The Influence of Agility Training on Physiological and Cognitive Performance

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Abstract

Lennemann, LM, Sidrow, KM, Johnson, EM, Harrison, CR, Vojta, CN, and Walker, TB. The influence of agility training on physiological and cognitive performance. *J Strength Cond Res* 27(12): 3300–3309, 2013—Agility training (AT) has recently been instituted in several military communities in hopes of improving combat performance and general fitness. The purpose of this study was to determine how substituting AT for traditional military physical training (PT) influences physical and cognitive performance. Forty-one subjects undergoing military technical training were divided randomly into 2 groups for 6 weeks of training. One group participated in standard military PT consisting of calisthenics and running. A second group duplicated the amount of exercise of the first group but used AT as their primary mode of training. Before and after training, subjects completed a physical and cognitive battery of tests including $\dot{V}O_2$max, reaction time, Illinois Agility Test, body composition, visual vigilance, dichotic listening, and working memory tests. There were significant improvements within the AT group in $\dot{V}O_2$max, Illinois Agility Test, visual vigilance, and continuous memory. There was a significant increase in time-to-exhaustion for the traditional group. We conclude that AT is as effective or more effective as PT in enhancing physical fitness. Further, it is potentially more effective than PT in enhancing specific measures of physical and cognitive performance, such as physical agility, memory, and vigilance. Consequently, we suggest that AT be incorporated into existing military PT programs as a way to improve war-fighter performance. Further, it seems likely that the benefits of AT observed here occur in various other populations.

Key Words traditional linear training, Illinois Agility Test

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27(12)/3300–3309

Journal of Strength and Conditioning Research

Introduction

Functional fitness has recently been championed for its military relevance (23) and has gained much traction in the combat athlete community as evidenced by the creation and implementation of the Marine Corps Combat Fitness Test. In addition, functional training has been included in military physical training (PT) programs like those of the 720th Special Tactics Training Squadron at Hurlburt Field, FL, USA. Functional training is task or occupation specific and for the combat athlete includes a great deal of agility training (AT). Not surprisingly, specific foot-speed and agility drill training improves performance in agility tests (14). Conversely, traditional linear or "nonskilled" exercise, such as jogging or running, does not seem to benefit agility (33). Anecdotally, AT programs also improve performance in the combat environment. In a study by Harman et al. (15), subjects who exercised with agility and cardiovascular training significantly improved performance on combat relevant tests such as load carrying, obstacle courses, and casualty rescue compared with those who exercised with calisthenics and aerobics alone.

In addition to the physical benefit of AT, it may also improve cognitive performance. In animal studies, both running and agility exercise increase hippocampal neurogenesis (31), resulting in improved spatial navigation and memory. Agility exercise also results in synaptogenesis in the motor cortex (16,17) and cerebellum (1,6,18,19) whereas running alone may not (6,17–19). The ability of AT to positively affect a number of regions of the brain may influence cognitive function.

The human literature also supports a relationship between fitness and cognition. The review of 11 studies by Angevaren et al. (3) showed that aerobic exercise benefited cardiovascular performance and cognitive function in healthy older adults. Effects were observed for motor function, cognitive speed, delayed memory functions, and auditory and visual attention. Studies that have examined the link between physical fitness and cognition in children (8,10) and young adults (30) have reached similar conclusions. Interestingly, recent studies have found that strength or resistance training can also improve aspects of cognition (2,22). Therefore, we intend to explore the possibility that a related aspect of physical fitness, such as agility, can influence cognitive performance.

Such evidence suggests that engaging in AT may be more effective in enhancing physical and cognitive performance than engaging in traditional military PT. The objective of this study was to determine how AT influenced physical and cognitive performance as compared with traditional PT. Second, we wished to determine if AT may be effectively substituted for PT in a military setting although still offering the same cardiovascular benefits that PT provides.

Methods

Experimental Approach to the Problem

Each subject completed a 2.5-hour baseline testing session before 6 weeks of training. The tests included the following: (a) body composition; (b) physical fitness tests including a 10–12 minutes incremental treadmill run for maximal oxygen uptake ($\dot{V}O_2max$), the Illinois Agility Test (IAT), and a Makoto reaction time test; (c) a cognitive test battery that included dichotic listening, continuous memory, and visual vigilance tests.

After the pretest, subjects were randomly placed in either the PT or AT group. Subjects neither were allowed to select their group nor were they allowed to move between groups. Each training program was 3 days per week for 6 weeks. The progression of the training mimicked that of a training plan recently adapted by the 720th Special Tactics Training Squadron.

All subjects were asked to keep their physical activity level stable throughout the training period and to log any additional workouts completed outside their respective training group. The PT group was instructed to refrain from activities/sports that included rapid change of direction (e.g., basketball) for the duration of the study, although they could run linearly as much as they desired. The AT group was not given any other exercise restrictions. Activity logs were reviewed at the conclusion of the protocol to ensure adherence with this policy.

