Leonard Wood Institute Research Project
Final Report

LWI Subaward Number:	LWI 26-1004
Project Title:	Effects of Sleep on Training Effectiveness in Soldiers at Fort Leonard Wood
Principal Investigator:	Nita Lewis Miller
Co-Investigator(s):	Lawrence Shattuck, Anthony Tvaryanas, Panagiotis Matsangas
Period of Research:	7/15/09 – 9/30/09

1) Project Overview: Military training often includes some degree of sleep deprivation, either by design or unintentionally, which may have important implications for Soldier physical health, well-being, and performance. This study was conducted to determine if adjusting scheduled sleep periods to better complement age-specific biologically driven sleep patterns would improve sleep and performance in Army recruits completing basic combat training (BCT). A total of 394 recruits and instructor cadre were enrolled in the study: 185 participants in the control group (a training company using the standard sleep regimen) and 209 participants in the treatment group (a training company using an optimized sleep regimen designed based on a fatigue modeling tool). Demographic and psychophysiological measures were collected at the start of the study using standard survey instruments and methods. A random sample of 95 recruits wore wrist activity monitors to non-obtrusively record sleep quantity and quality throughout the study period. Weekly assessments were made of subjective fatigue and mood throughout the training period. Data on physical fitness, marksmanship performance, and attrition were collected from organizational databases.

2) Project Schedule: The original project schedule is shown below with schedule overruns highlighted in red. Schedule tasks 1-4 were accomplished as originally planned. A contract was awarded for data entry services starting 24Aug09 and expired at the end of FY09. Significant administrative delays were encountered in working the Defense Contract Management Agency (DCMA) to renew the data entry contract at the start of FY10. The contract re-award was not accomplished until 14Dec09. Consequently, data entry was not completed until 25Jan10. This caused a 78-day slip in the start of the data analysis task. In response, tasks 5 and 7 were divided into Phase I and Phase II efforts. The Phase I effort focused on that portion of the dataset that could be analyzed and reported prior to the 12Feb10 suspense. The Phase II effort will include analysis and reporting for the full dataset.

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Project Schedule

Tasks	Start Date	Duration (days)	End date	Revised end date
1) Research proposal	18-Jun-09	7	25-Jun-09	
2) Research protocol	18-Jun-09	20	8-Jul-09	
3) Planning	18-Jun-09	51	8-Aug-09	
4) Data collection	9-Aug-09	90	7-Nov-09	
5) Data analysis	8-Nov-09	~~30~~	~~8-Dec-09~~	01-Mar-10
6) Outbrief	9-Dec-09	3	~~12-Dec-09~~	n/a
7) Report writing	8-Nov-09	60	~~7-Jan-10~~	15-Mar-10
8) Deliver final report	8-Jan-10	2	~~10-Jan-10~~	17-Mar-10

3) Project Outcomes: The results of the Phase I analysis are described in the accompanying technical report. To briefly summarize, analysis of actigraphic measures of sleep and activity from the 94 recruits with actigraphy data found that a 2.5-hour phase delayed sleep schedule improved sleep relative to the standard BCT schedule, resulting in more than 30 minutes of extra sleep per night. Besides schedule, personal factors such as age and gender also influenced recruits' average total daily sleep, with younger and female recruits tending to obtain more sleep. While the schedule modification was shown to be effective in improving sleep, increased nightly sleep during the training of marksmanship skills was shown to result in greater improvements over subsequent serial marksmanship performance assessments. This finding is in line with other studies that show higher skill acquisition following adequate sleep. Hence, schedule modifications that improve sleep can be expected to result in improved marksmanship performance during BCT. Importantly, such benefits may be obtained with no change to the content or length of the training program, nor are investments required in any new technologies or facilities.

4) Overall Assessment of Project: The implementation phase of the study conducted at Fort Leonard Wood went well with excellent local support. Unfortunately, administrative delays related to contracting for data entry services significantly set back the data analysis phase. The limited Phase I analysis has identified promising preliminary results that will be explored during the Phase II analysis of the complete study dataset.

5) Way Ahead: The next step is to complete the Phase II data analysis and report writing. Determination of subsequent steps will need to await the Phase II findings.

6) Financial Summary: See attached final overall itemized voucher.

Nita Lewis Miller, Ph.D.
Associate Professor

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Associate Professor

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Budget Report for Job Order RORRJ

Report: 02-08-10 04:03:01 PM

DORS updated: 02-08-10 12:01:27 PM

Budget Page

FY: 2010

Title	EFFECTS OF SLEEP ON TRAINING...			Sponsor	LEONARD WOOD INST
Job Order	RORRJ	Funding Document	MIPR9KDAVBP028	Dept	OR
Indirect JON	IORRJ	Amendment	BASIC	PI	MILLER
CC/SCC	R9RJ	Expiration Date	12/31/2009	Analyst Name	Shana Batlin
Optar Code	RJ	Serial #	RRJ01-RRJ99	Analyst Phone #	1195

PLAN		ACTUAL COST		BALANCE	Negative Status
Authorized Faculty Labor	$20,926.14	Faculty Labor Cost	$20,653.99	$272.15	
Authorized Staff Labor	$0.00	Staff Labor Cost	$0.00	$0.00	
		Labor Adjustment			
Total Authorized Labor	$20,926.14	**Total Labor Cost**	$20,653.99	$272.15	
Authorized Travel	$9,171.77	Travel Cost	$1,866.29	$7,305.48	
Authorized Equip/Sup	$10,301.13	Equip/Supp/Mis Cost	$14,158.28	($3,857.15)	YES
Authorized Contract/Sev	$14,800.00	Contract/Service Cost	$15,000.00	($200.00)	YES
Total Planned Non-Labor	$34,272.90	**Total Non-Labor Cost**	$31,024.57	$3,248.33	
Authorized Indirect Cost	$17,084.10	**Indirect Cost**	$16,347.97	$736.13	
TOTAL AUTHORIZED	$72,283.14	**TOTAL OBLIGATED**	$68,026.53	$4,256.61	

Travel Cost: EE (Expense Element) = E
Equip/Supp/Mis Cost: EE (Expense Element) = All EEs excluding E, Q, P, N
Contract/Services Cost: EE (Expense Element) = Q, P, N

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Faculty Labor Report

2/8/2010 4:03:05 PM

FY	Name	Labor Category	Pay Period	Job Order	Hrs	Actual Cost
10	MILLER, NITA L.	Regular Work	12/19/2009	RORRJ	21.5	$2,433.22
10	MILLER, NITA L.	Regular Work	11/21/2009	RORRJ	25	$2,829.31
10	MILLER, NITA L.	Regular Work	11/7/2009	RORRJ	40	$4,526.90
10	MILLER, NITA L.	Regular Work	10/24/2009	RORRJ	40	$4,526.90
10	MILLER, NITA L.	Regular Work	10/10/2009	RORRJ	56	$6,337.66
			Total		**182.5**	**$20,653.99**

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Non Labor - Travel Cost

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FY	Document Num	Description	JON	ACRN	EE	Obligated	Received	Paid	Actual Cost (YTD)
10	N6227110TOWTQK1	TVARYANAS ANTHONY	RORRJ	AA	E	$0.00	$0.00	$1,866.29	$1,866.29
					Total	**$0.00**	**$0.00**	**$1,866.29**	**$1,866.29**

Travel Cost: EE (Expense Element) = E (Travel)
Equipment/Supplies/Mis. Cost: EE (Expense Element) = All EEs excluding E, Q, P, N
Contract/Services Cost: EE (Expense Element) = Q, P, N

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Non Labor - Equipment/Supplies Cost

2/8/2010 4:03:07 PM

FY	Document Num	Description	JON	ACRN	EE	Obligated	Received	Paid	Actual Cost (YTD)
10	N6227110RCRRJ10	SO/MILLER/MACPRO	RORRJ	AA	W	$8,678.90	$0.00	$0.00	$8,678.90
10	N6227110RQRRJ01	FEDEX/BOX/ONIGHT/FLW	RORRJ	AA	L	$35.99	$0.00	$0.00	$35.99
10	N6227110RQRRJ02	FEDEX	RORRJ	AA	L	$145.78	$0.00	$40.14	$185.92
10	N6227110RQRRJ03	RD/AMAZON/MILLER	RORRJ	AA	T	$52.62	$0.00	$0.00	$52.62
10	N6227110RQRRJ04	RD/FEDEX/MILLER	RORRJ	AA	L	$167.26	$0.00	$0.00	$167.26
10	N6227110RQRRJ05	AMAZON/ONE NEW	RORRJ	AA	T	$0.00	$0.00	$70.14	$70.14
10	N6227110RQRRJ06	RD/NITA/F.EX/RETURN	RORRJ	AA	L	$0.00	$0.00	$163.91	$163.91
10	N6227110RQRRJ08	SO/MILLER/FEDEX SHIP	RORRJ	AA	L	$0.00	$0.00	$32.25	$32.25
10	N6227110RQRRJ09	CDWG/APPLE MAC	RORRJ	AA	T	$0.00	$0.00	$1,068.00	$1,068.00
10	N6227110RQRRJ11	SO/MILLER/LATITUDE E	RORRJ	AA	T	$2,150.78	$0.00	$637.96	$2,788.74
10	N6227110RQRRJ12	SO/MILLER/TIME CAPSU	RORRJ	AA	T	$0.00	$0.00	$914.55	$914.55
					Total	**$11,231.33**	**$0.00**	**$2,926.95**	**$14,158.28**

Travel Cost: EE (Expense Element) = E (Travel)

Equipment/Supplies/Mis. Cost: EE (Expense Element) = All EEs excluding E, Q, P, N

Contract/Services Cost: EE (Expense Element) = Q, P, N

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Non Labor - Contract/Service Cost

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FY	Document Num	Description	JON	ACRN	EE	Obligated	Received	Paid	Actual Cost (YTD)
10	N6227110RCRRJ07	DCS 0039/0153	RORRJ	AA	Q	$15,000.00	$0.00	$0.00	$15,000.00
				Total		**$15,000.00**	**$0.00**	**$0.00**	**$15,000.00**

Travel Cost: EE (Expense Element) = E (Travel)
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Contract/Services Cost: EE (Expense Element) = Q, P, N

