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Pharmacological Optimization of Military Performance: Strength and Endurance

G. Jean Kant

Department of Medical Neurosciences, Division of Neuropsychiatry
Walter Reed Army Institute of Research

Abstract

A pill that could increase strength and endurance would be of considerable benefit to soldiers. Combat can be exhausting, straining physical and mental resources beyond the breaking point. Heavy loads, sleep loss, fear and anxiety, wet clothing, cold or heat, jet leg and other factors often present in a combat situation can be expected to decrease endurance and strength and further impair military performance.

Historically, various drugs have been used to attempt to increase endurance in combat. These drugs include alcohol, amphetamines, caffeine, nicotine and methylphenidate (Ritalin) in US forces and possibly other drugs in non US forces. In addition, purported performance enhancers have been used by athletes all over the world in hopes of improving strength or speed in athletic competitions. The belief that drugs can improve performance is widespread among athletes, as is shown by the need to drug test athletes (and horses) to keep athletic contests fair.

Surprisingly, given this wide acceptance of the power of drugs, very little objective evidence exists that drugs do actually improve performance. It is the purpose of this report to review various drugs from the standpoint of their usefulness in enhancing militarily relevant performance.

As a result of this review, it is concluded that currently available pharmaceuticals do not significantly improve speed or endurance in healthy rested individuals, although drugs that increase wakefulness are available. Very little testing of drugs has been conducted in fatigued subjects. Thus it is possible that some currently available drugs might be effective in preventing fatigue-induced degradations in performance or in revitalizing performance in already fatigued subjects. Drugs of the future might actually be able to improve endurance and strength and enhance performance in non-fatigued soldiers.

Introduction

The ability of the individual soldier to maintain optimal physical and mental performance over a sustained period of time is critical to the success of military operations. The urgency, the excitement, the need for action may carry a soldier through a short period on the battlefield, but inevitably the physical and mental stress of sustained combat can be expected to take its toll on performance. How can these performance decrements be prevented or slowed?

Physical fatigue can be minimized by conditioning. Training and conditioning increase the blood supply to affected muscle groups, increase muscle glycogen stores , increase muscle mitochondrial number and oxidative capacity to provide fuel for exercising muscle (1). Since fear can interact with fatigue to speed performance deterioration under stress, mental conditioning prior to stress challenge can also presumably improve performance. Adequate training reinforces coping behavior which in turn reduces stress and thus fatigue. Adequate sleep can forestall mental fatigue. When

possible, judicious use of sleep/rest cycles and jet lag countermeasures can reduce fatigue. Thus, to some extent, non-pharmacological measures can improve performance if these training techniques are implemented prior to stress challenge.

Nonetheless, drugs potentially could improve performance beyond what is achievable through training and conditioning. Alcohol and amphetamines have been issued to troops in past wars to reduce fear and decrease fatigue (5,8). The results achieved are difficult to objectively evaluate. In addition to the anecdotal nature of the data, these drugs affect mood and perception so that a soldier may feel that the drugs enhanced his performance when they actually did not.

Potential Performance Enhancers: Strength and Endurance

Amphetamines

Moderate doses of amphetamines have been reported to elevate mood, increase alertness, decrease sleep time, increase motor and verbal activity, increase anger and verbal aggression and decrease appetite (2). For various of these effects, students, truck drivers, dieters, athletes and soldiers have used and abused amphetamines since their rediscovery in the 1920's. While the euphoric, appetite suppressant and sleep reducing effects of amphetamine have been documented in scientific studies, data regarding the effects of amphetamines on endurance or speed is contradictory with various studies reporting no significant effects of amphetamines or small positive effects (6,8).

One extensive double-blind study of the effects of amphetamine sulfate on athletic performance concluded that amphetamine had no effect on athletic performance (6). This study is described in detail below because it is one of the best scientifically conducted studies available on the effects of amphetamine on human performance.

