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## OVERTRAINING AND EXERCISE MOTIVATION: A RESEARCH PROSPECTUS

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Prepared By: Anthony C. Hackney, Ph.D.  
Academic Rank: Assistant Professor  
University & Department: University of North Carolina  
Exercise Physiology Laboratory  
Department of Physical Education,  
Exercise and Sport Sciences  
Chapel Hill, NC 27599-8700

NASA/JSC  
Directorate: Space and Life Sciences  
Division: Medical Sciences  
Branch: Biomedical Laboratories  
JSC Colleague: Pat Santy, M.D.  
Steve Siconolfi, Ph.D.  
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## ABSTRACT

The problem of exercise "overtraining" has recently become one of great interest to professionals in the field of human performance assessment. Quite obviously, the ultimate goal of the training process is to improve physical performance. However, excessive training can result in the opposite effect, that is, a performance decline and an impairment in the functional work capacity of the body. Research indicates that both psychological as well as physiological disturbances are quite common in overtrained individuals (32, 33, 34). For example, psychological changes include increased levels of depression, fatigue, and a lack of motivation (34, 45, 51). Similarly, impairment of the physiological function of the cardiovascular, metabolic, and endocrine systems also have been found (3, 8, 12, 13, 14).

Some similarities may be found in the psychological and physiological states of crew members exposed to extended space flight and overtrained individuals. Therefore, the possibility exists that the crew members subjected to extended missions in space may develop over stressed or overtrained or both states during their flights. If such states do develop within the crew members, mission performance may be impaired.

With these points as a background, the intent of this prospectus is to address potential research directions that NASA may consider viable and of a mutual interest to this investigator. A clear framework by which to begin discussion of research topics is needed, therefore working definitions of "overtraining" and "exercise motivation" are presented. Subsequently, a proposed conceptional model of how exercise overtraining and motivation interact is presented. In support of the proposed model is brief literature review of relevant areas. Potential research projects are presented and discussed.

## INTRODUCTION

A major concern in the space program has been the detrimental effects of prolonged space flight on the physiological functions of the human body (28, 39, 40). Biomedical research from Skylab and Salyut indicated prolonged exposure to space flight results in cardiovascular deconditioning, bone mineral loss, muscular atrophy, and fluid shifts (28, 39). These changes appear to be the physiological consequences of exposing the body to zero gravity and a reduction in the typical level of earth bound activity. Exercise training is a proposed requirement to attenuate these effects on the body's systems while the astronauts are in space. In addition to this exercise training during space flight, many other physical as well as mental demands (i.e., mission operations) will be made of the astronauts. Potentially, the combination of exercise training and demanding work requirements (e.g., isolation) could lead to an over stressed state in the astronauts. The latter issue, psychological stress of the astronauts, is becoming an increasingly important concern. Specifically, future NASA space missions will be of greater duration and crew make-up will become more heterogeneous (i.e., multi-national) in nature. These combined stressors could lead to adverse coping strategies or negative group interaction, both which could endanger the success of the mission.

For example, psychological changes include increased levels of depression, fatigue, and a lack of motivation (34, 45, 51). Similarly, impairment of the physiological function of the cardiovascular, metabolic, and endocrine systems also have been found (3, 8, 12, 13, 14).

Furthermore, the motivation to continue exercising frequently diminishes when the over stressed states occur (10, 11, 33). This lack of motivation (i.e., exercise adherence) has been reported by the Soviet Union for their cosmonauts on a number of the extended duration space missions (Salyut and Mir) (36). As exercise adherence becomes reduced, muscle strength and bone mass losses would be accelerated in the zero gravity of space. These latter effects could act in a synergistic fashion with the other stressors associated with space flight to further augment the performance decline of the crew members. Work examining the interaction of exercise training, over stressed states, and exercise motivation seems warranted as NASA enters an era where the duration of space missions are lengthened such as the Extended Duration Orbiter, Space Station Freedom, Lunar Base, and Mars projects.