Immediately after the 6 weeks of training, subjects completed a test battery identical to the one completes before the training. Each subject was posttested in the same location and at the same time of day and same day of the week as their pretest. Results of these tests were analyzed to detect pretraining to posttraining changes.

Subjects

Forty-five US Air Force School of Aerospace Medical technical training students aged 18–34 signed institutional review board informed consent documents before beginning the study. Forty-one subjects (29 male, 16 female) completed the study in its entirety.

Technical training students all live in a community dormitory, eat at a community mess hall, and follow the same daily schedule. These students had all graduated from the 8.5-week Basic Military Training course at Lackland Air Force Base (AFB). Data collection was performed at the Air Force Research Laboratory at Brooks City-Base, Texas, just 14 km from Lackland AFB. The 6 weeks of training was conducted at the Base Fitness Center at Brooks City-Base, Texas.

Procedures

The following physiological tests were chosen to serve as metrics of exercise-induced changes in body composition, cardiorespiratory endurance, and agility-like skills.

Body Composition. Subjects' body composition (percent fat and lean muscle mass) was measured using a dual energy X-ray Analysis Lunar Prodigy scanner by General Electric.

Cardiorespiratory Endurance. $\dot{V}o2max$, running economy, and time to exhaustion (TTE) protocols were conducted on a Woodway DESMO treadmill (Woodway USA, Waukesha, WI, USA). Each subject was fitted with a harness and a facemask to collect expired air for the Parvo Medics' TrueOne 2400 metabolic measurement system (Consentius Technologies, Sandy, UT, USA). Subjects wore a Polar heart rate monitor transmitter (Polar Electro, Inc., New York, NY, USA) around the chest to measure heart rate (HR) response throughout the warm-up, test and recovery phases of the protocols. After a 1-minute rest period to verify transmitter communication, subjects performed a 2-minute walk at 2.0 mph and 0% grade. Upon completion of the 2-minute walk, treadmill speed increased to 6.0, 6.5, or 7.0 mph, depending on the self-reported fitness level of each subject. This speed and grade was maintained for 3 minutes to test running economy. After that stage, speed was maintained although the grade increased by 2% increments every minute until it reached a 10% grade, after which it increased by 1% each minute until it reached a 15% grade or until subjects reached volitional fatigue. Time to volitional fatigue indicated the TTE score (in seconds) and ends the test. The treadmill's speed slowed to a 2.0 mph pace at 0% grade to induce active recovery until the subject's HR dropped below 120 $b \cdot min^{-1}$.

Illinois Agility Test. The IAT measured the subjects' ability to turn and accelerate in different directions at different angles. Subjects ran a course marked by 4 cones, measuring 10 m in length by 5 m wide. The cones were used to mark the start, finish, and 2 turning points. Another 4 cones were placed down the center in equal distance apart from each other, 3.3 meters. Subjects were given 1 demonstration of how to run the course and a trial run before doing the actual test. The subjects started face down on the pavement behind the start cone with their hands by their shoulders. They were then given the command "ready, set, go," with the instruction to complete the course as quickly as possible. The time to complete the course was hand timed to tenths of a second and recorded.

Whole Body Reaction Time. Eye-hand reaction speeds were measured using the Makoto Interactive Sports Arena (Makoto USA, Centennial, CO, USA). The Makoto arena

Table 1. Physiological within-group mean changes.

	PT (*n*=18)					AT (*n* = 23)				
	Mean ± *SEM*					Mean ± *SEM*				
Variable	Pre	Post	Pre to post	*t*-test *p*	% Pre to post	Pre	Post	Pre to post	*t*-test *p*	% Pre to post
Weight (lb)	158.4 ± 5.4	161.0 ± 5.5	2.6 ± 0.8	0.0074	1.6	151.1 ± 5.2	151.0 ± 5.2	−0.1 ± 0.8	0.8980	−0.1
Body fat (%)	22.8 ± 1.9	24.6 ± 1.9	1.8 ± 0.4	0.0002		21.4 ± 1.1	22.7 ± 1.1	1.3 ± 0.3	0.0011	
Total mass (kg)	72.9 ± 2.5	74.3 ± 2.5	1.4 ± 0.4	0.0030	1.9	69.5 ± 2.4	70.0 ± 2.4	0.5 ± 0.3	0.0973	0.7
$\dot{V}O_2max$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	48.3 ± 1.8	49.2 ± 2.2	0.9 ± 0.9	0.3559	1.8	47.9 ± 1.6	50.5 ± 1.4	2.6 ± 0.8	0.0047	5.4
HR max ($b \cdot min^{-1}$)	191.2 ± 2.5	192.8 ± 2.4	1.6 ± 3.6	0.6644	0.8	191.3 ± 2.4	189.0 ± 2.5	−2.4 ± 2.1	0.2667	−1.2
Time to exhaustion (s)	603.1 ± 17.9	641.1 ± 18.1	38.0 ± 7.9	0.0002	6.3	612.5 ± 16.3	595.8 ± 18.0	−16.7 ± 9.5	0.0937	−2.7
Ventilatory threshold (min)	5.9 ± 0.3	6.7 ± 0.4	0.9 ± 0.3	0.0191	14.5	5.9 ± 0.3	6.8 ± 0.4	0.9 ± 0.4	0.0184	15.4
Ventilatory threshold (%$\dot{V}O_2$)	75.8 ± 2.1	79.2 ± 1.9	3.3 ± 1.8	0.0796		75.9 ± 1.2	82.8 ± 1.8	7.0 ± 1.8	0.0009	
Ventilatory threshold (HR)	169.8 ± 2.5	173.5 ± 3.5	3.8 ± 4.0	0.3596	2.2	166.5 ± 2.5	174.8 ± 3.3	8.3 ± 2.8	0.0069	5.0
Makato (s)	1.08 ± 0.01	1.05 ± 0.01	−0.03 ± 0.01	0.0096	−2.5	1.06 ± 0.01	1.05 ± 0.01	−0.02 ± 0.01	0.0576	−1.5
Makato (%)	57.8 ± 4.5	68.6 ± 3.7	10.7 ± 2.5	0.0004		61.6 ± 4.0	67.2 ± 4.3	5.6 ± 2.3	0.0237	
Illinois agility test (s)	18.7 ± 0.5	18.6 ± 0.5	−0.1 ± 0.2	0.5649	−0.5	19.5 ± 0.5	18.6 ± 0.4	−0.9 ± 0.4	0.0347	−4.4

