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Functionality Variables and Accelerometry Energy Expenditure Estimate Improvement in Individuals with Locomotor Dysfunction

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ABSTRACT

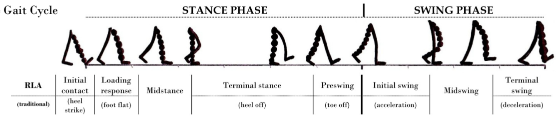
The act of walking is a complex series of actions involving a number of different body systems and is considered a critical contributor to quality of life. One's gait, the manner of walking, can therefore be used by healthcare providers to evaluate patient health, functionality, and prognosis.

Accelerometers serve as both a valid and reliable instrument to measure activity level in able-bodied persons over extended periods of time. Currently, the Actical® (Mini Mitter, Bend, OR, USA) accelerometer includes age, gender, height, and weight data in its calculations. For individuals with locomotor dysfunction, however, current algorithms do not suffice for accurate estimates as they underpredict actual energy expenditure. Thus, there is a need for a variable(s) to take into account the magnitude of gait impairment and produce a revised equation to accurately estimate energy expenditure.

In search of those variables this study explored various functionality measurements of subjects (n=35) with gait impairments diverse in both etiology and extent. The Timed Up and Go (TUG), 10 Meter Walk (10mW), 30-second Chair Stand (30CS), 4 stage standing balance (4SB), and Six Minute Walk (6MWT) tests were used.

Using the conservative statistical model of backwards regression analyses produced an R=0.718 by taking into account variables of gender, weight, age, 30CS, 4SB, the fast 10mW, and its difference to the slow 10mW. The best regression model produced an R=0.724 and included height, TUG, and 6MWT in addition to those variables of the more conservative model. Demand for accelerometer use in gait impaired individuals requires a revised equation taking into account important and frequently tested functionality variables. These variables demonstrate themselves as quality tests for better energy expenditure estimates and can lead physical therapists and healthcare professionals to the potential of providing gait impaired patients Actical® technology for more accurate results and therefore improve care.

Fig. 1: the Gait Cycle



BACKGROUND I

- Walking is a wonderfully complex and clinically revealing task
  - –muscle contractions/relaxations are agonists/antagonists for specific movements
  - –visual integration, cerebellar and inner ear function
  - –environmental and personal factors, emotional variables (3)
- Gait—the manner of walking (4)

Gait cycle (stride)

- 2 phases (2)
- 8 subphases (2)
  - –more current Rancho Los Amigos (RLA) terminology has more biomechanical focus (3)
  - –traditional nomenclature focuses on manifestly observable components of gait (3)

Estimating EE (Energy Expenditure)

- A plethora of devices exist for movement analysis: camera-assisted motion analysis, pedometers, force platforms, accelerometers, and so on (30,31)
  - –simplicity, cost, convenience, and patient-friendliness are important for clinical application
    - ◦accelerometry a great option
- **Actical® Accelerometers**
  - –small, lightweight, water-proof
    - ◦3.7 x 2.9 x 1.1-cm, only 16g (33,34)
  - –donned at ankle, hip, or wrist, using a Velcro or elastic band (30,35)
  - –deformable sensor produces electric charge proportional to applied stress, such as from acceleration (change in velocity) (33,34,35)
    - ◦triaxial (also referred to as omnidirectional), sensing acceleration in all x-, y-, and z-axes
  - –records physical activity intensity and thereby estimates EE
    - ◦validated in both children and adults (30,31)
- **VO2**
  - –oxygen uptake, measured in [L/min]
  - –continuous VO2 recorded by way of an ambulatory metabolic analyzer, Oxycon Mobile
    - ◦tight-fitting mask covering nose and mouth
    - ◦connected to lightweight backpack wirelessly relaying the data to a nearby computer
  - –excellent method to record actual EE (AEE)
    - ◦used to validate accelerometry estimates (30,31)

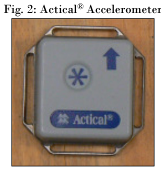


Fig. 2: Actical® Accelerometer

Fig. 3: Oxycon Mobile (CareFusion, San Diego, CA, USA)

BACKGROUND II

- Accelerometers calculate individual EE by taking into consideration several variables:
  - –age, sex, weight, and height
- **Current Actical algorithms underpredict EE estimates in individuals with abnormal gait**
  - –an enhanced equation is required to expand Actical® use to this population
    - ◦**this study seeks new variable(s) to create such an equation**

