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AWARD NUMBER: DAMD17-03-2-0053

TITLE: Gait Dynamics and Locomotor Metabolism

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REPORT DATE: October 2013

TYPE OF REPORT: Annual

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

DISTRIBUTION STATEMENT: Approved for Public Release;
Distribution Unlimited

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
October 2013	Annual	1 Oct 2012 – 31 October 2013

4. TITLE AND SUBTITLE

Gait Dynamics and Locomotor Metabolism

5a. CONTRACT NUMBER

5b. GRANT NUMBER
DAMD17-03-2-0053

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

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5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Southern Methodist University, Inc.
Dallas, TX 75275

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

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

The proposed work has two objectives to improve prediction and assessment capabilities. The first objective is to determine if the generalized equation provided by our new gait mechanics model predicts the metabolic cost of weighted and unweighted walking more accurately than existing generalized equations. Our second objective is to determine how accurately weighted and unweighted walking metabolic rates can be estimated in field settings from simple technologies. Metabolic rates will be measured from expired gases. The timing of each walking stride, as well as its subcomponents (i.e. the contact and leg swing portions) will be determined from video. In addition, the periods of muscular activity responsible for executing the movements of the walking stride will be also assessed from electrical activity using surface electrodes attached to the skin above target muscles. The forces that subjects apply to the ground during locomotion may be measured from either a force plate or force sensors built into a treadmill. Finally, heart rate monitors to measure heart beat frequency, miniature motion sensors mounted to the shoe or other parts of the body to measure movement speeds and rates may also be utilized.

15. SUBJECT TERMS
Locomotion, gait, metabolism, body size, load carriage

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
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INTRODUCTION

The proposed work has two objectives coordinated to fulfill the overall objective of improving quantitative estimates of locomotor metabolism and activity in field settings. The objective of the first portion of the experimental work is to develop generalized equations that relate height, weight and speed to the metabolic rates incurred during walking. Fulfilling this objective will involve assessing whether the generalized equations provided by our new gait mechanics model will predict the metabolic cost of weighted and unweighted walking more accurately than existing generalized equations under controlled conditions. Our second objective is to determine how accurately weighted and unweighted walking metabolic rates can be estimated in field settings using simple, inexpensive wearable technologies.

Metabolic rates will be measured from expired gases. The timing of each walking stride, as well as its subcomponents (i.e. the contact and leg swing portions) will be determined from video and/or ground reaction force data. In addition, the periods of muscular activity responsible for executing the movements of the walking stride may be assessed from electrical activity using surface electrodes attached to the skin above target muscles. The forces that subjects apply to the ground during locomotion may be measured from either a force plate or force sensors built into a treadmill. Finally, miniature motion sensors and geolocation devices mounted to the shoe or other parts of the body to measure movement speeds and rates will also be utilized. Field trials will be conducted using lightweight, portable indirect calorimeters. Subjects will walk both with and without weighted backpacks during both the laboratory and field trials.

BODY

In this no-cost extension year, our efforts have been primarily focused on data analysis, model development, report and manuscript preparation. Over the course of the last year, we had 10 additional subjects complete testing to bring the total number tested completed to 64.

In keeping with the focus above, we published one manuscript, one abstract, and have a second manuscript in preparation with a third to follow in the coming year. The published manuscript represents many years of work on developing and validating a new model for predicting walking metabolism on firm level surfaces. The manuscript and abstract are provided as attachments to this report along with a technical report that provides a working

description of the technique developed to predict maximal aerobic power from submaximal heart rates during walking. A second manuscript is currently in preparation.

The additional work that remains is to further validate and refine the algorithm for our walking model and to continue to work toward the final algorithm and publication of a walking test for predicting aerobic fitness.

The number of subjects tested in the last year was limited and targeted toward enrolling highly aerobically fit subjects needed for objective two. Successfully identifying and testing these subjects increased the range of maximum aerobic power values in our sample and the aerobic stratification of the subjects in our sample. For this purpose an additional 10 subjects were enrolled per above.

In each of the quarterly periods below, our primary efforts were directed toward data analysis, report and manuscript writing for the two objectives of the award: developing a robust generalized equation to predict walking metabolic rates on firm, level surfaces, and developing a walking test to predict maximal aerobic power from submaximal heart rates. These were the appropriate and warranted objectives in this no-cost extension year.

Below we provide the number of subjects tested in each quarter in our effort to add subjects with very high maximal aerobic power to our sample for more robust algorithm development.

November 2012 through January 2013

In the three months that elapsed between October 2012 and January 2013 we had one subject complete testing.