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Budget Report for Job Order RORRJ

Report: 02-08-10 04:03:23 PM

DORS updated: 02-08-10 12:01:27 PM

Budget Page

FY: 2009

Title	EFFECTS OF SLEEP ON TRAINING...			Sponsor	LEONARD WOOD INST
Job Order	RORRJ	Funding Document	MIPR9KDAVBP028	Dept	OR
Indirect JON	IORRJ	Amendment	BASIC	PI	MILLER
CC/SCC	R9RJ	Expiration Date	12/31/2009	Analyst Name	Meghan Sagon
Optar Code	RJ	Serial #	RRJ01-RRJ99	Analyst Phone #	3049

PLAN		ACTUAL COST		BALANCE
Authorized Faculty Labor	$23,502.28	Faculty Labor Cost	$2,678.68	$20,823.60
Authorized Staff Labor	$0.00	Staff Labor Cost	$0.00	$0.00
		Labor Adjustment		
Total Authorized Labor	$23,502.28	**Total Labor Cost**	$2,678.68	$20,823.60
Authorized Travel	$10,614.00	Travel Cost	$1,467.04	$9,146.96
Authorized Equip/Sup	$10,967.42	Equip/Supp/Mis Cost	$538.94	$10,428.48
Authorized Contract/Sev	$14,800.00	Contract/Service Cost	$0.00	$14,800.00
Total Planned Non-Labor	$36,381.42	**Total Non-Labor Cost**	$2,005.98	$34,375.44
Authorized Indirect Cost	$18,534.00	**Indirect Cost**	$1,449.90	$17,084.10
TOTAL AUTHORIZED	$78,417.70	**TOTAL OBLIGATED**	$6,134.56	$72,283.14

Travel Cost: EE (Expense Element) = E
Equip/Supp/Mis Cost EE (Expense Element) = All EEs excluding E, Q, P, N
Contract/Services Cost: EE (Expense Element) = Q, P, N

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Faculty Labor Report

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FY	Name	Labor Category	Pay Period	Job Order	Hrs	Actual Cost
09	MILLER, NITA L.	Regular Work	10/10/2009	RORRJ	24	$2,678.68
			Total		**24**	**$2,678.68**

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Non Labor - Travel Cost

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FY	Document Num	Description	JON	ACRN	EE	Obligated	Received	Paid	Actual Cost (YTD)
09	N6227109TOWCFP2	MILLER NITA	RORRJ	AA	E	$0.00	$0.00	$1,467.04	$1,467.04
					Total	**$0.00**	**$0.00**	**$1,467.04**	**$1,467.04**

Travel Cost: EE (Expense Element) = E (Travel)
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NAVAL POSTGRADUATE SCHOOL

Non Labor - Equipment/Supplies Cost

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FY	Document Num	Description	JON	ACRN	EE	Obligated	Received	Paid	Actual Cost (YTD)
09	N6227109RQRRJ01	FEDEX/FTLEONARD	RORRJ	AA	L	$0.00	$0.00	$180.45	$180.45
09	N6227109RQRRJ02	DOD EMALL/LSR LABELS	RORRJ	AA	T	$0.00	$0.00	$185.78	$185.78
09	N6227109RQRRJ03	FEDEX/FTLENORWOOD,	RORRJ	AA	L	$0.00	$0.00	$20.68	$20.68
09	N6227109RQRRJ04	FEDEX/PAK/3LB/OREGON	RORRJ	AA	L	$0.00	$0.00	$6.20	$6.20
09	N6227109RQRRJ05	SO/MILLER/FEDEX SHIP	RORRJ	AA	L	$0.00	$0.00	$126.93	$126.93
09	N6227109RQRRJ06	FEDEX/ON/BX/FTLWODM	RORRJ	AA	L	$0.00	$0.00	$18.90	$18.90
					Total	**$0.00**	**$0.00**	**$538.94**	**$538.94**

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NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

Effects of Sleep on Training Effectiveness in Soldiers at Fort Leonard Wood (Phase 1)

by

Nita Lewis Miller, Ph.D.
Lawrence G. Shattuck, Ph.D.
Anthony P. Tvaryanas
Panagiotis Matsangas

February 2010

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Prepared for: Leonard Wood Institute
197 Replacement Avenue
Fort Leonard Wood, MO 65473

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NAVAL POSTGRADUATE SCHOOL
MONTEREY, CA 93943-5001

Daniel T. Oliver
President

Leonard A. Ferrari
Executive Vice President and
Provost

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4. TITLE AND SUBTITLE: Effects of Sleep on Training Effectiveness in Soldiers at Fort Leonard Wood (Phase 1)

5. FUNDING NUMBERS LWI 26-1004

6. AUTHOR(S) Nita Lewis Miller, Ph.D.; Lawrence G. Shattuck, Ph.D.; Anthony P. Tvaryanas; Panagiotis Matsangas

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11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.	**12b. DISTRIBUTION CODE** A

13. ABSTRACT *(maximum 200 words)*

This study assessed where adjusting scheduled sleep periods to better complement biologically driven sleep patterns would improve sleep and performance in Army recruits in basic combat training (BCT). A total of 394 recruits and instructor cadre, 185 in a training company using the standard BCT sleep regimen and 209 in a company using an optimized sleep regimen, were followed throughout BCT using a variety of psycho-physiological measures. A random sample of 95 recruits wore wrist activity monitors to record sleep quantity and quality. Data on physical fitness, marksmanship, and attritions were collected. We report here on the analysis of actigraphic measures and marksmanship for the 94 recruits for whom actigraphy data were available. The 2.5-hour phase delayed sleep schedule improved sleep relative to the standard BCT schedule, resulting in more than 30 minutes of extra sleep per night. Besides schedule, personal factors such as age and gender also influenced recruits' average total daily sleep, with younger and female recruits tending to obtain more sleep. Increased nightly sleep during the training of marksmanship skills was also shown to result in greater improvements over subsequent serial marksmanship assessments.

14. SUBJECT TERMS Actigraphy, marksmanship, schedule	**15. NUMBER OF PAGES** 60
	16. PRICE CODE

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DISCLAIMER

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ABSTRACT

This study assessed where adjusting scheduled sleep periods to better complement biologically driven sleep patterns would improve sleep and performance in Army recruits in basic combat training (BCT). A total of 394 recruits and instructor cadre, 185 in a training company using the standard BCT sleep regimen and 209 in a company using an optimized sleep regimen, were followed throughout BCT using a variety of psychophysiological measures. A random sample of 95 recruits wore wrist activity monitors to record sleep quantity and quality. Data on physical fitness, marksmanship, and attritions were collected. We report here on the analysis of actigraphic measures and marksmanship for the 94 recruits for whom actigraphy data were available. The 2.5-hour phase delayed sleep schedule improved sleep relative to the standard BCT schedule, resulting in more than 30 minutes of extra sleep per night. Besides schedule, personal factors such as age and gender also influenced recruits' average total daily sleep, with younger and female recruits tending to obtain more sleep. Increased nightly sleep during the training of marksmanship skills was also shown to result in greater improvements over subsequent serial marksmanship assessments.

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LIST OF FIGURES

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LIST OF TABLES

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EXECUTIVE SUMMARY

Military training often includes some degree of sleep deprivation, either by design or unintentionally, which may have important implications for Soldiers' physical health, well-being, and performance. This study was conducted to determine if adjusting scheduled sleep periods to better complement age-specific, biologically-driven sleep patterns would improve sleep and performance in Army recruits completing basic combat training (BCT). A total of 394 recruits and instructor cadre were enrolled in the study: 185 participants in the control group (a training company using the standard sleep regimen) and 209 participants in the treatment group (a training company using an optimized sleep regimen based on a fatigue modeling tool). Demographic and psycho-physiological measures were collected at the start of the study using standard survey instruments and methods. A random sample of 95 recruits wore wrist activity monitors to nonobtrusively record sleep quantity and quality throughout the study period. Participants reported subjective assessments of fatigue and mood at weekly intervals throughout the training period. Data on physical fitness, marksmanship performance, and attritions were collected from organizational databases.

We report here on the analysis of actigraphic measures and marksmanship performance for the 94 recruits for whom actigraphy data were available. Based on actigraphic data, the 2.5-hour, phase-delayed sleep schedule improved sleep relative to the standard BCT schedule, resulting in more than 30 minutes of extra sleep per night. Besides schedule, personal factors such as age and gender also influenced recruits' average total daily sleep, with younger and female recruits tending to obtain more sleep. While the schedule modification was shown to be efficacious in improving sleep, increased nightly sleep during the training of marksmanship skills was shown to result in greater improvements over subsequent serial marksmanship assessments. Hence, schedule modifications that improve sleep can be expected to result in improved marksmanship performance during BCT. Importantly, such benefits may be obtained with no change to the content or length of the training program, nor are investments required in any new technologies or facilities.

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ACKNOWLEDGEMENT

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I. INTRODUCTION

A. STATEMENT OF THE PROBLEM

Military training regimes often include some degree of sleep deprivation, either by design or unintentionally. Several studies have demonstrated that sleep deprivation is prevalent in military training and education programs. For example, Killgore, Estrada, Wildzunas, and Balkin (2008), using actigraphy to assess sleep in Soldiers attending military training at the Noncommissioned Officer Academy and the Warrant Officer Candidate School, reported Soldiers obtained an average of 5.8 hours of sleep per night. Miller, Shattuck, Panagiotis, and Dyche (2008), reporting on the preliminary results of a 4-year longitudinal study of sleep in U.S Military Academy (USMA) cadets, based on actigraphy data, found that cadets averaged 5.4 hours of sleep per night. This is substantially less than the approximately 8 hours of sleep per night required by healthy adults to maintain cognitive effectiveness (Anch, Browman, Mitler, and Walsh, 1988). As reported by Miller (2005), this also is more than 2 hours less sleep per night than cadets stated receiving prior to arriving at the USMA. It is also important to recognize that military recruits are adolescents or young adults in their early twenties. Biologically-driven sleep patterns in this age group differ from those of more mature adults, with delayed bedtimes, later awakenings, and longer sleep periods (i.e., on the order of 0.5 to 1.25 more hours of sleep per night) (Carskadon, Acebo, Richardson, Tate, and Seifer, 1997, 1998; Wolfson & Carskadon, 2003). Thus, the general population of military recruits may actually require from 8.5 to 9.25 hours of sleep per night for optimal performance (Miller & Shattuck, 2005).

