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Exploring the Link Between Physical Endurance Training and Psychological Resilience

SUBMITTED IN PARTIAL FULFILLMENT
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MASTER OF MILITARY STUDIES

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Executive Summary

Title: Exploring the Link Between Physical Endurance Training and Psychological Resilience

Author: Lieutenant Commander Matthew Rouse, United States Navy

Thesis: US service members who perform at least three bouts of physical endurance training per week (defined as continuous exercise of greater than or equal to 30 minutes duration) will strengthen the areas of the brain associated with psychological resilience more than those who do not perform similar training.

Discussion: Numerous studies have correlated physical fitness regimens that incorporate at least three bouts of continuous aerobic activity lasting no less than thirty minutes with positive effects on brain structures and mental health outcomes. Incorporating this type of training into routines of U.S. armed forces service members could improve their psychological resilience. Combining the physical training regimen with meditative practices may have a synergistic effect.

Conclusion: Though formal definitive evidence in the form of randomized controlled trials is still lacking, policy makers should consider formalizing MAP (mental and physical) training programs for service members and adjusting the various services physical fitness test (PFT) to indirectly require incorporation of more endurance training with the aim of improving resilience of service members based on current evidence.

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Preface

Ten years ago, in 2011, I commissioned as a Naval health care provider and became interested not only in my specialized area of dentistry but also in all aspects of warfighter health, not least of which is mental health. As a dental officer I began seeing the effects of PTSD commonly in my patients who had deployed as part of Operation Iraqi Freedom and Operation Enduring Freedom. Surely these tough, veteran warfighters couldn't be shaken by something as innocuous as a dental procedure! However, this was commonly the case; my interest into this aspect of human psychology was piqued. Dating back much further than my Naval career is my passion for endurance sports, especially running. Through participation in college track and cross country, and, more recently marathons and triathlons, I have become intimately acquainted with the psychological and emotional aspects of endurance sports, which many used to believe was only a physical challenge. Eventually I began to see the overlap of the observations in my professional and athletic endeavors and as I started to read more and peel back the layers I realized how much is being done in the field of neurophysiology that could have a huge impact on the readiness of service members. I feel incredibly blessed to have the opportunity to research this fascinating topic more thoroughly and am ridiculously indebted to my mentors for their support and my wife Kate and our five beautiful girls: Nadia, Lucy, Fiona, Audrey, and Mercy for their love, support, and sacrifice throughout this challenging yet rewarding year.

Introduction

“The first quality of a soldier is patient endurance of fatigue and privation; valour is but a secondary virtue¹.”

-Napoleon Bonaparte

Most members of the United States Armed Forces have more in common with one another than uniforms and hairstyles; they belong to an organization that promotes specific values. The U.S. Navy and U.S. Marine Corps proclaim the core values of “honor, courage, and commitment” as hallmarks of their organizations, but these are not the values to which I am referring. “Endurance” is listed as a key leadership trait in official Marine Corps doctrinal publications, yet the term “endurance” can be interpreted many ways². Endurance has many aliases: grit, tenacity, perseverance, resolve, etc. These terms likely evoke many different mental images of people in a wide variety of situations, but the specific term that this paper will focus on is a specific kind of mental toughness known as resilience. When used in the context of material engineering resilience is defined as the ability of a material to absorb a certain amount of energy, or undergo a given amount of stress, and still return to its original state without being permanently distorted or deformed. The parallel to the human psyche is apparent; just as a rubber band can be stretched and return to its original state without any permanent distortion, a human being can experience a stressful circumstance and mentally recover afterward without lasting consequences. However, if the metaphorical rubber band is stretched too far it cannot recover and it breaks. Similarly, if a material is put under strain repeatedly it will break at a stress far below its expected maximum. Not all rubber bands are created equally; some are much tougher than others and can withstand much more strain while others snap fairly easily. Again, this metaphor’s applicability to the human spirit is obvious. Unfortunately for the rubber band, the

specifications to which it is manufactured determine its mechanical properties. The rubber band will not grow or strengthen over time; here the analogy falls apart. Fortunately, as human beings, the capacity for resilience that one is born with is not necessarily the one he/she has today, and one's current capacity for resilience is not necessarily the one that he/she will die with. To combat the stresses of daily life, various methods to improve resilience have been investigated and practiced extensively in recent years. Many of these methods will be discussed in varying degrees of detail in the following sections. Mindfulness and meditation have become very popular in recent years in many circles, but the armed forces have not seen the sweeping incorporation of these practices that the general population has. This may possibly be because the intangibility of these methods can be off-putting to a group which, stereotypically speaking, is more comfortable with concrete, observable, cause-and-effect practices. Fortunately, recent research suggests that such a practice may actually exist, hard-wired within our brains. Plentiful scientific evidence correlates physical endurance exercise of thirty minutes duration with excellent psychological resilience. Though this correlation does not necessarily prove causation, the quantity of evidence certainly warrants investing in further research and proactively encouraging incorporation of physical training into the weekly routines of Armed Forces service members, specifically in the form of the Mental and Physical (MAP) method.