February 2013 through April 2013

In the months of February through April, we had three subjects complete testing.

April 2013 through June 2013

In the months of April through June, we had four subjects complete testing.

July 2013 through October 2013

In the months of July through October, we had two subjects complete testing.

Recent illustrations from our data sets of how well our model predicts metabolic data on firm, level surfaces are provided below.

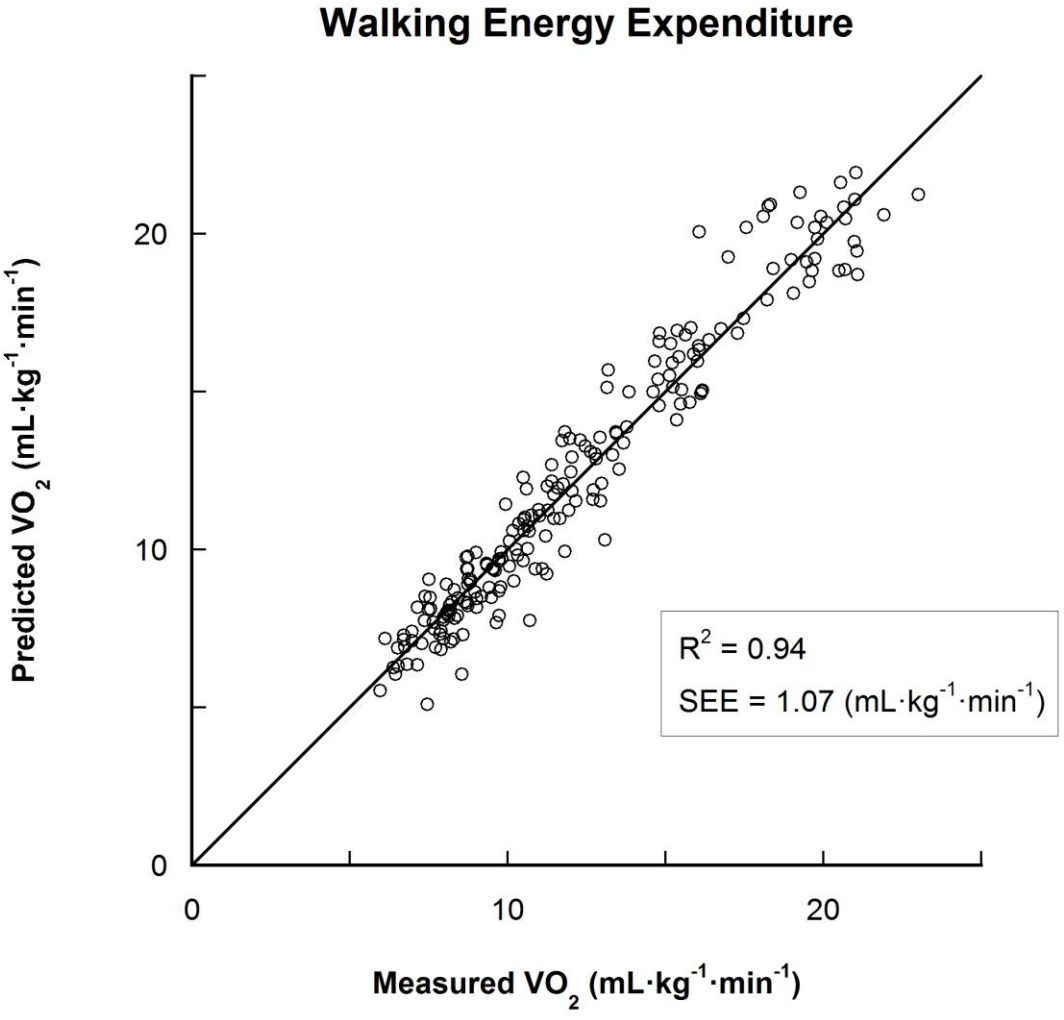

Figure 1. The agreement between measured and predicted rates of oxygen uptake (n=34 subjects) at six different treadmill walking speeds from 0.4 to 1.9 meters per second.

At this juncture, 21 subjects have completed a three-speed protocol on level asphalt with metabolic measurements being acquired using the Douglas bag technique. The agreement between the treadmill data from the laboratory and the over-ground data for these subjects is illustrated in Figure 2 below.