Clinical testing

- 4 key considerations for implementing a clinical test or measure:
  - –safety, cost effectiveness, ease in administering, ease in grading/interpreting results (8)
- 5 examinations (30CS, 4SB, TUG, 10mW, and 6MWT) used in this study met those criteria
  - –standardized instructions and procedures available from sources such as the CDC, ATS
    - ◦tried and true tests
- **30CS** – (*30-second Chair Stand*) - first step to walking mobility is standing up
  - –assesses ability to stand up and sit down repeatedly in a set amount of time
  - –indicator of lower body strength and endurance (5,9,10,11)
    - ◦vital role in day-to-day routine, including climbing stairs (11)
    - ◦predicts fall risk in the elderly (6,11)
- **4SB** – (*4 Stage Balance test*) – assesses static balance with eyes open (9)
  - –assistive devices (such as a cane or walker) not used
  - –each position maintained for 10 seconds
    - ◦easy scale from 0 to 4 marking the highest stage completed
- **TUG** – (*Timed Up-and-Go*) - both static and dynamic balance assessed (19)
  - –essentially a complete chair-stand with an inserted 6m walk
  - –subject walks at normal pace using his regular walking aid and normal footwear
- **10mW** – (*10 Meter Walk*) – measures (averaging 3 trials) walking speed over a 6m distance
  - –walking speed lauded by some as "the sixth vital sign" (5,6,22,23)
    - ◦predicts and assess functionality, fall risk, and health status at a gross-systems level
    - ◦five vital signs: temperature, pulse and respiration rate, blood pressure, and pain level
  - –high inter-rater and test-retest reliability
  - –two flavors: **10mW-f** (*10mW-fast*) - at a quick but safe speed
    10mW-p (*10mW-preferred*) - at a self-selected regular pace
    - ◦10mW-difference is also a revealing measure
- **6MWT** – (*6 Meter Walk Test*) - measures distance covered in 6 minutes
  - –walking aids and stopping/resting are allowed whenever subject feels necessary
  - –self-paced, therefore a better reflection of daily life activities than other walking tests (25,26)
  - –test commonly used to assess chronic heart failure patients
    - ◦predictor of morbidity and mortality from heart or lung disease

Fig. 4: **30CS** (*30-second Chair Stand*)

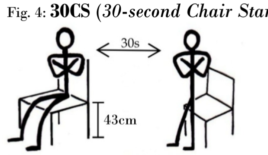
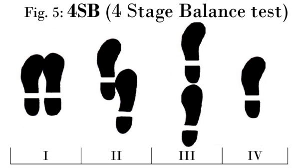


Fig. 5: **4SB** (4 Stage Balance test)



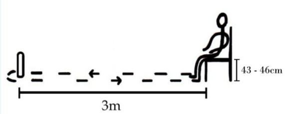


Fig. 6: **TUG** (Timed Up-and-Go)

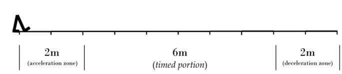


Fig. 7: **10mW** (10 Meter Walk)

METHODS

Study Design

- Two cohorts of ambulatory subjects with diverse degrees of gait impairment
  - –ranging from mild to severe, requiring use of assistive devices
    - ◦morbidity spectrum included stroke, accidents, and osteoarthritis
- Thai cohort – from Ban Suan Dok Nursing Home in Chiang Mai, Thailand
- U.S. cohort – from UM New Directions Wellness Center in Missoula, MT

Subjects completed the following:

- the 5 functional tests outlined in Background II
- (with VO2 and Actical® recording) 6MWT and a baseline 5 minute supine resting period

Statistical Analysis

- Actical® EE estimates and VO2 actual EE could then be compared from the 6MWT
- Developed multivariable regression equations using results from the 5 functional tests as well as the conventional age, gender, weight, and height
  - –these 9 variables used to improve EE estimates to better match VO2-derived actual EE (AEE)

	♀, ♂	Age	Range
Thai (n=35)	21, 14	64.2 ± 17.4	[18,91]
U.S. (n=6)	0, 6	56.7 ± 23.0	[24,78]

Table 1: Demographics of Thai and U.S. Cohorts

Table 2: Variables (and their Units) Considered in the Multivariable Regression Equations

