Department of Behavioral Sciences and Leadership

West Point Resilience Project (WPRP)

Research Report PL488E11

Measuring Stress and Ability to Recover from Stress with Salivary α-Amylase Levels

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April 2011

Report Documentation Page

Form Approved OMB No. 0704-0188

1. REPORT DATE **APR 2011**	2. REPORT TYPE	3. DATES COVERED
4. TITLE AND SUBTITLE **Measuring Stress and Ability to Recover from Stress with Salivary Alpha Amylase Levels**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S) **Brandon Mulrine; Michael Sheehan; Lolita Burrell; Michael Matthews**		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **United States Military Academy,Department of Behavioral Sciences and Leadership,626 Swift Road,West Point,NY,10996**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
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15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**		**23**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

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ABSTRACT

In recent years, an increasing number of Soldiers have experienced multiple deployments in combat zones, thus increasing the potential for disorders such as posttraumatic stress disorder to occur. In order to better understand the relationship between the stress of combat and well-being, this paper includes a review of the impact of stress on humans, and the impact that resilience has on moderating certain stress-related conditions. The findings suggest that measuring salivary α-amylase levels may help to determine a Soldier's resilience or risk of developing PTSD as part of the research efforts associated with the Comprehensive Soldier Fitness program.

MEASURING STRESS AND ABILITY TO RECOVER FROM STRESS WITH SALIVARY α-AMYLASE LEVELS

CONTENTS

Introduction

Many studies have been recently conducted that show a positive correlation between stress and salivary alpha amylase (sAA) levels. However, these studies have focused primarily on an individual during, or immediately after a period of psychosocial stress, and have not focused on an individual's ability to recover from stress. The purpose of the proposed study is to use salivary alpha amylase measurements to determine one's ability to recover from stress by measuring a Soldier in as relaxed a state as possible before and after an exposure to stress, and then compare the alpha amylase levels. We hypothesize that Soldiers who have been trained using Comprehensive Soldier Fitness (CSF) methods will, on average, show levels of sAA, that after exposure to a stressful event, will more closely correspond with their baseline test when compared to those who did not receive the training. If this is the case, it would mean that sAA would be a viable biobehavioral marker that could be used to measure a Soldier's ability to bounce back from a stressful experience such as a deployment.

Throughout a human being's lifetime, he or she is exposed to countless stressful and uncomfortable situations and forced to deal with them. Some people respond to these stressors in positive ways, by growing and excelling, while others seek comfort in activities that only hurt them more. Most people fall somewhere in the middle in terms of their reaction to stress, between these two extremes. Several possible explanations exist for the differences in responses to stress, including differing approaches towards adapting to stress, differing levels of resilience, length of time the stressor is present and a number of other factors. In order to understand the way that these factors affect different individuals' stress responses, one must first have a firm grasp of not only stress but also of some other concepts closely related to it.

General Adaptation Syndrome

All living things survive by maintaining a state of “dynamic and harmonious equilibrium”, know as homeostasis, in their environment. Stress can be best defined as the forces that constantly challenge this state of equilibrium (Chrousos & Gold, 1992). Stress forces living things to constantly adapt in order to maintain homeostasis through a series of actions known as “adaptational responses” (Chrousos & Gold 1992). These adaptation responses are generally categorized by using a classification system known as the general adaptation syndrome (GAS) (Citizens Centre Report, 2003). This system, developed by Canadian endocrinologist Hans Selye, classifies reactions to stressors into one of three categories; alarm, resistance and exhaustion (Selye, 1950).

When an individual or an animal is exposed to a stressor, the initial reaction is the alarm phase, also commonly referred to as the “fight or flight” stage, during which physiological changes ready the person to either flee or fight. If the stressor is prolonged and persists over a longer period of time than expected, the second stage of the GAS, resistance, begins. In this stage, the individual’s body works to counteract the stressor. However, this places the individual at risk from other homeostatic interruptions, or other stressors. If the stressor is maintained for some unspecified length of time the third phase of the GAS comes into play, exhaustion. It is not a definite fact, but many believe that this stage begins when one’s adaptation resources are depleted and one has no more energy to work to maintain the homeostasis that the stressors are trying to interrupt (McCarty & Pacek, 2000).

