EAST AFRICA HIGH ALTITUDE RESEARCH EXPEDITION

Mt. Kilimanjaro, Tanzania
January 2009

Explorers Club Flag #114

Submitted by Scott Hamilton, FR 82, Expedition Leader

ABSTRACT:

A 24 member biomedical research project, “the East Africa High Altitude Research Expedition” traveled to Africa’s Mt. Kilimanjaro., located in the country of Tanzania, in January of 2009. The team conducted high altitude physiology research in a joint project with The Explorers Club, the Thermal and Mountain Medicine Division of the US Army Research Institute of Environmental Medicine (USARIEM), and Massachusetts General Hospital / Harvard. The project was organized by Scott Hamilton, of The Explorers Club, who also served as the Expedition Leader & USARIEM Study Coordinator. Principal Investigators were Stephen Muza Ph.D. & Robert Kenefick Ph.D. of USARIEM, and N. Stuart Harris M.D., Director of Wilderness Medicine at Massachusetts General Hospital. Kenneth Kamler M.D. served as the expedition physician.

RESEARCH PROTOCOLS:

USARIEM:

“Field study of altitude acclimatization and sickness, and hydration during a graded ascent to 5895 m”.

Mass. General / Harvard:

“Kilimanjaro Research Expedition: Ultrasonographic Evaluation of Optic Nerve Sheath Diameter, Pulmonary Edema, and Cardiac Function During Exposure to Hypobaric Hypoxia”

Expedition Field Activities

Depart USA on 1/10/09
Return USA on 1/22/09

EXPEDITION TEAM MEMBERS

SIMBA TEAM

1- Scott Hamilton - Expedition Leader
2- Luke Morehouse
3- Mark Slovenkai MD
4- Granis Stewart RN - Expedition Medical Team
5- Richard Gilbane
6- Melissa Ryan
7- Robert Metcalfe Ph.D.
8- Kenneth Kamler MD – Chief Expedition Physician
9- Brian Lawrence
10 - Kevin Chambers
11 - Stephen Muza Ph.D. - USARIEM Primary Investigator
12 - Stuart Harris MD - Mass. Gen / Harvard Primary Investigator

TEMBO TEAM

13- Robert Hyman – Team Leader
14- Deb Atwood
15- Josh Grossman
16- Katy Kunzer
17- Briana Dema
18- John Dema
19- Jack Dema
20- Andrew Fields
21- Diann DeFebbe
22- Orme Wilson
23- Robert Kenefick Ph.D. – USARIEM Co-Investigator
24- Coleen Keller

* Underlined name denotes Explorers Club Members

RESEARCH INVESTIGATORS

USARIEM, US Army Research Institute of Environmental Medicine
Thermal & Mountain Medicine Division
Kansas St. Natick, MA

Stephen R. Muza, Ph.D., Research Physiologist
- Principal Investigator

Robert Kenefick, Ph.D., Research Physiologist
- Co-Investigator

Scott W. Hamilton, MBA
- Study Coordinator

Beth Biedelman, Sc.D., Research Physiologist
- Research Collaborator

John W. Castellani, Ph.D., Research Physiologist
- Research Collaborator

Charles S. Fulco, Sc.D., Research Physiologist
- Research Collaborator

Samuel N. Cheuvront, Ph.D., Research Physiologist
- Research Collaborator

Allen Cymerman, Ph.D., Research Physiologist
- Research Collaborator

Massachusetts General Hospital / Harvard Medical School
Department of Emergency Medicine
Zero Emission Place, Suite 3B
Boston, MA

N. Stuart Harris, MD, MFA, FACEP, Assistant Professor of Medicine
- Principal Investigator

Peter Fagenholz, MD,
- Co-Investigator

Vicki Noble, MD
- Co-Investigator

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Executive Summary

A 24 member biomedical research project, “the East Africa High Altitude Research Expedition” traveled to Africa’s Mt. Kilimanjaro., located in the country of Tanzania, in January of 2009. The team conducted high altitude physiology research in a joint project with The Explorers Club, the Thermal and Mountain Medicine Division of the US Army Research Institute of Environmental Medicine (USARIEM), and Massachusetts General Hospital / Harvard. The project was organized by Scott Hamilton, of The Explorers Club, who also served as the Expedition Leader & USARIEM Study Coordinator. Principal Investigators were Stephen Muza Ph.D. & Robert Kenefick Ph.D. of USARIEM, and N. Stuart Harris M.D., Director of Wilderness Medicine at Massachusetts General Hospital. Kenneth Kamler M.D. served as the expedition physician.

USARIEM Research activities included a field study of altitude acclimatization, acute mountain sickness (AMS), a detailed study of hydration and sweat loss under field conditions and gathering data for developing the first predictive model(s) for estimating altitude acclimatization status and risk of developing AMS. Stuart Harris M.D. conducted a study involving ultrasound imaging of the optic nerve sheath for evidence of intracranial swelling. Hamilton and Muza had collaborated on a previous successful joint altitude research project on Mt. Everest in 2007.