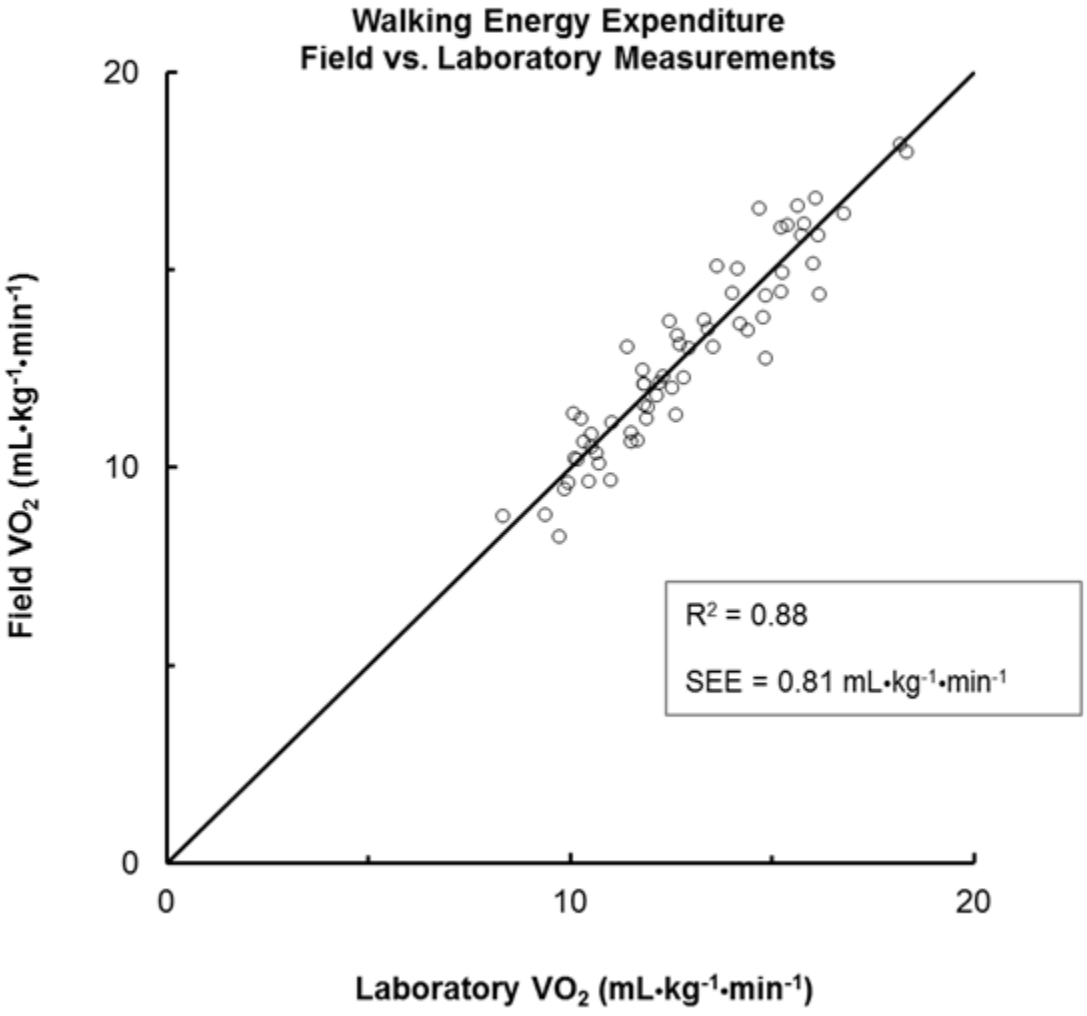

Figure 2. The agreement between treadmill and over-ground rates of oxygen uptake (n=21 subjects) at three walking speeds: 1.0, 1.3 and 1.6 meters per second.

The predictions provided by our stature-based model on the over-ground trials thus far completed appear below in Figure 3.