## WORKING DEFINITIONS

Initially, this investigator wishes to propose a simplistic model dealing with overtraining and exercise motivation. It is suggested that overtraining be viewed as the process leading to a state of being overtrained (or overstressed) which should be considered a response. This response state will be termed staleness. It should be noted, however, within the research literature the name given to the response state due to overtraining varies somewhat. The term "overtrained" (6, 51) or "overtraining syndrome" (32) frequently appear in the physiological research, while in the psychological research the terms "staleness" (934) or "burn-out" (50) have been used more prevalently. To prevent difficulty in the semantics of terms, it is proposed that the following working definitions be used to separate and clarify the terms.

**OVERTRAINING** - an abnormal extension of the physical training process with the results culminating in the state of staleness. Therefore, in this paper the term overtraining will be viewed and used only in the context of "a process".

**STALENESS** - a state in which the individual has difficulty maintaining a standard training regimen and can no longer achieve previous performance results (i.e., a consistent lack of performance improvement and/or a progressive decline in performance). This term can be defined as "the response" to the overtraining process. The most common signs and symptoms of individual who have progressed to the state of staleness are listed in Table 1 (3, 34).

TABLE 1.

Psychological	Physiological
Apathy	Muscle Pain or Soreness
Heavy Feeling	Performance Decline
Low Motivation	Retarded Recovery
Lethargy	After Exertion
Mood Changes	Weight Loss
Withdrawal	Lymphadenopathy
Altered Perception	Drawn Appearance
	Appetite/Sleep Loss

**EXERCISE MOTIVATION** - a series of qualities and characteristics displayed by an individual doing exercise training which affects their exercise experience in such a fashion that it may aid or distract from the person's adherence/compliance to their training regime (10, 11). For

example, factors associated with motivation as reported by Dishman and Ickes (11) are: willpower, organization, determination, persistence, apathy, lethargy, diligence, dependability, and commitment.

#### PROPOSED CONCEPTUAL MODEL

A conceptual model of the training process and exercise motivation, based upon the preceding working definitions as well as available research findings, is presented in Figure 1. The basic premise of this model is the "stimulus - response" paradigm. In Figure 1, section A - B represents a normal exercise training response (1, 5, 18). As a training stimulus is applied (i.e., loads are increased) and the body adapts and improves, positive psycho-physiological responses occur. However, if too much of a stimulus occurs (i.e., overtraining) negative responses develop. This response is depicted in section C. Section D of Figure 1 represent a detraining or undertraining scenario (i.e., lack of enough of a training stimulus) which also results in negative responses. However, this aspect of the model is not addressed currently since it is not entirely within the purpose of this prospectus. Figure 2 attempts to summarize some of the interactions for psychological and physiological stimuli and responses within the model.

#### EXPERIMENTAL PROTOCOLS TO INDUCE OVERTRAINING

It is proposed that the initial step in conducting research into the area of overtraining/staleness/motivation should involve the development of an experimental tool. That is, currently a standardized protocol or prescription for induced overtraining does not exist. The development of a standardized experimental procedure or manipulation is essential if successive studies analyzing the various psycho-physiological aspects of overtraining, staleness, and exercise motivation are to be conducted.

#### Existing Protocols

In the research, two basic approaches have been reported for studying individuals subjected to overtraining: 1) "expo facto", and 2) experimental. In the former, investigators have evaluated subject characteristics after self-reporting of indicators suggestive of overtraining (9, 12, 27, 30, 32). In these studies no controls as to training load had been employed and in many cases evaluations of training regimes are highly anecdotal. Conversely, the experimental methodology has involved investigator manipulation of the training load to