Chronic sleep deprivation from multiple nights of less than 8 hours of sleep will cause sleep debt and fatigue. A vast body of research has shown that the effects of fatigue include decreased vigilance, adverse mood changes, perceptual and cognitive decrements (Krueger, 1990; Belenky, Wesensten, Thorne, Thomas, Sing, Redmond, et al., 2003; Van Dongen, Maislin, Mullington, and Dinges, 2003), impaired judgment and increased risk taking (Killgore, Balkin, & Wesensten, 2006), and even decreased marksmanship (Tharion, Shukitt-Hale, & Lieberman, 2003; McLellan, Kamimori, Bell,

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Smith, Johnson, and Belenky, 2005). Contrary to popular opinion in the military, research has shown that motivation can only partially compensate for the adverse effects of sleep deprivation (Pigeau, Angus, & O'Neil, 1995). Of particular relevance to military training, the ability of individuals to learn and retain information is reduced by sleep deprivation (literature summarized in Miller et al., 2008). For example, Graham (2000) reports that learning curves drop dramatically for adolescents obtaining 4-6 hours of sleep relative to those obtaining 8 hours per night. In the military training environment, Andrews (2004) conducted a retrospective comparison of the academic performance of Navy recruits before and after the training command changed the sleep regimen from 6 to 8 hours per night. It was observed that recruits who received 8 hours of sleep per night scored, on average, 11% higher than their counterparts who received only 6 hours of sleep, although Andrews was unable to discount the impact of other, concurrent changes at the training command. However, Killgore and colleagues (2008), evaluating the effectiveness of actigraphy as a predictor of cognitive performance, found significant positive correlations between Soldier test scores in six military training programs and both average hours of sleep per night and hours slept in both the 24 and 48 hours preceding a test. They also report that the average amount of sleep obtained by Soldiers accounted for approximately 40% of the variance in exam scores—a finding that underscores the impact of fatigue on learning and memory. A similar result was reported by Trickel, Barnes, and Egget (2000), who found that sleep habits accounted for most of the variance in the academic performance of freshman college students.

Physical health is an equally important concern in recruit populations, particularly because the close living conditions are conducive to the spread of communicable disease. Individual physical health and, in turn, public health, also depends on individuals receiving adequate amounts of sleep. Research has shown that disturbances of sleep-wake homeostasis are accompanied by alterations in the immunological, neuroendocrine, and thermal functions of the body, and hence contribute to pathological processes such as infectious disease (Moldofsky, 1995). Lange, Perras, Fehm, and Born (2003) also reported that sleep enhances antibody production and the immune response to vaccination. Besides illness, sleep deprivation threatens health by increasing the risk for

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injuries resulting from accidents. For example, Thorne, Thomas, Russo, Sing, Balkin, Wesensten, et al., (1999) demonstrated that accidents increase progressively as sleep duration decreases to 7, 5, and 3 hours per night over a 1-week period.

The above research literature suggests there is a high prevalence of fatigue in military recruits, which has important implications for Soldier training, health, and safety. Well-controlled laboratory experiments have demonstrated a convincing dose-response relationship between sleep deprivation and degraded cognitive performance (Miller et al., 2008). However, prior studies of fatigue in military training environments have utilized uncontrolled, descriptive study designs that were limited to correlations between sleep and academic test performance, and many of the recommendations for follow-on research have yet to be addressed. Whether designing schedules to minimize fatigue has a direct effect on outcomes in the military training environment remains an open question.

The scarcity of information on the training benefits of sleep scheduling interventions in the military training environment is regrettable because it is the sort of evidence that senior decision makers appear to require if they are to support fatigue-sensitive revisions to training doctrine. If sleep scheduling is found to have a significant effect on overall training effectiveness and recruit attrition, then two options become available for the military training community:

- Performance thresholds of achievement for basic military training can be increased, while maintaining the present length of training (optimizing training effectiveness), or
- Thresholds of achievement can be maintained and the length of training decreased (optimizing training efficiency).

Preliminary evidence suggests that sleep and, conversely, fatigue, may account for nearly half the variability in academic performance during military training (Killgore et al., 2008), making sleep scheduling a potentially powerful lever for manipulating the performance of military training programs—and one that is immediately within our grasp, without significant investment in new technologies. Since training is a potential bottleneck in meeting wartime manpower needs as well as a recurring life-cycle cost for all weapon systems, even a more modest 10% improvement in trainee performance, as

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suggested by Andrews (2004), is significant when one considers the cumulative impact across military training programs.

This study attempts to contribute to the knowledge base by exploring the influence of sleep scheduling in the basic military training environment on recruits' achievement of entry-level Soldier standards and combat skills. This study examines both the direct effect of sleep scheduling on sleep obtained and training outcomes and the extent to which these effects are moderated by sleep habits, personality, and personnel aptitudes.

B. PURPOSE OF THE STUDY

The purpose of this study is to examine the relationship between both sleep schedule and personal characteristics and the performance of U.S. Army recruits attending basic combat training (BCT) at Fort Leonard Wood, Missouri. The study design compares recruits assigned to one of two training companies—a company using the standard BCT sleep regimen (i.e., a sleep period of 8:30 p.m. to 4:30 a.m.) or a company using a more physiologically complimentary sleep regimen (i.e., a sleep period of 11:00 p.m. to 7:00 a.m.). Personal characteristics are divided into background information about the recruit (i.e., age, gender, caffeine and tobacco habits, prior experience with firearms, etc.) and information about recruits' sleep habits, personality, resilience, and personnel aptitudes. The examination of personal characteristics is important to this study because it is hoped that it will be possible to identify characteristics and factors moderating the effect of sleep schedule on performance. The second part of the study examines the association between sleep and a major measure of performance in the military training organization—basic rifle marksmanship.

C. STUDY HYPOTHESES

The following hypotheses guided this study:

H_1: Recruits on the modified sleep schedule will obtain more daily sleep than recruits using the standard BCT sleep schedule.

H_2: There is a relationship between recruits' personal characteristics and recruits' sleep habits, personality, and resilience, and the effects of the sleep schedule modification.

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H_3: Recruits on the modified sleep schedule will exhibit greater improvement in marksmanship scores than recruits using the standard BCT sleep schedule.

D. DELIMITATIONS AND LIMITATIONS

A delimitation:

This study confines itself to assessing and observing U.S. Army recruits assigned to two companies within a combat support training battalion at Fort Leonard Wood, Missouri.

A limitation:

The study sample consists of recruits being accessed into military occupational specialties within the U.S. Army's combat support branch. Since combat support units may differ from combat arms and combat service support units in terms of the distributions of gender and personnel aptitudes, this study may not be generalizable to all Army training programs.

A limitation:

The study sample consists of recruits being accessed into the U.S. Army in the month of August. Since recruit demographics exhibit temporal variations, the findings of this study may not directly apply to other BCT classes at the study location.

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II. METHODS

A. RESEARCH DESIGN

The study protocol was approved by the Naval Postgraduate School Institutional Review Board in accordance with 32 Code of Federal Regulations (CFR) 219 and SECNAV Instruction 3900.39D. The study used a quasi-experimental study design that was embedded within the Army's 63-day BCT program of instruction. The experimental and comparison groups were selected without random assignment, although group assignment to the treatment condition was random. Participant assignment to group was made by the U.S. Army based on factors that were unobservable by the research team, but which were not altered for the purpose of this study. That is, the research team took the groups as they had been created by the U.S. Army based on their normal mode of operations for managing BCT. The study intervention consisted of a modification of the timing of sleep and wake periods; otherwise, no change was made to the content, instructional methods, or sequence of BCT training events. The experimental group used a 2300-0700 (i.e., 11:00 p.m.-7:00 a.m.) sleep regimen with opportune midday naps, while the comparison group maintained the standard 2030-0430 (i.e., 8:30 p.m.-4:30 a.m.) sleep regimen. The barracks used by the experimental group were modified with black-out curtains to mitigate the effect of morning light; no modifications were made to the barracks used by the comparison group.

B. PARTICIPANTS

Participants for the comparison group were solicited from among those recruits starting BCT on August 14, 2009, and assigned to Charlie Company, 3rd Battalion, 10th Infantry Regiment, 3rd Chemical Brigade (C/3-10 IN BN), Fort Leonard Wood, Missouri. Similarly, participants for the experimental group were solicited from among those recruits starting BCT on August 21, 2009, and assigned to Bravo Company, 3rd Battalion, 10th Infantry Regiment (B/3-10 IN BN). Participants were solicited during BCT inprocessing by a civilian member of the research team to mitigate the potential for implied coercion by rank. Recruits who chose not to participant in the study still

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followed the training company's schedule and accomplished all training events, but they did not complete any of the study-related instruments.

C. DATA COLLECTION INSTRUMENTS AND VARIABLES

1. Actiwatch

The Actiwatch® (Model AW-64, Philips Respironics, Bend, Oregon) is a 16-gram, 28 x 27 x 10-millimeter wristwatch-like device worn on the nondominant wrist that objectively measures activity and rest patterns. With each participant movement, a highly sensitive accelerometer generates a variable voltage that is digitally processed and sampled at a frequency of 32 Hertz. The signal is integrated over a user-selected epoch and a value expressed as activity counts is recorded in the on-board memory. Data are downloaded to a computer and may be expressed graphically as an actogram, or reported in American standard code for information interchange (ASCII) format numerically as total activity counts per epoch.

2. Basic Rifle Marksmanship

Objective evaluation of rifle marksmanship skill was made based on "record fire" score. During a BCT record fire, recruits are given an M16/M4 series rifle and 40 rounds of ammunition and presented with 40 timed target exposures at ranges from 50 to 300 meters. Twenty targets are engaged with 20 rounds from the prone supported position, ten targets are engaged with ten rounds from the prone unsupported position, and ten targets are engaged with ten rounds from the kneeling position—while wearing a helmet and load-bearing equipment. The standard is to obtain at least 23 target hits on the 40 targets exposed. Recruits complete a practice record fire on days 29 and 30 of BCT and an official record fire on day 32 of BCT, for a total of three sequential record fires (Directorate Basic Combat Training Doctrine and Training Development, 2008, March).