Variable	Age	Gender	Height	Weight	30CS	4SB	TUG	10mW-p	10mW-f	10mW-dif	6MWT
[Units]	[years]	[♀=0;♂=1]	[cm]	[kg]	[chair-stands]	[0 to 4]	[sec]	[sec]	[sec]	[sec]	[m]

Table 3: Regression equations A-E

			Associated independent variable										
			Age	Gender	Height	Weight	30CS	4SB	TUG	10mW-p	10mW-f	10mW-dif	6MWT
		Constant	α	g	h	ω	c	β	τ	ρ	f	d	s
PAEE Equation	A	0.07101	-0.00032	0.01651	0.00017	-0.00044	0.00083	-0.00163	0.00021	0	-0.00146	-0.00121	-0.00001
	B	0.06648	-0.00031	0.01616	0.00018	-0.00043	0.00079	-0.00209	0.00016	0	-0.00125	-0.00113	0
	C	0.06028	-0.00030	0.01596	0.00021	-0.00042	0.00079	-0.00231	0	0	-0.00095	-0.00085	0
	D	0.09067	-0.00031	0.01807	0	-0.00038	0.00075	-0.00206	0	0	-0.00104	-0.00072	0
	E	0.08483	-0.00030	0.01777	0	-0.00036	0.00065	0	0	0	-0.00103	-0.00050	0

Predicted EE= constant + α(age)+ g(gender) + h(height) + ω(weight) + c(30CS) + β(4SB) + τ(TUG) + ρ(10mW-p) + f(10mW-f) + d(10mW-dif) + s(6MWT)

		Mean ± SD	Range	p value	R	R^2
AEE		**0.0457 ± 0.020**	**[0.012,0.094]**			
PAEE Equation	A	0.0466 ± 0.014	[0.016, 0.084]	0.77	0.724	0.525
	B	0.0466 ± 0.014	[0.017, 0.084]	0.78	0.724	0.524
	C	0.0459 ± 0.014	[0.016, 0.083]	0.97	0.723	0.522
	D	0.0463 ± 0.014	[0.016, 0.081]	0.89	0.718	0.516
	E	0.0467 ± 0.014	[0.016, 0.083]	0.74	0.712	0.507

Table 4: Thai-Predicted EE equations and AEE data statistical analyses

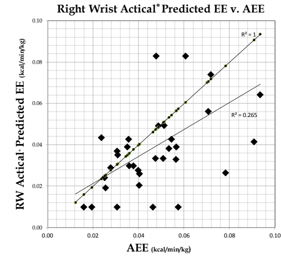


Fig. 8: Thai Right Wrist Actical® Predicted EE v. AEE

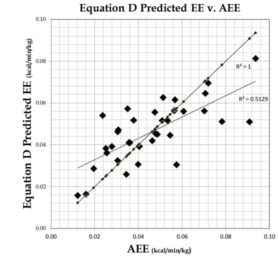


Fig. 9: Thai Equation D Predicted EE v. AEE

RESULTS

- Regression equations A through E produced significantly similar predictions of AEE (*Table 4*)
  - –Equation A had the highest R^2 (=0.525) and used all variables except 10mW-p
  - –Equation E had the lowest R^2 (=0.507) using 6 variables
  - –Equation D seen as the most appealing
    - ◦Used 7 variables
    - ◦Did not sacrifice much in terms of R^2 value (=0.516) in comparison to Equation A (R^2=0.525)
- Model data centered around the mean more tightly than the AEE data
  - –seen numerically in mean±SD (*Table 4*) and graphically as well (Fig. 8 and 9)
- Predicted EE regression equation simple to calculate (*Table 3*)
  - –relatively weak R and R^2 values (*Table 4*)

CONCLUSIONS

- Actical® accelerometers underpredict energy expenditure estimates when used by individuals with locomotor dysfunction (abnormal gait)
- Regression equations with variables of the 5 functional tests (30CS, 4SB, TUG, 10mW, and 6MWT)—as well as with the conventional age, sex, weight, and height—produce improved energy expenditure estimates for gait impaired individuals in comparison to Actical® estimates
  - –**these standard and simple tests are fitting variables to be incorporated into Actical® calculations for those with abnormal gait**
    - ◦future studies with much larger sample sizes would be desired to improve R^2 values