The alarm stage is when many of the most noticeable physiological changes occur in the body as a result of stress. The alarm stage is broken down into two phases, shock and counter shock (McCarty & Pacek, 2000). A stressful event that causes one to enter the alarm stage activates neural, neuroendocrine and neuroendocrine-immune mechanisms (McEwen, 2006). These activations make up the shock phase of this stage, and they are counteracted, in part by the counter shock phase, which activates the adrenal cortex, releases corticosteroids and epinephrine, and activates the adrenal medulla (McCarty & Pacek, 2000). This combination of chemical releases comprises the alarm stage of the general adaptation syndrome, and once these processes are complete, the individual is as physiologically prepared as they can get to deal with a stressor (Chrousos & Gold, 1992).

As previously stated, if a stressor is prolonged over a period of time, the individual being subjected to the stress will more than likely move into the resistance stage. During this stage, more physiological changes occur; however this time the body is readying itself for more of a prolonged engagement than in the alarm stage. The adrenal cortex plays a key role by balancing the release of syntoxic and catatoxic steroid hormones. The syntoxic hormones work to inhibit inflammatory responses in tissues throughout the body, while the catatoxic hormones attack pathogens by promoting inflammation in them and thus making them vulnerable (McCarty & Pacek, 2000). In this period, an individual being inundated with stressors has made the physiological changes that allow them to deal with the stressors and maintain homeostasis for a prolonged period of time.

However, at a certain point, when one's resources needed to fight to maintain homeostasis have been depleted, the third stage of exhaustion sets in. In the first two stages, no matter how dire the situation may seem, a person generally has the resources to struggle against the stress that is causing them issues. However, when the level of exhaustion has been reached, they simply have no more resources to struggle with left (Friedman & Silver, 2007). Friedman elaborated on the state of exhaustion, commenting that it has some commonality with depression, a condition in which a person has given up struggling to move forward. Whether a person has run out of resources to move forward or has simply given up the goal of moving forward, the end state ends up very similar in both cases. When a person enters this level of the GAS, a number of things can happen to them. Quite often the individual will be fine and will simply need to take some time off in order to recover the resources they need to battle stress and be back in action almost right away. Other times the individual will experience acute distress from which they are able to almost immediately recover, and still others seem to recover quite quickly but can never fully shake the experience that caused them so much stress (Bonanno 2004). Such an experience can lead to that individual developing a stress disorder.

Posttraumatic Stress Disorder

One stress disorder that has received an incredible amount of attention recently due to the spike in Soldiers returning from the Global War on Terrorism (GWOT) being diagnosed with it, is posttraumatic stress disorder (PTSD). PTSD is a stress disorder that has a very foggy path to diagnosis. Certain methods for determining if someone has PTSD are extremely strict, while others are a bit more lenient in their interpretation of some symptoms of PTSD. One fairly commonly accepted set of diagnosis criteria are those noted by Ironson, Cruess, & Kumar (2007). In the article, the authors state that the first requirement for a PTSD diagnosis is exposure to a traumatic event that involved a threat of death or serious injury. In addition, the person's response involved fear, helplessness or horror. Also, the person being diagnosed must experience three symptom clusters such as re-experiencing the traumatic event, avoidance and numbing, and increased arousal, or hyper arousal . Patients from the re-experiencing cluster noted events such as flashbacks, recurrent distressing dreams of the trauma, intense distress at exposure to things reminding them of the trauma, intrusive and recurrent thoughts of the event, and physiologic reactivity to reminders of the event. Patients classified as demonstrating avoidance reported “avoidance of thoughts of the event and avoidance of activities, places or people that remind one of the event; an inability to recall significant aspects from the event; withdrawal from activities; feelings of detachment from others; an inability to have loving feelings; and lowered expectations about having a future” (Ironson, Cruess, & Kumar 2007). Patients in the final cluster displaying increased arousal experienced “such symptoms as difficulty concentrating, hypervigilance, an exaggerated startle response, problems sleeping and increased irritability” (Ironson, Cruess, & Kumar 2007).