3. General Technical Aptitude

Objective evaluation of individual aptitude was made based on General Technical (GT) score as derived from the Armed Services Vocational Aptitude Battery (ASVAB). The ASVAB is a 216-item inventory containing nine separately timed subtests: General

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Science, Arithmetic Reasoning, Word Knowledge, Paragraph Comprehension, Auto and Shop, Mathematics Knowledge, Mechanical Comprehension, Electronics Information, and Assembling Objects. The ASVAB is not an intelligence test, but rather, is specifically designed to measure an individual's aptitude to be trained in specific jobs. GT score is a composite of the Arithmetic Reasoning, Word Knowledge, and Paragraph Comprehension subtests, and it is often a major determinant of the occupational specialties that a person can be considered for in the military.

4. Personality

A personality assessment was accomplished using the Neuroticism-Extroversion-Openness Five-Factor Inventory (NEO-FFI) (Costa & McCrae, 1992). The NEO-FFI is essentially a short form of the Revised NEO Personality Inventory (NEO-PI-R). It consists of 60 items from the NEO-PI-R that are used to score the five domains: (a) neuroticism, (b) extraversion, (c) openness, (d) agreeableness, and (e) conscientiousness. It does not contain the items for assessing the facets within each domain. The NEO-FFI is designed for use in circumstances in which time is too limited to present the entire NEO-PI-R or only scores on the five domains are required (Weiner & Greene, 2008).

5. Resilience

Assessment of resilience to stress was accomplished using the Response to Stressful Experiences Scale (RSES) (Johnson, Polusny, Erbes, King, Litz, Schnurr, Friedman, and Southwick, 2008). The RSES was developed by researchers with the National Center for Post Traumatic Stress Disorder (PTSD) to rate psychological traits that promote resilience, whih is the ability to undergo stress and still retain mental health and well-being. It consists of 22 items and identifies six factors that are keys to psychological resilience: (a) positive outlook, (b) spirituality, (c) active coping, (d) self-confidence, (e) learning and making meaning, and (f) acceptance of limits. The RSES has been tested on more than 1,000 active-duty military personnel (Naval Center for Combat and Operational Stress Control, 2009).

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6. Sleep Habits

Subjective assessments of sleep habits were made using three validated survey instruments. The first instrument is the Pittsburgh Sleep Quality Index (PSQI), a self-rated questionnaire designed to measure sleep quality in clinical populations by looking at a 1-month long interval. Nineteen individual items generate the following seven scores: (a) subjective sleep quality, (b) sleep latency, (c) sleep duration, (d) habitual sleep efficiency, (e) sleep disturbances, (f) use of sleeping medications, and (g) daytime dysfunction. A review of this survey's reliability asserted that the PSQI is useful to both psychiatric clinical practice and research activities (Buysse, Reynolds, Monk, Berman, and Kupfer, 1989).

The second instrument was the Epworth Sleepiness Scale (ESS) (Johns, 1991), an 8-item scale commonly used to diagnose sleep disorders and considered a valid and reliable self-report of sleepiness. Participants use a number from 0 to 3, corresponding to the likelihood (never, slight, moderate, and high, respectively) that they would fall asleep in eight situations such as sitting and reading, watching TV, as a passenger in a car for an hour, etc. Ratings above 10 out of a possible 24 are cause for concern with respect to an underlying sleep disorder.

The third instrument was the Morningness-Eveningness Questionnaire (MEQ) published by Horne and Ostberg (1976), which contains 19 questions aimed at determining when, during the daily temporal span, individuals have the maximum propensity to be active. Most questions are preferential, in the sense that the respondent is asked to indicate when they would prefer, rather than when they actually do, wake up or begin sleep. Questions are multiple-choice and each answer is assigned a value such that their sum gives a score ranging from 16 to 86, with lower values corresponding to evening types.

7. Study Questionnaire

The study questionnaire contained ten questions aimed at potential covariates that could influence study outcome measures. Four questions asked participants for their age,

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gender, height, and weight. One question asked participants to quantify their frequency of exercise during the preceding month, both in terms of the number and duration of exercise sessions. Another question asked whether participants regularly used firearm(s) and, if so, to characterize the type of firearm(s), reason(s) for use, and frequency of use. Three questions addressed use of caffeinated beverages, tobacco, and medications. Lastly, one question asked participants to quantify the amount of sleep per day they required to feel ready to start the day.

D. PROCEDURES

1. General

Prior to beginning the study, each participant received a full briefing on the purposes of the study and assurances about the confidentiality of the data. Once informed consent was obtained, each participant completed the study questionnaire followed by the ESS, PSQI, MEQ, RSES, and NEO-FFI (see Table 1). All performance evaluations were conducted by the BCT military cadre. For each participant, data were collected on general technical aptitude, basic rifle marksmanship, and physical fitness scores from preexisting local databases. Attritions were determined from training company graduation rosters.

Table 1. Schedule for data-generating events.

	Week								
↓Data Event	1	2	3	4	5	6	7	8	9
Actigraphy	X	X	X	X	X	X	X	X	X
Basic Rifle Marksmanship					X				
ESS	X								
MEQ	X								
NEO-FFI	X								
PSQI	X								
RSES	X								
Study Questionnaire	X								

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2. Actigraphy

Participants were issued an Actiwatch® on Day 1 in order to track sleep/activity rhythms in a relatively unobtrusive fashion. Participants were asked to wear the Actiwatch® continuously on the wrist of their nondominant hand during all awake and sleeping periods, and not to remove it for bathing. The Actiwatch® was collected from each participant during Week 4 (intervention group) or Week 5 (comparison group) for downloading of data and reinitialization of the data collection mode. Once the data collection period was complete, the data were taken back to the laboratory and, using Actiware® version 5.57.0006 software, scored for sleep times and graphed.

3. Statistical Analysis

Microsoft® Office Excel® 2007 was used to develop the study database; histograms of the actigraphy data were created using the Analysis ToolPak add-in. Data from this study were analyzed using SPSS® (IBM® Company, Chicago, Illinois) version 10.0. All data were assessed for normalcy, and parametric and nonparametric approaches were used accordingly for descriptive statistical analyses. Linear mixed effects models were used to describe relationships between response variables of interest and covariates in the data when observations were hierarchically grouped according to *platoon* and *recruit within platoon*. Mixed effects models in this study were produced using version 3.3.1 of the nlme library with S-Plus® (TIBCO Software, Inc., Palo Alto, California) version 8.0.4 running on a Windows XP platform. The approach used to fit and assess the linear mixed effects models was as described in Pinheiro and Bates (2000).

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III. RESULTS

A. PARTICIPANTS

The overall study population was composed of 394 recruits and instructor cadre, with 209 in the intervention group and 185 in the comparison group. Within each group, recruits were assigned to one of four platoons whose military cadre was responsible for recruit instruction and performance evaluation. What follows is limited to the subsample of 95 recruits, 53 in the intervention group and 42 in the comparison group, randomized to wear Actiwatches®. Due to unexplained technical difficulties, data were not recorded on Actiwatches® given to one recruit in the comparison group. Consequently, this recruit's other data were censored in the subsequent analysis, thereby leaving us with a study sample of 94 recruits. Across the study sample, on average 83.8 (standard deviation 9.6; range 36-92) recruits had a valid Actiware® score for any given day of BCT. A one-way analysis of variance (ANOVA) was used to compare the number of recruits per day with a valid Actiware® score by week of training. Overall, there was a significant difference by week ($F_{8,52} = 3.205$, $p = 0.005$), but Bonferroni post-hoc tests showed that this difference was only between Week 2 (mean 90.7 recruits) and Week 9 (mean
73.4 recruits).

Recruits' responses on the study questionnaire and survey instruments are summarized in Tables 2-4 by treatment condition, that being either assignment to the intervention or comparison group. Figures 1-3 display histograms for a select subset of questions from the PSQI, asking recruits about their baseline sleep schedule. Overall, the intervention and comparison groups were comparable on practically all measured variables. The only statistically significant difference between the groups was in the percentage of those using firearms who reported using a rifle. All the recruits in the intervention group who reported using firearms used a rifle, while slightly more than half of those in the comparison group did so. There was also a tendency for recruits in the intervention group to have a higher body mass index (i.e., body weight corrected for

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height) than those in the comparison group, but this difference was not statistically significant. Likewise, there was a tendency for a greater proportion of recruits in the intervention group to be in the National Guard/Reserves, as compared to the comparison group, but this difference was also not statistically significant.

Table 2. Summary of intervention and comparison study groups.

Variable	Group: Intervention	Group: Comparison	*p*-value
Age (yrs), median (IQR)	19 (18-23)	20 (18-24)	0.320^{M}
Body mass index ($kg \cdot m^{-2}$), median (IQR)	25.1 (22.2-27.8)	23.1 (21.4-26.0)	0.074^{M}
Body mass index category, no. (%)			
Underweight	1 (1.9)	1 (2.4)	0.232^{V}
Normal	24 (45.3)	27 (65.9)	
Overweight	18 (34.0)	9 (22.0)	
Obese	10 (18.9)	4 (9.8)	
Caffeine			
Consume caffeinated beverages, no. (%)	35 (66.0)	20 (48.8)	0.092^{C}
Caffeine use ($mg \cdot d^{-1}$), median (IQR)	164 (108-288)	144 (72-305)	0.327^{M}
Component, no. (%)			
National Guard/Reserve	30 (56.6)	16 (39.0)	0.091^{C}
Regular	23 (43.4)	25 (61.0)	
ESS			
Total score, mean (SD)	7.94 (3.15)	7.44 (3.51)	0.473^{T}
Excessive fatigue (score > 10), no. (%)	9 (17.0)	7 (17.1)	0.991^{C}
Exercise frequency ($hrs \cdot wk^{-1}$), median (IQR)	2.0 (1.4-4.2)	3.0 (1.4-6)	0.226^{M}
Firearms			
Regularly use firearm, no. (%)	11 (20.8)	7 (17.1)	0.653^{C}
Type of firearm, no. (%)			
Rifle	11 (100)	4 (57.1)	0.043^{F}
Handgun	4 (36.4)	4 (57.1)	0.630^{F}
Use of firearm, no. (%)			
Hunting	7 (63.6)	3 (42.9)	0.630^{F}
Sport shooting	8 (72.7)	4 (57.1)	0.627^{F}
Other	0 (0)	2(28.6)	0.137^{F}

^{C}Chi square statistic, ^{F}Fisher's Exact Test, ^{M}Mann-Whitney U, ^{T}Student's *t*-test, ^{V}Cramer's V.
Notes: IQR = interquartile range; SD = standard deviation.

