Tharion, WJ., Karis, AJ., Potter, AW., and Hoyt, RW. Seasonal differences in performance of the Ranger School qualifying road march. J Sport Human Perf 2014;2(2):1-14.
DOI: 10.12922/jshp.0047.2014

JSHP
JOURNAL OF SPORT AND HUMAN PERFORMANCE

ORIGINAL RESEARCH OPEN ACCESS

SEASONAL DIFFERENCES IN PERFORMANCE OF THE RANGER SCHOOL QUALIFYING ROAD MARCH

Tharion, WJ., Karis, AJ., Potter, AW., and Hoyt, RW.

U.S. Army Research Institute of Environmental Medicine, Natick, MA 01760

ABSTRACT

The U.S. Army Ranger School conducts a 61-day training course several times per year to train soldiers in combat skills. One of the qualifying tests is a timed road march. Warmer weather imposes greater thermal strain on the body which in turn compromises endurance performance. This presents a problem in assessing performance across classes and making the road march fair for all students since some will be doing this event in cold or cool conditions (winter, spring and fall classes), whereas others will be doing it in hot conditions (summer classes). **Purpose:** To assess the influence of seasonal differences on road march performance. **Methods:** Road march times and per-mile pace were obtained from three Ranger School course classes (total: n = 66; [spring: n = 24, summer: n = 23, and winter: n = 19]). Road marches were ~19.3 km for the spring and winter marches and ~12.9 km for the summer march. Heart rates (HRs) and core body temperatures (Tcores) were obtained throughout each march. Weather conditions were spring: air temperatures (Ta): 17.2 to 21.0 °C; relative humidity (% RH): 53 to 75%; summer: Ta: 24.4 to 25.0 °C, RH: 82 to 89%; and winter: Ta: −4.4 to −6.2 °C, RH: 51 to 60 %. **Results:** The per-mile pace of the spring class (15:35 ± 0:45) [min: sec] was significantly slower ($p < 0.05$) than the summer class (14:57 ± 0:58) or the winter class (14:46 ±1:19). A significant main effect of Tcore was observed by class; with the summer class students exhibiting significantly ($p < 0.05$) higher Tcore than spring or winter students (spring: 37.7 ± 0.4 °C; summer: 38.2 ± 0.5 °C; winter: 37.7 ± 0.5 °C). **Conclusions:** The Ranger School's goal of having equally challenging road marches across classes was not met. Even with the shorter course, the thermal strain was greatest for summer students, and a greater number of spring class students passed the standard with less than maximum effort.

Keywords: Army Ranger School, road march, backpack, military, performance, physiology

INTRODUCTION

The U.S. Army Ranger Training Brigade (RTB) is located at Ft. Benning, Georgia and operates the Ranger School to train soldiers in small unit combat skills. To qualify as a U.S. Army Ranger, a soldier must pass the Ranger School's physically- and mentally-challenging 61-day course that tests small unit dismounted combat skills. The

Ranger School course takes place at Camp Rodgers and Camp Darby at Ft. Benning, in the mountains of northern Georgia at Camp Merrill in Dahlonega, and in the swamps of Florida at Camp Rudder at Eglin Air Force Base. Ranger School starts at Ft. Benning with a physically demanding week called the Ranger Assessment Phase (RAP). The RAP activities are designed to identify individuals capable of completing Ranger School and drop those who cannot perform to standards. The RAP week involves intense training with high physical demands with energy expenditures in excess of 5000 kcal/day (21 MJ/day) [9]. Students are required to complete one demanding activity after another with little time for recovery. These energy demands are higher than many other combat field training exercises [12].

Students need to successfully complete all elements of the RAP to remain in Ranger School. For example, an ~8 km run (5 miles) held on the first day of RAP week, must be performed at a five min per-km (eight min per-mile) pace while running in formation. In contrast, there is a self-paced road march, typically ~19.3 km (12 miles), held on the 4th day of RAP week. The course instructors adjust elements of the road march, e.g., pace, load, distance, time of day, and clothing worn, in an attempt to impose consistent thermal strain upon the students across winter, spring, summer, and fall classes. However, there are no data documenting the outcome of these modifications to this event.

The Ranger School's course road march is typically performed in the standard Army Combat Uniform (ACU) while carrying a rifle and a 15.8 kg (35 pound) backpack, and completed in under 3:15 (h: min) for the 19.3 km course. As in a typical running road race, this road march begins with a mass start. Students can choose any racing strategy (run/walk) that will allow them to complete the march under the required time standard. For motivation to excel, top performers, such as the winner of the event receive Ranger School merit points. From a practical standpoint, to finish the march within the required time, students need to complete the road march without rest breaks and at a pace faster than a fast walk, i.e., they need to run at least some of the time. If they fail to complete the march in the required time, they are removed from the Ranger School course. The road march is one of a number of tasks during RAP week that seeks to identify and remove students who do not have the physical strength, stamina, and mental tenacity needed for the subsequent weeks of Ranger School training.

