Effects of Age and Military Service on Strength and Physiological Characteristics of U.S. Army Soldiers

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ABSTRACT Soldiers must maintain tactical performance capabilities over the course of their career. Loss in physical readiness may be a function of age and the operational demands associated with increasing years of service. The purpose of this study was to assess strength and physiological characteristics in different cohorts of U.S. Army Soldiers based on years of service and age. A total of 253 Soldiers (age: 28.1 ± 6.8 years; height: 1.76 ± 0.11 m; mass: 84.1 ± 12.2 kg) participated. Individual subject cohorts were created based on years of service (1–5 years, 6–10 years, 11–15 years) and age (20–24 years, 25–29 years, 30–34 years, 35–39 years, 40–44 years). Testing included shoulder, knee, ankle, and torso strength, aerobic capacity/lactate threshold, anaerobic power/capacity, and body composition/total mass. Those with 11 to 15 years of service and between ages 30 and 34 had a higher percentage of body fat, and lower aerobic capacity and lactate threshold than younger Soldiers with fewer years of service. Physical training interventions should focus on maintenance of physiological characteristics to offset the loss of readiness at the similar time point of 11 to 15 years of service and 30 to 34 years of age.

INTRODUCTION

A career in the armed forces is demanding given the high operational tempo and wide spectrum of mission requirements. Service members must maintain a high level of physical readiness to meet the operational demands.[1,2] Although service members are a diverse cohort,[3–5] those with the same military occupational specialty are required to complete similar training and operational tasks despite differences in age and years of military service.[6–8]

Changes in aerobic fitness because of age have been well documented in the civilian population. As age increases, maximum heart rate decreases,[9–12] reducing maximum cardiac output during exercise.[13] The resulting decline in maximal oxygen consumption[9,11,14] is nonlinear,[15,16] with an accelerated deterioration after 45 to 50 years old.[15,17] Power and strength decreases are also nonlinear,[18,19] with power decreasing by 3% per decade from ages 24 to 50 and a 7% decline per decade from ages 50 to 74.[20] Brown, et al[14] measured a 0.048 watt per kilogram decline per year when exercising at maximum aerobic capacity, demonstrating the decline in power produced at maximal effort as age increases.

Ageing results in decreased in cardiorespiratory fitness and increased body fat,[16] and these deficits are of particular concern to service members in physically demanding military occupational specialty that are compounded by other external factors. The weight added by basic protective equipment alone is enough to decrease maximum aerobic capacity by 50% and increase overall caloric expenditure by 20%.[21] Previous research has also found decreased aerobic fitness after deployment[22–24] and decreased anaerobic power after as little as 72 hours of sustained operational training.[25,26] Deployment has been associated with increased body mass, fat mass, and percentage of body fat,[22] with small strength gains[22,24] as Soldiers self-select strength exercises more frequently than aerobic conditioning.[23,24,27] Although these changes because of deployment and training are relatively small, they may be amplified by age-related physiological changes. If there is insufficient dwell time to rest, recover, and retrain between deployments and sustained operational training, these effects may become permanent.[23]

Strength and physiological characteristics such as aerobic and anaerobic capacity are essential to performance of military tasks. The relationship between these characteristics, age, and years of military service are unknown. The purpose of this study was to assess strength and physiological characteristics in different cohorts of U.S. Army Soldiers based on years of service and age. We hypothesized that older Soldiers and those with more years of service would have a poorer physical and physiological profiles than their younger, less experienced counterparts.

METHODS

PARTICIPANTS

A total of 253 male Soldiers from the Army 101st Airborne Division (Air Assault) were recruited to participate in this study (age: 28.1 ± 6.8 years; height: 1.76 ± 0.11 m; mass: 84.1 ± 12.2 kg). Human subject's approval was obtained from the respective civilian and military Institutional Review Boards.

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Study Design

This study is a cross-sectional cohort design comparing groups of Soldiers based on years of service (1–5 years, 6–10 years, 11–15 years) and age (20–24 years, 25–29 years, 30–34 years, 35–39 years, 40–44 years). All testing was performed at the University of Pittsburgh Human Performance Research Center at Fort Campbell, Kentucky. Testing was performed on two separate days, with at least 24 hours between test days.