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Table 3. Summary of intervention and comparison study groups (continued).

Variable	Group: Intervention	Group: Comparison	*p*-value
Firearms (continued)			
Frequency of use (days·yr^{-1}), median (IQR)	30 (20-45)	45 (25-50)	0.340^{M}
Gender, no. (%)			
Female	20 (37.7)	15 (36.6)	0.909^{C}
Male	33 (62.3)	26 (63.4)	
GT score, median (IQR)	108 (96-116)	110 (99-121)	0.354^{M}
MEQ			
Total score, mean (SD)	50.6 (8.9)	47.2 (9.7)	0.086^{T}
Chronotype, no (%)			
Evening type	11 (20.8)	15 (36.6)	0.226^{C}
Neither type	31 (58.5)	20 (48.8)	
Morning type	11 (20.8)	6 (14.6)	
NEO-FFI			
Neuroticism, median (IQR)	52 (44-56)	51 (46-63)	0.706^{M}
Extraversion, mean (SD)	53.5 (11.5)	54.1 (9.0)	0.786^{T}
Openness to experience, mean (SD)	50.7 (12.6)	49.7 (11.1)	0.683^{T}
Agreeableness, mean (SD)	45.4 (11.4)	43.7 (11.4)	0.495^{T}
Conscientiousness, median (IQR)	46 (42-59)	48 (41-53)	0.359^{M}
PSQI			
Global score, mean (SD)	6.3 (2.5)	6.71 (2.8)	0.468^{T}
Poor sleep quality (score > 5), no. (%)	32 (60.4)	28 (68.3)	0.428^{C}
Component scores, median (IQR)			
Subjective sleep quality	1 (1-1)	1 (1-2)	0.147^{M}
Sleep latency	2 (1-4)	2 (1-3)	0.745^{M}
Sleep duration	0 (0-1)	0 (0-1)	0.504^{M}
Habitual sleep efficiency	0 (0-0)	0 (0-0)	0.211^{M}
Sleep disturbances	1 (1-2)	1 (1-2)	0.114^{M}
Use of sleeping medication	0 (0-0)	0 (0-0)	0.699^{M}
Daytime dysfunction	1 (0-1)	1 (0-1)	0.378^{M}

^{C}Chi square statistic, ^{F}Fisher's Exact Test, ^{M}Mann-Whitney U, ^{T}Student's *t*-test.
Notes: IQR = interquartile range; SD = standard deviation.

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Table 4. Summary of intervention and comparison study groups (continued).

Variable	Group: Intervention	Group: Comparison	*p*-value
Rank, no (%)			
E01	18 (34.0)	16 (39.0)	0.759[C]
E02	20 (37.7)	12 (29.3)	
E03	12 (22.6)	9 (22.0)	
E04	3 (5.7)	4 (9.8)	
RSES			
Global score, mean (SD)	68.3 (12.0)	65.1 (13.0)	0.233[T]
Factor scores, median (IQR)			
Positive appraisal	7.6 (6.1-8.3)	6.8 (6.2-8.5)	0.819[M]
Spirituality	2.9 (2.9-3.8)	2.9 (2.9-3.8)	0.716[M]
Active coping	8.7 (10.2-11.9)	10.2 (8.4-11.5)	0.778[M]
Self-efficacy	3.2 (2.4-3.2)	2.4 (2.4-3.2)	0.778[M]
Learning and meaning-making	7.2 (5.0-8.0)	6.5 (5.4-8.3)	0.310[M]
Acceptance of limitations	4.3 (3.5-5.6)	4.3 (3.5-5.6)	0.816[M]
Tobacco			
Regularly use tobacco, no (%)	22 (41.5)	15 (36.6)	0.628[C]
Frequency of use (cigs·wk^{-1}), median (IQR)	49 (19-101)	35 (8-105)	0.577[M]

[C]Chi square statistic, [F]Fisher's Exact Test, [M]Mann-Whitney U, [T]Student's *t*-test.
Notes: IQR = interquartile range; SD = standard deviation.

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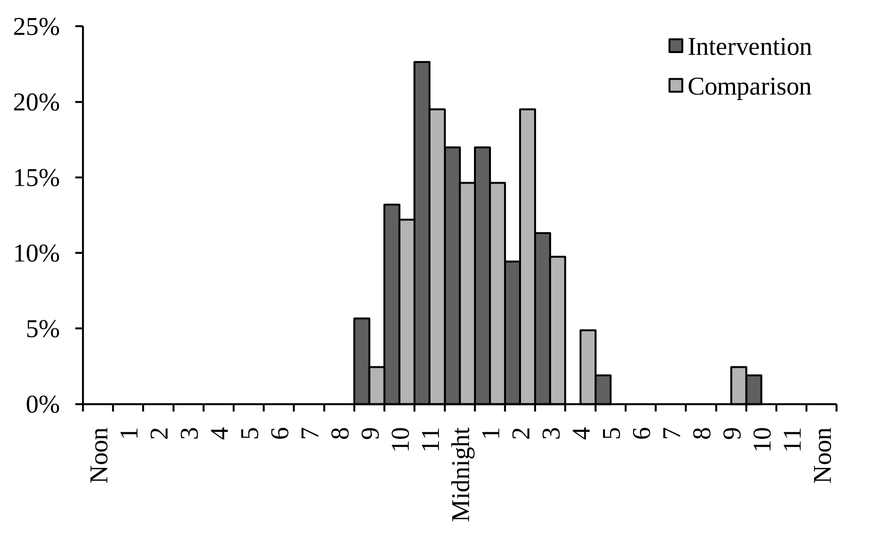

Figure 1. Histogram of recruits' reported usual bed time (PSQI question 1).

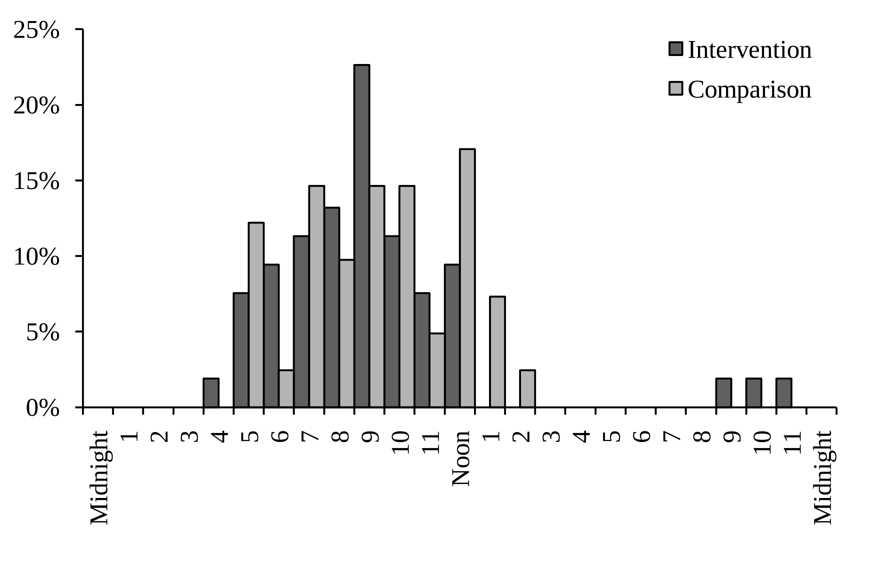

Figure 2. Histogram of recruits' reported usual getting up time (PSQI question 3).

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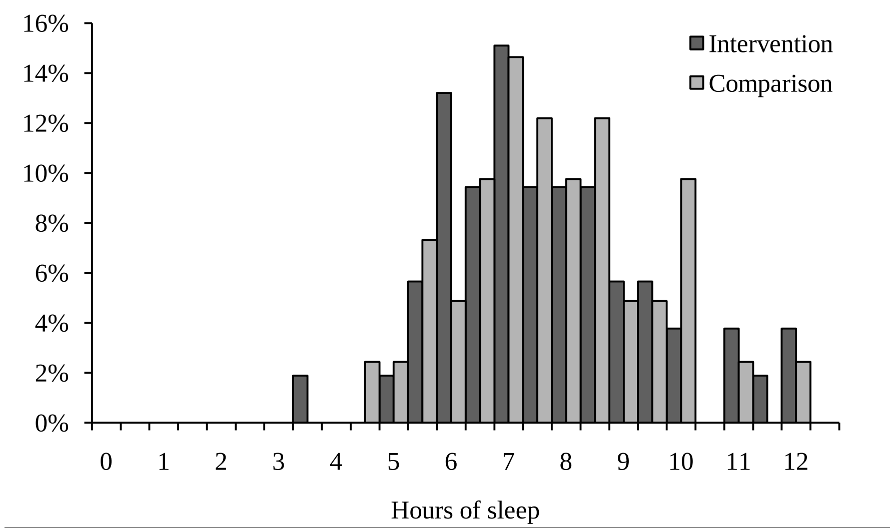

Figure 3. Histogram of recruits' reported hours of sleep per night (PSQI question 4).