PT = physical training; AT = agility training; HR = heart rate.

TABLE 2. Physiological between-group mean changes.

Variable	Pre to post mean change ± *SEM* PT	AT	2-Sample *t*-test *DF*	*t*	*p*	95% CI for mean difference in pre to post	Cohen's *d*
Weight (lb)	2.57 ± 0.85	−0.10 ± 0.77	39.0	−2.32	0.0254	0.35–5.00	0.75
Body fat (%)	1.80 ± 0.37	1.29 ± 0.34	39.0	−1.00	0.3255	−0.52 to 1.54	0.32
Total mass (kg)	1.37 ± 0.40	0.46 ± 0.27	39.0	−1.97	0.0555	−0.02 to 1.85	0.64
$\dot{V}O_2max$ (mL/kg/minute)	0.87 ± 0.92	2.56 ± 0.81	38.0	1.38	0.1743	−4.16 to 0.78	0.45
HR max ($b \cdot min^{-1}$)	1.61 ± 3.65	−2.35 ± 2.05	27.0*	−0.95	0.3525	−4.63 to 12.55	0.32
Time to exhaustion (s)	38.00 ± 7.92	−16.68 ± 9.50	38.0	−4.30	0.0001	28.92 to 80.44	1.40
Ventilatory threshold (min)	0.85 ± 0.33	0.90 ± 0.35	38.0	0.11	0.9122	−1.05 to 0.94	0.04
Ventilatory threshold (%$\dot{V}O_2$)	3.33 ± 1.79	6.95 ± 1.81	38.0	1.41	0.1670	−8.82 to 1.58	0.46
Ventilatory threshold (HR)	3.76 ± 3.99	8.27 ± 2.76	37.0	0.96	0.3444	−14.05 to 5.03	0.32
Makato (s)	−0.03 ± 0.01	−0.02 ± 0.01	38.0	0.95	0.3506	−0.04 to 0.01	0.31
Makato (%)	10.74 ± 2.46	5.63 ± 2.31	38.0	−1.51	0.1395	−1.74 to 11.97	0.49
Illinois AT	−0.09 ± 0.15	−0.86 ± 0.38	27.4*	−1.88	0.0711	−0.07 to 1.61	0.57

*Indicates approximate t test was performed.
CI = confidence interval; PT = physical training; AT = agility training; HR = heart rate.

is roughly in the shape of a triangle that is 8 feet from base to apex. Each corner of the triangle holds a 6-foot tower; each with 10 embedded target lights. Whole body reaction time was measured during a 90-second test interval, during which target lights illuminated at random with a corresponding tone. The task was for subjects to contact each illuminated target with a hand-held medicine ball although remaining inside the arena. Each target stayed active for 1.2 seconds; the average time to hit the targets and percentage of targets hit were recorded. If the subject did not hit the target in the allotted time, then it was recorded as a miss. Before testing, a 30-second practice interval was completed.

Cognitive Testing

Cognitive performance tests were selected using the NTI Armory Test System (NTI ATS; NTI Inc., Fairborn, OH, USA). The NTI ATS is a performance battery generation system that selects performance tests most applicable to particular jobs (25). This battery consists in total of 22 well-validated performance tests. The following 3 were selected for their relevance to performance across a wide variety of occupations within a military population.