In order for a client to be diagnosed with PTSD, it is not enough to simply experience some of the symptoms listed in the previous paragraph. Instead, the client must have experienced symptoms from all three clusters for at least one month. Additionally, these symptoms must “have caused significant distress or impairment in ability to function in social or occupational roles” (Ironson, Cruess, & Kumar 2007). If all of these conditions are met, according to this rubric, then PTSD is a proper diagnosis. Some rubrics allow for a diagnosis of PTSD with fewer or less consistent symptoms than the previous rubric. As a result, individuals who are on the borderline of having PTSD or not having PTSD may be treated with the same methods.

Coping

Some of the methods that have been used to resolve one or more of these symptoms and prevent PTSD have been shown to work, and others are less conclusive. Overall, any action taken by an individual in an attempt to try and lower their level of stress is known as coping. More specifically, Brett (1996) defines coping as “any attempt to increase the gap between actual stress and subjective distress.” As such, coping is an incredibly important process and the manner in which a particular individual copes with external stressors plays a huge role in the amount of subjective distress an individual experiences. Coping generally can take one of two forms, adaptive or maladaptive coping. Maladaptive coping consists of taking action in an effort to lower one's subjective personal distress levels that end up actually harming oneself in the long run. Some examples of maladaptive coping include attempting to use alcohol or drugs to try to forget about a stressful experience, avoiding speaking or thinking about a stressful experience, or engaging in dangerous activities such as fast driving or taking reckless risks. These types of actions are often the result of isolated stressors where an individual doesn't feel as though they need a long term solution and are simply reacting to a single event (Bonanno, 2005).

Adaptive coping on the other hand is coping that has a positive impact on the individual and can include things such as displaying dispositional optimism and working through some of the issues causing the stress with social networks that to which one might belong (Westphal & Bonanno, 2007). Oftentimes these coping mechanisms both help an individual to lower their stress level as well as protect them from some of the negative outcomes associated with having a high stress level. For example, "it appears that social support can protect people in crisis from a wide variety of pathological states; from low birth weight to death, from arthritis through tuberculosis to depression, alcoholism and the social breakdown syndrome" (Cobb, 1995).

Those who react in a neutral or even in a positive manner in response to some terribly stressful situation may be referred to as "hardy" or "resilient". These individuals always seem to engage in adaptive coping and rarely delve into any maladaptive behaviors, keeping themselves fit and ready to move forward. It has become a very contentious point of debate recently whether these individuals are resilient because of their choice of coping skills, or if their predisposition to be resilient allows them to choose adaptive coping methods. It might seem reasonable to conclude then, that the majority of people are not all that resilient, and that those who can manage the stress better than everyone else are among the few resilient individuals around. However, studies show that "resilience is the most common response to potential trauma (Bonanno, 2005)." In fact, every once in a great while an event occurs that truly showcases the incredible capacity of humans to endure through hardship and stress and be resilient against the pressure of that stress. One shining example of that occurred on September 11, 2001, when the World Trade Center in New York City was attacked. This event was a horrible tragedy that put an incredible number of people under unimaginable amounts of stress, and according to research conducted since, the level of resilience following such an event is far higher than it had been thought (Bonanno et al., 2006). These same researchers found that as many as 65% of those at risk for PTSD showed resilience in their response to the bombings.

These findings bring about a question that has been asked over and over again since this subject began to be explored, "How does one measure resilience?" Many different methods have been used in the past, including the one used by Bonanno in his studies of the 9/11 attacks, and a new scale recently created to try and objectify the entire process a little more, known as the Connor-Davidson Resilience Scale (Connor & Davidson, 2003). Many of these metrics are reliable and valid, but they rely on a Soldier being exposed to the type of stress that puts one at risk for PTSD to provide feedback concerning resilience. If a rubric existed that could use some sort of a biobehavioral marker that could be quantitatively measured, scientists would have the capability to test people for resilience before they were ever exposed to crushing levels of stress and as a result, target training towards those who display less of a predisposition towards resilience. One method that may have potential to work in this area is the measurement of salivary alpha amylase before, during, and after a stressful event to determine the time it takes a Soldier to recover from the controlled stress. Knowing this would give researchers an idea of the

Soldiers' resilience scores, and might help in the future with preventing PTSD and other stress disorders.