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B. TOTAL SLEEP TIME

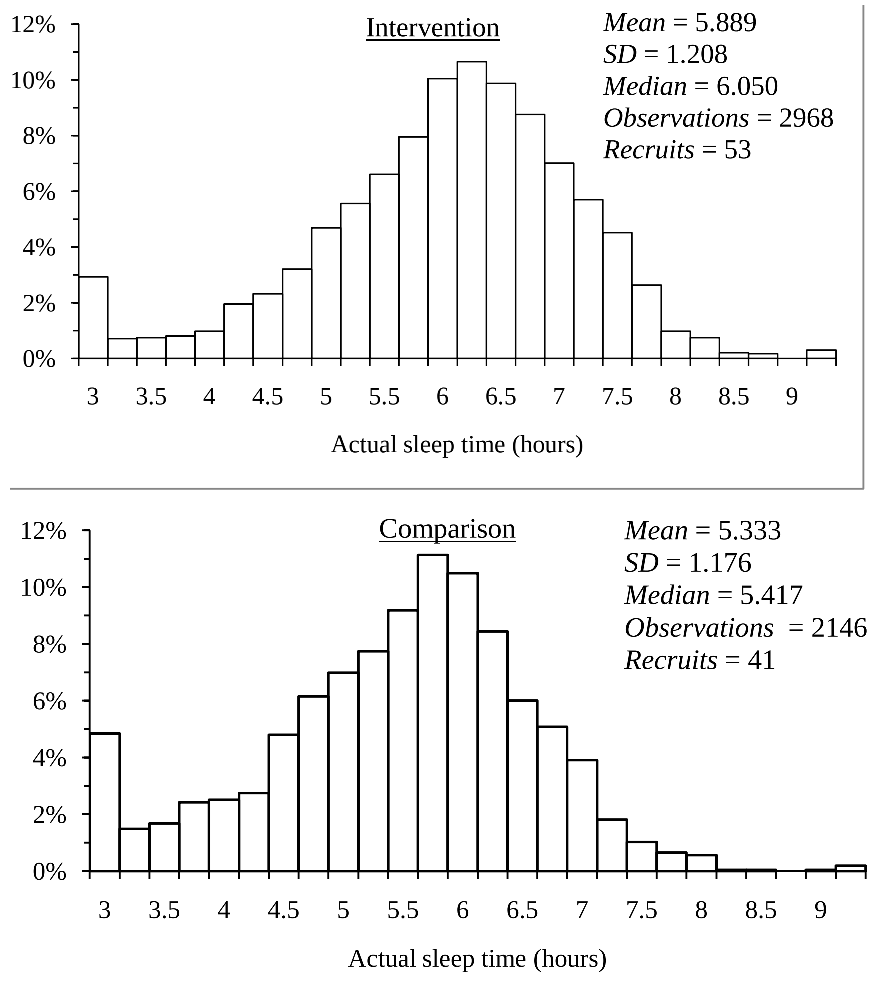

Figure 4. Histograms of all total daily sleep observations by study group.

Figure 4 shows the distribution and distributional parameters for daily total sleep time for all sleep observations gathered during BCT, according to the study group. The spike at 3 hours in both histograms was believed to be attributable to recruits performing night watch duties. The median total sleep obtained per night across all weeks of BCT was significantly greater for recruits in the intervention vice comparison study group (intervention group mean rank = 2,884.0; comparison group mean rank = 2,105.9; $p < 0.001$ based on Mann-Whitney test). The National Sleep Foundation recommends that adults obtain 7-9 hours of sleep per night. In this study sample, 15.5% of sleep observations in the intervention group satisfied the recommendation versus only 4.6% in the comparison group—a significant difference ($\chi_1^2 = 152.282$, $p < 0.001$). Restated

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another (i.e., public health) way, the odds ratio of an episode of total daily sleep being less than the National Sleep Foundation's recommendation was 3.802 (95% CI 3.037-4.761) for the comparison group relative to the intervention group.

It was also of interest to examine how daily total sleep related to the intervention condition, while accounting for covariates and week of training. Since we were really interested in Army recruits in general, rather than this specific sample of recruits, recruit was considered a random effect. Additionally, to account for the hierarchical nesting of a recruit within a platoon, the following linear mixed effects model was estimated:

$$Y_{ijt} = \alpha + \mathbf{X}_{ijt}\boldsymbol{\beta} + \gamma \mathrm{COND}_i + \sum_{t=2}^{9} \nu_t WEEK_t + b_i + b_{ij} + \varepsilon_{ijt}$$

$$i = 1, \ldots, 8, \quad j = 1, \ldots, 94, \quad t = 1, \ldots 9$$

$$b_i \sim N(0, \sigma_1), \quad b_{ij} \sim N(0, \sigma_2), \quad \varepsilon_{ijt} \sim N(0, \sigma),$$

where *i* indexes platoons, *j* indexes recruits, and *t* indexes weeks. Y_{ijt} is the response variable representing the average daily sleep for each recruit during each time period. α is the regression intercept (which is also the conditional mean of *Y*), $\mathbf{X}_{ijt}$ is the matrix of observed characteristics that influence *Y*, and $\boldsymbol{\beta}$ is the vector of slopes associated with the variables in $\mathbf{X}_{ijt}$. $COND_i$ is an indicator variable that equals 1 if platoon *i* was using the modified sleep schedule and 0 otherwise, $WEEK_t$ is an indicator variable that equals 1 if the measurement is from week *t* (*t* > 1) and 0 otherwise, and γ and υ_t are coefficients to be estimated. b_i is a random variable that is specific to platoon *i* and reflects the shared traits of the recruits within platoon *i*. Similarly, b_{ij} is a random variable that is specific to recruit *j* in platoon *i* and captures the correlation among observations within a platoon-recruit combination. ε_{ijt} is a random variable that is unique to each recruit and time period and, therefore, represents an independent and identically distributed (i.i.d.) random error term.

Based on a restricted maximum likelihood (REML) fit of the model, and using a *p*-value of less than 0.05 as a threshold for keeping covariates in the model, the final

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model included *Age*, *Gender*, and *RSES* in the $\mathbf{X}\boldsymbol{\beta}_{ijt}$ term. The conditional *F*-tests for the factors and covariates in the model were as follows:

- *Intercept* (α): $F_{1,5011} = 9563.292$, $p < .001$
- *Age*: $F_{1,84} = 5.663$, $p = 0.020$
- *Condition (COND)*: $F_{1,6} = 25.555$, $p = 0.002$
- *Gender*: $F_{1,84} = 5.663$, $p = 0.020$
- *RSES*: $F_{1,5011} = 5.605$, $p = 0.018$
- *Week*: $F_{8,5011} = 103.162$, $p < 0.001$

Table 5 provides results for the REML estimates of the model parameters as well as associated standard errors and *p*-values, as determined from the conditional *t*-tests. The REML estimates, with 95% confidence intervals, for the random effects parameters were:

$$\hat{\sigma}_1 = 0.128\ (0.051, 0.321), \quad \hat{\sigma}_2 = 0.307\ (0.255, 0.370), \quad \hat{\sigma} = 1.062\ (1.041, 1.083).$$

It appears that σ and σ_2 were estimated relatively precisely, whereas σ_1 can vary by a factor of three.

Table 5. Estimates for total daily sleep model parameters.

Analysis Variable	Estimate
Age	–0.019** (0.008)
Gender (male is reference category)	0.135* (–0.007)
RSES	–0.007** (0.003)
Time (week 1 is reference category)	
Week 2	0.027 (0.061)
Week 3	0.140** (0.061)
Week 4	0.094 (0.063)
Week 5	0.013 (0.063)

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Week 6	–0.600*** (0.062)
Week 7	0.340*** (0.063)
Week 8	–0.910*** (0.064)
Week 9	–0.918*** (0.069)
Condition	0.577*** (0.116)
Intercept	6.295*** (0.265)

*$p \leq 0.10$, **$p \leq 0.05$, ***$p \leq 0.01$
Note: Standard errors in parentheses.

Overall, recruits in the intervention condition obtained approximately 0.6 hours more sleep, despite the fact that all recruits were provided identical length sleep intervals in their respective schedules. There was a small age effect, with younger recruits tending to obtain more sleep than older recruits. However, there was no significant interaction between age and intervention condition. There was also a small resilience effect with increasing resilience being associated with decreasing daily sleep. Finally, recruits tended to get between 0.5 to 1.0 hours less sleep during the latter half of training.

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C. SLEEP EFFICIENCY

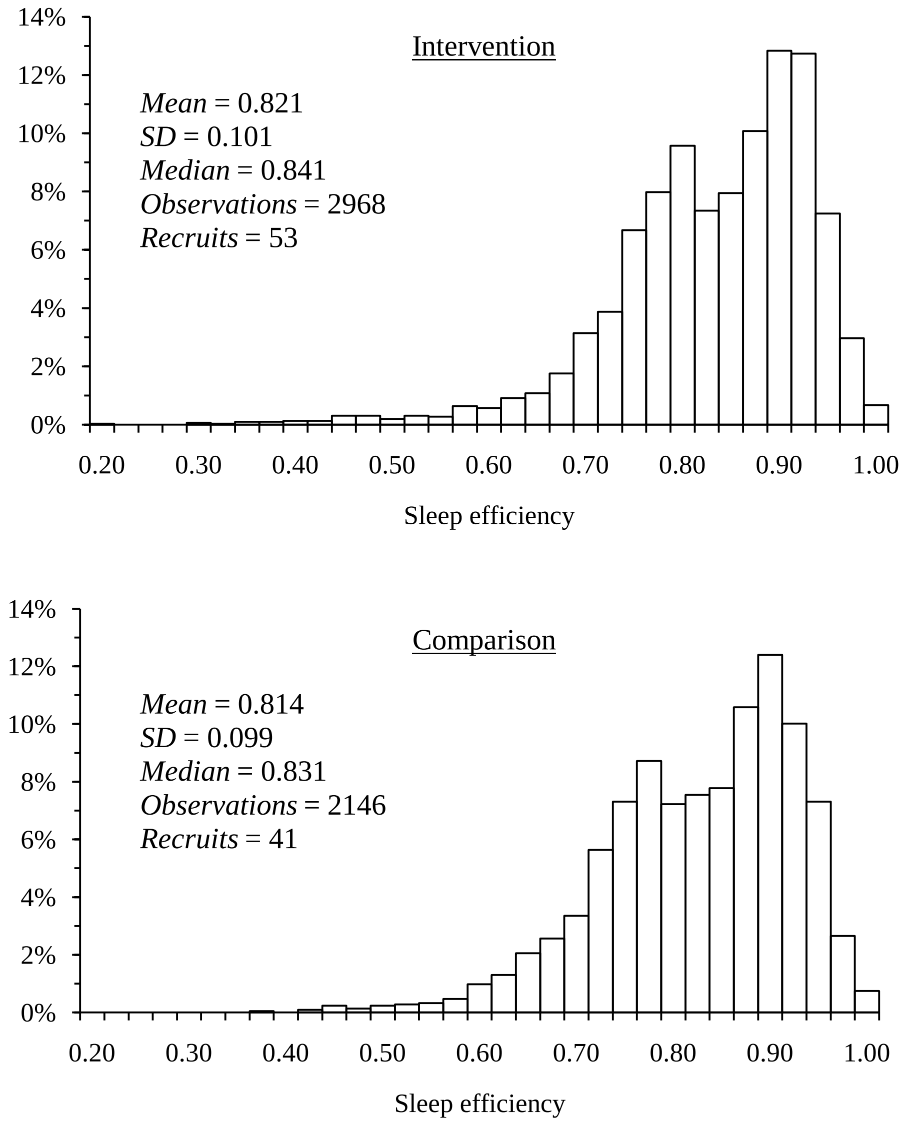

Figure 5. Histograms of sleep efficiency for all sleep observations by study group.