The performance of Ranger students during the Ranger School's timed road march performance has not been studied. However, Knapik et al. [7, 8] conducted two studies where performance capabilities were assessed through examining maximal efforts with various loads during timed road marches. For the first study, terrain was generally flat with rolling hills in the middle of the march [8]. The second study's course was flat terrain, split between paved (12 km) and dirt roads (8 km) [7]. In the first study, infantry soldiers carried a total load of 46 kg while completing a timed 20 km road march. The mean time to complete this road march was 5:14 $\pm$ 1:10 (h: min) [8]. In the second study, Special Operations Forces soldiers completed a 20 km road march with a total carried load of 34 kg. Mean completion time was 2:51 $\pm$ 0:31 (h: min) [7]. In another study, two groups of British soldiers completed a 29 km road march while carrying a 20 kg backpack in 6:00 $\pm$ 0:37 and 5:40 $\pm$ 0:30 (h: min) respectively [11]. These British soldiers' marches were completed over a course with eleven hills ranging in elevation from 160 to 573 m above sea level with a total ascent of

1933 m and total descent 1650 m. Weather conditions (ambient temperatures, relative humidity, solar radiation, and wind speed) were not documented in any of these studies [7, 8, 11].

Hot weather can adversely impact the physical performance and well-being of military personnel [2]. With regard to endurance performance, it has been demonstrated that if metabolic heat production exceeds the ability to cool, core body temperature (Tcore) will rise, ultimately compromising endurance performance [4] to the point of increasing the risk of heat illness itself [10]. Research with experienced elite marathon runners has shown that increases in ambient air temperatures above 10 °C result in progressively slower race finish times [3]. More importantly, slower runners are affected to a greater extent than faster runners [3]. Runners capable of running faster than 2 hours and 10 min slowed approximately 3% when wet bulb globe temperature (WBGT) increased to 25 °C, while those male runners capable of running a 3 hour marathon showed a 12% decrement in race time. While there are differences between military road marches and marathons, most notably the clothing and equipment load worn, march and run times are similar for the Ranger School course road march and the marathon (2.2 to 3.5 h). Therefore, the research with marathon runners may provide some insight into the performance decrements that might be expected with the students' timed-for-performance road march during the Ranger School course.

The purpose of this study was to compare the performance and physiological responses of participants in the Ranger School course's spring, summer, and winter classes qualifying road marches. It was hypothesized that performance and physiological measures across classes would be similar after the Ranger School leadership made their adjustments to the road march for the added heat stress during the summer. A practical goal of this research is to provide the RTB leadership with evidence that shows whether their adjustments to the timed road march resulted in similar thermal strain experienced across classes and how that related to road march performance.

METHODS

Volunteers

Students (n = 66) participating in three Ranger School course classes (spring class: n = 24, summer class: n = 23, and winter class: n = 19) at Ft. Benning, GA volunteered for this study. All volunteers were male soldiers, as female soldiers at the time of the study, did not participate in Ranger School. Volunteers were briefed on the purpose, risks, and benefits of the study and gave their written informed consent prior to the start of the study. This study was approved by the Scientific Review and Human Use Review Committees at the U.S. Army Research Institute of Environmental Medicine.

Road March

The qualifying Ranger School course road march was conducted under the direction of the RTB leadership, and followed their normal training procedures. Distances for the marches varied for safety reasons. The spring and winter road marches were on the same distance ~19.3 km (12 miles) course and the summer road march was on a similar ~12.9 km (8 miles) course. Road marches were held on courses with rolling hills, primarily paved roads, with some limited (less than 2 km) of hard-packed dirt roads. The start and finish of all marches were at the same location. The required pace was 16:25 min per-mile or faster for all marches to meet the Ranger School standard. Therefore, a qualifying time of 3:15 (h: min) or faster was

required for the spring and winter marches and 2:11 for the summer march. These completion standards had to be met for a student to remain in the course.

Research Procedures

Each test volunteer was fitted with the Hidalgo Equivital™ EQ-01 physiological status monitoring (PSM) system (Hidalgo, Ltd., Swavesey, Cambridge, UK) the day prior to the road march. This PSM system measures heart rate (HR), respiration rate, body motion, body position, and skin temperature (Tsk). The system consists of a belt and sensor electronics module (SEM). The SEM serves as a receiver for Tcore transmitted from an ingestible thermometer pill. The thermometer pills (Mini Mitter, Inc., Bend, OR) were administered approximately 18 hours prior the start of the road march in order to minimize the effect of ingested water on Tcore [5, 15].