Salivary Alpha Amylase

Salivary Alpha Amylase (sAA) is an important biobehavioral metric which may help in determining who possesses the best characteristics to be resilient. So what is salivary alpha amylase? To start, an amylase is enzyme in the body that hydrolyzes starch (breaks it down) into oligosaccharides and eventually decomposes into two types of sugar, maltose and glucose (Chatterton, Ellman, Hudgens, Lu, & Vogelsong, 1996). These sugars are then used by the body for energy production and consumption. SAA concentrations contain catecholamines. The two most relevant catecholamines are epinephrine (EPI) and norepinephrine (NE). Epinephrine is more commonly known as adrenaline. EPI and NE are released by the body when there is sympathetic nervous system (SNS) activation. The "fight or flight" response is an innate, automatic response which determines whether someone will face adversity or flee from the unwanted situation. EPI and NE are released into the bloodstream and saliva during a situation such as this. This release creates a measurable amount which can be taken from sAA samples. Research shows that salivary amylase concentrations are predictive of plasma catecholamine levels and can be used as a measure of stress (Chatterton et al.1996).

The military has used sAA levels to determine the physiological stress levels of Soldiers for many years. In 1990 a wildfire ripped through Yellowstone National park that destroyed 2.2 million acres of land. Over four thousand active duty Soldiers were deployed to help save the national park. This was the first time in over 100 years that the U.S. Forest Service requested active duty Soldiers to combat the fire.[1] The army was interested in comparing the stress experienced by the fire fighting Soldiers and the stress that Soldiers on the battlefield

[1] Yellowstone report 5

experienced. Conducted by the U.S. Army Research Laboratory's Human Research and Engineering Directorate (ARL-HRED), it was determined that the stress the Soldiers experienced while fighting the fires was comparable to that of battlefield stress based on the hazards, dangers and consequences this job presented (Fatkin, King & Hudgens, 1990). This determination was based on the results analyzed from stress tests that the participants were given.

Another instance in which the ARL-HRED employed sAA as a physiological marker was to determine performance and retention statistics based on personal, situational and organizational factors during a Soldier's Advanced Individual Training (AIT). Patton, Fatkin & Breitenbach (Forthcoming) used sAA concentrations to compare the Soldier's baseline stress levels and the results of the tests they needed to take in order to pass their training requirements. Soldiers who were identified as having high stress levels during the training and testing phases were reported to have higher sAA concentration levels than those Soldiers who exhibited lower baseline stress levels during the same period of time. These results confirm that lower baseline stress levels correlate well with low sAA concentrations.

In a non-military related study, Rohleder, Nater, Wolf, Ehlert & Kirschbaum (2004) set forth to determine an easier method of collecting sympathodrenal medullary (SAM) activity. Rohleder *et al*. (2004) determined that current collection methods like skin conductance and heart rate were too invasive and catecholamine assessment took far too long to assess. The research sought out a different method to solve the problem associated with the SAM activity collection method. They hypothesized that sAA could be used to measure SAM activity because salivary gland innervations occur when the sympathetic and parasympathetic branches of the autonomic nervous system are activated. To test their hypothesis the researchers ran two experiments, one measuring the effect of the Trier Social Stress Test (TSST) and the other measuring sAA levels during the conscious parts of the circadian rhythm. The results for both experiments revealed that sAA levels were increased by the stressors which the participants were exposed to. More specifically, the first experiment revealed that sAA is increased in response to stress. The second experiment dealing with circadian rhythms revealed that sAA levels vary in response to where the individual is within their circadian rhythm. SAA levels drop after awakening, when the individual is most relaxed and begin to drop again around 15 hours later.

Davis and Lockhart (2003) conducted a study to investigate if stress associated with the fear of falling leads to increased numbers of falls amongst older individuals. The participants walked over a number of surfaces, ranging from dry and safe to slippery and unsafe. Besides looking at gait changes and differences in heel strike velocity while walking on potentially unsafe terrain, the researchers studied sAA levels as a physiological marker to identify stress in the participants. SAA levels were recorded prior to the experiment to establish a baseline, before a slip, during a slip and after a slip. The researchers found that the severity (distance) of the slip experienced of the participants was directly related to the stress level measured by the sAA samples. Further analysis revealed that even though the younger participants' slip severity was almost double than the older participants', the older participants' stress levels were significantly higher after a slip and while standing, looking at the slippery surface post fall. These findings suggest that increased stress levels may be caused by other factors beside slip severity, like the potential for bodily harm.

