Caucasian counterparts ($p < 0.001$), and recruits training at ATR Pirbright had a significantly lower risk of RI

TABLE V. Independent Model of Risk Factors for RI Referral during CMS(R)

Quintile	Low/High	Minimum to Maximum	*n*	RI Referral Rate (people injured per 100 person-days)	HR (95% CI)	*p* for Difference
2.4-km run time (seconds)						
1	Fastest	442–575	2,664	0.025	1.00	
2		576–605	2,661	0.041	1.68 (1.19–2.38)	<0.001
3		606–636	2,665	0.061	2.56 (1.85–3.55)	<0.001
4		637–684	2,719	0.089	3.76 (2.75–5.13)	<0.001
5	Slowest	685–840	2,688	0.154	6.64 (4.92–8.97)	<0.001
BMI (kg/m^2)						
1	Lowest	17–20	2,479	0.093	1.00	
2		21	1,835	0.074	0.83 (0.65–1.07)	
3		22	2,057	0.069	0.80 (0.59–0.96)	<0.05
4		23–24	3,424	0.063	0.66 (0.52–0.81)	<0.001
5	Highest	25–28	3,624	0.073	0.67 (0.54–0.82)	<0.001
Ethnicity						
Caucasian			10,877	0.079	1.00	
Other			2,467	0.051	0.72 (0.59–0.89)	<0.001
ATR						
Lichfield			2,906	0.087	1.00	
Pirbright			7,265	0.060	0.71 (0.59–0.86)	<0.001
Winchester			3,246	0.091	0.84 (0.69–1.03)	

referral than did those training at ATR Lichfield and ATR Winchester ($p < 0.001$). There were no significant interaction effects between variables in the model.

DISCUSSION

This study assessed the incidence of and risk factors for training injuries for recruits undertaking CMS(R). As expected, the incidence of RI referral was greater than that of MD, when expressed as person-time injury incidence rates. This is not surprising, because RI referral accounts for all injuries reported to RIs, including less-severe injuries and those eventually leading to MD.

Female recruits had a greater incidence of RI referral, compared with their male counterparts ($p = 0.041$) (Table III), and there was a trend for a greater incidence of MD in female recruits ($p = 0.096$), which is in agreement with previous findings in other military populations.[2,5,11,16] However, the multivariate models of independent risk factors (Tables IV and V) do not contain gender, which suggests that gender alone is not a significant risk factor for RI referral or MD. The underlying factor appears to be the slower 2.4-km run time for female recruits, in comparison with men (Table I), with run time being an independent risk factor in the multivariate models for both MD and RI referral

The multivariate models for both MD and RI referral contain 2.4-km run time; maximal-effort run times are a surrogate measure of aerobic fitness, because they are highly correlated with maximal oxygen consumption ($\dot{V}O_2max$).[20] Therefore, the models in Tables IV and V show that recruits with lower aerobic fitness have greater risks of MD and RI referral. These results agree with findings in both U.S.[4,5] and Australian[10] military populations. The explanation for the importance of aerobic fitness in determining training injuries is likely to be that individuals with lower aerobic fitness experience greater physical strain for any given task.[21] This is particularly significant during military training, because most tasks are group-based, with recruits of varying aerobic fitness levels working at the same absolute intensity. Knapik et al.[4] suggested that additional cardiovascular strain could result in injury through a wide range of mechanisms, because individuals with lower fitness levels perceive tasks to be more difficult, fatigue more quickly, and change their gait, resulting in more biomechanical stress in certain anatomical locations.

Ethnicity is a significant risk factor in the independent models for MD and RI referral. The models show that Caucasian recruits had a greater incidence and risk of injury than did recruits of ethnic minorities (primarily African Caribbean), and these results were independent of gender and aerobic fitness. The results may be attributable to the ethnic minority group containing a large proportion of African Caribbean individuals, who have greater bone and muscle mass and less fat mass than Caucasian individuals,[22,23] which may protect them from sustaining the type of musculoskeletal injuries that are a common cause of RI referral and MD. This hypothesis is speculative because, during analysis, all ethnic minority groups had to be combined, because of the relatively small numbers in some of the subgroups. The only other study to report a difference in injury rates and ethnic origin supports these findings; it was conducted in women undertaking U.S. Army basic training and showed that African American recruits were less likely to sustain fractures than were Caucasian recruits and recruits of other races.[6]