Volunteers had their age and two-mile run times from their most recent Army Physical Fitness Test (APFT) recorded. The APFT is a fitness test consisting of push-ups, sit-ups, and a two-mile run that soldiers must do every six months to certain age and sex standards to remain in good standing in the U.S. Army. Self-reported two-mile run times from the latest APFT test have been shown to correlate with actual run times (r = 0.85), allowing self-reported times to be used as a valid substitute for actual run times [6]. Body weight, height, and body circumferences were measured. Percent body fat was estimated from body circumferences following procedures outlined in Army Regulation 600-9 [1]. Body circumferences were measured at the neck just below the larynx and the abdomen coinciding with the midpoint of the navel. Each measurement was repeated three times by the same trained individual. The median measurements along with height were used in calculating percent body fat using the tables in Army Regulation 600-9 [1].

Within 30 min prior to the start of the road march, total weight (i.e., body weight and weight of all the equipment) was obtained by having each volunteer step on a calibrated electronic scale (Model 6800, Cardinal Detecto; Webb City, MO). The weight of water carried was obtained by weighing all canteens (hard and soft) with and without water. Canteens were placed within a box centered on the scale after the scale had been tared with only the box placed on it. Non-water equipment and clothing weight carried and worn was obtained by subtracting out body weight and the weight of water carried. Volunteers donned their PSM systems and wrist-worn global position systems (GPS) (Fortrex 101; Garmin, Olathe, KS) before the weight of all clothing and equipment they were going to wear was measured. The GPS devices were covered in electrical tape so that volunteers could not use them to aid their performance during the road march. The GPS devices were used to track the time and distance covered on the course and to determine the pace of the march.

Environmental Conditions

The spring and winter road marches began at 0400, while the summer road march began at 0300. Local meteorological data were obtained from Weather Underground [14]. Road march conditions were: spring air temperatures (Ta): 17.2 to 21.0 °C; percent relative humidity (% RH): 53 to 75%, wind speeds (WS): 0 to 2.1 m/s; summer, Ta: 24.4 to 25.0 °C; % RH: 82 to 89%, and WS: 2.1 to 3.1 m/s; and winter Ta: -4.4 to -6.2 °C; %RH: 51 to 60 %; and WS: 0 to 2.1 m/s. Solar radiation was not considered as all marches were completed prior to sunrise.

Data Analyses

Data are reported as means ± standard deviations. Ranges are also used to describe variability of the data. Pearson correlation coefficients were calculated for road march performance and body weight, percent body fat, and the APFT two-mile run times. Repeated measures analyses of variance (ANOVAs) were used to determine differences among time periods, the within factor (i.e., pre-, mid- and end-of-the road march times), and a between factor (between spring vs. summer vs. winter) was used to determine differences between classes. Univariate ANOVAs were used to determine difference between classes in various demographic characteristics.

For HR and Tcore, the median value for the five minutes just prior to starting the road march was used for the pre-road march baseline. For the mid-march measure, the median value for the five minutes (mid-point and two min on each side of the mid-point) was used. For the end-of-the road march, the median value of five minutes just prior to ending the road race was used. Using the median value for these five minute time blocks controlled for spurious values such as an individual positive or negative spike in HR.

It was hypothesized that some individuals tried to just meet the qualifying standard, while others may have tried to do the best they could. It was also hypothesized that the perceived and/or real difficulty of the summer march due to the thermal stress imposed would result in significantly more students just trying to pass the road march in the summer and conserve energy for subsequent training. Alternatively, it was thought in the thermally less challenging winter class, more students would try and do the best they could. Therefore, in addition to looking at passing rates between the classes, the proportions of students that were ≥ 5 percent under the standard or 9:45 (min: sec) for the winter and spring classes (3:15 [h: min] qualification standard) and ≥ 5 percent under the standard or 6:33 (min: sec) for the summer class (2:11 [h: min] qualification standard) were examined. Chi-square analyses were performed to examine if there were significant proportional differences between classes in performance, based on the actual standards and the proportions that were ≥ 5 percent under the Ranger School's passing standards.

RESULTS

Participants (n = 66) were 25.1 ± 4.6 yrs of age, 176.5 ± 6.1 cm tall, weighed 79.5 ± 8.8 kg, and had 15.2 ± 3.8% body fat. They self-reported a recent APFT two-mile run of 12:55 ± 0:54 (min:sec). No statistically significant differences existed between classes for these measures. There were no or very weak correlations between road march finish time and height (r = −0.05), body weight (r = 0.19), self-reported two-mile run time (r = 0.22), or percent body fat (r = 0.26).

Road March Performance

A significant main effect of road march pace (min per-mile) existed among classes. The pace of the spring class (15:35 ± 0:45) [min: sec] was significantly slower (p = 0.05) than the summer class (14:57 ± 0:58) or the winter class (14:46 ±1:19). No difference existed in average pace between summer and winter classes. Table 1 shows the finish times by class and the percent of students that met the standard and passed. The Ranger student/test volunteer with the fastest 12.9 km time during the summer class group of volunteers in this study (1:38:09) [hr: min: sec] also had the fastest time of more than 200 students participating in this summer class. The top times of 2:29:30 and 2:54:16

for the winter and spring classes reported for this study respectively, for the 19.3 km road march were among the 10 best times for each of those classes.