Background

Ascertaining who was truly the first to recognize the intimate link between physical endurance and mental resilience is difficult for multiple reasons. The first is that the famous Lao Tzu of China and Plato of Greece were roughly contemporary, and, furthermore, the dates of their philosophical writings are only estimates. Lao Tzu is credited as the writer of Tao Te

Ching, the fundamental document of Taoism³. In the Tao Te Ching, he states "...he who values his body more than dominion over the empire can be entrusted with the empire. He who loves his body more than dominion over the empire can be given custody of the empire." Lao Tzu was not suggesting that he approved of an emperor who would neglect his official duties in lieu of physical exercise, but rather he intuited that one who was disciplined in the area of physical conditioning would also be disciplined in his official management of the empire; someone who could exhibit the self-control to subject himself to a somewhat uncomfortable experience on a daily basis would be able to endure the discomfort of carrying out his other numerous duties consistently. Around the same time on the other side of the world, Plato made a similar observation. He stated that "lack of activity destroys the good condition of every human being, while movement and methodical physical exercise save it and preserve it."⁴ Like his Chinese contemporary, Plato did not have the benefit of modern scientific methodology but had the distinct advantage of living in a time when the early foundations of what would be called stoicism were prominent in Greek society.

This wisdom likely predates Lao Tzu and Plato; this is the second reason why attributing credit is difficult. If writings on this complex relationship have been documented for thousands of years, the reality of this concept has likely always existed in our collective imagination as human beings. A few hundred years later Marcus Cicero of the Roman Empire took Plato and Lao Tzu's contemplations a step further, stating that "it is exercise *alone* that supports the spirits, and keeps the mind in vigor [emphasis added]."⁵

One cannot discuss philosophies of achieving superior mental resilience in ancient times without mentioning the idea of stoicism, founded by Zeno of Citium in the early third century BC in Greece⁶. Stoicism can be summarized by the famous maxim "virtue is sufficient for

happiness,” meaning that a true stoic would be resilient in the face of life’s challenges⁷. Though stoicism is commonly misunderstood by some lay people as a lack of apparent emotion, stoic philosophy encompasses much more than one’s personality; stoicism involves experiencing emotions while also controlling them through honest, objective self-reflection⁸. Stoicism rests on the core principle of hardening the body to harden the mind; this can be seen through the practice of the first stoics of voluntarily submitting themselves to discomforts, such as extreme temperatures, to develop “psychological endurance⁹.” An opposing school of thought was introduced in the seventeenth century by philosopher René Descartes who proposed the idea of “dualism,” stating that while mind and body interact, they are separate entities¹⁰. Dualism and stoicism coexisted through the seventeenth and eighteenth centuries. The introduction of stoic philosophy to the U.S. military can arguably be credited to Captain Alden Partridge in the early nineteenth century, though he never used the word stoic, specifically. In addition to being a military educator and West Point superintendent, Partridge was an exercise enthusiast who firmly believed that the link between physical and mental strength was obvious to even the most “superficial observer.” Partridge further postulated that unless soldiers trained themselves physically, they would be “deficient” of the mental endurance necessary to overcome the challenges they were sure to encounter in their careers¹¹. Four hundred years of scientific advancement have gradually chipped away at Descarte’s dualism and the fundamental practice of stoicism has resurfaced in the twenty-first century under the synonym of mindfulness. Today, practicing mindfulness is highly encouraged for military service members specifically by numerous experts ranging from clinical psychologists to the Deputy Assistant Secretary of Defense Michael “Mick” Mulroy¹².