BMI is a significant risk factor in the independent model for RI referral. No other anthropometric measures are significant in the MD independent model, which concurs with findings for U.S. Army basic combat training.[5] We hypothesize that the RI referral independent variable model contains BMI because recruits with a higher BMI are able to cope better with the load carriage tasks,[24] which form a significant component of British Army initial training and are known to be a common cause of injury.[25] We suggest this is because larger recruits use less of their aerobic capacity to carry any given load, compared with smaller recruits,[24] which reduces the aerobic demands and physical strain on them during the most strenuous periods of training (e.g., marching with or carrying loads), thereby reducing their risk of injury.

The independent model for MD shows there to be significantly higher incidence of MD at ATR Lichfield, compared with ATR Pirbright and ATR Winchester, independent of any other risk factors. In contrast, the independent model for RI referral shows there to be significantly lower incidence and risk of RI referral at ATR Pirbright, compared with ATR Lichfield and ATR Winchester, independent of any other risk factors. Billings[2] suggested that recruits' willingness to report an injury to a clinic is also a reflection of how the training staff views these visits, as well as the occurrence and severity of the injury. The willingness of recruits and staff members to report injuries may also explain the differences in MD and RI referral rates between ATRs. This could not be determined in the current investigation, however, and requires further research.

None of the strength tests (SAE, DLS, SLS, BES, and heaves) was significant in the independent multivariate models. Muscular endurance scores from push-ups and sit-ups have been correlated with injury in trainees undertaking U.S. Army basic combat training.[4,5] Although push-ups and sit-ups are conducted as tests at various stages of CMS(R), the data are not recorded electronically and therefore were not available for statistical analysis.

The majority of MDs and RI referrals were for the lower limbs, which is similar to results seen during U.S. Army military training.[5] This is likely to be attributable to the nature of military training, which requires extensive use of the lower limbs while performing ambulatory work during the majority of training activities, resulting in overuse injuries.

There are two main limitations of this study. First, it examined only high-level injuries that resulted in discharge or treatment, because minor injuries are not recorded in British Army databases. Second, we were unable to obtain data on recruits' smoking habits and activity levels before the start of training, both of which have been shown to be highly significant risk factors for the development of training injuries during other military training courses.[1,5,6,13,17,18] To overcome these shortcomings, an injury monitoring program to collect detailed data on more minor injuries sustained during training and other potential risk factors is required.

The British Army uses the physical tests described in this article as part of a selection procedure, which potential recruits must pass before beginning training. Despite this screening procedure, certain recruits are at greater risk of injury than others, as this study shows. The risk of MD and RI referral during CMS(R) could be reduced through changes in the training program. Improving the aerobic fitness of both male and female recruits before U.S. Army basic combat training was shown to significantly reduce the risk of injury, compared with recruits of equal physical fitness who had not undertaken the additional physical training program ($p < 0.01$).[26] On the basis of the findings of the current study, a 3-week, progressive, aerobic training program for recruits with low aerobic fitness before initial infantry training (24-week course) has been implemented by the British Army, with the aim of reducing the incidence of injury. The effect of this intervention has not yet been assessed.

The results of this study show that, during CMS(R), 2.4-km run time (aerobic fitness), ethnicity, and ATR attended are all risk factors for MD and RI referral; in addition, BMI is a risk factor for RI referral. These risk factors are independent of gender. These findings suggest that injury risk during CMS(R) may be modified through adjustments to selection (by modifying entry aerobic fitness standards) and training (by reducing the stress and strain on recruits). It remains to be established why injury rates at some ATRs are higher than others, although differences in employment groups, training ethics, and attitudes toward injury reporting and discharge may play a role.

