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14. ABSTRACT

The proposed work has three 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. The second objective is to determine how accurately weighted and unweighted walking metabolic rates can be estimated in field settings from simple technologies. The third objective is to develop a walking test of aerobic fitness. Metabolic rates will be measured from expired gases. The timing of each walking stride, as well as its subcomponents will be determined from video. In addition, periods of muscular activity 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, load carriage, aerobic fitness

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INTRODUCTION

The proposed work has three objectives coordinated to fulfill the overall objective of improving quantitative estimates of locomotor metabolism, activity and fitness 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. Our third objective is to develop a short, practical and accurate method to estimate aerobic fitness from submaximal heart rates during walking.

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. 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. Heart rates will be measured using chest strap monitors in both laboratory and field testing. Subjects will walk both with and without weighted backpacks during both the laboratory and field trials.

BODY:

<u>September 2009 though January 2010</u>:

We completed many of the requisite preliminary steps to prepare for our upcoming experimental work to fulfill our statement of work.

Since early November of 2009, we submitted our full protocol to the local IRB here at SMU. Full submission occurred on November

28th. On January 12th, we have received local IRB approval for the protocol pending further explanation of several issues. We are now in the process of clarifying these issues with the local IRB.

In parallel with the local IRB approval process, we are also continuing to procure and prepare equipment and the laboratory as will be necessary to conduct the experiments once both levels of IRB approval have been procured. Toward this end, we have purchased a portable oxygen analyzer (Cosmed K4 unit) to take field measurements of metabolic rates. A training session with the manufacturer is scheduled for next week. We are currently testing the new portable unit and integrating the data acquisition and storage with a new laptop computer. We are also validating the portable unit against our laboratory metabolic system (Parvomedics TrueOne) for agreement.

In addition, we are researching commercially available treadmills that will be best suited to the proposed laboratory work on the award. We are also continuing to analyze the preliminary data that led to the formulation of our dynamic similarity model to better predict walking metabolic rates. This includes extensive literature searching to have a comprehensive library of all the previous work undertaken. A significant portion of this work predates 1960 and is often not available in original electronic form.

Manuscript preparation and publication of data from the original award period has also continued. On November 19, we published a manuscript in the *Journal of Applied Physiology* (with experimental work and data completed in the first award period) that appeared as part of a point/counterpoint style debate in this journal. This analysis led to feature articles in: The New York Times, Sports Illustrated, Popular Science, and Discover Magazine. The story was also covered by papers and magazines throughout the world (including USA Today, ESPN and others) that picked up either the Associated Press or Agency French Press (AFP) versions of the story.

<u>January 2010 through April 2010</u>:

We are currently fully focused on doing everything possible to obtain full human subjects approval as quickly as possible. Due to a number of circumstances (institutional award transfer, obtaining institutional safety compliance approvals, major revision/supplementation of the statement of work, and an expansion of the protocol to include children) we have experienced multiple significant delays, each setting us back

several months. As such, we have been unable to begin experimental work on the current objectives.

As of our quarterly report in early January of 2010, we had just received tentative local IRB approval for the protocol pending further explanation of several issues. In the last 3-month period efforts have focused heavily on procuring full approval so experiments can commence. We have obtained additional assent forms scripts, consent forms and other documentation from institutions that have performed exercise tests on children. We have submitted a protocol draft to our HSRP officer, Brigit Ciccarello and obtained her feedback. We have subsequently drafted a more comprehensive protocol taking into account the information garnered from other institutions, the feedback from the SMU IB, other institutions and Ms. Ciccarello. Our revised protocol will be resubmitted to Ms. Ciccarello within 5 business days so that she may proof the protocol for appropriate inclusion of all DOD-required elements.

In parallel with the local IRB approval process, we are also continuing to procure and prepare equipment and the laboratory as will be necessary to conduct the experiments once both levels of approval (SMU IRB, TATRC HSRPO) have been procured. We have purchased installed and tested a new treadmill. We have validated our new portable calorimeter against our laboratory system and we have streamlined data acquisition systems.

In addition, we are also continuing to analyze the preliminary data that led to the formulation of our dynamic similarity model to better predict walking metabolic rates.

April 2010 through August 2010:

We are currently fully focused on doing everything possible to obtain full human subjects approval as quickly as possible. After extensive revisions of the protocol per the input of our compliance specialist, Ms. Brigit Ciccarello, our protocol documents were resubmitted and approved locally at SMU on May 24, 2010. Our protocol then moved forward to the next level of review by the HRPO. Ms. Ciccarello put the documents into this next level of the review process on June 1, 2010. As of today, August 10, 2010, we have not heard back from the review board. We do have an inquiry in with respect to our status.

While awaiting the response of the HRPO review, we have continued to analyze preliminary data collected previously. This effort has helped us to further refine the algorithms for predicting walking metabolic rates and aerobic fitness. We have made

reasonable progress with these data. Our most recent data and algorithms were presented at the June PLR in Frederick. A consensus was formed that intellectual property on the algorithms should be pursued and we are working with TATRC guidance to do so in an organizationally-appropriate way.

In addition, an original manuscript analyzing the influence of height on mass-specific walking metabolic rates was submitted to the *Journal of Experimental Biology* in June. We received reviews in mid-July. A revised version of the manuscript was submitted yesterday. We are also preparing a second manuscript that presents a technique that allows walking metabolic rates to be estimated form height, weight, and walking speed.