This wisdom was not promoted in modern Western society as it was in ancient cultures; this was not because the notion was inconsequential but because promotion was largely unnecessary. Before the United States was settled in the eighteenth and nineteenth centuries, for example, men, women, and children all had to be physically active on a daily basis. No one had to make a conscious effort to walk for thirty minutes each day when his/her daily routine involved hours of demanding manual labor. Before every family owned a vehicle, children walked or ran several miles to school. The Industrial Revolution, despite the remarkable improvements it brought to the world, marked the beginning of the end of this way of life. In fact, the typical American lifestyle had begun a downward trend toward sedentation so sharply that by 1908 President Theodore Roosevelt decided that members of the United States Armed Forces needed to complete some type of Physical Fitness Test (PFT) to prove their fitness to serve¹³. Although this test was called the Physical Fitness Test, it may have been appropriate to simply call it the Fitness Test because the purpose of the test was not solely physical. The PFT demanded successful completion of one of three different options: a fifty-mile walk/run, a ninety-mile ride on horseback, or a one-hundred-mile bicycle ride. Whichever option the service member chose had to be completed over the course of three consecutive days. While this test obviously demanded some basic level of physical fitness, the length of this test demanded more psychological endurance than physical endurance. Riding a horse for ninety miles over three days does not require strong muscles or speed, but it does demand the ability to cope with a level of sustained discomfort. The psychological insights indicated by this test were acknowledged by Rear Admiral Presley Rixley, the Chief of the Navy Bureau of Medicine (BUMED) when he told President Roosevelt that “it is the opinion of the Bureau [of Medicine] that many such officers

[seeking a waiver from the PFT] will suffer breakdown upon the advent of war and fail to render any adequate return to the Government....”¹⁴

By the early twenty-first century technological advances had advanced exponentially to the point where one could potentially press a button on a microwave to make breakfast, complete a full day of work from a desk,, shop for groceries and other commodities on the internet, make dinner in the kitchen using an array of technologically advanced appliances, watch television for a few hours, and go to bed without taking more than a combined hundred steps and never raising his/her heart rate much above a state of rest. Although this example is likely hyperbolic, it clearly illustrates the contrast to past ways of life. It is likely no coincidence that this lack of physical exertion has coincided not only with obesity and physical ailments but also a high incidence of mental health issues associated with poor psychological resilience. Unfortunately, this sedentary lifestyle may not be a choice for many working-class citizens in current Western society. To add a nuanced perspective to the previous hypothetical example, the employee may wake up with only enough time to make a fast breakfast before taking children to school and beginning a long commute in rush hour traffic. He is possibly expected by his supervisor to be seated at his desk for the entire day with only a thirty-to-sixty-minute break for lunch. After work he may have family events to attend followed by dinner and miscellaneous chores at home, leaving only enough time to relax for an hour or so before going to sleep again to repeat this mentally exhausting series of events the next day. Even with stellar motivation and time management this person may still not be able to predictably find thirty minutes to exercise, shower, and groom, more than a few times per week. Fortunately, this problem set has prompted a torrent of productive scientific research in recent decades and society at large is beginning to notice; this research is the subject of the following literature review.

Literature Review

The concept of psychological resilience, described as the ability to successfully overcome significant stress, distress, or adversity, has been discussed in psychological research for more than forty years at the time of this writing¹⁵. Of this research, a modest portion pertains to members of the armed forces. Though the research is proportional to the percentage of the world who serves in the armed forces, one can assert that few groups outside the notable exceptions of law enforcement experience more abrupt, acute, stressful circumstances on a fairly routine basis than members of the armed forces. For this reason, many psychologists, neurologists, behavioral therapists, and other mental health professionals conducting resilience research have begun using the previously underutilized armed forces population in recent years.

Around the same time that the idea of resilience was being defined and studied, the third edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM III) included a new diagnosis of Post-Traumatic Stress Disorder (PTSD)¹⁶. While no research publication has unequivocally stated that PTSD is totally synonymous with a lack of psychological resilience, or, similarly, that a lack of resilience is the primary cause for PTSD, studies do suggest that a negative correlation between resilience and PTSD¹⁷. Accordingly, improving psychological resilience is likely an effective means of reducing the risk of suffering from PTSD in the future¹⁸.

Though initial research in the 1980s regarding PTSD was instrumental to the medical community's current understanding of the disorder, modern psychology and neurobiology research has exponentially advanced the understanding of PTSD in the last forty years. An advantage objectively defining PTSD and assigning standard criteria for diagnosis has allowed tracking its incidence of diagnosis over the past decades. While some may argue that increase in

incidence of PTSD can be attributed to a period of mental health practitioners becoming accustomed to diagnosing a newly categorized disorder, this phenomenon would certainly taper off within a few years if individuals were truly being affected at a similar rate each year. However, this has not been the case with PTSD incidence in the United States Armed Forces. A retrospective cohort study comparing the incidence of PTSD in United States Armed Forces service members from 1999-2008 showed a seven-fold increase over that time period with new cases increasing by forty-three percent each year¹⁹.