Instrumentation and Procedures

Body composition (percent body fat: %BF) was measured using a BOD POD Body Composition System (Cosmed, Italy). The BOD POD uses air displacement plethysmography to measure body volume and calculate body density. This has been shown to be a reliable (intraclass correlation coefficient [ICC] = 0.98–0.996) and valid (standard error of measurement [SEM] = 0.47% BF) method of measuring body composition[28] in heterogeneous samples across a variety of populations.[29–31] The system was calibrated using the manufacturer recommended two-point calibration before each test. Subjects were tested according to the manufacturer's protocol and as previously reported.[32]

Bilateral isokinetic strength of the knee flexors/extensors, shoulder internal/external rotators, and torso rotators were measured using the Biodex Multi-Joint System 3 Pro (Biodex Medical Systems, Shirley, New York). Isokinetic dynamometry has been shown to be highly reliable (knee flexion: ICC = 0.93–0.98, knee extension: ICC = 0.96–0.97, shoulder internal and external rotation: ICC = 0.784–0.798, trunk rotation: ICC = 0.89–0.906) and a valid measure of the strength of the primary movers in each of these ranges of motion.[28,33–36] Subjects were positioned and stabilized according to the manufacturer's guidelines, ensuring proper alignment for testing and restricting accessory movements. The subject then performed three practice trials at 50% maximal effort and three warm-up trials at maximal effort, followed by 1 minute of rest. Peak isokinetic torque was then recorded across five maximal effort repetitions (concentric/concentric at 60° per second) and reported normalized to percent body weight. Strength ratios were calculated to compare agonist–antagonist strength of knee flexion to extension, shoulder external to internal rotation, and left to right torso rotation.

Anaerobic power and capacity were measured using an electronically braked Velotron cycling ergometer (Racermate, Seattle, Washington) during a Wingate protocol. This has been shown to be a valid.[37,38] and reliable (ICC = 0.91) measure of an individual's ability to perform short-term, high intensity exercise.[28] The Velotron was calibrated according to factory recommendations, and the seat and handle bars were adjusted to fit each subject. After warming up at a self-selected pace, subjects pedaled at 125 W for 20 seconds, and then performed a maximal effort sprint for 30 seconds against a braking torque of 9% body weight. This protocol has been previously reported.[28] Anaerobic power was reported as the peak watts normalized to body weight during the first 5 seconds of the test, and anaerobic capacity was reported as the average watts normalized to body weight produced during the entire 30 seconds.

Aerobic capacity (VO_{2max}) and lactate threshold were measured during an incremental treadmill protocol using a portable metabolic system (Oxycon Mobile; Viasys, San Francisco, California), heart rate monitor (Polar USA, Lake Success, New York), and lactate analyzer (Arkray, Inc., Kyoto, Japan). These systems are valid measurement tools,[28,39] and were calibrated according to factory specifications before each test. Subjects performed a warm-up at a self-selected pace on the treadmill for 5 minutes before testing. The modified incremental protocol used a constant speed and a 2.5% increase in grade at the end of each 3 minute stage until volitional fatigue.[28,40] Treadmill speed was set at 70% of the mile pace from the subject's most recent Army Physical Fitness Test 2-mile run time.[28] Aerobic capacity was normalized to body weight (mL/kg/min) to evaluate differences in aerobic fitness between subjects. Blood lactate levels were collected via finger stick at rest, in the last minute of the warm-up and each 3 minute test stage, immediately upon test termination, and 3 minutes after test completion. Lactate threshold (the inflection point where blood lactate increased nonelinearly) was reported in relation to absolute value of oxygen consumption (VO_2), and the relative values of percentage of VO_{2max} and heart rate at lactate threshold.

Statistical Analysis

Shaprio-Wilk and Levene's tests were used to determine normality of sample distribution and homogeneity of variance respectively. For normally distributed variables, one-way analysis of variance (ANOVA) and Tukey's post-hoc procedures were used to determine differences between age and years of service groups. For variables with significant Shapiro–Wilk tests, a Kruskal–Wallis ANOVA was used to determine differences between groups. For those with significant Levene's tests, an ANOVA with planned comparisons and adjusted p values were used. All statistical measures were obtained using IBM SPSS Statistics for Windows (Version 21, IBM Corp., Armonk, NY). Statistical significance was set at $p < 0.05$.