August 2010 through November 2010:

After a very lengthy award transfer process and lengthy human subjects approval process, we were notified on November 8, 2010 (just under two weeks ago) that we have been approved to being experimentation. In the last two weeks approximately 8 subjects have been recruited and experimental work has been undertaken with three of these subjects as of November 10, 2010.

Per our last report, while awaiting the response of the HRPO review, we have continued to analyze earlier data to further refine the algorithms for predicting walking metabolic rates and aerobic fitness. Following the presentation of our most recent data and algorithms at the June PLR in Frederick, a consensus was formed that intellectual property on the algorithms should be pursued and we are working with TATRC guidance to do so in an organizationally-appropriate way. We have been in contact with the Tech Transfer office of Rice University, where the original patent was filed, to determine how best to move forward with the intellectual property involved in the newly developed algorithms.

In addition, our first original manuscript analyzing the influence of height on mass-specific walking metabolic rates published the Friday before last on November 12th at the *Journal of Experimental Biology* in June. The journal editor wrote a research feature piece on the work for “Inside JEB” and issued a press release which received press coverage from a variety of news organizations ranging from wire services like UPI to newspapers like The Times of India to magazine style scientific publications such as Science magazine (website coverage) and Scientific American.

We have begun work on the second manuscript of tour new walking model that is distinct from previous models in that stature is

included as a predictor. The new paper will further develop the applications of the model by extending predictive relationships to the complete range of walking speeds. The new algorithms predict walking metabolic rates from height, weight and walking speed.

KEY RESEARCH ACCOMPLISHMENTS (Sept-Jan):

- Preparing human subjects protocols to gain local IRB approvals.
- Procuring equipment for upcoming experiments.
- Preparing laboratory and field sites for upcoming experiments.
- Analysis, write-up and publication of data from the prior award period.
- Literature searching and continued analysis of our current working model of walking metabolism and body size.
- Data from the last award period has led to a significant advance in the understanding of the influence of prosthetic limbs on locomotor performance.

No new experimental work has yet been undertaken. Human subjects approval is not yet in place.

KEY RESEARCH ACCOMPLISHMENTS (Jan-April):

- We obtained tentative approval from local IRB pending several items in early January.
- To properly revise IRB materials and also meet DOD protocol requirements, we obtained additional sample assent forms and scripts from other researchers working with children.
- We submitted a draft protocol to our HSRPO at TATRC.
- We obtained feedback from HSRP officer to further revise and prepare the full IRB protocol on March 30, 2010.
- We have drafted a revised and more comprehensive protocol with specific attention to required DOD elements. This revised protocol will be submitted to the HSRP officer within 5 business days or less of this report. [Upon return, the protocol will be revised again prior to resubmission to the SMU IRB.]
- We installed a new treadmill better suited to testing children.
- We tested and validated new portable calorimeter.

No new experimental work has yet been undertaken. Human subjects approval is not yet in place.

KEY RESEARCH ACCOMPLISHMENTS (April-June):

- Local IRB approval gained on May 25, 2010.
- IRB protocol submitted to HRPO June 1, 2010.
- Manuscript submitted to *Journal of Experimental Biology* on June 16, 2010.
- Revised manuscript submitted to *Journal of Experimental Biology* on August 9, 2010.

KEY RESEARCH ACCOMPLISHMENTS (August-November):

- HRPO approval was received on November 8, 2010
- Human subjects recruiting and experimentation commenced on November 10, 2010.
- Manuscript published at the *Journal of Experimental Biology* on November 12, 2010.
- Inside JEB feature article published on November 12, 2010.
- Press coverage of the new walking model just published in the J. Experimental Biology included the following media outlets in addition to the JEB journal feature:
  - United Press International
  - The Times of India
  - Science magazine online (Science: shot)
  - Scientific American
  - Canadian Broadcasting Corporation: "Quirks and Quarks" weekly science radio show syndicated and broadcast throughout Canada.

REPORTABLE OUTCOMES:

As partially detailed in the list of accomplishments and outcomes provided in the key research accomplishments section above, experimental work from the last award period contributed to the publication of the following manuscripts over the course of the last year:

- Weyand P, Smith B, Payau M, Butte N. The mass-specific energy cost of human walking is set by stature, *Journal of Experimental Biology*, **213:** 3972-3979, 2010.

- Weyand P, Bundle M. Last Word: Artificial limbs do make artificially fast running speeds possible. *Journal of Applied Physiology*, **108**: 1019, 2010.

- Weyand P, Sandell RF, Prime DNL, Bundle M. The biological limits to running speed are imposed from the ground up. *Journal of Applied Physiology*, **108**: 950-961, 2010.

- Weyand P, Bundle M. Artificial limbs do make artificially fast running speeds possible. *Journal of Applied Physiology,* **108:** 1011-1012, 2010.

CONCLUSIONS:

Pending results from experimental work now commencing.

REFERENCES:

Weyand P, Smith B, Payau M, Butte N. The mass-specific energy cost of human walking is set by stature, *Journal of Experimental Biology,* **213:** 3972-3979, 2010.

Weyand P, Bundle M. Last Word: Artificial limbs do make artificially fast running speeds possible. *Journal of Applied Physiology*, **108**: 1019, 2010.

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Weyand P, Bundle M. Artificial limbs do make artificially fast running speeds possible. *Journal of Applied Physiology,* **108:** 1011-1012, 2010.

APPENDICES:

None