In addition to the sheer increase in the amount of research performed on PTSD is the sophistication of the research. The advent of computed tomography (CT) and functional magnetic resonance imaging (fMRI) allows researchers to view oxygen utilization of different brain regions in real time and postulate which regions of the human brain are responsible for cognitive functions such as memory, higher-order attention, and inhibition control. These technological advances allow scientists to make reasonable assertions as to the brain regions which are detrimentally affected in PTSD patients and attempt to objectively verify their hypotheses. Brain regions of particular interest include: the anterior cingulate cortex (ACC) which is responsible for emotional regulation, inhibitory control, and autonomic integration, the dorsomedial prefrontal cortex (dmPFC) which is thought to be responsible for the conceptualization/understanding of emotions, and the hippocampus which is thought to be responsible for storage of long-term memories (Figure 1). Significant observable differences in the physical structure of these brain regions in individuals diagnosed with PTSD has been abundantly documented in studies^{20,21,22,23,24,25}.

Around the turn of the twenty-first century research in the emerging field of exercise psychology began exploring neurobiology and neuropsychology from a different viewpoint;

whereas most scientists prior to this time century viewed physical performance as an independent task isolated from the effects of emotion and cognition, research began providing overwhelming evidence that this was not accurate. Various creatively designed studies have proven that a subject in a positive, non-fatigued mental state will likely perform better in a test of physical endurance than if his/her mind was fatigued, despite having fresh, non-fatigued muscles²⁶. This convincing link between body and mind prompted researchers, especially in the field of military readiness²⁷, to further investigate how one's mind and muscles can affect one another²⁸. An especially useful tool for determining mental endurance is known as the Stroop task, which requires a participant to observe a series of words in different colored font. The participant may see the word "blue" but the word may be any color. The objective is to select the actual color of the word, not the word itself. For example, if the word "blue" appears in green font, the correct answer is green, not blue²⁹. The instinctive response for participants is to select the word, not the color, so this task is very demanding of the brain region responsible for inhibitory control, the ACC³⁰. Hypothesized as a link between emotional and physical domains, the ACC has been shown to play a significant role in physical endurance performance as well, likely in a similar capacity of inhibitory control. A runner who has been racing hard for thirty-five minutes in the course of a forty-five minute race wants nothing more than to stop running and end his/her suffering; the ACC is the region of the brain which, if adequately strong, allows the runner to override the desire to quit and endure through the race, regardless of his/her discomfort. A brilliant example of the ACC's importance to endurance performance was highlighted in a study which recruited two groups of subjects, recreational cyclists and professional cyclists, and required them to complete a twenty-minute stationary bike ride at maximum effort on two separate occasions: once after completing a cognitively easy ten-minute

task and once after a thirty-minute Stroop task. The purpose of the Stroop task was to fatigue the brain, especially the ACC. Not surprisingly, the recreational subjects performed significantly better after the easy ten-minute task than after the Stroop task. More interestingly though, the professional cyclists were not only less affected by the Stroop task but performed significantly better on the Stroop task than the recreational cyclists, which may suggest that the professional cyclists had, on average, more developed ACCs than the recreational cyclists³¹. A similar study employing college students showed a similar positive correlation of weekly exercise time and Stroop task score³².

Studies such as these would not be significant in the context of improving psychological resilience if research had not established that a typical PTSD patient exhibits a damaged or underdeveloped ACC, but such studies do exist^{33,34}. In addition to the ACC, deficiencies in the prefrontal cortex, hippocampus, and amygdala, mentioned previously, have also been observed in PTSD patients³⁵. Such studies inspire the idea that physical endurance exercise can not only be affected by mental disorders³⁶, but also potentially prevent and/or improve mental disorders.

There is already a preponderance of evidence that shows that physical exercise is, in general, correlated with mental health^{37,38}. This assertion has been generally accepted by scientific communities and has been integrated into American culture for decades. However, hundreds of such articles cite mechanisms such as increased blood flow to the brain³⁹ during physical exercise and likely result only in a transient emotional response that would diminish after a few hours or days. Some studies have gone one step further, concluding that physical exercise has a more durable benefit regarding emotional well-being but do not propose a causal mechanism^{40,41}. A precise mechanism of action involving structural changes to the brain

stimulated by habitual physical endurance exercise through the amygdala-locus coeruleus-ACC pathway has been proposed, though evidence is currently limited⁴².