The overall takeaway from these three studies show that as stress levels increase so does sAA. Though these three examples just scratch the surface of what research exist, they are important because they show the link between levels of sAA present and the amount of stress that an individual is experiencing. In respect to the CSF program, determining and employing methods to help Soldiers to manage stress more efficiently, using sAA measurements will allow researchers to determine which Soldiers are benefitting from the program and which Soldiers need additional help.

Proposed Study Method

Participants

Soldiers ranging from Junior Enlisted to Field Grade Officers who are attending Ranger School or a National Training Center rotation will be asked to participate and randomly assigned to a CSF training group or a control group that does not receive training.

Apparatus

This section describes the apparatus needed to collect the sAA and methods which provide consistent readings and results. There are two main methods currently being used to measure sAA. One method is a lab-based analysis and the other method is more field expedient.

The first method used to analyze sAA is known as the Bosch method. The Bosch method collects sAA samples and sends them back to the lab. There are many pieces of equipment which are needed to run the Bosch method properly. To house the sample, salivettes are used. The most commonly used salivettes are manufactured by the Sarstedt group. A salivette is a conical tube that contains a swab that is used to collect a sAA sample. The participant places the swab in his or her mouth for approximately 30 to 45 seconds or until the swab is saturated. To retrieve this sAA sample, a centrifuge is needed to separate the saliva from the participant's swab. The centrifuge runs for 10 minutes in order to obtain clear saliva. A liquid handling system, generally a Genesis RSP4/100, is used to dilute the sAA sample with distilled water. The sample is then transferred to microplates and mixed with a solution called standard. The solution's commercial name is Calibrator f.a.s and is manufactured by Roche Diagnostics. SAA concentrations in levels of 326 to 5.01 U/L are mixed in with the standard. Another Roche Diagnostics product, Alpha-Amylase EPS System, a substrate reagent, is added to the standard and sAA mixture. This potion is then warmed in a water bath to 37ºC. The warmed potion is then analyzed by an ELISA reader at 405nm, which determines the sAA concentrations. The potion repeats the warming process and is analyzed again by the ELISA reader. A linear regression is calculated for each microplate using the original and final concentrations taken from the ELISA reader.

The second method is to use a handheld sAA activity monitor developed by Yamaguchi *et al*., in 2003 and refined in 2006. The handheld sAA activity monitor will be referred to as the sAA monitor from this point forward. The sAA monitor consists of a handheld monitor and test strips which are similar to litmus paper.

Image 1. Salivary Amylase Monitor designed by Yamaguchi

The test strips consist of an outer sleeve, a sheet, collecting paper, and an amylase reagent paper. These test strips are disposable, one-time use only. The monitor consists of a saliva transfer device, and an optical device which houses an LED light which emits at 430nm, and a photodetector. Figure 2 below shows the internal components of the sAA activity monitor.