Table 1 also shows the proportion of students that were ≥ 5 percent faster than the road march qualification standard for each class. The chi-square analysis showed no differences in the percent of students passing the road march by class ($p = 0.20$). However, there was a significant difference ($p = 0.02$) by class in the percent of students completing the road march by ≥ 5% faster than the qualification standards. As may be seen from the table, only seven of 24 students (29%) from the spring class performed better than the standard by ≥ 5 percent. For the summer and winter classes, 15 of 22 students (68%) and 11 of 19 students (58%), respectively, exceeded the standard by ≥ 5 percent, i.e., a 15:36 pace or better.

An examination of pace by mile is shown in Table 2. The average per-mile pace required to pass the road march was 16:02 (min: sec per-mile). During the summer class, there was one individual that did not pass the qualifying standard. He withdrew from the road march after three miles.

Table 1. Road march finish times by class and percent passing the Ranger School standard.

Class (Distance)	*n*	Mean Time (hr:min:sec)	Fastest	Slowest	% Meeting the Standard*	% 5 Percent Above the Passing Standard**
Spring (19.3 km)	24	3:07:45 ± 6:06	2:54:16	3:19:49	92%	29%
Summer (12.9 km)	22	2:00:18 ± 7:43	1:38:09	2:10:15	96%	68%
Winter (19.3 km)	19	3:03:07 ± 12:06	2:29:30	3:20:00	79%	58%

Values listed are Means ± Standard Deviations

*The passing standard was 3:15:00 for the Spring and Winter Classes and 2:11:00 for the Summer Class.

**Those completing the road march ≥ 5 percent under the standard for the Spring and Winter Class courses completed the road march in 3:05:15 or faster and for the Summer Class course 2:04:27 or faster.

Table 2. Road march pace per mile for students by class for those who passed versus those that did not; and for those who completed the march 5 percent faster than the qualifying standard versus those that were not faster than 5 percent of the qualifying standard.

Class & Performance	*n*	Mile 1	Mile 2	Mile 3	Mile 4	Mile 5	Mile 6	Mile 7	Mile 8	Mile 9	Mile 10	Mile 11	Mile 12
Spring Pass	22	14:12 ± 1:04	14:33 ± 0:38	14:20 ± 0:46	14:38 ± 0:57	16:00 ± 0:43	14:49 ± 1:04	15:56 ± 1:54	16:48 ± 0:49	17:37 ± 0:34	16:10 ± 1:06	14:57 ± 1:23	16:23 ± 1:34
Spring Fail	2	14:52 ± 0:52	15:50 ± 0:14	15:57 ± 0:04	15:47 ± 1:22	18:07 ± 0:32	16:34 ± 0:36	17:16 ± 0:19	17:15 ± 1:03	17:52 ± 1:14	18:30 ± 0:21	16:22 ± 0:53	13:30 ± 3:20
Summer Pass	21	13:32 ± 1:30	14:16 ± 1:00	14:18 ± 0:57	15:39 ± 1:10	16:43 ± 1:09	15:59 ± 1:04	14:53 ± 1:32	14:58 ± 1:19				
Summer Fail	1	14:30	15:30	15:00									
Winter Pass	19	13:37 ± 0:52	14:00 ± 0:44	13:48 ± 0:47	14:12 ± 1:15	15:10 ± 0:38	13:53 ± 1:47	14:41 ± 0:56	15:57 ± 0:49	15:55 ± 0:59	15:40 ± 1:32	14:12 ± 1:49	15:32 ± 1:51
Winter Fail	24	14:59 ± 0:30	14:54 ± 0:32	15:28 ± 0:43	15:43 ± 0:33	16:38 ± 0:48	15:40 ± 0:56	17:12 ± 1:39	17:13 ± 0:54	17:37 ± 1:06	16:21 ± 0:34	15:45 ± 0:43	16:33 ± 0:55
Spring ≥ 5% or Faster	7	13:45 ± 0:56	14:01 ± 0:43	13:57 ± 0:55	14:15 ± 1:13	15:17 ± 0:45	13:58 ± 1:43	14:42 ± 0:54	16:00 ± 0:49	15:57 ± 0:57	15:45 ± 1:30	14:19 ± 1:47	15:34 ± 1:46
Spring < 5% Faster	17	14:56 ± 0:32	15:00 ± 0:30	15:25 ± 0:47	14:52 ± 0:52	15:52 ± 0:28	15:48 ± 0:57	17:35 ± 1:27	17:18 ± 0:58	17:50 ± 1:03	16:17 ± 0:36	15:45 ± 0:47	16:39 ± 0:58
Summer ≥ 5% or Faster	15	12:59 ± 1:18	13:49 ± 0:46	13:57 ± 0:54	15:17 ± 1:11	16:21 ± 1:06	15:33 ± 0:52	14:24 ± 1:29	14:57 ± 1:31				
Summer < 5% Faster	7	15:02 ± 0:54	15:27 ± 0:32	15:10 ± 0:15	16:35 ± 0:27	17:40 ± 0:38	17:05 ± 0:41	16:13 ± 0:24	15:00 ± 0:41				
Winter ≥ 5% Faster	11	13:35 ± 1:12	14:01 ± 0:38	13:34 ± 0:26	13:50 ± 0:35	15:32 ± 0:38	14:09 ± 0:42	14:55 ± 0:45	16:10 ± 0:37	17:24 ± 0:38	15:47 ± 0:49	14:40 ± 1:01	16:12 ± 1:12
Winter < 5% Faster	8	14:35 ± 0:52	14:57 ± 0:30	14:52 ± 0:40	15:11 ± 0:53	16:26 ± 0:56	15:20 ± 1:04	16:29 ± 1:53	17:15 ± 0:45	17:40 ± 0:36	16:46 ± 1:17	15:23 ± 1:28	16:03 ± 2:03