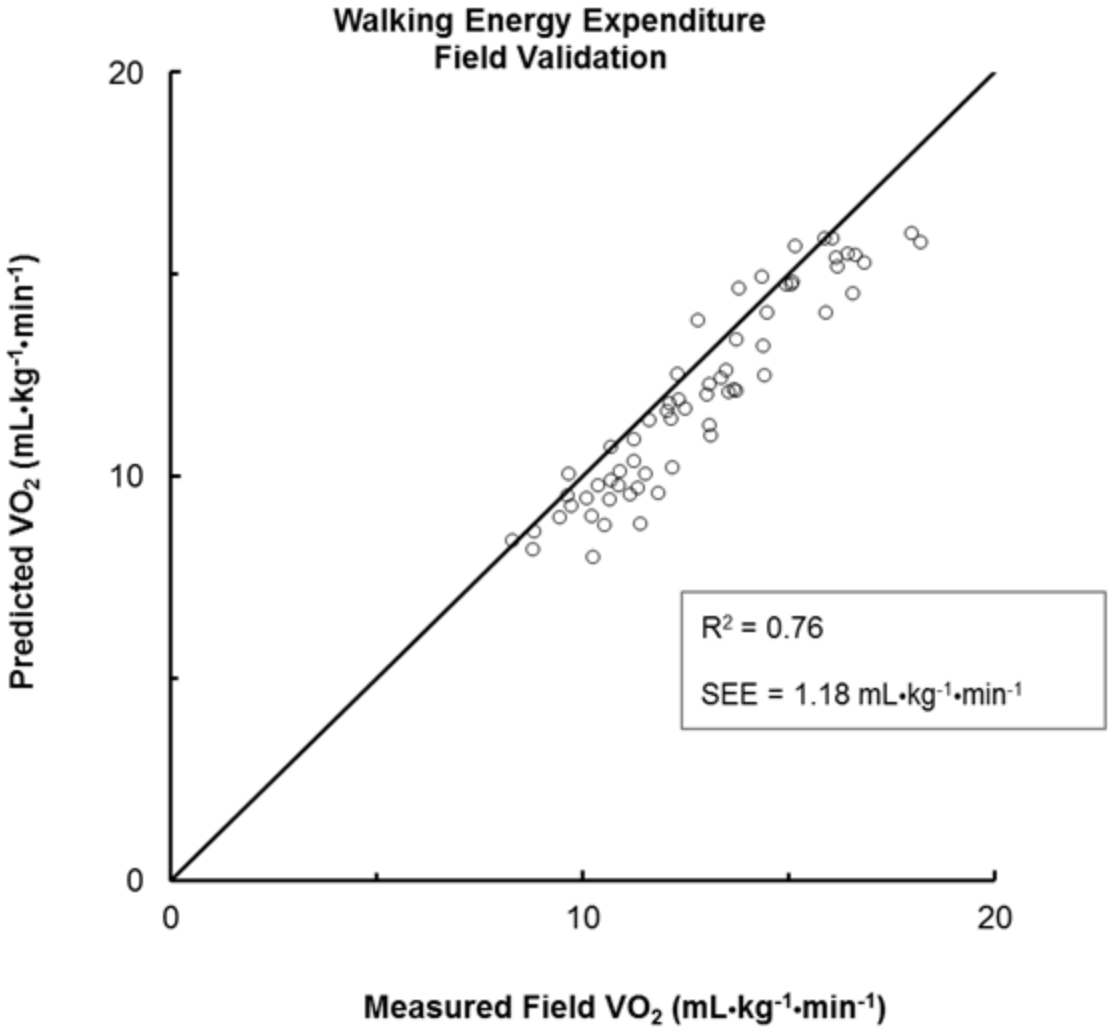

Figure 3. The agreement between measured rates of oxygen uptake (n=21 subjects) during over-ground walking at 1.0, 1.3 and 1.6 meters per second vs. the rates predicted by our stature-based model.

The walking metabolic rates of the 10 subjects who completed both treadmill and grass-field testing appear below in Figure 4. We found that walking on grass elevated the metabolic cost of walking by 5-10% with a slight speed-dependency. Therefore, our treadmill-based model under-predicted the metabolic rates measured on grass. However, the re-optimized model does provide a good fit to the grass data per the figure.