FIGURE 1

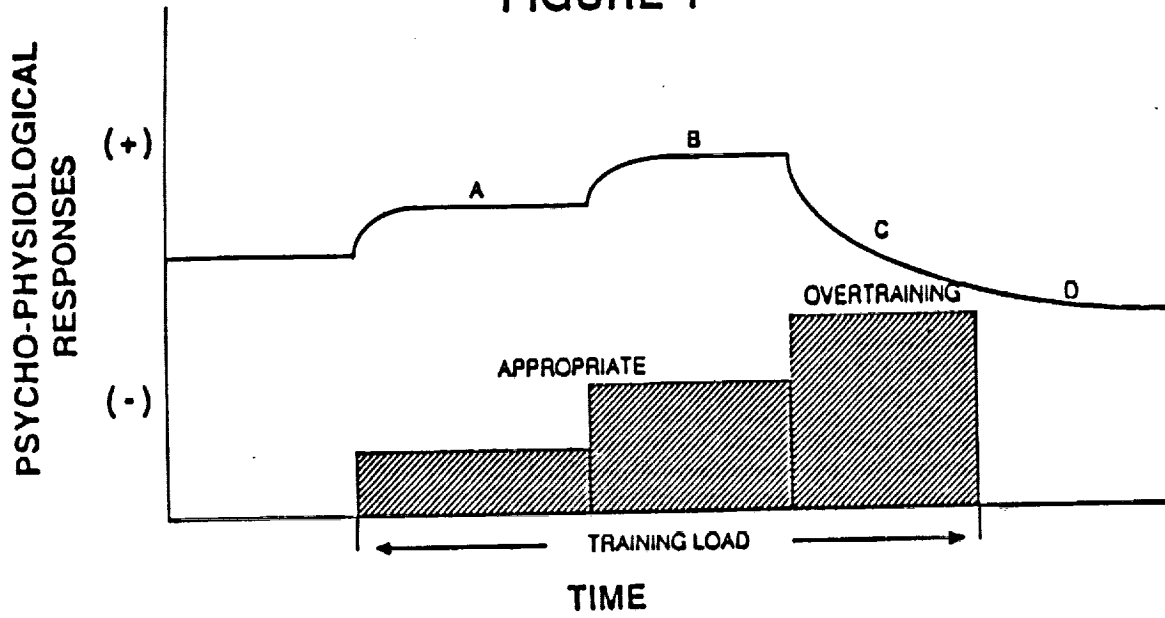


FIGURE 2

	STIMULUS	RESPONSE
PHYSIOLOGICAL	APPROPRIATE TRAINING	↑ PERFORMANCE
	OVERTRAINING	↓ PERFORMANCE
	UNDERTRAINING	↓ PERFORMANCE
	↕	↕
PSYCHOLOGICAL	HIGH MOTIVATION	↑ WELL BEING POSITIVE MOOD
	LOW MOTIVATION	↓ WELL BEING NEGATIVE MOOD ↑ ANGER/CONFUSION

produce overtraining and induce staleness. Within the intent of this prospectus, the methodology of the experimental studies are of a more applicable nature; therefore; only the experimental studies will be discussed.

The literature suggest that the overtraining process involves increases in the amount of daily work requirements (i.e., training volume) for the exercising individual. These work requirements can be in the form of absolute work (training volume) performed as well as evaluations in the intensity of work performed (1, 18).

It would appear increases in absolute amounts of training volume (i.e., total work performed [ = frequency x duration x intensity of exercise]) have been the major means of inducing overtraining. The degree of training volume increases have varied from 50% up to 370% of the amount the subjects performed prior to the experiments beginning (8, 13, 31, 40, 41, 52). This large range in volume increases seems to be influenced by several factors; 1) the initial fitness levels of the subjects, 2) the amount of pre-experiment training being performed, and 3) the time-frame in which the investigators are subjecting the individual to the overtraining stimulus. Primarily, the larger increases in training loads were found in those studies submitting their subjects to relatively short periods of overtraining (10 to 14 days) (8, 13, 31). Conversely, lower increases in absolute training load were associated with studies of extended duration (approximately 4 weeks or greater) (37, 41, 48, 53). The type of training associated with these studies has tended to be of a combined variety (continuous duration and intermittent activities) and has involved cycling, swimming, or running as an exercise modality (8, 13, 31, 37, 41, 48, 52). Principally, in designing the set-up of these studies the investigators have attempted to mimic a program that a competitive individual may encounter during the course of their training.

Almost all the experimental studies also have attempted to manipulate the intensity at which the overtraining individuals were working. However, the manipulation of this variable has been typically to a much smaller degree than that of the total volume of work performed. In the majority of the studies the training intensities were maintained at relatively moderate to high levels (65 to 94% of maximal capacity) (8, 13, 31, 37, 41, 48, 53). The one exception to this was the study performed by Sharp and Hackney (47). In this investigation, the subjects were required to perform repeated weekly training sessions (>30 % total training volume) involving intermittent bouts of exercise at supra-maximal work (125-175% of maximal capacity). This training intensity, while high, is not outside of the range that competitive athletes perform in training practices.