The research team members gathered important “continuous data” by wearing a series of miniaturized bio-monitoring devices that included actigraphs (mini accelerometers) to measure energy expenditure, pulse oximeters which were worn every night while sleeping to record blood oxygenation saturation and heart rate, computer based health status questionnaires, fluid intake, skin temperature & urine specific gravity measurements to measure hydration status, respiratory volume, and cognitive function tests. Supplementary data on ambient temperature, solar radiation & barometric pressure was also collected.

Mass General Research was focused on the assumption that lower oxygen levels at high altitude may cause the brain to swell. N. Stuart Harris M.D. studied intracranial pressure (ICP) by examining the changes in the diameter of the team member’s optical nerve sheath during the climb. This is the covering around the nerve that connects to eyes to the brain. The optic nerve sheath diameter (ONSD) is another way of telling how much pressure there is in the brain; larger diameter in the optic nerve sheath indicated higher ICP.

EAST AFRICA HIGH ALTITUDE RESEARCH EXPEDITION

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Executive Summary (cont.)

This was measured with a compact portable ultrasound machine, used to provide a non-invasive “window” into each team members’ brain.

After a seven day ascent to the summit via the Western “Lemosho” route, the entire team camped in the Kilimanjaro crater at 18,700’ before descending the mountain via the “Mweka” route. All 24 team members reached the summit. Research data is currently being analyzed at USARIEM and Massachusetts General and is expected to result in several academic publications.

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Background

This expedition engaged in a high altitude physiology research project with both USARIEM (US Army Research Institute for Environmental Medicine) and with Massachusetts General Hospital / Harvard.

The USARIEM research was similar to a prior expedition on Mt. Everest in the spring of 2007. The research protocol on Everest was titled "A field study of AMS (acute mountain sickness) and evaluation of a prototype model for assessing individual altitude sickness during a graded ascent to 5400m." (see Flag Report for details).

Based on the success of the Mt. Everest project in 2007, USARIEM desired to conduct a follow-up study with a larger cohort (Mt. Everest study cohort size was 12). This expedition gathered data on 24 individuals (2 groups each comprised of 12 individuals) during a graded ascent of Mt. Kilimanjaro. The teams were in the field from January 10 thru January 22, 2009.

The USARIEM research primarily consisted of miniaturized biomonitoring devices, questionnaires, and basic measurements such as weight and lung capacity, hydration etc. On the second trekking day, all team members participated in an extensive supplementary study of sweat loss and hydration. This included very precise measurements of body weight, skin temperature, and fluid intake. It is believed that this was possibly the largest field study of its type conducted under rigorous field conditions.

The Mass General Research, conducted by N. Stuart Harris M.D. studied intracranial pressure (ICP) by using a portable ultrasound machine to examine the changes in the diameter of the team member's optical nerve sheath during the climb. The optic nerve sheath diameter (ONSD) is another way of telling how much pressure there is in the brain; larger diameter in the optic nerve sheath indicated higher ICP

Other than involving travel to high altitude, the research aspects themselves did not involve anything dangerous or invasive (no needles, blood samples etc). All participants in this project were fully informed in advance about the research, and voluntarily signed informed consent documents relative to the research aspects.

Purpose/Objectives and Plan of Expedition

The USARIEM portion of the project was titled “Field study of altitude acclimatization and illness, and hydration during a graded ascent to 5895 m“ In order to accomplish this objective, our 2 groups, each comprised of 12 individuals, participated in a climb to the Kibo summit (Uhuru Peak) of Mt. Kilimanjaro.

USARIEM has been working on developing predictive models of altitude acclimatization, AMS, and hydration status, and PC-based decision aids for high altitude deployments. Although they have significant laboratory data, they need real-world data to supplement it, and that was the goal of this project. Our team collected important “continuous data” by wearing a series of miniaturized biomonitoring devices. The devices used during the expedition had been tested previously in ARIEM’s hypobaric (high altitude) chamber, at their Pikes Peak, Colorado laboratory, and on our 2007 Mt. Everest field study.

The devices included "actigraphs" (mini accelerometers) to measure energy expenditure, multiple GPS (global positioning) units to log team members ascent profile and distance traveled, plus a 2x daily computer based (iPAQ) subjective mountain sickness / acclimatization monitoring questionnaire that each participant completed, while simultaneously logging arterial oxygen saturation by pulse oximetry, heart rate, ambient temperature & barometric pressure. Each participant also had their blood oxygen saturation and heart rate measured throughout the night while sleeping, every night during the climb, plus two nights prior to the climb to establish valid base-line levels. The USARIEM researchers also measured daily hydration status by logging all liquid intake and measuring urine specific gravity each morning. Prior to starting the climb, lung capacity was measured by spirometry to establish base-line levels for each team member.. The research protocol was developed by Stephen Muza, Ph.D., Research Physiologist at USARIEM, who served as Principal Investigator as well as a participant in the field research team. Each team of 12 individuals included 11 team members plus a research investigator from USARIEM.

Most previous altitude research projects have involved "discontinuous" research, performed at intervals several days apart. A unique element of this project was that it was both "continuous" and largely sensor based. This research has potential application not only to our military, but also to all participants in activities involving high altitude, including skiing, mountaineering, high altitude geology etc.