Continuous Memory Task. Working memory was measured by the continuous memory task. O'Donnell et al. (25) defined working memory as the ability to have a continuous awareness of many elements in the environment or many activities that are to be performed at the same time. This task presented a series of numbers that the subjects were required to encode, although simultaneously also presenting a probe number. The subjects compared this probe number to a previously presented item (1 position back in the number series) and then determined if that item matched the probe number. Thus, the task measured working memory functions by requiring subjects to accurately maintain, update, and access stored information on a continuous basis. Subjects were scored on percentage of and latency to correct responses.

Visual Vigilance. Sustained attention was measured using the visual vigilance task. O'Donnell et al. (25) defined sustained attention as the ability to concentrate on a task without letting the mind wander. Although attending to an easily discriminated stimulus over a period of time seems to be a relatively simple task, it turns out in practice to be extremely demanding. Over long periods of time, subjects find it hard to maintain performance at initial levels (the "vigilance decrement"). They also report high workload and considerable stress. The present study followed a 12-minute test procedure from Temple et al. (29). At the start of the test, the letters "O," "D," and a backward "D" were randomly presented on a computer screen at 0.4-second intervals. The subjects' task was to press a response key every time the "O" was presented. No response was required for either of the other 2 letters. Subjects were scored by the percentage of correct answers.

Dichotic Listening. Directed attention was measured with the dichotic listening task. O'Donnell et al. (25) defined directed

Table 3. Cognitive within-group mean changes.

Variable	PT (*n* = 18)					AT (*n* = 23)				
	Mean ± *SEM*			*t*-test,	% Pre to	Mean ± *SEM*			*t*-test,	% Pre to
	Pre	Post	Pre to post	*p*	post	Pre	Post	Pre to post	*p*	post
Dichotic listening % correct	88.7 ± 3.0	84.2 ± 4.6	−4.6 ± 4.4	0.3144		79.0 ± 4.3	79.8 ± 4.3	0.8 ± 1.9	0.6594	
Dichotic listening time to correct (s)	3.15 ± 0.06	3.25 ± 0.05	0.10 ± 0.05	0.0700	3.2	3.19 ± 0.05	3.17 ± 0.04	−0.02 ± 0.03	0.5478	−0.6
Continuous memory % correct	89.0 ± 2.4	90.3 ± 3.3	1.3 ± 1.8	0.4835		79.1 ± 3.9	87.9 ± 3.1	8.8 ± 3.6	0.0223	
Continuous memory time to correct (s)	1.77 ± 0.08	1.65 ± 0.08	−0.12 ± 0.06	0.0605	−6.7	1.86 ± 0.07	1.67 ± 0.08	−0.18 ± 0.07	0.0195	−9.9
Visual vigilance % correct	95.5 ± 1.1	97.0 ± 0.9	1.5 ± 0.8	0.0700		95.5 ± 0.8	97.4 ± 0.5	1.9 ± 0.6	0.0027	

PT = physical training; AT = agility training.

attention as the ability to allocate resources to a particular task on demand. This test required subjects to attend to auditory information presented in one ear (the "attending" ear), whereas at the same time, distracting information was delivered to the "nonattending" ear. To accomplish this, different digits (no letters) were presented to the 2 ears simultaneously. Just before the digits were presented, a cueing tone was heard in 1 ear, informing the participant to attend only to the information presented in that ear. Subjects were required to report what digit was presented to the attended ear and were scored on percentage of and latency to correct responses.

Injury. Subjects were instructed to report injuries sustained during training to the principle investigator or medical monitor.

Agility Training. Each AT session was led and monitored by an instructor. Agility training started each day with a functional warm-up (e.g., ankle/knee/hip rotations, walking lunges, carioca, side shuffles, skips, etc.) for 10 minutes followed by over/under hurdles to stretch the hip flexors.

During the first 2 weeks, training consisted primarily of preconditioning. Subjects were instructed on and then practiced how to properly change direction and move laterally. They performed cone drills at a 135° angle; box cone drills (shuffle to 1 cone, carioca to the next, back pedal, and finish with shuffling to the last cone); 1 foot at a time over the mini hurdles; and 1-foot dot drills. They practiced the following ladder drills: fast feet, icky shuffle, scissor, high knees, and stack-n-out ladder drills and they carried a slosh tube (8′-PVC pipe partially filled with 1–3 L of water) through a set of cones.

The third and fourth weeks focused on acceleration, deceleration, and more dramatic changes of direction. The third week's drills consisted of cone drills to train participants on their 90° angle cut techniques; the ladder drills included fast feet, scissors (inside and outside of the boxes), stack-n-out, and fast feet to the side although catching a reaction ball; with the mini hurdles they worked on 1 foot at a time and then using 2 feet at a time changing 90° angle directions within the jump; and more complex dot drills. The fourth week continued work on cutting 90° angle with the cones; mirror drills where 1 subject had to mirror another inside their own boxes; shuttle runs with mini hurdles; more advanced ladder drills; and an obstacle course combining all drills they had practiced. The ladder drills consisted of fast feet backwards, scissors out of the boxes, and an in/in/out/out drill.