Generally, the overtraining protocols have manipulated training volume with either a rapid (10-14 day) or slow (3-4 months) onset of supra-normal training loads. There is no evidence to suggest that the variety of psychological and physiological responses to these ends of the overtraining continuum (see next section) differ. However, rapid on-set protocols may introduce an acute stress responses in the body which could potentially interfere with experimental interpretation. A protocol employing a moderate amount of time ( 4 weeks) for introducing a training overload presents a means to avoid this potential problem. Furthermore, work from our laboratory indicates that staleness characteristics are manifested significantly by 4 weeks and are relatively unchanged by additional overtraining (6 weeks) (25, 38, 47, 48).

### Psycho-Physiological Findings

Psychological disturbances have frequently been reported for overtrained and stale individuals (6, 33, 34, 51). The research suggest that mood disturbances may increase in a progressive manner with step-wise increases in training load (34, 35, 41). Therefore, several investigator (35, 41) have hypothesized that this relationship is dose-dependent, and reductions in training load should be accompanied by improved mood states. However, the current prospective research findings are inconclusive as to whether such a relationship exist.

Some specific mood alterations reported in response to overtraining and staleness have been increased levels of depression, anger, and fatigue (35, 41). Typically, these behavioral states have been assessed by the "Profile of Mood States" (POMS) test. Another measure from the POMS also found to be elevated due to overtraining is the composite indicator, global mood state (35, 41). Studies by Morgan et al. (33, 35) indicate that a person's perception of their "general state of well-being" declines as overtraining occurs. Furthermore, as well-being declines the perception of exercise difficulty (i.e., rating of perceived exertion) increases (34, 35). Research evidence suggest that as these behavioral changes take place an individual's self-motivation decreases and this facilitates a reduction in the adherence to their training regime (44, 45).

Physiologically, one of the most common complaints of the overtrained athlete is muscle soreness and chronic muscle fatigue (6, 12, 25, 35, 51). Serum levels of creatine kinase (muscle tissue damage marker) show concomitant increases that mirror that of the reported cases of muscle soreness (4, 12). These creatine kinase changes suggest that the subjective soreness increases have a physiological basis in muscle tissue damage. Some researchers have reported declines in muscle



function coinciding with the increased complaints of soreness (44, 45, 52). In a study by Ness (38) subjects performed the "Wingate" anaerobic power test (indicative of muscular power) at 2 week intervals during 8 weeks of intensive training. It was found that the subjects who complained of severe muscle soreness showed a lack of power improvement after the initial 4 weeks of training. This response occurred even though the subjects received a continuous anaerobic training stimulus throughout the study. Similarly, Hakkinen and associates (26) have reported that overtrained subjects do not show improved muscular strength development even with exposure to an appropriate training stimulus. Coinciding with these changes in muscle function in the Hakkinen study were lowered serum testosterone-cortisol ratios (anabolic vs catabolic status). This finding of a reduced testosterone-cortisol ratio during the overtraining process has also been reported by several other investigators (23, 24, 25, 56). Additionally, numerous studies have found elevated resting serum and salivary cortisol levels during overtraining (25, 41, 53, 56). Concomitant with the elevations in cortisol have been increases in serum and urinary urea nitrogen levels (protein breakdown byproduct) (25, 30). These urea nitrogen changes are reflective of an increased catabolic state in overtraining subjects (15). Also research indicates that the rate of nitrogen loss can result in a chronic negative nitrogen balance in the overtraining athlete (25, 54).

Barron and colleagues (3) have evaluated hormone responses to insulin induced hypoglycemia challenges in ultra-marathoners with and without diagnosed staleness. The ultra-marathoners displaying staleness showed reduced ability to release growth hormone, adrenocorticotropin hormone, and cortisol as compared with the control ultra-marathoners. After a four week rest period the endocrine function of the stale ultra-marathoners was found to improve and approach that of the control marathoners. The authors concluded these hormonal findings imply a state of pituitary-adrenal gland "exhaustion" may be associated with overtraining and have physical and psychological effects. Several preliminary reports have suggested the changes in testosterone levels and pituitary function associated with overtraining may produce an impairment in reproductive capacity (2, 22, 23, 24); however, the findings are currently inconclusive and can not suggest a disruptive relationship exist.