Sleep efficiency was calculated as the ratio of a recruit's total sleep time to total time in bed; it represents the proportion of time that a recruit was assumed to be "in bed" or attempting sleep that was actually spent asleep (Paquet, Kawinska, & Carrier, 2007). Figure 5 shows the distribution and distributional parameters for sleep efficiency for all sleep observations gathered during BCT, according to the study group. The median sleep efficiency across all weeks of BCT was significantly greater for recruits in the intervention vice comparison study group (intervention group mean rank = 2,614.3;

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comparison group mean rank = 2,479.0; $p < 0.001$ based on Mann-Whitney test). Nevertheless, the practical significance of a difference in median sleep efficiency of 0.010 is questionable. However, the histograms suggest that the distributions of sleep efficiency for the two study groups are different. This impression was investigated further by estimating the population moments using the sample k^{th} moments (see Table 6). While the 95% confidence intervals overlapped for the first and second moments, there was a significant difference in the third and fourth moments, which are functions of the distributions' skewness (i.e., symmetry) and kurtosis (i.e., peakedness), respectively.

Table 6. Population moment estimates based on sample k^{th} moments.

k^{th} moment	Intervention Group		Comparison Group	
	Estimate	95% CI	Estimate	95% CI
First	0.821	(0.817, 0.825)	0.814	(0.810,0.818)
Second	0.684	(0.678, 0.690)	0.672	(0.666, 0.679)
Third	0.577	(0.571, 0.584)	0.562	(0.555, 0.570)
Fourth	0.492	(0.485, 0.499)	0.476	(0.467, 0.484)

Note: CI = confidence interval.

D. ACTIVITY COUNTS DURING SLEEP

Activity counts reflect movements during sleep and may be a function of the stage of sleep (Monk, Buysse, & Rose, 1999). Figure 6 shows the distribution and distributional parameters for mean activity counts for all sleep observations gathered during BCT, according to the study group. The median mean activity count during sleep across all weeks of BCT was significantly less for recruits in the intervention vice comparison study group (intervention group mean rank = 2,504.8; comparison group mean rank = 2,630.4; $p < 0.001$ based on Mann-Whitney test). However, the histograms appear quite similar, so as in the analysis of the sleep efficiency data, population moments were estimated for each distribution using the k^{th} sample moments. It was found that the 95% confidence intervals overlapped for the first four moments of each sample distribution, thereby suggesting that the observed distributions do not significantly differ. See Figure 6 below.

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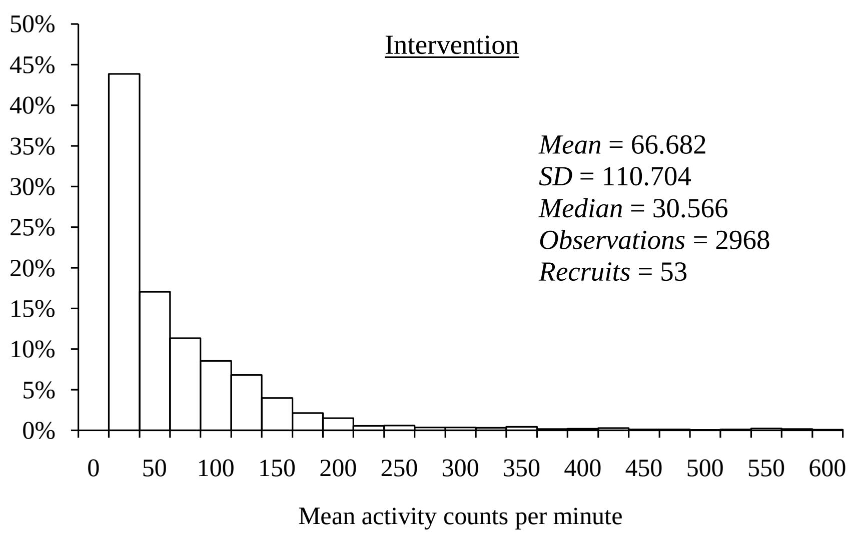

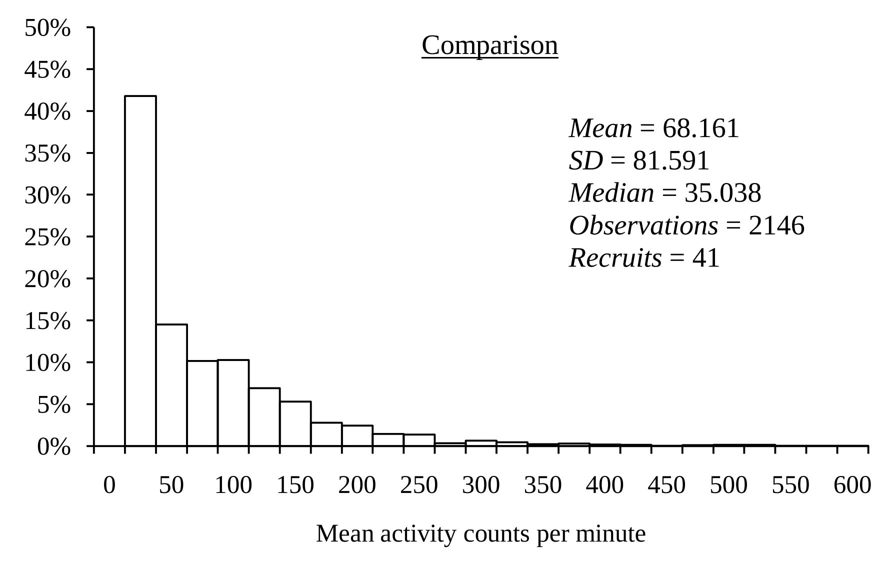

Figure 6. Histograms of mean activity counts for all sleep observations by study group.

E. RELATIONSHIP BETWEEN TOTAL SLEEP AND PERFORMANCE

Given that basic marksmanship fundamentals are taught during the week prior to the practice and official record fires, the average daily total sleep during both the week prior to ($Week_{t-1}$) and the week of ($Week_t$) the record fires were of interest. Actigraphically-measured sleep during $Week_{t-1}$ and $Week_t$ were entered into a correlational analysis with performance on the record fires. Several measures of

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performance on the record fires were considered: maximum score ($score_{max}$), average score, ($score_{avg}$), and difference score ($score_{diff}$), with the latter calculated as the difference between the first practice record fire and the official record fire, and reflecting a learning effect. There was a significant, albeit weak positive, correlation between average daily total sleep during $Week_{t\text{-}1}$ and $score_{diff}$ (Spearman's $\rho = 0.349$, $p = 0.001$). Likewise, there was a similar significant and weak positive correlation between average daily total sleep during $Week_t$ and $score_{diff}$ ($\rho = 0.214$, $p = 0.049$). There were no correlations between average daily total sleep during either $Week_{t\text{-}1}$ or $Week_t$ and $score_{max}$ or $score_{avg}$. Finally, a strong correlation was noted between average daily total sleep during $Week_{t\text{-}1}$ and $Week_t$ ($\rho = 0.729$, $p < 0.001$), suggesting that recruits' sleep habits were stable over the period of interest.

Figures 7 and 8 show the distributions and distributional parameters for $score_{diff}$, according to study group. The median $score_{diff}$ was significantly larger for recruits in the intervention vice comparison study group (intervention group mean rank = 2,758.0; comparison group mean rank = 1,247.0; $p < 0.001$ based on Mann-Whitney test). The two distributions appear quite different, with that of the intervention group appearing much more leptokurtic relative to the distribution of the comparison group.

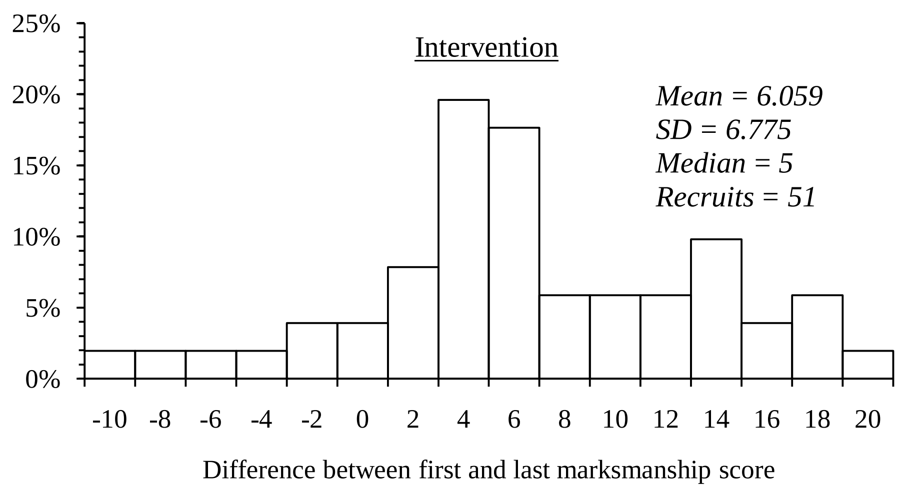

Figure 7. Histogram of the difference between recruits' marksmanship scores on the first and last record fire for the intervention study group.