Weeks 5 and 6 focused on explosive change of direction. During these weeks, everything the subjects had learned was combined together to practice their ability to accelerate, decelerate, and change direction in a controlled, efficient, and explosive manner, even when the change was not anticipated. Week 5 consisted of change in

TABLE 4. Cognitive between-group mean changes.

Variable	Pre to post mean change ± *SEM* PT	AT	2-Sample *t*-test *DF*	*t*	*p*	Cohen's *d*
Dichotic listening % correct	−4.57 ± 4.40	0.85 ± 1.89	21.9*	1.13	0.2704	0.41
Dichotic listening time to correct (s)	0.10 ± 0.05	−0.02 ± 0.03	38.0	−2.09	0.0430	0.69
Continuous memory % correct	1.31 ± 1.82	8.83 ± 3.59	31.9*	1.87	0.0710	0.55
Continuous memory time to correct (s)	−0.12 ± 0.06	−0.18 ± 0.07	38.0	−0.67	0.5092	0.22
Visual vigilance % correct	1.51 ± 0.78	1.90 ± 0.56	39.0	0.43	0.6731	0.14

PT = physical training; AT = agility training.

direction cone drills with unexpected 90° angle cuts during shuttle runs; change in direction drills in which the subjects reacted to the blowing of a whistle and hand movements directing which way to turn; box drills (sprint diagonally, then backpedal, then sprint forward, then shuffle); and ladder drills. Ladder drills consisted of hop scotch, lateral high knees, lateral scissors with double feet backwards jump in between, and 90° angle turns although advancing forward in the ladder. Subjects also completed a more advanced obstacle course consisting of cone drill cuts, 2 ladder drills, hurdles, shuttle runs, and box drills. Week 6 worked on combining all previous work and perfecting each drill. A catching task was added to the cone drills and to the ladder drills so that subjects were forced to look away from their feet and concentrate on catching although still executing proper changes of direction.

Traditional Training. Traditional PT was also led and monitored by an instructor. Like the AT sessions, PT session always began with a warm-up. However, PT warm-ups consisted only of linear walking and jogging, along with jumping jacks and in-place lunges. After the warm-up, PT consisted primarily of running on Mondays and Fridays, with in-place calisthenics on Wednesday. The running was self-paced with subjects being told to run at a moderately hard pace. Instructors provided verbal encouragement throughout each run. Wednesday calisthenics consisted of jumping jacks, 8-count body

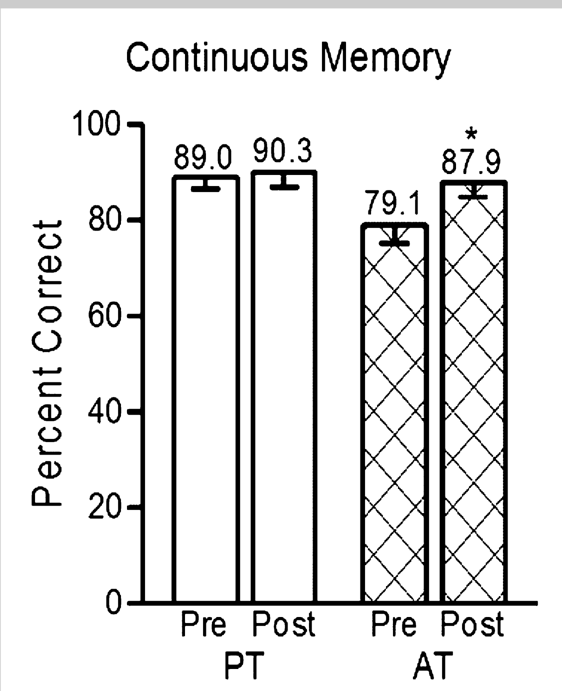

Figure 1. Continuous memory percent correct (*$p < 0.05$).

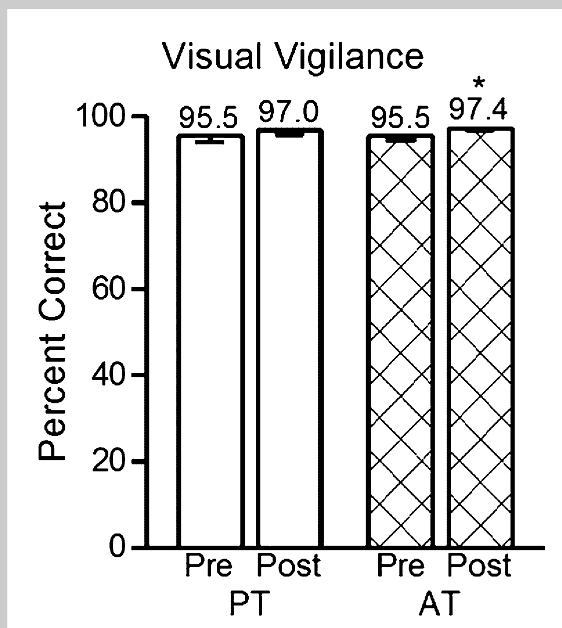

Figure 2. Visual vigilance percent correct (*$p < 0.05$).