Values are Means ± Standard Deviations

Students during the spring class carried significantly more total weight (body weight, clothing and equipment, rifle, and water carried) and non-water weight (all weight except for the weight of the water) than the students in the summer or winter classes ($p = 0.05$) (Table 3). Students during the winter class carried significantly less water during their march ($p = 0.05$) than the students in the other two classes.

Physiological Assessments

There were significant interaction effects among classes (spring, summer, and winter) and over time during the road march (pre-march, mid-march, and end-of-the march) for HR ($p = 0.04$) (Figure 1). Heart rate increased most dramatically (~35 bpm increase) in the summer class from pre-march to mid-march, then plateaued to the end-of-march. Students in the summer class began with the lowest HR pre-march, but had the highest HR at the end-of-the march indicating heat strain. The winter class students' HRs showed the same pattern as the summer class, although their HRs were higher prior to the start of the march and just slightly (non-significantly) lower at the end-of-the march than those in the summer class. Heart rates for the spring class' students were higher than those for the summer class and comparable to the winter class at the start of the road march. After the beginning of the march, HRs were consistently lower for the spring class than the summer or winter classes. There was a main effect of time during the road march (pre-march: 112 $\pm$ 20 bpm, mid-march: 134 $\pm$ 19 bpm, end-of-the march: 138 $\pm$ 21 bpm; $p < 0.001$). Post hoc testing showed that pre-march HRs were significantly lower than mid-march or end-of-march HRs. There was no significant difference between mid-march and end-of-march HRs.

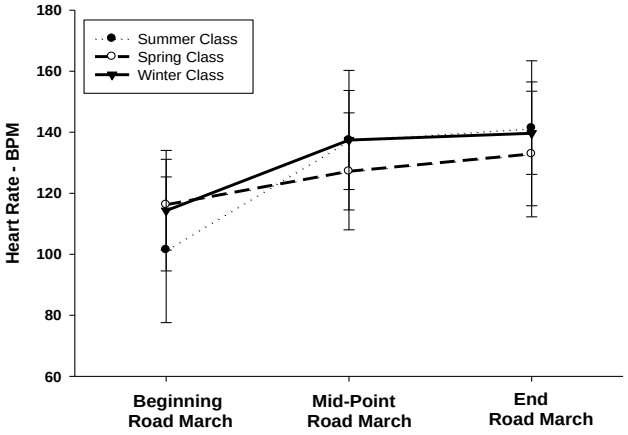
Table 3. Total weight, water weight and non-water weight carried during the road march for all three classes.

Class	*n*	Total Weight Carried (kg)	Water Weight Carried (kg)	Non-Water Weight Carried (kg)
Spring 12-Mile	24	33.9 ± 1.9^{b}	8.0 ± 0.8^{b}	25.9 ± 1.6^{b}
Summer 8-Mile	22	31.6 ± 1.2^{a}	7.8 ± 0.8^{b}	23.8 ± 1.0^{a}
Winter 12-Mile	19	30.6 ± 1.6^{a}	6.5 ± 2.1^{a}	24.1 ± 1.2^{a}

Values are Means $\pm$ Standard Deviations

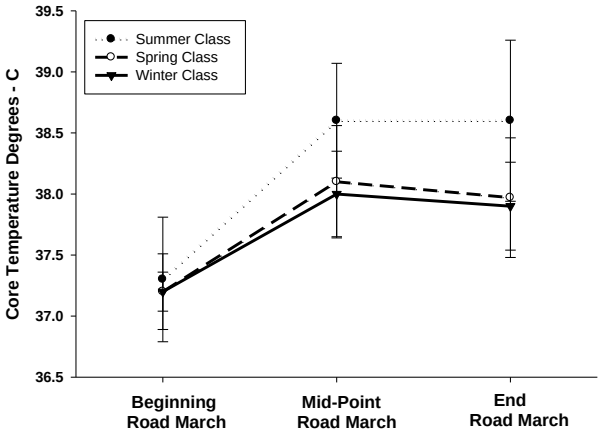
* Within a column, those values with different letters are significantly different from one another.