Subjects were 54 male college athletes. Each subject was tested 3 times with amphetamine sulfate (10 or 20 mg ingested orally 30 to 60 min prior to testing) and 3 times with placebo. The following activities were tested (1) running to exhaustion on a treadmill twice in succession with a 10 min rest in between (2) swimming 100 yd twice with a 10 min break (3) swimming 220 and 440 yd once on each test day (4) running 220 yd time trials (5) running distances from 100 yd to 2 miles in competition. Approximately 10 subjects were run for each of these activities. No significant differences in performance were seen in athletes on amphetamine tests versus placebo tests. Average performances were almost identical between treatment groups. Overall, no beneficial or deleterious effects of these doses of amphetamine (which were sufficient to cause some complaints of insomnia) were observed on speed or recuperation (the second swim or run). The performance of individual subjects varied with some performing "better" on amphetamine and some "worse". Some athletes attributed a good performance to the "miracle drug" that they took although later examination of the data revealed the "miracle drug" was placebo. "Most of the subjects felt a sense of euphoria after the 20 mg dose of amphetamine ... They also thought that they could run longer when they felt this effect, but they did not."

The lack of convincing data demonstrating that amphetamine improves physical endurance coupled with the drug abuse potential of this drug makes it an unsuitable drug for field use for this purpose. If better drugs are not available, amphetamine does have potential use as a "keep awake" drug that might decrease mental fatigue for short periods. When amphetamine intake is discontinued, a rebound period of increased sleep and lack of energy can be expected.

Ritalin

Ritalin (methylphenidate) is a central stimulant with some similarity to amphetamine but with much less euphoria and abuse potential. Its main use is in the treatment of hyperkinetic children. It has been used by US troops as a stimulant (5).

Anabolic Steroids

Athletes particulary those involved in strength sports, (e.g. weightlifting) abuse anabolic steroids to the extent that drug testing for these compounds in competitions is required. Obviously, many athletes believe that these steroids build muscles and improve strength performance. The endogenous steroid, testosterone, is believed to affect the development of muscles in males at puberty. However, scientific evidence that anabolic steroids can improve strength in adults is scant. In army basic training, at a time when muscle strength and endurance increase, the levels of testosterone decrease.

The effects of an anabolic steroid (Nibal, 20 mg) on physical performance were tested in a 16 week study on 47 young men (4). Eight men received placebo only, nine men took steroid, 15 men received placebo plus exercise and 15 men received steroid and exercise. The authors of this study conclude "There were no significant differences in strength, motor performance, or physical working capacity between the steroid and placebo groups." Exercise in both control and steroid groups did increase performance on some tasks. Steroid administration also did not affect vital capacity, limb circumferance or skin-fold thickness. However, the dose of steroid used in this study was much less than the reportedly massive doses taken by some power lifters. It is quite possible that these massive doses do increase muscle mass and strength. Steroids at high doses have been shown to produce serious liver and heart damage. The potential benefit of steroids seems to be clearly outweighed by the health risk they present.

Human growth hormone (hGH)

Human growth hormone is a pituitary hormone required for normal growth in humans. Extracts of pituitaries obtained from cadavers are used to treat children with growth hormone deficiencies. Recently, some power athletes have taken hGH for the purpose of increasing muscle mass and decreasing body fat. The probable side effects of hGH administered to a person who does not have a growth hormone deficiency include acromegaly and dangerous heart enlargement. Current supplies of hGH are very scarce and insufficient for required medical uses. However, drug companies are working on synthesizing growth hormone. If supplies become available at a reasonable price, abuse of this hormone can be expected. Given the probable deleterious side effects of this drug and the long time required for an effect on muscle mass, this hormone is not militarily useful.

Caffeine

Caffeine is probably the most widely used stimulant drug. One cup of coffee contains approximately 100 mg of caffeine, a therapeutic dose. Cola beverages contain about 50 mg of caffeine. The stimulant actions of caffeine and related xanthines (theophylline, theobromine) undoubtedly contribute to the popularity of the beverages that contain them (coffee, tea, cocoa, cola).

Caffeine and related xanthines are central nervous system stimulants, reportedly facilitating rapid, clear thought, allaying drowsiness and fatigue, decreasing reaction time, increasing sensitivity to sensory stimuli and increasing motor activity (3,7).