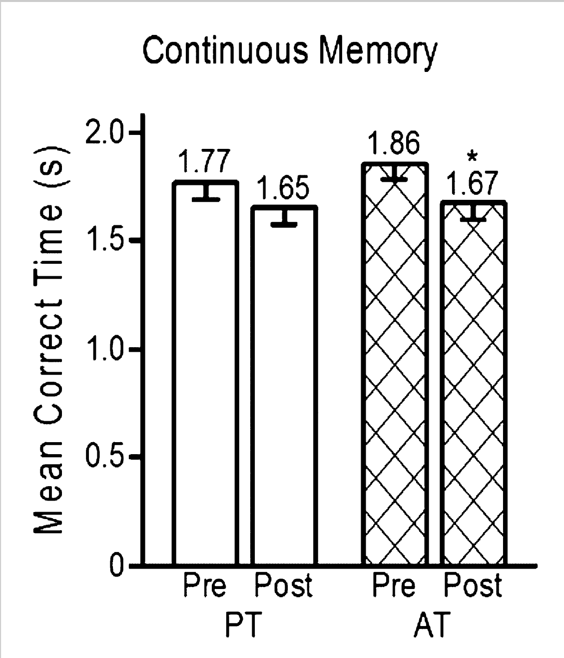

Figure 3. Continuous memory mean correct time (* $p < 0.05$).

builders, mountain climbers, lunges, squat-reach jump, sit-ups, push-ups, burpees (a combination push-up, squat, and vertical jump), and trunk twists, along with a 6–8 linear sprints of approximately 50 m. Each day ended with a cool down period

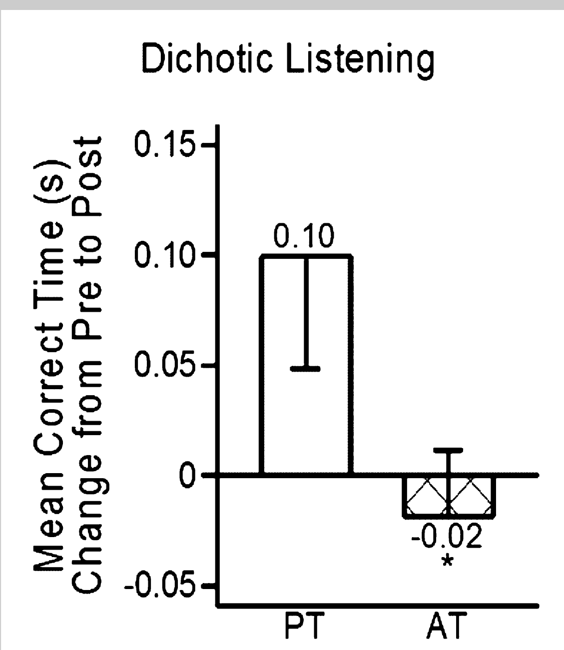

Figure 4. Dichotic listening mean correct time (* $p < 0.05$).

of walking and stretching. These training sessions were modeled after traditional military PT sessions.

Statistical Analyses

The dependent variable used in all analyses was a change from pretraining to posttraining. A 2-tailed paired *t*-test was used to determine whether the change was significant ($p \leq 0.05$) for each group separately. A 2-tailed 2-sample *t*-test (same as 1-way analysis of variance with group-the-factor) was used to determine whether the change was significantly different ($p \leq 0.05$) between the 2 groups, using an approximate *t*-test with Satterthwaite's approximation for degrees of freedom if variances were significantly different. An analysis of covariance (ANCOVA) was also performed comparing the groups, using post as the dependent variable, pre as the covariate, and group as the factor. Because conclusions from the ANCOVA and the *t*-tests were the same, *t*-test results were used because they would be better understood by a larger audience. Cohen's *d* is provided to help indicate an effect size with $0.05 \leq d < 0.8$ a possible medium effect, and $0.8 \leq d$ a possible large effect.

Results

Forty-one subjects completed the protocol. All physiological data can be found in Tables 1 and 2; however, only significant results will be discussed here.

The mean weight of the AT group remained steady over the course of the study ($p = 0.8980$); however, the PT group showed a significant mean weight gain ($p = 0.0074$), which was significantly different than the AT group ($p = 0.0254$). Additionally, both the PT and AT groups significantly increased their body fat percentage from pretesting to posttesting ($p = 0.0002$ and $p = 0.0011$, respectively). Although the PT group gained slightly more fat than the AT group, the difference between groups was not significant ($p = 0.3255$).

Maximal oxygen capacity increased by 5.4% or 2.6 $ml \cdot kg^{-1} \cdot min^{-1}$ ($p = 0.0047$) in the AT group. Interestingly, the PT group did not show significant improvement on this test ($p = 0.3559$); however, they demonstrated a significant 6.3% ($p = 0.0002$) improvement in TTE during the treadmill test.

