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14. ABSTRACT Martial Arts-Based High Intensity Interval Training in the Rehabilitation of Combat Amputees The US Armed Forces are currently engaged in the longest active period of continuous armed conflict in United States history. The advancements in Tactical Combat Casualty Care, rapid medical evacuation, and improvements in personal body armor and armored vehicles have resulted in unprecedented survival rates. The second-order effect of the improved survival of combat injuries is the increased clinical burden of extremity injuries to include amputations. ¹ These unique features of casualty care within OIF and OEF, couple with the widespread use of a myriad of Improvised Explosive Devices (IEDs – aka colloquially as roadside bombs) have given rise to the almost 1,700 individuals with major limb amputations from 2001 to 2015. ²⁻⁵					
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INTRODUCTION: The advancements in Tactical Combat Casualty Care, rapid medical evacuation, and improvements in combat equipment have resulted in unprecedented survival rates in combat injuries incurred in Operations Iraqi Freedom (OIF) and Enduring Freedom (OEF). The second-order effect of the improved survival of combat injuries is the increased clinical burden of survivable extremity injuries to include amputations. These unique features of casualty care within OIF and OEF, coupled with the widespread use of a myriad of Improvised Explosive Devices (IED) have given rise to the almost 1,700 individuals with major limb amputations from 2001 to 2015. Military orthopaedic surgeons are now charged with providing the highest level of treatment and rehabilitation for post traumatic combat amputees to ensure they regain the highest possible quality of life regardless the overwhelming challenges they face. The purpose of this paper is to summarize recent literature regarding the unique challenges known to combat amputee rehabilitation and how a variant of high intensity interval training using martial arts techniques (MA-HIIT) may be useful in optimizing the recovery of wounded warriors.

METHODS: With the assistance of the Army Medical Department Center & School (AMEDDC&S) Medical Librarians, a comprehensive literature search, to include Medline and Google Scholar, was conducted to identify pertinent studies within the last 20 years. Emphasis was placed on recent and higher-level studies with key words amputee, tactical athlete, interval training, martial arts, military training, rehabilitation, exercise physiology, and readiness.

RESULTS: High intensity interval training (HIIT) programs emphasize short, repetitive intervals of explosive exercises whereby allowing the trainee to exercise at or close to V02 max over a significant period of time. Several studies demonstrate that HIIT can lead to improvements in cardio-pulmonary fitness, musculoskeletal strength and several metabolic parameters. HIIT regimens are modifiable to optimize activity specific improvements at various points along the aerobic-anaerobic spectrum. Researchers have investigated the utility of modifying HIIT techniques and martial arts exercises to maximize the fitness requirements of men and women in the armed forces into a program called martial arts-based high intensity interval training or MA-HIIT – especially combat amputees who have several barriers to successful rehabilitation.

DISCUSSION: MA-HIIT programs offer an effective method of rehabilitation/reintegration to achieve and maintain optimal cardiovascular fitness and musculoskeletal strength while assisting with proprioceptive control and confidence of their residual limb and/or prosthesis. Additionally, working together with other amputees overcoming similar challenges to their recovery, improves general coping skills, and encourage comradery amongst wounded warriors and their care providers.

CONCLUSION: Creating a rehabilitative program that adequately addresses the challenges unique to combat amputees while providing the mental and physical training necessary can likely be achieved through implementing martial arts-based high intensity interval training but further well designed studies are necessary.

The views expressed are those of the authors and do not reflect the official views or policy of the Department of Defense or its Components.

Martial Arts-Based High Intensity Interval Training in the Rehabilitation of Combat Amputees

The US Armed Forces are currently engaged in the longest active period of continuous armed conflict in United States history. The advancements in Tactical Combat Casualty Care, rapid medical evacuation, and improvements in personal body armor and armored vehicles have resulted in unprecedented survival rates. The second-order effect of the improved survival of combat injuries is the increased clinical burden of extremity injuries to include amputations.¹ These unique features of casualty care within OIF and OEF, couple with the widespread use of a myriad of Improvised Explosive Devices (IEDs – aka colloquially as roadside bombs) have given rise to the almost 1,700 individuals with major limb amputations from 2001 to 2015.²⁻⁵

The long-term impact of musculoskeletal (MSK) combat injuries has a profound effect on service members' potential for continued military service as well as their quality of life after separation from service. In a cohort from 2001-2005, 69% of unfit-for-duty conditions were orthopaedic/MSK. In the midst of OIF and OEF, many advances were made with regards to rehabilitation and reintegration of service members with severe extremity injury – regardless of limb-salvage or amputation. Unfortunately, the return to duty rate post-amputation is low, on average 8.8% for lower extremity amputations and 8% for upper extremity amputations.^{6,7} Furthermore, regardless of whether the injured service members medical disposition is return to duty, continuation on active duty in another Military Occupational Specialty, or separation from military service, their emotional wellness remains significantly degraded. An estimated 28.7-35% of combat amputees have co-morbid depressive symptoms.^{8,9} The toll that a traumatic amputation has on a soldier's physical and mental wellbeing cannot be overstated. In a study of resource utilization in the care of combat injuries, "extremity injuries require the longest average inpatient stay, were responsible for 64% of total inpatient resource utilization and ultimately disabled 64% of those injured."¹⁰ It is clear that extremity injuries represent

the largest clinical burden of the current and recent past military conflicts, the most severe of which are combat amputations. Military orthopaedic surgeons are now charged with providing the highest level of treatment and rehabilitation for post traumatic combat amputees to ensure they regain the highest possible quality of life regardless the overwhelming challenges they face – while also retaining these critical lessons learned for the betterment of casualties from future wars.