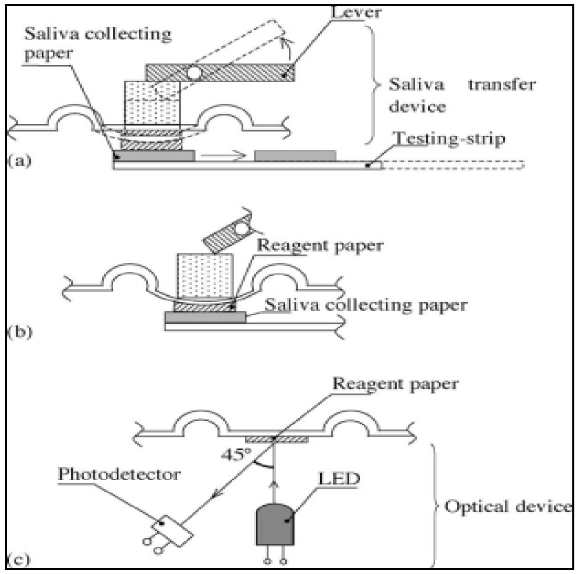

Figure 2. Internal Components of Handheld sAA Activity Monitor

The monitor has an LCD screen that displays the analyzed information. To use the sAA monitor, the participant places a test strip in their mouth and under the tongue for approximately 30 seconds. After this time period, the test strip needs to be placed on the automatic saliva transfer device and/or sleeve. Upon closing the lever, saliva is transferred from the test strip to the reagent paper. Concurrently, a timer begins when the lever is closed and rings after the saliva transfer is complete. This process takes approximately 10 seconds. After the alarm rings, it is necessary to pull the strip from the sleeve. The optical device within the monitor reads the reflectance of the test strip as it has changed colors because of the hydrolyzing process between the reagent paper and the amylase on the test strip. After 30s and a signal from an automatic time within the monitor, a reading of sAA is available. Complete technical information associated with the sAA monitor can be found in reports by Yamaguchi et al., 2004 and 2006.

Another hand held testing device is the Cocoro Meter, manufactured by the Japanese corporation Nipro. The Cocoro Meter performs the same as the device created by Yamaguchi *et* *al*. but is available on the public market. Both the Yamaguchi device and the Cocoro Meter are able to produce readings that are on average 94% percent accurate in under a minute. The main difference between the two devices is the user interface. The Cocoro Meter presents a pictorial representation of the stress level in the form of icons which range from eustress to distress. Both meters display sAA levels which allow the user or the researcher to see the sAA level.

Figure 3. Nipro Corporation Cocoro Meter

Because the CSF encompasses every member in the Army, looking into the feasibility of the testing methods is necessary. Turnaround time to determine sAA levels is one of the most important aspects for determining this as an important biophysical marker for resilience. The testing method's simplicity also plays a large factor because the individuals administering the tests will not always be scientists who have expert knowledge on the subject. A third factor that is also important is how accurate the sAA readings are. An incorrect or false reading may inaccurately categorize a Soldier. The impact of an incorrect or false reading may inadvertently cause the Soldier to be marked as not fit for duty when he or she really is or it may miss pinpointing a Soldier with issues that need to be addressed to ensure they will be effective in the fighting force. With that being said, employing the use of a handheld device that measures sAA levels will be the optimal solution for the CSF's physiological assessment.

SAA monitors will provide the CSF program the easiest and quickest method of retrieving a Soldier's sAA level. The process of obtaining the sAA levels is straightforward and fast compared to the Bosch method. SAA levels can be recorded in as little as two minutes as compared to the lengthy process which the Bosch method requires. With the sAA monitor, there is no sending the saliva samples to the lab to get them tested and there is no requirement to chill, heat or store saliva samples. The ability to quickly measure a large sample set will prevent wasted time and training interruptions. One concern with the sAA monitors is the accuracy of the results that they report. Whereas the Bosch method returns results with almost near perfect accuracy, the sAA monitors average a 94% accuracy rating. While not necessarily a bad percentage, it does leave room for errors. Fortunately for the CSF program, physiological markers are only one third of the program's assessment criteria.

Procedure

In order to more accurately determine if sAA is a factor in stress recovery, there must be a baseline measure of the individual's sAA levels. This baseline level will serve as the benchmark when comparing sAA levels during different parts of the research.

This biobehavioral marker should be tested using a between subjects design. The apparatus used to measure the sAA concentration levels will be the Yamaguchi sAA handheld activity monitor or a similar product. One group will receive CSF training prior to an intentionally stressful training event, such as Ranger School or a National Training Center rotation. The other group will not receive training prior to a stressful situation. The test will begin by taking a saliva sample and measuring the sAA levels while the subject is in a controlled, relaxing environment before the training event. This will allow the researchers to determine the baseline sAA levels of subject at their most relaxed level. Additional sAA level measurements will be taken during and after the event. It will be important to attempt to replicate the same relaxed setting in order to determine the sAA levels while not actively involved in the stressful event. The inspiration for measuring sAA levels at different times throughout the training came from the previously mentioned Davis and Lockhart (2003) study. The sAA levels collected prior, during and after the stressful event will be compared.

Conclusion

Ultimately, the aim of this research is to determine if there is a link between an individual's ability to recover from stressful situations and levels of sAA in the body. Historically, studies that have shown a positive correlation between stress and sAA levels focused on the subject during or immediately after a stressful situation but the proposed study will also include a baseline measurement of sAA, Ideally, the sAA levels of the Soldiers that received the CSF will be lower than the baseline sAA level originally measured. This method may show how the CSF training impacted the Soldier's ability to both deal with and recover from a stressful environment. If this is the case, it would mean that sAA would be a viable biobehavioral marker that could be used to measure a Soldier's ability to bounce back from a stressful experience, such as a deployment.