Ventilatory threshold (VT), as measured by time, significantly increased for both groups from pretesting to posttesting (PT: $p = 0.0191$, AT: $p = 0.0184$), but VT as a percent of $\dot{V}O_2max$ increased significantly only for the AT group ($p = 0.0009$).

The AT group improved their IAT time from pretesting to posttesting by a significant 0.86 seconds or 4.4% ($p = 0.0347$). The pre-to-post delta between groups was not significant ($p = 0.0710$) but trended moderately toward the AT group improving more than the PT group (Cohen's $d = 0.57$).

Both groups significantly improved reaction time from pretesting to posttesting as demonstrated by an increase in percentage of Makoto targets hit (PT: $p = 0.0004$, AT: $p = 0.0237$). The PT group also improved significantly on the speed to hit targets ($p = 0.0004$).

No training-related injuries were reported for either group, although several subjects reported minor injuries from activities outside the study. None of the subjects' training logs indicated that they violated our guidelines regarding extra physical activity.

All data obtained from cognitive testing is provided in Tables 3 and 4; however, only significant results will be discussed.

The AT group significantly improved percent correct scores in the continuous memory ($p = 0.0223$) (Figure 1) and visual vigilance tasks ($p = 0.0027$) from pretesting to posttesting, although the PT group did not ($p = 0.0700$) (Figure 2). Additionally, the AT group significantly reduced time to the correct response ($p = 0.0195$) in the continuous memory task, although the PT group did not ($p = 0.0605$) (Figure 3).

The dichotic listening test revealed no significant within-group changes in percent correct responses. However, posttesting revealed a significant difference between groups, with the AT group performing faster relative to pretesting than the PT group ($p = 0.0430$) (Figure 4).

Discussion

The primary findings show that 6 weeks of AT resulted in significant within-group performance improvements in cardiorespiratory capacity, physical agility, sustained attention, and working memory (both in accuracy and speed), although 6 weeks of traditional PT did not.

The AT group significantly improved their maximal oxygen-carrying capacity during the training period although the traditional group did not. As the $\dot{V}O_2max$ test was a treadmill test, it seemed probable that due to specificity of training, the PT group might improve on it to a greater degree than the AT group; however, that was not the case. We suspected the lack of improvement in $\dot{V}O_2max$ for the PT group may have simply been due to their greater weight gain, but a review of absolute $\dot{V}O_2max$ for each group reveals that the PT group increased by 0.13 L per minute althouhg the AT group increased by 0.21 L per minute. These data support that of Sporis et al. (28) who observed a significant improvement in $\dot{V}O_2max$ with 6 weeks of AT and a lack of improvement in $\dot{V}O_2max$ in a running group. Sporis et al. (28) also demonstrated that an agility group improved running performance over short (200 m) to moderate (2400 m) distances, whereas a running group did not. This indicates that for general cardiorespiratory fitness, AT is just as, if not more, effective than linear running although potentially providing other physiological and cognitive benefits.

Interestingly, during the 6-week period, the PT group gained significantly more weight than did the AT group, suggesting an ameliorating effect of AT in that physical regard as well. Although both groups' percentage of body fat increased, there was no significant difference in body composition between groups from pretesting to posttesting. It may initially seem surprising that both exercise groups gained body fat, but that is readily explained by their condition at the start of the protocol. Before arriving at technical school, subjects had immediately graduated from basic military training (BMT) where meal times are regulated and trainees are not allowed to eat or drink except at meal times. Trainees are allowed to eat ad lib during technical school and likely increased their calorie intake from BMT. Furthermore, they are not allowed sodas, snacks, or alcohol in BMT, whereas they are allowed those items during technical school. It is likely that the quality of calories they consumed also worsened. Last, although programmed PT sessions are not appreciably different, general daily physical activity is greater at BMT than in technical training. We did not measure exact caloric intake or expenditure during the protocol, but we did strictly equilibrate duration, frequency, and intensity of exercise between the 2 groups. Therefore, the AT group likely consumed fewer calories or expended more calories after exercise training than did the PT group. The latter could have been due to more general activity or to greater excess post-exercise oxygen consumption (EPOC). The magnitude of EPOC after exercise generally depends on both the duration and intensity of exercise. However, differences in exercise mode may contribute to the discrepant findings of EPOC magnitude and duration (7). Future studies comparing AT to PT may further explore this possibility.

As AT has been demonstrated to improve performance of vertical jump and various agility tests (14,26,33), significant differences on the IAT within the AT group were expected and observed. Differences in the changes between groups were also expected but not observed; yet moderate trends (Cohen's $d = 0.57$) suggest that with slightly more power, we likely would have seen such differences. The AT group's 4.4% improvement on the IAT compares favorably to that measured in a recent 6-week study of plyometric training (24) which utilized a similar volume of training and observed a 2.9% improvement.