Caffeine also has significant peripheral effects: increasing respiration, cardiac output, peripheral vasodilation, peripheral blood flow, force of skeletal muscle contraction, capacity for muscular work, basal metabolic rate, lipolysis and

glycogenolysis.

High doses of caffeine can cause insomnia, excitement, restlessness and even mild delirium. Other non-desireable effects include sensory disturbances (e.g. ringing in the ears) and muscular tremor. There is a wide range of individual sensitivity to caffeine with some individuals reacting to very low doses and others (especially chronic users) developing tolerance to caffeine.

Caffeine use is self-prescribed for the most part as people reach for another cup of coffee to keep them alert to study or drive or man a radar screen. Caffeine is available, however, in pill form and could be used as a performance enhancer. The major drawback of caffeine is its limited maximum effect. Particularly in people who already use caffeine and have developed some tolerance, the boost in performance might not be large. Taken at certain times of the day, perhaps late at night when caffeine is not usually consumed, caffeine might significantly affect performance.

New Methylxanthines

The primary mechanism of action of methylxanthines such as caffeine is not yet proven. Methylxanthines inhibit the enzyme phosphodiesterase which degrades cyclic AMP. This potentiation of cyclic AMP was thought to be the mechanism of action for methylxanthines. However, recently a more potent action of methylxanthines, adenosine receptor blockade, is believed to be the more important effect of methylxanthines in the central nervous system. Since the known methylxanthines are so effective, research should be directed at determining (1) the sites of action of methylxanthines (phosphodiesterase, adenosine receptors, an unknown site?) and (2) new methylxanthines or analogs that share a similar site of action but may be more active than caffeine. This research may yield a militarily useful drug with caffeine-like actions but with increased potency. Possibly, a drug with no cross-tolerance with caffeine could be developed.

Vitamins

Vitamin supplements (e.g. "Stress Tabs") have been advertised to replace the vitamins depleted by exercise, stress or illness. There is no good evidence that vitamin intake in excess of normal requirements improves performance. Physicians often prescribe multivitamins for dieters or other patients who might not ingest sufficient food to provide daily requirements for vitamins. Perhaps soldiers in the field could take a multivitamin in case their food intake was inadequate. In rats, vitamin E deficiency diminishes exercise endurance capacity.

Ginsing and other substances

A variety of substances including Ginseng and bee products have been used as performance enhancers especially in non-US cultures, e.g. USSR and China. Scientific evidence for their effects on performance is lacking.

Discussion

Optimal nutrition, hydration, sleep and conditioning can improve physical and mental performance. The degree to which these measures can boost performance far exceeds the effects of currently available pharmacological aids. Training and conditioning increase blood supplies to exercised muscle, increase mitochondrial oxidative capacity to provide energy for work and improve the resistance of muscle to fatigue (1). Optimal nutrition provides adequate muscle and liver glycogen stores. Strategies of "carbohydrate loading" as practiced by marathon athletes might be useful to test scientifically to see whether endurance is really improved. Adequate water is

required to maintain performance especially when work generates sweat and water loss.

Many drugs are used by healthy normal civilians and soldiers. Stimulants are ingested daily as coffee, cola, tea, and cigarettes. Athletes continually are on the lookout for drugs that will improve performance. However, no effective currently available drug significantly increases speed, strength and endurance in rested healthy individuals. Some stimulants can increase alertness and delay sleep onset. These drugs have been used in special situations in past wars and will probably continued to be used. Improved training and conditioning, adequate hydration and nutrition, attention to sleep/rest cycles can significantly affect endurance and offer the best currently available methodology for optimizing human endurance at this time.

However, most scientific studies of performance enhancers have been performed on healthy rested individuals. It is possible that some of these drugs (methylxanthines, amphetamines, Ritalin) would significantly improve performance in a fatigued soldier. In addition, since fear can affect physical performance, anti-anxiety drugs might also counteract fatigue. Research into the effects of these stimulants and other drugs on performance in tired and/or stressed animals and man might produce useful guides for the use of these compound in military environments.

The potential usefulness of performance enhancing drugs should spur efforts to develop new compounds in this area.

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