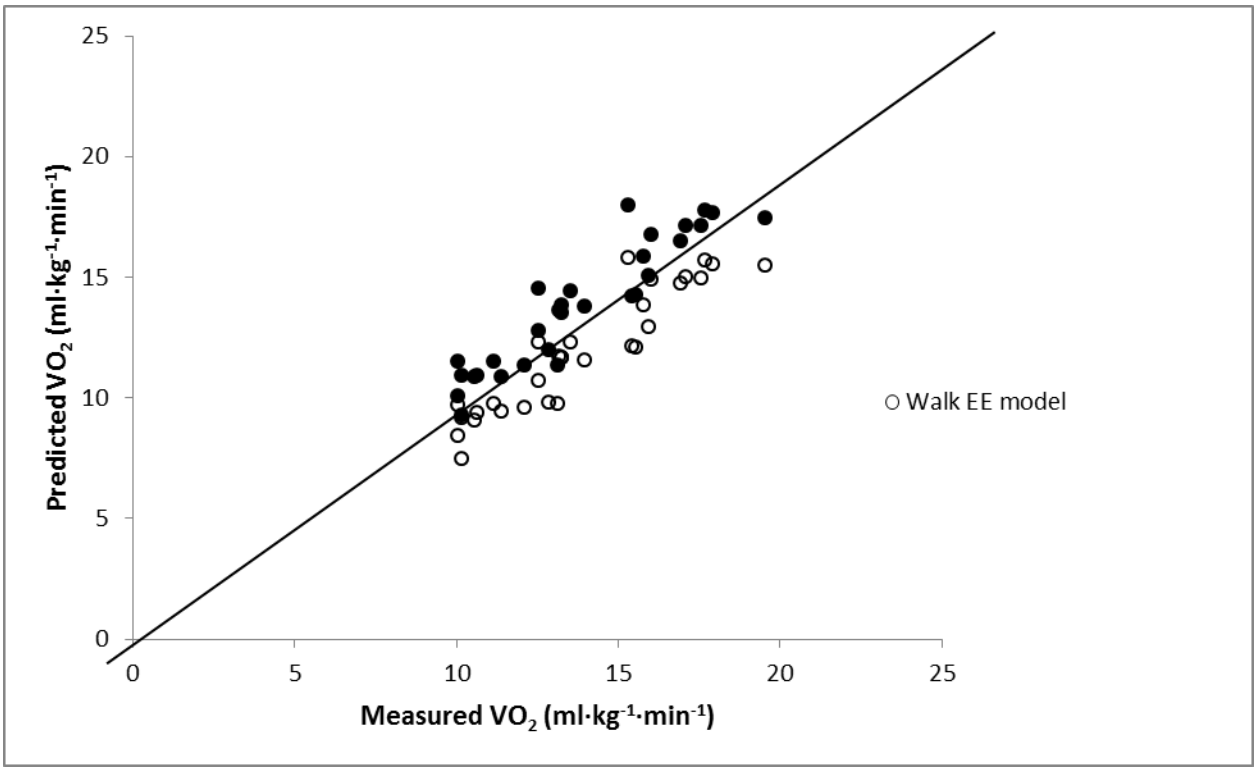

Figure 4. The agreement between measured rates of oxygen uptake (n=21 subjects) during over-ground walking on pavement (open circles) and grass (closed circles) at 1.0, 1.3 and 1.6 meters per second vs. the rates predicted by our stature-based model.

Our work on the mechanics of locomotion was covered on a segment of PBS/NOVA's "Making Stuff; Faster" show that aired in October of 2013. A local NPR radio interview entitled "Fleet of Foot" aired on KERA radio in Dallas two days prior to the airing of the PBS show.

KEY RESEARCH ACCOMPLISHMENTS

YEAR-END SUMMARY OF KEY ACCOMPLISHMENTS

The major accomplishments for the last year of activity are as follows:

1) The formulation and publication of a new model and generalized equation for predicting metabolic rates during walking on firm level surfaces.

The new equation establishes the importance of a major factor that

has not been included in prior models and predictive equations: stature. We have formulated and introduced a new generalized equation to predict walking metabolic rates that is appreciably more accurate than existing standards (Pandolf et al for military usage and the American College of Sports Medicine equation for general population usage).

Weyand PG, Smith BR, Schultz NS, Ludlow LW, Puyau MR, Butte NF. Predicting metabolic rate across walking speed: one fit for all body sizes? J Appl Physiol (1985). 2013 Nov;115(9):1332-42. doi: 10.1152/japplphysiol.01333.2012. Epub 2013 Aug 8.

- The published version of the manuscript has been submitted with this report as a pdf

2) The evaluation of walking metabolic rates under two overground conditions: hard pavement and grass.

- See the abstract submitted with this report

3) Additional data collection and refinement of a walking test to predict maximal aerobic power from two parameters: an estimated rate of energy expenditure, and 2) stead-state heart rate.

- Please see attached technical report

4) Further evaluation of the new model introduced above in a manuscript that is in preparation entitled: "Walking metabolism: one biological signal or two?"

REPORTABLE OUTCOMES

Please see key research accomplishments and attached reports.

CONCLUSIONS

We have completed data collection and much, but not all, of the analysis to finalize our models and predictive relationships. The focus in the coming period will be finalizing and publishing these scientific techniques and models.

REFERENCES:

American College of Sports Medicine Guidelines for Graded Exercise testing and Prescription, 7th edition. Philadelphia, PA: Lippincott, Williams and Wilkins, 2006.

Pandolf KB, Givoni B, Goldman RF. Predicting energy expenditure with loads while standing or walking very slowly. *J Appl Physiol* 43: 577-581, 1977.

APPENDICES:

None