Improving Metabolic Workload Estimation Accuracy for Planning and Analyzing Exploration Traverses

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***Abstract*— A novel method is suggested to reduce estimation error on metabolic workload during surface extravehicular activity (EVA) traverse.**

***Clinical Relevance*— Assistive tools to efficiently plan exploration EVAs will be necessary for mission success.**

I. Introduction

The Crew State and Risk Model developed at National Aeronautics and Space Administration (NASA) Johnson Space Center (JSC) is a modular framework to predict and monitor crewmember's physical and cognitive state during EVA and associated risk implications. The traverse model is one component of this framework that aims to estimate the metabolic cost of EVA traverses accurately. Thus, a novel method was suggested to improve the estimation accuracy of metabolic workload in EVA simulation environments.

II. Methods

Decision support tools for planning EVA traverses utilize path information, metabolic expenditure, etc. [1]. The model employed for estimating metabolic rate builds upon an equation derived from laboratory treadmill data [2]. We aimed to improve the estimation accuracy of metabolic rate and provide a novel approach based on the modified field use Pandolf load carriage equation ((2), (3)) [3], which combines a factor for applying metabolic adaptation delays ((1), (4)).

$$M_F = (M_P - CF) * DF \text{ (where * is being convoluted.)}, \quad (1)$$

$$M_P = 1.5 \cdot W + 2.0 \cdot (W+L) \cdot (L/W)^2 + \eta \cdot (W+L) \cdot (1.5V^2 + 0.35 \cdot V \cdot G), \quad (2)$$

$$CF = \eta \cdot [(G \cdot (W+L) \cdot V)/3.5 - ((W+L) \cdot (G+6)^2)/W) + (25 - V^2)], \quad (3)$$

$$DF = (1/D) \cdot e^{-(1/D)}. \quad (4)$$

The model variables are final energy consumption (M_F), the estimated metabolic rate by the Pandolf equation (M_P), the correction factor (CF) in watts, and the delay factor (DF), body weight (W), external load (L) in kg, walking speed (V), slope grade (G) as a percentage, terrain coefficient (η), and delay (D). Four healthy adult subjects were instrumented with the K5 wearable metabolic system (COSMED, Italy), providing metabolic rate (BTU/h), walking speed (m/s), and GPS information. Subjects were tasked with traversing the terrain at JSC's Rock Yard (Figure 1(a)), consisting of shallow craters, sand dunes, a hill, and a rock field, with durations up to 20 minutes at a self-paced speed.

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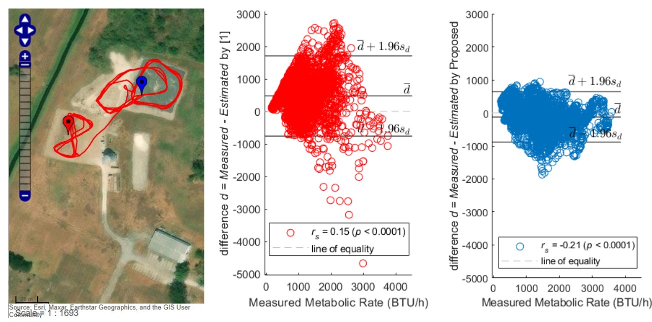
III. Results

This preliminary study showed that the proposed method predicts the metabolic rate of open-field ambulation measured by K5 with the highest accuracy. Figure 1(b) and Figure 1(c) show the Bland Altman plots, and Table I summarizes the regression coefficients in the conventional [1] and proposed models.



(a) (b) (c)

Figure 1. (a) Example of a walking path (red line) at JSC's Rock Yard, Bland-Altman plots (b) the conventional method [1] and (c) the proposed method of estimating metabolic rate.

TABLE I. Regression Coefficients.

Method		*Estimate*	*Standard Error*
Conventional [1]	(Intercept)	234.82	21.87
	x	0.50	0.01
Proposed	(Intercept)	201.80	16.00
	x	0.95	0.01

IV. Discussion & Conclusion

Preliminary results show higher estimation accuracy of metabolic workload with the novel method compared to the conventional method. Supportive tools in planning EVA traverses may require a field-purposed model rather than a laboratory-based model to estimate metabolic rate during EVA ambulation robustly and accurately. Future work is ongoing to estimate the workload of ambulating in candidate Lunar South Pole landing sites to refine workload modeling and prediction efforts.

References

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