Annotated References

Bonanno, G. (2004). Loss, trauma and human resilience: How we underestimated the human capacity to thrive after extremely aversive events. *American Psychologist*, *59*(1), 20-28.

Bonanno discusses the remarkable nature of human beings, and the ability of people to keep moving forward despite a terrible event. This capacity to carry on in the face of hardship truly makes humans unique.

Bonanno, G. A. (2005). Resilience in the face of potential trauma. *Current Directions in Psychological Science*, *14*(3), 135-138.

Discusses the idea that the most common reaction to stress and large scale problems is for people to be resilient. Comments on this surprising fact and explores the idea that humans are quite a bit more resilient than we often give ourselves credit for.

Bonanno, G. A., Galea, S., Bucciarelli, A., & Vlahov, D. (2006). Psychological resilience after disaster: New York City in the aftermath of the September 11th terrorist attack. *Psychological Science, 17*(3), 181-186.

Investigates the reaction of a community after a specific larger scale stressor and applies a lot of the terms that are present throughout the paper to the 9/11 World Trade Center bombings.

Brett, E. A. (1996). The classification of post traumatic stress disorder. In B. A. van der Kolk, A. C. McFarlane, & L. Weisaeth (Eds.), *Traumatic stress: the Effects of Overwhelming Experience on Mind, body and Society* (pp. 117-129). New York: The Guilford Press..

Discussed what PTSD should be classified as in terms of whether or not it is actually a stress disorder.

Chatterton, T.R., Vogelsong, M.K., Lu, Y., Ellman, B.A., Hudgens, A.G. (1996). Salivary amylase as a measure of endogenous adrenergic activity. *Clinical Physiology*. 16, 433–448.

This source was helpful in defining what salivary amylase was and its functions. The research has shown that salivary amylase concentrations are predictive of plasma catecholamine levels and can be used as a measure of stress.

Chrousos, G. P., & Gold, P. W. (1992). The concepts of stress and stress system disorders: Overview of physical and behavioral homeostasis. *Journal of the American Medical Association, 267*(9), 1244-1252.

These authors presented a fairly detailed and quite wide ranging description of stress and other factors closely associated with stress. In addition, the researchers discussed the history of the study of stress and examined ideas that could be investigated further in the future.

Citizens Centre Report (2003, February 17). Stress: from symptoms to syndromes, 37-40.

This source discussed specifically the general adaptation syndrome as a way to explain how many people cope with stress. In addition, the author detailed a number of ways to manage stress.

Cobb, S. (1995). Social support as a moderator of life stress. In A. M. Eward (Ed.), *Toward an integrated medicine: Classics from psychosomatic medicine* (pp. 377-399). Washington D.C: American Psychiatric Press Inc.

This source discussed research on the topic of the effect of social support in mediating the negative effects of psychosocial stress. It defined several different types or variations of social support and examined the potential positive effects that each type could have on someone suffering due to stress.

Connor, K. M., & Davidson, J. (2003). Development of a new resilience scale: The Connor-Davidson resilience scale (CD-RISC). *Depression and Anxiety*, *18*, 76-82.

The authors discussed a new method of measuring resilience in a quantifiable manner in order to avoid a lot of the guesswork that accompanies the current subjective resilience measurement system.

Davis T., Lockhart T.E. (2003) The effects of age on stress and the biomechanics of slips and falls. In: Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting, October 13-17, Denver Colorado USA, Industrial Ergonomics, Stability and Gait, 1131-5.

Investigated if stress associated with the fear of falling leads to an increased numbers of falls amongst older individuals. Used salivary amylase to determine stress levels in individuals during different phases of the research. The research found that severity (distance) of the slip experienced of the participants was directly related to the stress level measured by the sAA samples. The method used in this section guided our proposed method.

Fatkin, L. T., King, J. M., & Hudgens, G. A. (1990). Evaluation of stress experienced by Yellowstone Army fire fighters (ARL-TM9-90). Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Provided a historical reference showing where the U.S. Army has used biophysical markers such as salivary amylase in determining stress levels of Soldiers in stressful situations. Research results showed that stress and anxiety levels could be predicted by salivary amylase levels.