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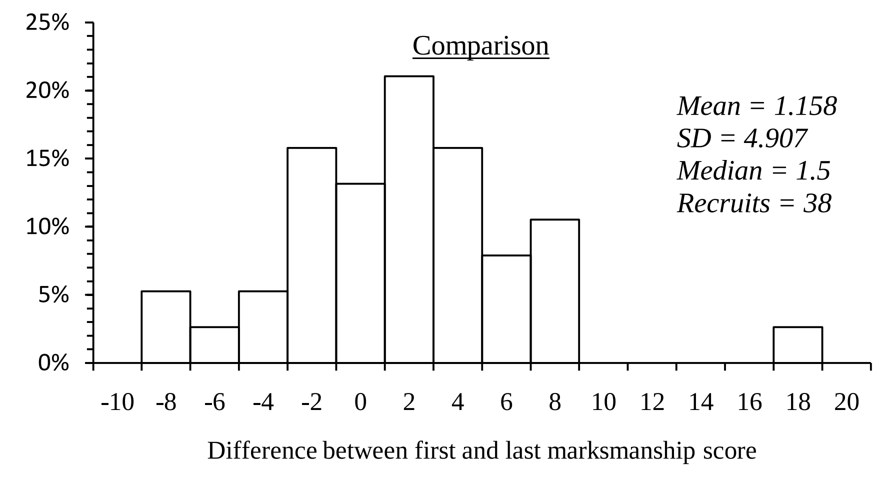

Figure 8. Histogram of the difference between recruits' marksmanship scores on the first and last record fire for the comparison study group.

A repeated measures analysis of covariance (ANCOVA) was then used to further examine the change in performance between the recruits' first and last recorded marksmanship scores during the record fires. For this analysis, the within subjects factor was *Time* and the between subject factors were *Group* (intervention versus comparison), $Week_{t-1}$, and *Firearm* (regularly used firearms prior to BCT). The results of the repeated measures ANCOVA are shown in Table 7. There was no significant within subject effect of *Time*, but there were significant *Time* x *Firearm* and *Time* x *Group* interactions. The estimated marginal means and standard errors for the *Time* x *Group* interaction are shown in Figure 8. It appears that marksmanship performance of the comparison study group was better on the first record fire, but the intervention study group exhibited greater learning such that there was no significant difference between the study groups on the last record fire. Since marksmanship performance was assessed using a post-only study design relative to implementation of the sleep schedule intervention, one must be cautious when interpreting the pattern observed in Figure 9. For example, one interpretation is that the intervention study group was relatively disadvantaged as compared to the comparison group at baseline, thereby suggesting that the interaction effect is, in fact, a selection-regression bias (i.e., regression to the mean phenomenon). However, given that the intervention study group surpassed, rather than approached, the comparison group's final score—which is to say there is a crossover pattern—suggests

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that this is not a selection-regression result (Trochim, 2001). Moreover, average daily total sleep during the week prior to the record fires was a significant between subject effect, thereby confirming the hypothesized mechanism of action. It is also worth noting that the effect size of $Week_{t-1}$ was greater than that of *Firearm*, suggesting that improved sleep had an equivalent effect as prior experience with a firearm. Finally, the fact that *Group* was not a significant between subject effect, suggests that leadership or cadre instructional differences are not likely explanations for the observed pattern.

Table 7. Results of the repeated measures ANCOVA for marksmanship scores.

Variable	Mean Square	*F*	df	*p*	η^2
Within Subjects Effects:					
Time	18.645	1.120	1	0.293	0.014
Time x *Firearm*	66.673	4.006	1	0.049	0.047
Time x *Group*	153.995	9.252	1	0.003	0.103
Time x $Week_{t-1}$	42.548	2.556	1	0.114	0.031
Error	16.644		81		
Between Subject Effects:					
Intercept	1,552.964	36.493	1	<0.001	0.311
Firearm	135.473	3.183	1	0.078	0.038
Group	35.824	0.842	1	0.362	0.010
$Week_{t-1}$	167.892	3.945	1	0.050	0.046
Error	42.555		81		

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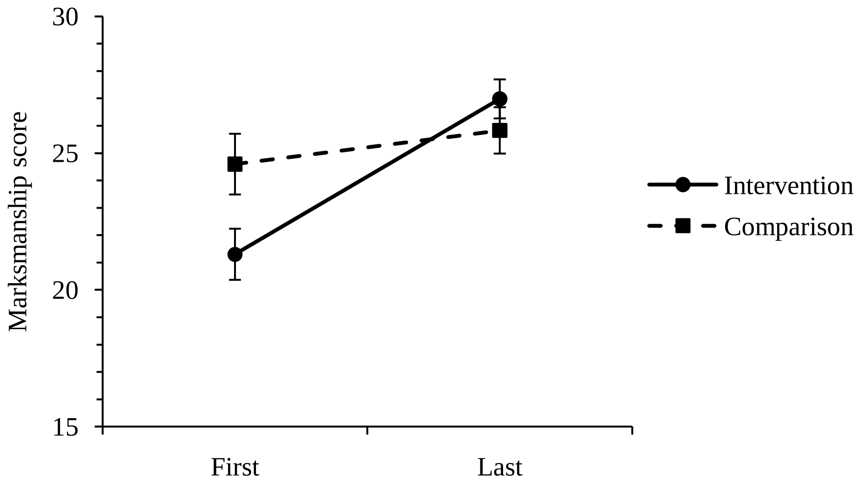

Figure 9. Plot of estimated marginal means for the first and last record fires.

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IV. DISCUSSION

The primary objective of this study was to obtain actigraphic measurements of sleep in a sample of recruits during military training, and to use that data to demonstrate the relationship between sleep scheduling and military performance. The present study yielded several important outcomes:

1. As demonstrated by Killgore and colleagues (2008), actigraphy-based objective measurement of sleep can be obtained successfully and unobtrusively within military-relevant environments.
2. Using actigraphic measurements of sleep, it was evident that changing the timing of sleep so as to make scheduled sleep periods physiologically conducive to sleeping resulted in recruits obtaining significantly more total daily sleep.
3. Increasing average total daily sleep during education/training of basic marksmanship skills was associated with greater improvements in subsequent marksmanship performance.

Together, these findings provide preliminary support for the redesign of sleep/rest cycles in the basic military training setting. These results also demonstrate the importance of adequate sleep during the learning and practice of new military-relevant skills.

This study reaffirmed the results of several other studies that have shown that sleep deprivation is prevalent in military training and education programs. The average daily sleep for recruits in this study was within the range of 5-6 hours reported by Killgore and colleagues (2008) and Miller and colleagues (2008) for other military training/education settings. This is significantly less than the 7-9 hours recommended by the National Sleep Foundation (http://www.sleepfoundation.org). Moreover, only 11% of over 5,000 observed sleep episodes in this study met the minimum recommended 7 hours of sleep per day. This suggests that the sleep habits of recruits while attending BCT is generally below what is considered adequate for the long-term health of normal adults. This is important given that poor sleep is related to a variety of health and performance problems (Miller et al., 2008). Thus, the potential consequences of chronic,

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inadequate sleep in terms of physical health, training effectiveness, and overall readiness of the force are issues that should be considered in the design and implementation of future BCT training schedules.

This study also adds to the existing literature on sleep in military training and education settings by demonstrating that daily sleep can be increased simply by altering the timing of sleep periods. Given that the traditional population of military recruits is comprised mainly of adolescents or young adults in their early twenties (e.g., the median age of this study population was 19-20 years of age), it is important to recognize that the biologically-driven sleep patterns of this age group differ from those of more mature adults with delayed bedtimes, later awakenings, and longer sleep periods (Carskadon et al., 1997, 1998; Wolfson & Carskadon, 2003). This study attempted to accommodate the phase delay typically observed in adolescent sleep patterns by delaying the scheduled sleep period during training by 2.5 hours. Based on actigraphic measurements of sleep, delaying the scheduled sleep period resulted in recruits obtaining, on average, an extra 35 minutes of sleep per night. This was accomplished without lengthening the scheduled sleep period, thereby requiring no change in the content or length of the recruits' training program. Additionally, in terms of moderating personal characteristics, a small age and gender effect was observed, with younger recruits and females tending to obtain more sleep.

While there is a robust literature on the importance of sleep in terms of physical health, well-being, and performance (Krueger, 1990; Moldofsky, 1995; Belenky et al., 2003; Van Dongen et al., 2003; Killgore, Balkin, & Wesensten, 2006), it was of interest in this study to examine whether the amount of sleep obtained during military training was meaningfully related to a specific training-related performance measure. Marksmanship was chosen because it was expected to be somewhat sensitive to the effects of fatigue (Tharion, Shukitt-Hale, & Lieberman, 2003, McLellan et al., 2005) and it is a major focus area of Army BCT. The analysis of marksmanship performance turned out to be far from straightforward given differences between training companies in initial performance on the first record fire and variability in the number of record fires accomplished by each recruit. Despite all this variability, however, it was possible to

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demonstrate that the degree of improvement in marksmanship performance over the serial record fires was significantly predicted, in part, by a sleep-related variable. It is noteworthy that sleep during the week preceding the record fires, when basic marksmanship tasks and subtasks were being learned, was more strongly correlated with subsequent performance than sleep during the week of the record fires. This suggests the possibility that sleep was acting as a modifier of training effectiveness. The authors believe this finding reflects improved sleep-mediated memory consolidation during the learning of basic marksmanship skills. This explanation is consistent with the scientific literature (as summarized in Miller et al., 2008) suggesting that learning and retention of information is reduced by sleep deprivation. Moreover, the effect size of sleep, while relatively small, was still greater than that attributable to prior experience with firearms.

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V. CONCLUSION

This study was conducted to determine if adjusting scheduled sleep periods to better complement age-specific, biologically-driven sleep patterns would improve sleep and performance in Army recruits completing BCT. Analysis of actigraphic measures of sleep and activity found that a 2.5-hour, phase-delayed sleep schedule did indeed improve sleep relative to the standard BCT schedule, resulting in more than 30 minutes of extra sleep per night. Besides schedule, personal factors, such as age and gender, influenced recruits' average total daily sleep, with younger and female recruits tending to obtain more sleep. While the schedule modification was shown to be efficacious in improving sleep, increased nightly sleep during the training of marksmanship skills was shown to result in greater improvements over subsequent serial marksmanship performance assessments. Hence, schedule modifications that improve sleep can be expected to result in improved marksmanship performance during BCT. Importantly, such benefits may be obtained with no change to the content or length of the training program, nor are investments required in any new technologies or facilities.

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