The cardiovascular system also displays a series of perturbations due to overtraining. Progressive increases in the resting heart rate and systolic blood pressure have been reported in overtraining individuals (9, 14). Several researchers have speculated that these changes in resting cardiovascular measures are due to enhanced neuroendocrine influences (14, 20), however, an exact mechanism for the changes remains uncertain. The research is somewhat

contradictory concerning overtraining effects on the cardiovascular function during exercise, primarily with respect to oxygen uptake capacity. Foster et al. (17) has shown a declining capacity, while Stray-Gundersen et al. (53) as well as Costill et al. (8) have demonstrated slight, but non-significant increases in oxygen uptake capacity during overtraining. In each of these studies an appropriate training stimulus was being applied such that improved oxygen uptake capacity should have occurred (1). Several investigators have found overtraining produces what is termed "sport anemia" (13, 19, 59). Others, however, have failed to demonstrate marked changes in hematological measures during overtraining (8, 31, 47, 48). These latter results are supported by Wishnitzer and associates (58) who evaluated bone marrow cellularity, bone marrow hemosiderin, hemoglobin, and serum ferritin levels in overtrained and healthy runners. A higher degree of bone marrow hypocellularity was found in the overtrained than in the healthy runners (54 % vs 66 %); however, all other measures were similar between the groups and within normal acceptable physiological ranges.

Costill et al. (8) have reported lower muscle glycogen levels were observed in overtrained athletes who exhibited staleness. Costill has proposed that this finding may be the result of inadequate dietary carbohydrate ingestion. That is, reduced carbohydrate intake results in lowered muscle glycogen levels, thereby reducing energy substrate availability and impairing energy metabolism (7, 46, 57). This in turn results in the reduced performance found in stale athletes. Suppressed lactate profiles (blood lactate levels in response to a fixed workload) are also found in the overtraining athletes. This indirectly supports Costill's theory as the suppressed profiles could be due to muscle glycogen depletion (1, 49).

Another common anecdotal reported symptom of individuals subjected to overtraining are increased numbers of head colds and respiratory infections (16, 27, 42, 45, 51). Total lymphocyte counts, salivary immunoglobulin A (IgA), helper T, and suppressor T levels/function have all been reported suppressed during period of overtraining (21, 29, 37, 43, 55). However, at this time since very little experimental work has been performed evaluating how overtraining affects the immune system the implication of these findings is uncertain.

#### FUTURE PROJECTS AND RECOMMENDATIONS

The completion of this pilot project and the refinement of an experimental protocol to produce overtraining and induce staleness presents many avenues for future joint as well as separate research projects such as; 1) Overtraining Threshold - is there a threshold level of training load at which overtraining starts to develop and can it accurately be

identified in individuals. Such information would be helpful in the establishment of exercise prescriptions; 2) Exercise Motivation Strategies - can motivation strategies be identified in overtraining individuals who develop staleness (responders) and those who do not (non-responders). This information could be useful in behavioral modulation to prevent staleness from occurring; 3) Social Intervention and Overtraining - if non-responders associate with responders during the overtraining process do the responders develop non-responder coping strategies (i.e., become less likely to become stale). This has potential implication in the selection of crew make-up; and 4) Recovery from Overtraining and Staleness - the steps and methods that are necessary to recovery from overtraining or staleness is uncertain. Such information could be help in the determination of the recovery time necessary between missions.

The intent of preparing this prospectus was to stimulate discussion of research relative to human health and well-being with prolonged exposure to microgravity. Historically, problems with microgravity exposure and space flight have been addressed in a retroactively fashion. The issue of "exercise overtraining and motivation" as a research topic is being presented in a proactive fashion. That is, planned space missions have a high potential risk for inducing the problems discussed within this prospectus. Hopefully, appropriate planning and measures can be taken prior to such problems developing. If research can take place to examine this issue early and extensive enough there can be an elimination for "quick or stop-gap" measures in the future.

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