REFERENCES

1. Altarac M, Gardner JW, Popovich RM, Potter R, Knapik JJ, Jones BH: Cigarette smoking and exercise-related injuries among young men and women. Am J Prev Med 2000; 18(Suppl 3): 96–102.
2. Billings CE: Epidemiology of injuries and illnesses during the United States Air Force Academy 2002 basic cadet training program: documenting the need for prevention. Milit Med 2004; 169: 664–70.
3. Henderson NE, Knapik JJ, Shaffer SW, McKenzie TH, Schneider GM: Injuries and injury risk factors among men and women in U.S. Army combat medic advanced individual training. Milit Med 2000; 165: 647–52.
4. Knapik JJ, Canham-Chervak M, Hauret K, Hoedebecke E, Laurin MJ, Cuthie J: Discharges during U.S. Army basic training: injury rates and risk factors. Milit Med 2001; 166: 641–7.
5. Knapik JJ, Sharp MA, Canham-Chervak M, Hauret K, Patton JF, Jones BH: Risk factors for training-related injuries among men and women in basic combat training. Med Sci Sports Exerc 2001; 33: 946–54.
6. Lappe JM, Stegman MR, Recker RR: The impact of lifestyle factors on stress fractures in female Army recruits. Osteoporos Int 2001; 12: 35–42.
7. Jones BH, Cowan DN, Tomlinson JP, Robinson JR, Polly DW, Frykman PN: Epidemiology of injuries associated with physical training among young men in the Army. Med Sci Sports Exerc 1993; 25: 197–203.
8. Knapik JJ, Canham-Chervak M, Hauret K, et al: Seasonal variations in injury rates during U.S. Army basic combat training. Ann Occup Hyg 2002; 46: 15–23.
9. Rauh MJ, Macera CA, Trone DW, Shaffer RA, Brodine SK: Epidemiology of stress fracture and lower-extremity overuse injury in female recruits. Med Sci Sports Exerc 2006; 38: 1571–7.
10. Pope RP, Herbert R, Kirwan JD, Graham BJ: Predicting attrition in basic military training. Milit Med 1999; 164: 710–4.
11. Rudzki SJ, Cunningham MJ: The effect of a modified physical training program in reducing injury and medical discharge rates in Australian Army recruits. Milit Med 1999; 164: 648–52.
12. Heir T, Eide G: Age, body composition, aerobic fitness and health condition as risk factors for musculoskeletal injuries in conscripts. Scand J Med Sci Sports 1996; 6: 222–7.

13. Heir T, Eide G: Injury proneness in infantry conscripts undergoing a physical training programme: smokeless tobacco use, higher age, and low levels of physical fitness are risk factors. Scand J Med Sci Sports 1997; 7: 304–11.
14. Harwood GE, Rayson MP, Nevill AM: Fitness, performance, and risk of injury in British Army officer cadets. Milit Med 1999; 164: 428–34.
15. Gemmell IM: Injuries among female Army recruits: a conflict of legislation. J R Soc Med 2002; 95: 23–7.
16. Allsopp AJ, Scarpello EG, Andrews S, Pethybridge RJ: Survival of the fittest? The scientific basis for the Royal Navy pre-joining fitness test. J R Nav Med Serv 2003; 89: 11–8.
17. Jones BH, Knapik JJ: Physical training and exercise-related injuries: surveillance, research and injury prevention in military populations. Sports Med 1999; 27: 111–25.
18. Kaufman KR, Brodine S, Shaffer R: Military training-related injuries: surveillance, research, and prevention. Am J Prev Med 2000; 18(Suppl 3): 54–63.
19. Mahesh KB, Parmar DM: Survival Analysis: A Practical Approach, Vol 1. Chichester, U.K., Wiley, 1995.
20. Knapik J: The Army Physical Fitness Test (APFT): a review of the literature. Milit Med 1989; 154: 326–9.
21. Astrand PO: Human physical fitness with special reference to sex and age. Physiol Rev 1956; 36: 307–35.
22. Gasperino J: Ethnic differences in body composition and their relation to health and disease in women. Ethn Health 1996; 1: 337–47.
23. Barondess DA, Nelson DA, Schlaen SE: Whole body bone, fat, and lean mass in black and white men. J Bone Miner Res 1997; 12: 967–71.
24. Bilzon JL, Allsopp AJ, Tipton MJ: Assessment of physical fitness for occupations encompassing load-carriage tasks. Occup Med (Lond) 2001; 51: 357–61.
25. Knapik JJ, Reynolds KL, Harman E: Soldier load carriage: historical, physiological, biomechanical, and medical aspects. Milit Med 2004; 169: 45–56.
26. Knapik JJ, Darakjy S, Hauret KG, et al: Increasing the physical fitness of low-fit recruits before basic combat training: an evaluation of fitness, injuries, and training outcomes. Milit Med 2006; 171: 45–54.