This research study provided necessary information to accomplish elements of U.S. Army Medical Research and Development Command, Military Operational

Medicine research task 3.1- Warfighter Sustainment (Performance Optimization) in Environmental Extremes, and task 3.T- Environmental (Altitude, Cold & Heat) Illness / Injury Protection. Specifically, this study contributed to the development of: 1) prediction models of altitude sickness and military work performance, and 2) a prototype decision aid to plan and manage unit altitude acclimatization, altitude sickness, task performance and logistical needs.

Further information is contained in the appendix section of this report, which includes additional information about the specific tests and measurements performed.

Mass General / Harvard Research Protocol

The Mass. General / Harvard Research Protocol was titled “Kilimanjaro Research Expedition: Ultrasonographic Evaluation of Optic Nerve Sheath Diameter, Pulmonary Edema, and Cardiac Function During Exposure to Hypobaric Hypoxia”

Chief Investigator was N. Stuart Harris MD., Director of Wilderness Medicine in the Emergency Medicine Department of Mass. General.

Despite the research protocol title, the research activities were primarily limited to the optic nerve sheath due to limitations on available time, and to limited power supply for the ultrasound machine.

Starting at 8,000 feet above sea level, low oxygen levels cause sometimes dangerous changes in the body. Illnesses can range from common and usually benign acute mountain sickness (AMS) to more serious illnesses like high altitude cerebral edema (HACE) that affects the brain, and high altitude pulmonary edema (HAPE) that affect the lungs. High altitude illness symptoms include headache, nausea, vomiting and in some extreme cases, ataxia, disorientation and death.

While there have been numerous prior studies, it is still not clear physiologically what specifically causes some of these health problems. Dr. Harris’s goal was to accrue a consecutive set of data to correlate changes in the optic nerve sheath diameter with the timing and severity of AMS, starting from the very beginning at relatively low altitude stages through the summit of Kilimanjaro at 19,340 ft amsl. The goal was to assess early changes in the brain that happen when people start to climb at high elevation in an effort to identify the role of increases in intracranial pressure (ICP) in the development of AMS.

Testing the hypothesis that lower oxygen levels at high altitude causes the brain to swell, Harris studied ICP by examining the changes in the diameter of the climbers’ optical nerve sheath during the climb. The optic nerve sheath diameter (ONSD) is a way of telling how much pressure there is in the brain – increasing diameter of the optic nerve sheath over time in the same patient indicates higher ICP’s.

A compact, portable ultrasound machine (Sonosite 180) was used to provide a safe and noninvasive “window” into each study participant’s brain. The device was powered by both internal and external batteries supplemented by a portable solar power array. Measurements were taken non-invasively by placing a plastic covering on the subject’s closed eyelids while the hand-held device was used to study the ONSD. Dr. Harris is currently analyzing the data with help from co-investigator Peter Fagenholz, MD, of the Department of Surgery, and Emergency Medicine colleague, Vicki Noble, MD.

Further information is contained in the appendix section of this report, which includes additional information about the specific tests and measurements performed.

Logistics & Operations

To simplify the ground and climbing logistics the expedition team engaged the services of Thomson Safaris, based in Watertown, MA. Thomson has many years of experience operating climbing projects in Tanzania, and has an excellent reputation. Thomson coordinated the expedition arrangements in Tanzania including local services, meals, accommodations and guide and porter service during the climb. The expedition found the services of Thomson to be quite satisfactory.

Preliminary Results and Discussion

The USARIEM Electronic Data Collection Platforms (HP iPAQ Handheld PCs) performed well, and had very good user acceptability. The ambulatory devices (Actical by MiniMiter, Inc., Wrist Pulse Oximeter by NONIN, Inc.,) performance/reliability were robust and also had very good user acceptability. The Sonosite 180 similarly performed well in the ultrasonographic research activities.

The results indicate that a substantial volume of physiological and symptom data can be efficiently collected using validated techniques in a field environment with minimal logistical footprint both in terms of equipment and research personnel. The use of these data collection methods can substantially reduce the cost of high altitude research by opening up opportunities for “piggy-backing” data collection on regularly scheduled military training exercises and civilian recreational activities in the high mountainous field environment. Work is underway to use the data collected on this expedition to develop better models of altitude acclimatization and susceptibility to AMS. Data gathered during this research expedition is currently being analyzed and, therefore it is too early to infer any conclusive results.

As of March 5, 2009, all of the altitude acclimatization, sickness, and energy expediture data had been “cleaned” and entered in the data base. Sleep data entry is currently underway. Sweat loss and hydration data will follow.
Actual data analysis will be undertaken when the database is complete, cleaned and verified. Results, as they become available, will be appended to this report. Several research papers are expected to be submitted for publication in peer-reviewed academic journals. The expedition was quite successful in that a vast quantity of valuable data was gathered.

APPENDIX

The following 47 pages are the USARIEM Research Protocol. Also included is t3 pages from the Mass. General / Harvard Protocol. These are included to provide further information about specific aspects of the scientific tools used, and measurements taken during the East Africa High Altitude Research Expedition.