Interestingly, the PT group significantly improved on 1 facet of the Makoto test (speed), whereas the AT group did not. The Makoto test was an attempt to test "reactive: agility: rapid whole body movement with change of velocity or direction in response to a stimulus, such as occurs in sports (avoiding a defender, intercepting the path of a ball, etc.) and on the battlefield (seeking cover, clearing a building, etc.). A strong and rational case for including this type of decision-making as a component of agility has been advanced in recent publications (27,33). Two such tests have been developed (12,27) and validated as accurate measures of unplanned or "reactive" agility. However, both are very sport specific (and claim that specificity is very important) and have not yet gained wide use. The Makoto arena certainly demands a reaction in response to a stimulus. However, it is not sport or task specific. We suspect that there is a greater learning curve and higher technique requirements than we originally predicted and that with only one 30-second practice session, our subjects may not have been trained to asymptote before being tested. Further, we only incorporated what we considered "reactive" agility during the last 2 weeks of the training protocol. Future investigations of AT training should consider developing, validating, and incorporating reactive agility tests specific to their population.

Notably, no study-related injuries occurred in either group during training. Admittedly, this was not an expressed purpose of our protocol. We mention it here to encourage future researchers to consider including an injury comparisons as an a priori measure. Anecdotally, it seems fears of being injured during AT are often greater than for PT. With zero AT injuries, the current study refuted such anecdotal evidence. Recent investigations have indicated that AT may actually reduce training-related injuries when compared with traditional training (9,20) and that AT may reduce the chance of injury during real-world (sport or occupational) activity (5,23). Work from our laboratory with combat controller trainees supports the premise as well (32). After substituting AT for nearly half of the previously performed linear running, we observed a 67% decrease in overuse injuries with a concurrent increase in several physiological performance variables.

The AT group showed significant improvements in the continuous memory and visual vigilance tasks, whereas the PT group did not. The magnitude of these effects, obtained in adults through only a 6-week intervention, suggests that AT is a viable training tool for enhancing cognitive performance. The significant improvement in continuous memory performance for the AT group may seem inflated due to the AT group baseline being lower than the PT group baseline. However, the AT group's significant improvement demonstrates that AT may ameliorate a baseline cognitive deficit, and the possibility of this should be explored further. As the significant improvement in the visual vigilance task occurred despite nearly identical pretest scores between groups, AT may boost performance even when baseline levels do not reflect a deficit.

The significant effect of AT in dichotic listening response time is interesting but difficult to interpret. A small decline of performance in the PT group was observed. This may indicate that there was some factor in the students' environment during the 6-week period that tended to impact performance on selective attention as measured by dichotic listening, the negative effect of which was ameliorated by AT. The environment during this 6-week testing period was significantly more liberal than that of BMT (environment immediately before the study), with multiple distractions available that were not present during BMT. Selective attention is sensitive to a number of environmental factors (for example sleep deprivation) (11) that might be mitigated by exercise. Baker et al. (4) found that aerobic exercise reduced selective attention deficits caused by mild cognitive impairment, although stretching did not. The AT used here is a third alternative for improving selective attention as it is both high intensity and demanding of integrative coordinated motor control and cognitive processes that many exercise modalities are not. The present data may suggest that AT offers a more effective intervention than the aerobically intensive condition.

Kramer et al. (21) presented evidence that improvements in fitness should be reflected in enhanced performance on executive control processes such as working memory, coordination, inhibition, scheduling, and planning. The current cognitive data are consistent with that result, but further suggestive that AT in particular may provide an additional pathway to cognitive enhancement through exercise.

Also noteworthy was the apparent preference of the subjects to perform AT over traditional training. Four subjects who were randomly placed in the PT group dropped out of the protocol within the first week of training, and claimed they did so due to disappointment over their grouping. None of the agility subjects withdrew from the study for that reason. As subjects were not blinded and preferred to be placed in the AT group, motivation was a possible confounding factor in subject performance.

Finally, several of the AT group subjects requested the AT continue after the conclusion of the study, as opposed to returning to traditional unit-led PT. Previous research has indicated that intrinsic motivation, such as enjoyment and challenge, may facilitate improved adherence to exercise regimens (13). This may be another reason to incorporate AT into PT programs.

Practical Applications

This investigation provides evidence that in a military population, AT offers several physical and cognitive performance benefits that PT does not. Although both forms of exercise have their pros and cons, AT could easily be incorporated into existing Air Force physical training programs as a noninvasive cost-effective way to improve war-fighter performance. Further, it seems likely that the benefits of AT observed here occur in various other populations. Trainers, coaches, and therapists may be well served to incorporate AT into the programs of their clients, athletes, and patients.

Acknowledgments

The authors thank the study participants for their cooperation and enthusiasm. This study was funded in part by the Air Force Research Laboratory, whose mission is leading the discovery, development ,and integration of affordable war-fighting technologies for America's aerospace forces, and in part by a grant from the United States Special Operations Command. The authors also wish to gratefully thank Dr Art Kramer and Mr Rene Klein for their technical expertise and advice, and Mr Chuck Goodyear for his invaluable assistance with statistical analysis.

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