Figure 1. Heart rate (HR) interaction effect (class x time during the road march) for Ranger School students during their qualifying road march. The pre-march HR was significantly lower than the mid- or end-of-march HR as designated by the different letters (a and b) on the figure.



Core temperatures showed a significant interaction effect ($p = 0.05$) among classes and over time during the road march. Core temperatures increased more dramatically (~ 1.4 °C) in the summer class from the beginning of the march to mid-march compared to mid-march to the end-of-march; Tcore plateaued mid-march to end-of-march (Figure 2). Core body temperatures were highest throughout the march in the summer session, but below levels likely to cause heat illness or injuries (39.5 °C) (Figure 2). For the one individual that withdrew at Mile 3 of the road march, Tcore was 38.8 °C indicating thermal strain was present but below a level likely to induce heat illness. Six other individuals who successfully completed the road march without heat illness also had Tcore at the Mile 3 split that were 38.8 °C or higher. Main effects of time during the road march ($p < 0.001$), and between classes ($p < 0.001$) for Tcore were observed. Post hoc testing (set at $p < 0.05$) showed that for the main effect of time, the pre-road march Tcore were significantly lower than the mid-point or end-of-march Tcore (pre-march: 37.2 $\pm$ 0.4 °C; mid-march: 38.2 $\pm$ 0.5 °C, end of march: 38.1 $\pm$ 0.6 °C). No significant difference existed between the mid-march Tcore and the end-of-road march Tcore. There was a significant main effect of Tcore by class, with the summer class students possessing significantly ($p < 0.05$) higher Tcore than spring or winter class students (spring: 37.7 $\pm$ 0.4 °C, summer: 38.2 $\pm$ 0.5 °C, winter: 37.7 $\pm$ 0.5 °C).

Figure 2. Core body temperature (Tcore) interaction effect (class x time during the road march) for Ranger School students during their qualifying road march. The pre-march Tcore was significantly lower than the mid- or end-of-march Tcore as designated by the different letters (a and b) on the figure. Summer Tcore was significantly higher than the spring or winter Tcore as designated by the different numbers (1 and 2) on the figure.



DISCUSSION

Few previous studies have examined road march maximal timed performance. Comparing performance of these Ranger School students to soldiers' performances in

previous road marches (Table 4) showed these Ranger School students' paces were generally faster than those of infantry soldiers [8] and elite British soldiers [11]. The Special Operations Forces soldiers' pace was likely superior to these Ranger School students [7]. However, all studies had different course lengths, different loads carried, and different terrain factors. The British soldiers traversed up and down significant elevations [11]. The present study's marches took place on courses with rolling hills with paved and hard-packed dirt roads. Weather conditions were not described or accounted for in the previous comparative road march studies [7, 8, 11]. While not described explicitly, it is likely in the previous studies that once the road march tasks were completed, soldiers' activities for that day were done and they had a recovery period before having to participate in future strenuous military training. In contrast, in the present study the road march was embedded within the Ranger School's program of instruction. The Ranger School course road march is one of many graded tasks towards becoming a qualified U.S. Army Ranger. The Ranger School course road march took place on the 4th day of a 61-day course, and there were other activities that students were required to do that day. On subsequent days there were additional strenuous graded training activities; hence there was no recovery period for these students.

Table 4. Comparison of road march performance (pace sustained) in present study with previous road march performance times.

Class	Road March Length (km/ miles)	Total Weight Carried (kg)	March Pace in Minutes per Mile (Min:Sec)
RTB Ranger School Soldiers – Spring Present Study	19.3 (12 miles)	33.9	15:35
RTB Ranger School Soldiers – Summer Present Study	12.9 (8 miles)	31.6	14:57
RTB Ranger School Soldiers – Winter Present Study	19.3 (12 miles)	30.6	14:46
Special Operation Forces Soldiers Knapik et al. [7]	20.0 (12.4 miles)	34.0	13:47
Elite British Soldiers Simpson et al. [10]	29.0 (18 miles)	20.0	19:32
Infantry Soldiers Knapik et al. [8]	20.0 (12.4 miles)	46.0	25:19

No significant correlation existed between reported 3.2 km (2-mile) run time and road march completion time. Previously, a significant correlation (r = 0.77) between a 3.2 km run with a 20 kg backpack and a 29 km road march with the same 20 kg backpack was observed [11]. These results combined with previous work indicate that fast road marching with a load is a different skill than running with no load. Supporting this conclusion it has been observed that direct maximal oxygen uptake is a poor indicator of both a 3.2 km and a 29 km road march with a 20 kg backpack [11]. Previous research has also found little or no correlation of height, body weight, or percent body fat to road march completion time [11].