Many studies demonstrate a positive correlation between physical endurance training and structural changes in the brain regions responsible for resilience. Two studies use a quantifiable index of endurance fitness known as VO₂ max, which measures the maximum volume of oxygen uptake proportionate to bodyweight during exercise; VO₂ max is represented by a number and increases when subjects regularly partake in aerobic exercise. The first of these studies found that three sessions of sixty-minute cardiovascular endurance exercise sessions per week (defined as continuous exercise at 40-70% of maximum heart rate reserve) significantly increased the volume of the ACC and also improved VO₂ max by sixteen percent when compared to three bouts of sixty-minute stretching and toning exercises⁴³. Ten years later, a second study compared endurance athletes in their fifties with an average VO₂ max of fifty-five to similarly aged healthy adults with an average VO₂ max of thirty-eight. This study showed a significant correlation between aerobic fitness and brain thickness, specifically in the prefrontal cortex, a region commonly deficient in PTSD patients. While this study did not observe a volumetric change in the ACC, hippocampus, or amygdala, the athletes' brains exhibited a cortical "reserve" which is thought to protect against damage to those brain regions⁴⁴. A new study goes a step further by proposing a specific mechanism by which the brain is augmented by physical endurance training. Earlier this year, Lippi, et al. asserted that molecules called neurotrophins cause nerve structures in the brain to proliferate in response to physical endurance training. The authors define their endurance exercise protocol as no less than thirty minutes per session, at least two to three times a week, for at least three months⁴⁵.

Conversely, another prominent belief is that physical endurance training should not be used as the primary method of mental health treatment but as a supplement to behavioral therapy, specifically meditation. One study showed improved function and physical changes to the hippocampus in patients suffering from schizophrenia and major depressive disorder when frequent aerobic endurance training was combined with behavioral therapy⁴⁶. A separate study utilizes a concept known as “MAP” training. “MAP” is an acronym which stands for “mental and physical.” This protocol combines twenty minutes of still, silent meditation, ten minutes of slow-walking meditation, and thirty minutes of aerobic exercise in a single sixty-minute session. When completed twice each week for six consecutive weeks, victims of sexual trauma suffering from PTSD reported a sixteen-percent decrease in symptoms while the groups participating in either meditation or aerobic exercise alone experienced less than ten-percent reduction of symptoms. This protocol was likewise effective in decreasing symptoms of major depressive disorder by forty percent⁴⁷.

The current body of literature provides an excellent picture of the problem that the United States Armed Forces faces with respect to resilience and PTSD. Ample scientific evidence also declares that the link between physical and psychological wellbeing is more hardwired than understood twenty years ago. However, ambiguities exist in the literature that complicate the creation of a practical, effective, standardized aerobic training protocol to improve resilience. Variables including age, exercise duration, frequency, and intensity, and integration with behavioral therapy require further consideration.

Arguments

Without restating all the aforementioned studies, a preponderance of evidence suggests an association between frequent aerobic training lasting thirty to sixty minutes, increased/improved structure and function of numerous brain regions, and improvement of mental health conditions related to a lack of resilience. Unfortunately, these studies are puzzle pieces, and until all the pieces are put together one cannot definitively comment on the big picture. Association does not prove causation, but these studies do lay an excellent foundation for future research which would give credibility to this theory that physical endurance training is the variable that achieves the end state of improved resilience. The recommended details of such a research project will be outlined in a subsequent section.

One controversy that arises upon closer examination of this issue is the recommended intensity of exercise. Exercise physiologists and coaches have spent endless hours studying how the human body responds to different types of exercise. Subsequently, these experts have assigned specified intensity zones. These zones correspond to rating of perceived effort (RPE), heart rate (HR), power output, or pace. Some of these zone range calculations are extremely sophisticated and seem to require an advanced degree in mathematics to understand with up to ten distinct zones. Others are somewhat more basic encompassing somewhere between four and seven zones. For the purpose of this discussion three zones will be used for intensity of exercise: easy, moderate, or hard. Easy exercise is characterized by the participant staying below the ventilatory threshold, or the point where he/she begins to breath harder and cannot carry on a conversation. Above the ventilatory threshold, conversation becomes difficult and breathing intensifies so that the participant can still speak in a few short sentences and sustain the exercise for up to an hour if he/she is well trained; this zone can be defined as moderate intensity.