RESULTS

Descriptive data for each age cohort are presented in Table I. There were no significant differences for height or mass between age cohorts ($p > 0.05$). Physiological data for the age cohort are presented in Table II. Soldiers aged 30 to 34 had more body fat than Soldiers aged 20 to 24 ($p = 0.005$) and 25 to 29 ($p = 0.012$). Aerobic capacity (VO_{2max}) was higher in 20 to 24 year olds than 30 to 34 year olds ($p = 0.041$), 35 to 39 year olds ($p = 0.047$) and 40 to 44 year olds ($p = 0.041$). Although there was no change in the percentage

TABLE I. Descriptive Statistics by Age

Age	n	Age (Years)		Experience (Years)		Height (cm)*		Weight (kg) No.	
		Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
20–24	77	21.13	1.35	3.83	1.36	176.98	7.55	80.82	12.10
25–29	79	26.61	1.29	5.96	2.54	178.12	7.13	86.11	11.43
30–34	45	31.53	1.50	9.69	2.63	177.4	6.31	85.43	13.70
35–39	19	36.79	1.62	10.58	3.34	176.2	7.21	86.33	8.22
40–44	21	42.1	1.76	12.81	1.57	175.15	9.33	83.34	12.54

*No significant differences between age cohorts ($p > 0.05$).

of VO_{2max} at which lactate threshold occurred, the absolute value of VO_2 at lactate threshold decreased with age: VO_2 at lactate threshold was higher in 25 to 29 year olds than 30 to 35 year olds ($p = 0.0207$). Heart rate at lactate threshold was significantly greater in those age 20 to 24 than those age 40 to 44 ($p = 0.035$). The overall analysis for anaerobic capacity was significant ($p = 0.01$), but there were no significant post-hoc comparisons. No significant strength differences existed for knee flexion, knee extension, shoulder internal rotation, shoulder external rotation, torso rotation, right knee flexion/extension ratio, left and right shoulder external rotation/internal rotation ratio, or torso rotation ratio ($p > 0.05$). The overall analysis for left knee flexion/extension ratio was significant ($p = 0.035$), but there were no significant post-hoc comparisons.

Descriptive data for each years of service cohort are presented in Table III. There were no significant differences for height or mass between the years of service cohorts ($p > 0.05$). For physiological data (Table IV), Soldiers with 1 to 5 years of experience had lower body mass index (BMI) than those with 11 to 15 years of service ($p = 0.023$).

TABLE II. Results Summary by Age

	20–24		25–29		30–34		35–39		40–44	
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
Physiological Data										
Body Fat (%)[a]	18.79	7.26	19.26	7.55	23.32	7.67	24.52	5.31	21.61	5.63
BMI	25.82	3.48	27.38	3.62	27.42	3.93	27.82	2.02	27.82	2.51
HR_{max} (bpm)	191.99	9.05	187.35	9.18	188.43	7.03	184.41	8.64	179.42	8
VO_{2max} (mL/kg/min)[b]	48.73	6.33	48.07	7.22	45.11	6.41	43.65	4.76	43.07	6.88
VO_2 at LT (mL/kg/min)[c]	39.06	6.28	40.07	6.61	36.35	5.56	36.23	4.38	37.09	6.23
LT (%VO_{2max})	80.33	9.04	83.37	6.53	80.82	7.11	83.17	7.73	86.25	6.56
HR at LT (bpm)[d]	170.86	12.82	170.04	11.55	166.78	9.34	165.76	9.6	164.63	8.31
%HR_{max} at LT	89.01	5.39	90.76	4.38	88.55	4.39	89.94	4.38	91.81	3.74
Anaerobic Power (w/kg)	13.29	1.92	14.07	2.13	13.43	1.89	13.05	2.19	12.99	1.51
Anaerobic Capacity (w/kg)	7.84	0.93	7.97	1.17	7.57	0.95	7.43	0.82	7.46	0.92
Strength Data*										
Left Knee Flexion (%BW)	113.06	27.75	114.52	26.11	115.84	22.75	109.79	21.94	109.49	27.53
Right KF (%BW)	115.49	26.66	120.52	26.36	112.87	26.62	116.15	20.92	115.09	22.57
Left KE (%BW)	229.81	43.67	228.74	45.36	231.62	43.8	208.75	34.28	204.04	46.78
Right KE (%BW)	241.67	48.92	238.68	49.37	243.41	45.92	223.93	40.78	224.58	44.19
Left KF:KE Ratio	0.49	0.08	0.5	0.09	0.51	0.08	0.53	0.09	0.55	0.12
Right KF:KE Ratio	0.48	0.08	0.51	0.08	0.47	0.09	0.53	0.08	0.52	0.07
Left Shoulder IR (%BW)	54.61	16.02	55.63	15.22	56.64	15.14	53.14	13.36	57.82	15.84
Right Shoulder IR (%BW)	60.82	14.95	61.35	14.4	62.79	14.8	57	12.93	59.18	17.1
Left Shoulder ER (%BW)	38.61	7.21	37.54	8.07	37.35	8.29	35.86	6.31	35.99	7.56
Right Shoulder ER (%BW)	42.99	8.61	41.69	8.69	41.89	8.62	39.35	7.26	38.49	7.7
Left Shoulder ER:IR Ratio	0.74	0.16	0.7	0.15	0.68	0.11	0.69	0.12	0.64	0.12
Right Shoulder ER:IR Ratio	0.73	0.16	0.69	0.12	0.68	0.1	0.7	0.1	0.67	0.12
Left TR (%BW)	150.18	37.47	157.75	29.56	154.15	31.99	144.52	25.79	153.65	38.35
Right TR (%BW)	149.99	34.43	156.21	30.26	155.57	33.15	144.87	22.13	153.69	36.04
Left:Right TR Ratio	1.01	0.12	1.02	0.12	1	0.11	1	0.11	1	0.1