Treating the combat amputee requires careful consideration of a number of characteristics unique to these patients when compared to amputees amongst the general population. Of the amputations performed in the U.S. general population, over 80% are due to non-traumatic causes with the majority of which being vascular and oncologic disease.¹¹ These patients are typically older, have several comorbidities, are less active at baseline, and have decreased functional demands when compared to post-traumatic amputees, especially the military amputees.¹² In fact, nearly half of the patients that receive an amputation secondary to vascular disease will die within five years of the operation.¹³ Post-traumatic amputees, on the other hand, are often younger, in better physical and cardiovascular shape at the time of injury, desire more active lifestyles, and carry a higher survival rate after amputation.¹⁴ Many combat amputees also sustain other injuries associated with their combat trauma. As many as 16% of amputees have lost more than one extremity, 39% also have long bone fractures, 45% have active infections, and 12% have peripheral nerve injuries.¹⁵ Additionally, post-traumatic stress disorder (PTSD) is commonly associated with patients with orthopaedic combat injuries.⁶ Taking into consideration the characteristics unique to the post-traumatic combat amputee is essential in providing comprehensive rehabilitative care with several nuances that differ from standard non-combat amputee care.

Since the onset of the post-9/11 armed conflicts, several advances related to the rehabilitation of the combat amputee have been developed to achieve maximum function in these patients. Research shows a number of positive aspects of exercise routines relevant to combat amputees to include

improved health outcomes including quality of life, functional capacity and mood states, decreased metabolic cost of ambulation, and reduced anxiety.¹⁴⁻¹⁶ Previous studies have shown that participation in sports can help amputees cope with their perceived physical impairments by providing adaptive athletic opportunities that maximize engagement in new activities while minimizing disability.

Additionally, pursuing sports as an amputee, allows patients to discover the options available to them with regards to different types of activities and prostheses as well as gain the motor control necessary to control the prosthetic limb for athletic participation.¹² One study showed that rehabilitation programs with the use of the prosthesis to achieve activity correlates with improved overall quality of life and satisfaction with the prosthesis.¹⁹ Specifically, measures of quality of life and self-esteem are higher in amputees who participate in sports as well as “enhanced psychological well-being, self-confidence and coping behavior.”¹² Amputee participation in athletics leads to improvements in the cardiopulmonary system, muscle force generation and lean body mass as well as decreased rehabilitation time.¹² Using sports to develop a physical fitness regimen for combat amputees is a component of culturally competent care process for veterans that is proving to be essential to their overall rehabilitation.¹²

High intensity interval training (HIIT) has become a popular evidence based approach to developing cardiovascular fitness as well as improving muscular strength. HIIT programs emphasize short, repetitive intervals of less than 4 minutes of explosive exercises whereby allowing the trainee to exercise at or close to $\dot{V}O_2$ max over a significant period of time.²⁰ Several studies demonstrate that HIIT can lead to improvements in cardiopulmonary fitness, musculoskeletal strength and several metabolic parameters. HIIT regimens are modifiable to optimize activity specific improvements at various points along the aerobic-anaerobic spectrum. A number of different exercises can be used within the HIIT model to include sprints, seated rows, cycling and martial arts. Recently, researchers have investigated the utility

of modifying HIIT principles to maximize the fitness requirements of men and women in the armed forces into a program called martial arts-based high intensity interval training or MA-HIIT.²¹

MA-HIIT is a fitness program used to maximize the many known benefits of both HIIT and martial arts type training to optimize military physical training and the rehabilitation of combat amputees. Benefits of an integrated MA-HIIT program include “observed cardiovascular and metabolic improvements, decreased injury rates, increased team building within participants, and the low relative costs of these regimens.”²¹ The numerous studies demonstrating the benefits of HIIT, such as improvements in aerobic fitness without impairing strength training and lower rates of military training overuse injury secondary to lower mileage, make MA-HIIT an optimal model of physical training in the military. Additionally, MA-HIIT better equips the warfighter for the anaerobic demands of the modern battlefield with the cardiovascular reserve to sustain prolonged combat engagements.²¹

Since 2010, the Center for the Intrepid and the Department of Orthopaedic Surgery at the San Antonio Military Medical Center have utilized a martial arts-based high intensity interval training program to rehabilitate over 500 combat veterans who sustained severe extremity injuries—both amputees and limb salvage patients (Figure 1). Patients receive coaching during MA-HIIT sessions by Orthopaedic Sports Medicine specialists trained in martial arts. While several combat amputees have thrived in this program with much anecdotal support from the patients, there remains a dearth of scientific evidence based practices to guide best practices on the use of MA-HIIT for rehabilitating these combat injured patients. Though some authors advocate gradual orientation to exercise regimens and limiting amputees to moderate or low intensity exercises, little empiric evidence exists to support these reservations.²² In fact, one study showed similar injury rates among amputees and able bodied players competing in non-contact football.¹² Patients that begin a rehabilitation program sooner after their amputation achieve better walking ability post-operatively.²³ Though more studies are needed to explore the impact of MA-HIIT on this subset of traumatic amputees, the potential of providing a

comprehensive and effective rehabilitation program remains promising given the current body of knowledge.

The combat amputee has several barriers to successful rehabilitation to premorbid function that are unique to young, healthy, and motivated patients who underwent extremely traumatic injuries. MA-HIT programs offer an excellent method to achieve and maintain maximal cardiovascular fitness and musculoskeletal strength while providing the opportunity for patients to become more aware and confident of their control of their residual limb and/or prosthesis. Additionally, working together with other amputees overcoming similar challenges to their recovery embodies the warrior ethos and encourages comradeship amongst wounded warriors and their care providers. Creating a rehabilitative program that adequately addresses the challenges unique to combat amputees while providing the mental and physical training necessary can likely be achieved through implementing martial arts-based high intensity interval training but further well designed studies are necessary.

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