Hard/high intensity efforts can only be sustained for no more than a few minutes without taking breaks of a few minutes. This intensity scale is simple and correlates with the distinct ways that these different intensities affect the body as validated by numerous studies⁴⁸. In the last decade high intensity interval training (HIIT) has become in vogue. Evidence has suggested that HIIT workouts are more effective at maintain or even building muscle, burning fat, and improving hormone function/metabolism in less time when compared with steady-state endurance training⁴⁹. Both high intensity and low intensity exercise raise maximal oxygen uptake, but HIIT does it with less time devoted to training. With the promise of achieving a fit, healthy, strong body in less time, it may seem illogical that anyone with this knowledge would ever choose to use longer, easy-intensity workouts instead of HIIT training. There is one advantage of longer duration endurance training that HIIT does not achieve, which is interleukin-6 (IL-6) secretion. At first glance, activity which increases IL-6 levels is not something to be desired. After all, IL-6 causes fatigue and has been associated with decreased brain cortical thickness, decreased hippocampal volume, and major depressive disorder⁵⁰; this sounds like the exact opposite of the resilience-inducing benefits exercise has been purported to produce. Using up the body's glycogen fuel stores during endurance exercise is what stimulates IL-6 release in the body. While a hard two-mile run may double an athlete's IL-6 release, a six-mile run at a much lower intensity increases IL-6 release by a factor of ten and a full marathon (26.2 miles) increases IL-6 levels one hundredfold⁵¹. Again, this IL-6 increase seems to be a negative consequence to be avoided until one considers that well-trained endurance athletes actually produce less IL-6 than untrained or minimally trained athletes. By frequently exposing their musculoskeletal and nervous systems to this fatigue inducing molecule, they build up a resistance and actually have lower levels of IL-6 than the average person⁵². Although the proposed mechanism of resistance

to IL-6 would explain the physiological brain changes cited by the 2016 Wood study discussed earlier, touting this effect as the cure for depressive disorders and/or PTSD would be wildly irresponsible until clinical trials examining this effect can show not only correlation but causation. Given the existing body of evidence, randomized clinical trials designed to show consistent association and/or causality are the logical next steps. The reason the benefit of IL-6 resistance is mostly observed in low intensity endurance exercise is because IL-6 release is directly related to duration of exercise, and only at low intensity can an individual consistently exercise for an extended duration. One may run a ten-kilometer race at moderate intensity but would require several days of recovery before the feat could be repeated again. By adopting an approach that consists of at least roughly eighty percent of time spent at low intensity, one can reap the benefits of training his/her body to cope with fatigue and, in turn, become more resilient.

A second concern involves exercise intensity specifically for armed forces service members. While low-intensity steady-state exercise may be sufficient for the general population who wish to reap the benefits of resilience, the men and women of the U.S. armed forces need to maintain a state of combat readiness that may not be achieved by frequent long, easy efforts. Combat readiness involves aspects of speed, power, and anaerobic strength in addition to aerobic endurance. The Marine Corps Combat Fitness Test (CFT) consists of an 800-meter run, a thirty-pound ammunition can lift for maximum repetitions in two minutes, and an obstacles course of approximately two to three minutes requiring agility, speed, and strength. This test is designed to simulate challenges that may arise in a forward-deployed environment under fire. A Marine or Sailor who is conditioned for endurance but lacks speed and power will likely not perform especially well on the CFT and possibly be underprepared for a combat environment. For this reason, the recommendation of allotting around eighty percent of total training time for low

intensity endurance training still leaves ample time for anaerobic training, including HIIT and weightlifting, for example.

A third issue that arises from the research is whether to decrease the amount of physical training in favor of incorporating meditation at the beginning of training sessions, e.g. MAP training, or to maximize time spent physically training to leverage the neurophysiologic pathways previously discussed in depth. If one approaches this question with an evidence-based mindset, the choice is apparent. While evidence suggests that psychological benefits are derived from participating in physical training lasting thirty to sixty minutes, there is no evidence that the constructive effects have a direct linear relationship to the amount of time devoted to exercise alone. If the psychological effects of endurance training are gained in a similar fashion to the musculoskeletal and cardiovascular effects, there will be an effect of diminishing returns; riding the bike for thirty minutes will derive a given amount of benefits for the rider, but doubling the time spent riding will not double the benefits. Doubling the duration again from one hour to two hours will not even come close to doubling the benefits and, factoring in the risk of overuse injury, could even do more harm than good. For this reason, service members would be wise to incorporate the recommended ten minutes of meditation/self-reflection at the beginning of each session to compound the benefits of both practices within each session. MAP training is, after all, not new. When one recalls that the stoics of ancient civilizations built a large part of their philosophy on the practice of meditation and self-reflection, the congruency of these ideas is apparent. An intriguing twentieth century case study that illustrates the revival of stoicism, or rather the precursor of MAP training, is the Australian athlete Herb Elliot who trained under the notoriously eccentric Percy Cerutti in the 1950s and 1960s. Cerutti is regarded as one of history's most controversial coaches and trained his athletes using what he dubbed "Stotan"- a