BMI, body mass index; VO_2, aerobic capacity; VO_2max, maximum aerobic capacity; LT, lactate threshold; HR, heart rate in beats per minute; HR_{max}, maximum heart rate; KE, knee extension; KF, knee flexion; IR, internal rotation; ER, external rotation; TR, trunk rotation. Physiology data. [a]Body fat higher in Soldiers aged 30 to 34 compared to 20 to 24 ($p = 0.005$) and 25 to 29 ($p = 0.012$). [b]Aerobic capacity (VO_{2max}) was higher in 20 to 24 year olds than 30 to 34 year olds ($p = 0.041$), 35 to 39 year olds ($p = 0.047$) and 40 to 44 year olds ($p = 0.041$). [c]VO2 at LT was higher in 25 to 29 year olds than 30 to 35 year olds ($p = 0.0207$). [d]Heart rate at LT was significantly greater in those age 20 to 24 than those age 40 to 44 ($p = 0.035$) Strength data. *No significant differences between age cohorts for knee, shoulder, or torso strength ($p > 0.05$).

TABLE III. Descriptive Statistics by Years of Experience

		Experience (years)		Age (years)		Height (cm)*		Weight (kg)*	
Years	n	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD
1–5	123	3.53	1.08	23.68	3.42	177.36	7.60	82.95	12.88
6–10	67	7.63	1.23	28.46	3.89	177.02	7.62	84.91	10.88
11–15	63	12.49	0.95	36.51	5.77	176.49	7.79	85.49	11.99

*No significant differences between age cohorts ($p > 0.05$).

Soldiers with 1 to 5 ($p < 0.001$) and 6 to 10 years ($p = 0.016$) of service both had significantly less body fat than those with 11 to 15 years of service. Soldiers with 1 to 5 ($p < 0.001$) and 6 to 10 ($p < 0.001$) years of service had higher VO_{2max} than those with 11 to 15 years of service. Lactate threshold was also higher in those with 1 to 5 years of service compared to the 11 to 15 years of service group ($p = 0.017$). Heart rate at lactate threshold was significantly greater in those with 1 to 5 years of service than those with 11 to 15 years of service ($p = 0.012$). Left knee flexion/extension ratio was significantly lower in the 1 to 5 years of service compared to the 6 to 10 years of service group, and both the 1 to 5 and 6 to 10 years of experience groups had lower ratios than the 11to 15 years of service group ($p < 0.001$ for all three comparisons). Left and right shoulder internal/external rotation strength ratios were significantly