Heart rates observed in the present study were less than those seen previously in a 20 km road march [7]. In that study, mean HR was calculated every 4 km. When soldiers wore the all-purpose lightweight individual carrying equipment (ALICE) pack with 34 kg, the most similar condition to the load carried in the present study, mean HRs were between 154 bpm and 160 bpm [8]. The mean HR observed in the Knapik et al. [7] study was higher than the HR observed for any class in the present study, where HR never exceeded 140 bpm. This suggests that Ranger Students during their qualifying road march were exerting less than a maximal effort. Those that did not pass the march most likely failed for reasons other than a lack of strength or aerobic conditioning, perhaps as a result of prior injury, poor pacing strategies, or a lack of psychological readiness for the Ranger School course tasks. Other research has shown no relationship of "mental toughness" and road march performance [11]. However, the act of completing a timed road march, with or without a set of performance standards has resulted in more feelings of psychological fatigue and lack of vigor upon march completion [8, 13].

As mentioned previously no work has been published on the impact of weather conditions on road march performance. However, a nomogram for runners that predict changes in finishing times for the marathon based on differences in weather conditions has been developed [3]. However, unlike the marathon runners, pacing for the Ranger School course students was highly variable whether they passed this timed event or not. One explanation is that these students had little experience with road marching for time. Furthermore, they were not allowed to carry watches to self-monitor their pace. In contrast, marathon runners are afforded incremental feedback on their performance throughout their event. The lack of feedback for the Ranger School course students combined with their lack of timed road march experience most likely resulted in the initial pace of all students being significantly faster than the pace required to complete the course within the Ranger School course standard. As the march progressed all students slowed, but the faster students were ahead of schedule; therefore a pace slower than the average 16:25 per-mile pace required still allowed them to finish within the required time.

From the running literature it is known that more evenly paced running [3] results in superior performance when the fastest time is the objective. One recommendation for soldiers would be to practice road marching with a load and a stopwatch prior to the Ranger School course to allow them to obtain a better sense of the pace that they can maintain for distances between 12.9 and 19.3 km. It is especially important for these students to gain an awareness of pace with loads since they cannot use a watch to correct pace by intentionally slowing down if they start out too fast for their ability and level of

conditioning. From the data (Table 2) it appears that students are initially being competitive with one another (see Miles 1 and 2), resulting in too fast a pace. This results in a reduced pace due to fatigue and perhaps motivational factors as the group begins to spread out, leaving soldiers to pace themselves during the mid-part and near the end of the road march. It is likely that if each soldier completed the event based on their own even pacing, it would likely result in better performance times for most students.

With regard to the seasonal differences between classes, a similar analysis to what Ely et al. [3] performed could be done with road march performance. Since the Ranger School conducts a number of classes of this course over many years, a similar analysis of examining pace and weather conditions seems feasible if past road march performances were maintained. While some insight into these differences are presented here, the data set is small with limited (three) weather conditions. Since the Ranger School course road march is more complex than running a marathon, applying the methods of Ely et al. [3] should be done with some caution. Two important variables with regard to the road march are that the Ranger School leadership varies the length of the road march and individual soldiers carry varying weights in their packs and on their bodies; although these weights must be at or above the minimum weight required by the Ranger School. Furthermore, it is likely that even within this group of soldiers, who are above the average soldier in terms of fitness and training, they are less homogenous than the marathon runners who would be classified as elite or near elite runners (1^{st} to 300^{th} place at a major marathon such as the Boston, New York City, etc. marathons) used in the Ely et al. [3] study.

CONCLUSIONS

The Ranger School goal of having equally challenging road marches across classes was not met. The shorter summer class march distance allowed road march performance (defined as per-mile pace) to be equivalent to the winter class. However, the spring class march, in relatively warm weather with heavier loads, was slower than either the summer or winter marches. The road march during the summer class was the most physiologically stressful, but was conducted within safe physiological limits. The spring class participants' thermal strain level was below their summer cohorts. The percent passing was not significantly different between classes. However, only 29% of spring students were $\geq$ 5 percent under the standard compared to 68% of summer and 58% of winter class students. These results suggest a majority of spring class students chose to pass the Ranger School course qualifying road march with the minimum amount of effort necessary. For the Ranger School course student, passing with a less than maximum effort may serve as a prudent strategy. Passing the entire Ranger School course is the real goal and there are other events the students must successfully complete on the same day as the road march. Additionally, students must complete successfully an additional 57 days of training to pass Ranger School. From the pacing table (Table 3) it may be observed that all students whether passing, not passing, or passing by $\geq$ 5 percent under the standard did not use the most efficient pacing to optimize performance for themselves.

