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Measurement of Daily Activity in Restrictive Type Anorexia Nervosa

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Abstract

Objective—The assessment of daily activity in patients with restrictive type anorexia nervosa is limited by an absence of accurate and precise technology. We wanted to test a daily activity detecting device named, the Physical Activity Monitoring System (PAMS).

Method—Women participants with restrictive type anorexia nervosa ($n = 8$, 36 ± 11 years, 17 ± 2 kg/m²) and healthy women participants ($n = 8$, 30 ± 11 years, 27 ± 7 kg/m²) were asked to lie, sit and stand motionless, and walk at 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 mph whilst wearing PAMS.

Results—For all restrictive type anorexia nervosa and healthy participants, body posture was correctly detected for all measurements (300/300). There was excellent correlation of an individual's body acceleration with walking velocity and walking energy expenditure ($r^2 > 0.99$).

Conclusions—The PAMS technology could serve as a tool for lending insight into the pathophysiology of restrictive type anorexia nervosa; and potentially measuring compliance with activity recommendations for medical professionals treating individuals with restrictive type anorexia nervosa.

Anorexia nervosa is common affecting up to 1% of young women in Western cultures (Klein, Mayer, Schebendach, & Walsh, 2007) and is associated with 4% mortality (Signorini, et al., 2007). Daily activity (the sum of non-exercise and exercise activity) is thought to be important in the etiology and maintenance of restrictive type anorexia nervosa (RTAN) (Casper, 1998; Davis, et al., 1997; Hebebrand, et al., 2003) particularly for patients who are refractory to treatment (Klein, et al., 2007).

The hypotheses we tested are that the Physical Activity Monitoring System (PAMS): 1) could be used to accurately and precisely distinguish between different postures: lying, sitting and standing, 2) could be used to distinguish a motionless stance from walking at 0.5 mph, 3) could be used to differentiate different speeds of walking, and 4) acceleration measured using PAMS will increase with progressively increasing walking energy expenditure in participants with RTAN compared to healthy adults.

Confirming the preliminary validity of PAMS in RTAN may assist future research to gain insight into the pathophysiology of this disorder and potentially allow health care professionals in monitoring their patient's activity and their response to therapy.

METHODS

Participants

Eight women volunteers with a Diagnostic and Statistical Manual IV (American Psychiatric Association, 2000) RTAN diagnosis confirmed by a psychiatrist who were continuing their usual outpatient mental health care were recruited. Participants were all past the weight restoration recovery phase of their illness. Participants were excluded if they were not receiving current mental health care, had a BMI $>19 \text{ kg/m}^2$, smoked, used alcohol, had concurrent psychiatric disorders or were pregnant.

Eight healthy women volunteers were also studied. Participants were excluded if they smoked, used alcohol, were pregnant, had an unstable body weight ($> 2 \text{ kg}$ fluctuation over the 3 months prior to the study), BMI <20 or $>35 \text{ kg/m}^2$, had an eating or other psychiatric disorder, or used any medications that may effect the results of the study at the time of study participation or during the preceding 6 months.

Measurement of body posture, movement and energy expenditure

The physical activity monitoring system (PAMS) has been described in detail previously (J. Levine, Melanson, Westerterp, & Hill, 2001, 2003; J. A. Levine, Baukol, & Westerterp, 2001). PAMS (1.3 kg) is comprised of 4 inclinometers and 2 accelerometers which are placed on the participant attached to specially designed undergarments. Measurements of energy expenditure were performed using a high precision indirect calorimeter (Columbus Instruments, OH) as previously described (J. A. Levine, et al., 2005).

Experimental protocol

Participants were fasted for >7 hours, had not consumed caffeine or alcohol for >12 hours and did not exercise for the 12 hours preceding the study. Throughout the study, participants were in thermal comfort ($68\text{--}74^\circ\text{F}$; $20\text{--}23^\circ\text{C}$). Participants initially rested for 30 minutes. Resting metabolic rate (RMR) was then assessed for 30 minutes. Energy expenditure was then measured for 15 minutes each under the following conditions: a) sitting, b) standing, and c) walking at each 0.5, 1, 1.5, 2, 2.5 and 3.0 mph on a calibrated treadmill (True 600, O'Fallon, MO). Informed written consent was obtained after the nature and possible consequences of the study were explained. The study was approved by the Mayo Clinic Institutional Review Board.

Data analysis

Mean energy expenditure for each 30 and 15 minute activity was calculated. All values are provided as mean $\pm$ SD. Post-hoc unpaired t-tests were used to compare changes in energy expenditure and PAMS output between RTAN and healthy participants. Data on posture and motion were analyzed using Matlab (MathWorks Inc, Natick, MA). Statistical significance was defined as, $P<0.05$.

RESULTS

Sixteen participants were recruited, 8 of whom had RTAN (mean; $36 \pm (\text{SD})11$ yr; 47 ± 7 kg; BMI $17 \pm 2 \text{ kg/m}^2$) and 8 were healthy (30 ± 11 yr; 74 ± 23 kg; $27 \pm 7 \text{ kg/m}^2$). The participants were taking a variable combination of antidepressants, antipsychotics, benzodiazepines, levothyroxine, estrogen, methadone, levetiracetam, lansoprazole, adenosine and simvastatin at the time of the study. Two healthy participants were each taking antidepressants and the oral contraceptive pill. The physical activity monitoring suit (PAMS) and all the experimental procedures were well tolerated by all participants.