TABLE IV. Results Summary by Years of Experience

	1–5		6–10		11–15	
	Mean	±SD	Mean	±SD	Mean	±SD
Physiological Data						
Body Fat (%)[a]	19.11	7.43	20.48	7.72	23.25	5.73
BMI[b]	26.48	3.82	27.08	3.50	27.86	2.83
HR_{max} (bpm)	190.54	9.16	186.77	8.33	185.35	9.89
VO_{2max} (mL/kg/min)[c]	48.37	6.94	47.31	6.85	44.04	5.69
VO_2 at LT[d]	39.45	6.53	38.76	6.30	36.79	5.22
$\%VO_{2max}$ at LT	81.71	8.10	82.01	7.24	83.73	7.56
HR at LT[e]	171.15	11.35	167.32	11.85	166.78	9.61
$\%HR_{max}$ at LT	89.85	4.73	89.58	4.82	90.08	4.59
Anaerobic Power (w/kg)	13.42	1.80	13.69	2.12	13.49	2.14
Anaerobic Capacity (w/kg)	7.84	0.92	7.79	1.15	7.62	1.03
Strength Data						
Left KF (%BW)	112.92	27.03	113.31	24.18	113.57	24.50
Right KF (%BW)	116.54	27.44	114.56	23.27	117.06	24.55
Left KE (%BW)	230.17	45.92	224.59	39.41	215.97	45.07
Right KE (%BW)	244.44	52.04	230.78	39.60	233.53	43.07
Left KF:KE Ratio*	0.49	0.08	0.51	0.08	0.53	0.10
Right KF:KE Ratio	0.48	0.08	0.50	0.08	0.51	0.08
Left Shoulder IR (%BW)	54.60	16.07	58.01	14.01	54.39	13.95
Right Shoulder IR (%BW)	60.18	15.32	63.83	13.99	58.98	13.33
Left Shoulder ER (%BW)	38.30	7.86	37.29	7.70	36.09	6.61
Right Shoulder ER (%BW)	42.43	9.12	41.62	7.85	39.85	7.59
Left Shoulder ER:IR Ratio#	0.73	0.15	0.66	0.14	0.68	0.01
Right Shoulder ER:IR Ratio#	0.73	0.14	0.66	0.11	0.69	0.11
Left TR (%BW)	151.32	33.57	157.97	35.35	150.86	31.19
Right TR (%BW)	152.20	31.48	154.14	35.94	152.02	29.75
Left:Right TR Ratio	1.00	0.11	1.04	0.13	1.00	0.11

BMI, body mass index; VO_2, aerobic capacity; VO_2max, maximum aerobic capacity; LT, lactate threshold; HR, heart rate in beats per minute; HR_{max}, maximum heart rate; KE, knee extension; KF, knee flexion; IR, internal rotation; ER, external rotation; TR, trunk rotation. Physiology Data. [a]Soldiers with 1 to 5 ($p < 0.001$) and 6 to 10 years ($p = 0.016$) of service both had significantly less body fat than those with 11 to 15 years of service. [b]Soldiers with 1 to 5 years of experience had lower BMI than those with 11 to 15 years of service ($p = 0.023$). [c]Soldiers with 1 to 5 ($p < 0.001$) and 6 to 10 ($p < 0.001$) years of service had higher VO_{2max} than those with 11 to 15 years of service. [d]LT was higher in those with 1 to 5 years of service compared to the 11 to 15 years of service group ($p = 0.017$). [e]Heart rate at LT was significantly greater in those with 1 to 5 years of service than those with 11 to 15 years of service ($p = 0.012$) Strength Data. *Left knee flexion/extension ratio was significantly lower in the 1 to 5 years of service compared to the 6 to 10 years of service group, and both the 1 to 5 and 6 to 10 years of experience groups had lower ratios than the 11 to 15 years of service group ($p < 0.001$ for all three comparisons) #Left and right shoulder internal/external rotation strength ratios were significantly greater in those with 1 to 5 years of experience compared to those with 6 to 10 years of experience (Left: $p = 0.001$, Right: $p = 0.007$).

greater in those with 1 to 5 years of experience compared to those with 6 to 10 years of experience (left: $p = 0.001$, right: $p = 0.007$). There were no significant strength differences for knee flexion, knee extension, shoulder internal rotation, shoulder external rotation, torso rotation, or torso rotation ratio ($p > 0.05$).