marriage of stoic and Spartan- principles⁵³. The foundation of Cerutti's approach was the emphasis on mental and physical aspects of training. As expected of world class runners, Elliot and his teammates ran plenty, but they ran up and down sand dunes in the Australia heat and did open-ocean swims nearly every day, often without regard for sea conditions. In addition to their physical training, Cerutti prescribed his athletes poetry, philosophy, and Bible reading to stimulate meditation and spiritual health. Unlike some of his teammates, Elliot committed himself wholeheartedly to Cerutti's methods and devoted all his energy to building physical and spiritual fitness. Elliot was rewarded with a gold medal at the 1960 Rome Olympics in the 1500 meters and set a world record in the mile at 3:54.5. The Stotan athlete-philosopher in fact never lost a race at either of those distances his entire career; he retired undefeated⁵⁴. While it would be speculative to assume that Cerutti's approach built superior psychological resilience in Elliot, one cannot help but acknowledge the similarities between the Stotan approach of the mid-twentieth century and the current-day MAP approach and wonder if Elliot would have achieved his athletic victories without simultaneously cultivating such robust spiritual fitness. While no one is suggesting that everyone who enthusiastically adopts MAP training will become a philosophical, introspective, world-class athlete, a method with the potential to foster any one of these traits is worth attempting.

Limitations

One may notice that while the connection between physical endurance training and mental resilience seems to be supported by an abundance of scientific research, the randomized controlled clinical trials specific to demographics typical of U.S. Armed Forces service members are somewhat lacking. As of 2018, sixty-seven percent of active duty service members were

under the age of thirty, with more than two-thirds of that group under the age of twenty-five⁵⁵.

This shortfall may weaken the evidence necessary to make a compelling case to drastically alter the PFT and/or physical training regimens of service members, but no great leap is required to posit that the same beneficial physiologic effects in the brains of older adults, whose brains are less malleable, would occur in a younger population as well.

A shortfall to proving the efficacy of this revolutionary method to building resilience is the presumed lag period necessary before measurable benefits could be realized. Clinical trials can be expensive to conduct and become more difficult to carry to completion as the duration increases. If this statement is true for a relatively static general population it is doubly true for a military population which moves every two to three years on average. Additional training exercises and deployments limit the availability of service members to participate in any type of clinical trial even further. Assuming control of these variables also doesn't change the reality that physiologic changes to one's cardiopulmonary system take weeks or even months to be observed; that time is likely minor compared to the time necessary for changes in brain morphology. This is the reason that the overwhelming majority of the studies showing actual brain structural changes are either cross-sectional, cohort, or retrospective studies rather than prospective clinical trials since these research designs can produce results significantly faster.

Recommendations/Conclusions

Abundant correlations have been made between physical endurance training and mental resilience, but an irrefutable causal relationship can only be validated with a randomized controlled clinical trial which can be repeated and further validated by others. Unfortunately, this particular hypothetical clinical trial would be difficult, though not impossible, to execute due to very specific subject recruitment and possibility of subject noncompliance with study protocols.

Theoretically, this study would recruit healthy male and female subjects from diverse ethnic backgrounds representative of the U.S. Armed Forces. Most subjects would be between eighteen and thirty-five years of age and physically active but not trained endurance athletes. The final inclusion criteria, and the one most difficult to satisfy, would be past experience of a traumatic event; specifics for inclusion based on this criterion would be debated by the researchers on a case-by-case basis. A statistical power analysis would be completed before populating the study to determine how large the study would have to be to demonstrate statistical significance. Baseline physical and mental health assessments would be recorded as well as fMRI of the ACC, PFC, and hippocampus. Baseline VO2 max and IL-6 blood level would also be tested and documented. The first test group, consisting of roughly one third of the enrolled subjects, would be put on a physical training regimen including thirty to sixty minutes of continuous aerobic training at least three times per week combined with meditative exercises consistent with the MAP approach discussed earlier. The second test group, consisting of roughly one third of the enrolled subjects, would be put on the physical training regimen only with no meditative practices, while the control group continued their current fitness regimen with no intervention. The groups would be reassessed at six months, twelve months, two years, and, if feasible, annually for up to five years. Each reassessment would document all the same data collected at baseline and also note any notable new stressors in the subject's life not previously documented. While it is easy to design this hypothetical study, executing it would prove somewhat difficult, but the knowledge gleaned from such an endeavor could certainly be worth the toil.