ACKNOWLEDGEMENTS

We would like to thank Ms. Laurie Blanchard, Mr. Mark Buller, SGT Andrew Coggins, Mr. Fred Dupont, SGT Scott Harris,

Mr. Stephen Mullen, Mr. Kenneth Pitts, and Dr. William Santee for their assistance in data collection. We thank Dr. Karl Friedl, and Dr. Scott Montain for their reviews and editorial comments to the manuscript. We appreciate the opportunity to have worked with the Ranger School and thank their leadership for providing us the opportunity to collect this valuable data during their qualification course. Specifically, we would like to thank COL Gregory Hager, COL Douglas Flohr, MAJ Robert Proctor, MAJ Robert Boone, LTC Sean Mullen, MAJ Dwight Griffith, CPT John Walsh, CPT Paul Cluverius, SGM Erik Wilson, MAJ Thomas Sager, CPT Dustin Martin, and SGT Chris Duncan. Finally, we thank all the Ranger students who in addition to participating in the physically and mentally challenging aspects of the U.S. Army Ranger Training Course volunteered for this study.

Disclaimers: This study was funded by the U.S. Army Medical Research and Materiel Command, Ft. Detrick, MD. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official views of the Army, or the Department of Defense. The authors have no financial or personal interest in the results of this study. The investigators have adhered to the policies for protection of human subjects as prescribed in Army Regulation AR 70-25 and USAMRMC Regulation 70-25, and the research was conducted in adherence with the provisions of 32 CFR Part 219. Citations of commercial organizations and trade names in this report do not constitute an official Department of the Army endorsement or approval of the products or services of these organizations.

REFERENCES

1. Department of the Army. *Army Regulation 600-9, The Army Weight Control Program.* Washington, D.C.: Headquarters Department of the Army, 27 November 2006.

2. Department of the Army and Air Force. *Army Regulation TB MED 507 and Air Force Regulation AFPAM 48-152, Heat Stress Control and Heat Casualty Management*. Washington, D.C.: Headquarters Department of the Army and Department of the Air Force, 7 March 2003.

3. Ely MR, Cheuvront SN, Roberts WO, Montain SJ. Impact of weather on marathon-running performance. *Med Sci Sports Exerc*. 2007; 39(3): 487-493.

4. Gonzales-Alonzo, J, Teller C, Andersen SL, Jensen FB, Hyldig T, Nielsen B. Influence of body temperature on the development of fatigue during prolonged exercise in the heat. *J Appl Physiol*, 1999; 86(3):1032-1029.

5. Goodman DA, Kenefick RW, Cadarette BS, Cheuvront SN. Influence of sensor ingestion timing on consistency of temperature measures. *Med Sci Sports Exerc*, 2009; 41(3): 597-602.

6. Jones SB, Knapik JJ, Sharp MA, Darakjy S, Jones BH. The validity of self-reported physical fitness test scores. *Mil Med*, 2007; 172(2): 115-120.

7. Knapik JJ, Ang P, Meiselman H, Johnson W, Kirk J, Bensel C, Hanlon W. Soldier performance and strenuous road marching: influence of load mass and load distribution. *Mil Med*, 1997; 162(1): 62-67.

8. Knapik J, Staab J, Bahrke M, Reynolds K, Vogel J, O'Connor J. Soldier performance

and mood states following a strenuous road march. *Mil Med,* 1991; 156(4): 197-200.

9. Moore RJ, Friedl KE, Kramer TR, Martinez-Lopez LE, Hoyt RW, Tulley RE, DeLany JP, Askew EW, Vogel JA *Changes in Soldier Nutritional Status and Immune Function During the Ranger Training Course.* Technical Report T13-92. Natick, MA: U.S. Army Research Institute of Environmental Medicine, 1992.

10. Sawka, MN, Latzka WA, Montain SJ, Cadarette BS, Kolka MA, Kraning KK, Gonzalez RR. Physiologic tolerance to uncompensable heat: intermittent exercise, field vs. laboratory. *Med Sci Sports Exerc*, 2001; 33(3): 422-430.

11. Simpson RJ, Gray SC, Florida-James GD. Physiological variables and performance markers of serving soldiers from two "elite" units of the British Army. *J Sport Sci*, 2004; 24(6): 597-604.

12. Tharion WJ, Lieberman HR, Montain SJ, Young AJ, Baker-Fulco CJ, DeLany JP, Hoyt RW. Energy requirements of military personnel. *Appetite,* 2005; 44: 47-65.

13. Tharion WJ, Karis AJ, Potter AW. Mood states of U.S. Army Ranger students associated with a competitive road march. *J Sport Hum Perform*, 2013; 1(3): 1-9.

14. Weather Underground Web site [Internet]. Atlanta, GA: Weather Underground; [accessed 2013 Feb 3] Available from http:/www.wunderground.com/history/airport/KCSG

15. Wilkinson DM, Carter JM, Richmond VL, Blacker SD, Rayson MP. The effect of cool water ingestion on gastrointestinal pill temperature. *Med Sci Sports Exerc*, 2008; 40(3): 523-528