DISCUSSION

Older Soldiers and those with more years of service demonstrated poorer physiological characteristics, with large declines occurring at the similar time period of age 30 to 34 and 11 to 15 years of service. Most Soldiers enlist in the Army between ages 19 and 21,[5] meaning that a 30-year-old Soldier likely has 11 years of service. Those with 11 to 15 years of service and between ages 30 and 34 had a higher percentage of body fat, and lower maximum heart rate, aerobic capacity, and lactate threshold than younger soldiers with fewer years of service. Strength ratios at the knee and shoulder were significantly different across the experience groups, indicating that strength ratios may be more sensitive to change than discrete strength measures.

Although the Department of Defense's goal is to allow a service member twice the amount of recovery time as deployment time, the ratios of deployment to dwell time during Operation Iraqi Freedom and Operation Enduring Freedom were closer to 1:1.[41] This lack of recovery and retraining time may explain why older soldiers and those with more years of service had a larger decrement in performance variables than would expected in a civilian or younger population. Changes in aerobic capacity in civilian athletes have been attributed largely to declines in HR_{max},[42] which decreases at approximately 0.7 to 1 beat/min/year.[10,12,43] This steady decline is similar to that observed between age and experience groups in the present study. Astrand's classic study of maximal oxygen uptake and age reported a 7% decline in HR_{max} over the 20-year observation period[9]; nearly identical to the 6.7% decrease in HR_{max} between soldiers age 20 to 24 and those age 40 to 44.

Aerobic capacity decreases in a nonlinear pattern among civilian athletes, with large decreases in VO_{2max} measured after age 45 to 50,[15,17,20,44], unlike in this sample, where a large decrease occurred at age 30 to 34. These results are similar to those of Giovannetti, et al[45], who observed no significant change in estimated VO_{2max} until age 30 to 39 in members of the U.S. Air Force; with a large drop in aerobic capacity after age 30 and a steady decline continuing through age 50 and over. This decline in VO_{2max} may be due in part to increased body fat in older and more experienced Soldiers, as previous research has shown that men who are able to maintain lean body mass are more likely to see smaller declines in aerobic capacity[42] and cardiorespiratory fitness.[15] The absolute declines in HR_{max} and VO_{2max} observed here resulted in lower heart rate and VO_2 at lactate threshold: with no significant difference in percentage of maximum heart rate or percentage of VO_{2max} at lactate threshold, lower maximal values for these variables mean that the absolute values at lactate threshold must be lower as well.

Despite similarities in age-related changes in HR_{max} and body composition between civilian athletes and Soldiers, the combined effects of operational stress and deployment likely result greater decrements in in aerobic capacity in this cohort. Soldiers with fitness deficiencies must exert a larger percentage of their maximum effort when performing work related tasks, accelerating fatigue and potentially increasing risk for injury.[28,46,47] Studies of injury rates in Soldiers identify decreased aerobic capacity,[3,7,24,45–49] higher BMI[4,48,50] and increased percentage of body fat[28,49] as risk factors for injury development. Therefore, the decrease in aerobic capacity and increase in body fat observed in Soldiers of 30 to 34 years of age and with 11 to 15 years of service in this study are especially concerning for risk of injury.

Although it was statistically significant, left knee flexion to extension ratio only increased by 0.04 between the 1 to 5 and 11 to 15 years of service groups, and this measure was approximately 0.50 for all age and experience groups on the left and right knees. This is well below the 0.60 hamstring to quadriceps strength ratio recommended for ligamentous and muscular injury prevention.[51] Soldiers from all age and experience groups could benefit from a hamstring strengthening program. Bilateral shoulder internal to external rotation strength ratios were statistically higher in soldiers with 1 to 5 years of service compared to those with 6 to 10 years of service; however, the means for both of these groups (left: 0.73 ± 0.14 vs. 0.66 ± 0.14; right: 0.72 ± 0.14 vs. 0.66 ± 0.11) are within the normative range identified by Ellenbecker et al[52] of 0.66 to 0.75.

CONCLUSION

Changes in strength and physiological characteristics occurred at younger ages in this cohort of Army personnel than has been observed in the civilian population. Although the exact reasons for the early decline in aerobic capacity and increased body fat are not completely clear, they may be because of the cumulative effects of operational training and deployment. Strength findings in this study suggest that muscle balance is more sensitive to small changes than individual muscle measures; therefore, human performance staff should use strength ratios to monitor possible strength decrements across a Soldier's tactical lifecycle. Physical training interventions for force protection have been effective,[53–56] and the results of this study indicate that these efforts should focus on Soldiers age 30 to 34, particularly for those with more years of service.

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