A less daunting recommendation is to change the events evaluated by the armed forces various physical fitness assessments. Currently, the cardiovascular endurance section of the Navy and Air Force PFT is a one-and-a-half mile run or comparable swim or bike option. The

Army's PFT is slightly longer at two miles with the Marine Corps doubling the Navy and Air Force's event with a three-mile run. In order to ensure that armed forces service members are incorporating adequate endurance training into their routines the service member should be allowed to choose between a ten-kilometer (6.21 mile) run, a twenty-kilometer (12.4 mile) stationary bike, or fifteen-hundred-meter (0.93 mile) swim. The purpose of such a change would not be to make the event more painful or to transform service members into endurance athletes, but to fortify the minds of service members against the stress of daily life in the military. By increasing the distances of the events, the type of training to prepare for the events is necessarily changed to mimic the aforementioned routine which is hypothesized to improve mental resilience. This format would also reveal more about the psychological health of a service member than a shorter event. Many service members can go pass their service's PFT without training or having to push themselves psychologically, but the number of service members who could do so with this proposed format would diminish significantly. This may be met with heavy resistance initially if leadership from the various military services perceive that PFT scores will drop, but this is not necessarily the case. Service members who dutifully train for the proposed PFT may even find that the actual PFT event is easier to pass than the current PFT, but it would require more preparatory training. A drop in readiness statistics would likely not reflect a drop in physical ability but decreased preparation. The lifestyle of active duty service members should now be contrasted with the hypothetical working-class citizen who doesn't have adequate time to exercise regularly; current Navy and Marine Corps regulations allow up to three hours of physical training per week during normal working hours. Performance standards should be calibrated so that service members utilizing this time effectively three times per week should be able to achieve high scores on this section of the PFT. These standards should apply to all

military occupation specialties (MOSs) in keeping with the ethos that every member of the armed forces is expected to maintain the readiness of as a warfighter, even cryptologists and dentists.

Thirdly, since the only research that supports the resilience hypothesis shows association with long duration exercise and/or improvements in VO2 max, weightlifting should be prioritized only to the degree that allows the service member to maintain combat readiness and perform well on the PFT and CFT. In spite of the significant social component and anecdotal reporting of ephemeral stress reduction associated with body building, at the time of this writing there is not yet any documented evidence supporting body building as a method of improving psychological resilience or functional combat fitness.

A final recommendation would be to include service members to utilize the MAP training previously mentioned. This method has been shown to be effective at improving resilience; it is not unlikely that corroborating research will be forthcoming. Service members should receive face-to-face mandatory annual training by a trained professional who can take the trainees through a practice session. Instituting this recommendation may prove the most challenging as it would necessitate a culture change throughout the U.S. armed forces. Sadly, anecdotal evidence suggests that many are resistant to any type of mindfulness or meditative practices. The MAP method may gain more acceptance by presenting mindful meditation as one of the tenants of stoicism, which service members are more likely to be familiar with and readily adopt, and emphasizing the inherent physical component, which most service members are familiar and comfortable with. Identifying a select group of individuals from within the Armed Forces to receive training in the MAP approach from instructors outside the military and subsequently serve as a trainer for other military instructors. This process in which these instructors educate

larger groups within the Armed Forces, known as a train the trainer approach, is the most favorable course of action for dissemination of this information. Not only is the train the trainer approach likely to enhance acceptance but it also lowers the total cost of the program and allows the message to be tailored specifically for the target audience⁵⁶. In the end, encouraging this culture change is likely to be a slow process, but one that has the potential to pay dividends to the U.S. Armed Forces and beyond for generations to come.

Though the current scientific literature cannot prove a causal relationship between physical endurance training and psychological resilience, each study is a puzzle piece contributing to a much larger, more comprehensive work. The puzzle will only be complete when the aforementioned randomized clinical trials are completed, but one cannot deny the compelling evidence implied by the existing body of evidence. Though science has not yet quantified the exact physical training protocols that will yield the greatest psychological benefits, one can confidently state that implementing two or three weekly physical endurance training sessions of at least thirty minutes, ideally incorporating five to ten minutes of meditation, will likely yield psychological benefits. While anyone can reap these benefits, members of the armed forces are likely to be put in situations where psychological resilience may be the difference between recovering from a traumatic incident and suffering a lifetime of posttraumatic stress disorder. Military leaders can encourage the incorporation of endurance training by increasing the duration of the various services' physical fitness tests.

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Figure 1. Cross-sectional illustration of human brain with anterior cingulate cortex (ACC) highlighted (Brodmann, public domain, 2020).