Friedman, H. S., & Silver, R. C. (2007). *Foundations of health psychology* (pp. 130-131). New York: Oxford University Press.

Friedman and Silver's work covered a wide range of topics regarding psychological issues that have crossover concerns in the medical field. The focus for this paper was the examination of the exhaustion phase of the general adaptation syndrome.

Ironson, G., Cruess, D., & Kumar, M. (2007). Immune and neuroendocrine alterations in post-traumatic stress disorder. In R. Ader (Ed.), *Psychoneuroimmunolgy: Volume 1* (4th ed., pp. 531-539). Burlington, MA: Elsevier Academic Press.

This source included a discussion regarding the impact that PTSD might have on the immune and endocrine system of those who suffer from it. This article was primarily used for the information it provided about diagnosing PTSD.

McCarty, R., & Pacek, K. (2000). Alarm phase and general adaptation syndrome. In G. Fink (Ed.), *The encyclopedia of stress: Part 1* (pp. 126-131). San Diego: Academic Press Inc.

This source contained information about the general adaptation syndrome and specifically had information of the alarm stage and the physiological changes that occur during this stage.

McEwen, B. S. (2006). Stress, adaptation, and disease: allostasis and allostatic load. *Annals of the New York Academy of Sciences*, *840*, 33-44.

In this article McEwen introduces the concept of allostatic load and goes into detail about what types of changes happen in the body when it is faced with a stressor. It also discusses the potential issues if allostatic overload occurs.

Patton, D. J., Fatkin, L. T., & Breitenbach, J. S. (In Press). Identifying personal, situational, and organizational factors related to student performance and retention. Aberdeen Proving Ground, MD: U.S. Army Research Laboratory.

Soldiers at AIT who were identified as having high stress levels during the training and testing phases were reported to have higher sAA concentration levels than those Soldiers who exhibited lower baseline stress levels during the same period of time.

Rohleder, N., Nater, U. M., Wolf, J. M., Ehlert, U., & Kirschbaum, C. (2004). Psychosocial stress-induced activation of salivary alpha-amylase: An indicator of sympathetic activity? *Annals of the New York Academy of Sciences*, *1032*, 258.

Determined that current collection methods like skin conductance and heart rate were too invasive and catecholamine assessment took far too long to assess and that salivary amylase was a quick and viable option. The results for both experiments revealed that sAA levels were increased by the stressors which the participants were exposed to.

Selye, H. (1950, June 17). Stress and the general adaptation syndrome. *British Medical Journal*. 1383-1392.

This source is one of the seminal works discussing the theory surrounding general adaptation syndrome. Selye was the originator of this specific theory and in this work he outlines his basic ideas and the basis for his overall theory.

Westphal, M. & Bonanno, G.A.(2007). Posttraumatic growth and resilience to trauma:Different sides of the same coin or different coins? *Applied Psychology: An International Review*, *56*(3), 417–427.

This article is a brief review of the resilience and posttraumatic growth literature which focuses on the limitations of PTG studies and how it is not the same as resilience. The authors contend that most individuals are resilient following stressful situations and that such outcomes do not equate to a need or opportunity for PTG.

Yamaguchi, M., Kanemori, T., Kanemaru, Takai, N., Mizuno, Y., Yoshida, H. (2004). Performance evaluation of salivary amylase activity monitor. *Biosensors and Bioelectronics*. 20, 491–497.

Investigated a method that can quickly quantify salivary amylase levels. The researchers developed a monitor which could read salivary amylase levels. This study demonstrated that the broad-range salivary amylase activity monitor could be used with only 5 micro liters of saliva.

Yamaguchi M., Deguchi M., Wakasugi J., Ono S, Takai N., Higashi T., Mizuno,Y. (2006). Hand-held monitor of sympathetic nervous system using salivary amylase activity and its validation by driver fatigue assessment. *Biosensors and Bioelectronics.*; 21, 1007-1014.

This research presented an up-to-date salivary amylase monitor initially developed by the same research group in 2004. Validation of the monitor occurred in the concurrent testing of driver fatigue. This research provides information on the direction that salivary amylase testing is likely to take in the future.