We found that PAMS showed remarkable sensitivity and specificity with respect to detecting posture. In all participants, the PAMS data correctly distinguished lying from sitting and standing (300/300 cases) and sitting from standing (300/300 cases).

In all participants, the PAMS was able to distinguish walking at ½ mph from standing still. Progressive increase in PAMS output are seen for all participants ($r^2 \sim 0.99$) (Figure 1a).

Energy expenditure (Table 1) increased significantly with walking with each increment in velocity ($P < 0.001$ in all cases). There were significant linear relationships between walking speed and energy expenditure for all participants ($r^2 > 0.99$). When walking energy expenditure (and resting energy expenditure) was expressed relative to body weight, values for the RTAN participants were similar to healthy participants. Furthermore the PAMS showed excellent incremental response with respect to detecting walking energy expenditure (Figure 1b).

CONCLUSION

RTAN is a common (Klein, et al., 2007), difficult to treat illness which often follows a chronic and relapsing course (Walsh & Devlin, 1998), and is associated with a high mortality (Signorini, et al., 2007). Daily activity and in particular un-reported exercise is thought to play a significant role in the maintenance and possibly the pathogenesis of RTAN (Casper, 1998; Davis, et al., 1997; Hebebrand, et al., 2003). In this paper we provide laboratory validation for the PAMS demonstrating error-free human measurement of body posture and excellent characterization of the amount and energetic cost of walking. Interestingly when PAMS output and energy expenditure was expressed relative to the individual's body weight, there was no significant difference between the RTAN and healthy participants for either variable. These laboratory investigations are thus promising for facilitating studies in body posture, movement and non-exercise activity thermogenesis to investigate the pathophysiology of this disorder and potentially allow assessment of therapeutic compliance in individuals with RTAN.

The contribution of daily activity in anorexia nervosa individuals has previously been assessed, with variable results, in only a small number of studies (Birmingham, Hlynsky, Whiteside, & Geller, 2005; Casper, Schoeller, Kushner, Hnilicka, & Gold, 1991; Falk, Halmi, & Tryon, 1985; Klein, et al., 2007; Pirke, Trimborn, Platte, & Fichter, 1991; van Marken Lichtenbelt, Heidendal, & Westerterp, 1997; Westerterp & Bouten, 1997), most likely due to the difficulty in measuring daily activity accurately.

There were several limitations to our study which we acknowledge. First, expectedly we were unable to recruit RTAN participants whom were medication-free for this study. However we were aiming to obtain preliminary laboratory validation of PAMS in this population and these medications would not have affected these primary end-points and conclusions. Second, we recognized that these preliminary validation experiments were laboratory-based and not in the free-living state. Experiments in the free-living state (for example using doubly labeled water), however, are warranted from here to further examine the precision of the system in individuals with RTAN in the free-living state and in healthcare and various forms of stationary exercise equipment. Thirdly PAMS utility is limited by its size and complexity. Thus we are developing a miniaturized version of PAMS that is small, light weight and user friendly which may also be very amenable to evaluate fidgeting behavior in individuals with anorexia nervosa.

In conclusion, these studies demonstrate preliminary validation of PAMS for quantifying body posture and motion in patients with RTAN in the laboratory setting. We envision that PAMS may assist in assessing the underlying pathophysiology of RTAN and potentially monitoring daily activity in these patients to enhance their optimal medical care.

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Figure 1.

Figure 1a. Walking velocity versus acceleration measured by the physical activity monitoring suit (PAMS) for 16 participants (8 anorexia nervosa (AN) and 8 healthy). The slopes and intercepts were for the AN participants, slope 44.6 ± 9.6 , intercepts 0.6 ± 9.1 and for the healthy participants, slope 79.1 ± 15.5 ($p < 0.01$), intercepts -7.7 ± 7.8 ($p = 0.07$). Data are shown as Mean $\pm$ SE. AU = arbitrary units, mph = miles per hour.

Figure 1b. Change in energy expenditure (EE) relative to body mass, in kcal/kg/hr above standing while walking at 1, 1.5, 2, 2.5 and 3 mph versus the acceleration relative to body mass. The slopes and intercepts for the EE/physical activity monitoring system (PAMS) output-velocity relationships were for the anorexia nervosa participants, slope 0.92 ± 0.42 , intercepts

0.33 ± 0.55 and for the healthy participants, slope 0.66 ± 0.34 ($p = 0.2$), intercepts 0.77 ± 0.28 ($p = 0.1$). AU = arbitrary units.

Energy expenditure (kcal/hour) and energy expenditure per kilogram body weight (kcal/kg/hour) for 16 study participants. Data are expressed as mean $\pm$ SD. AN = anorexia nervosa.

Table 1

	Energy Expenditure (kcal/hr)			Energy Expenditure (kcal/kg/hr)		
	AN	Healthy	p value	AN	Healthy	p value
Resting	45 $\pm$ 7	64 $\pm$ 14	<0.01	1.0 $\pm$ 0.1	0.9 $\pm$ 0.2	0.4
Sitting	49 $\pm$ 6	74 $\pm$ 20	<0.01	1.1 $\pm$ 0.1	1.0 $\pm$ 0.2	0.8
Standing	57 $\pm$ 9	80 $\pm$ 27	0.04	1.2 $\pm$ 0.1	1.1 $\pm$ 0.3	0.3
Walking: 0.5 mph	99 $\pm$ 14	137 $\pm$ 42	0.03	2.1 $\pm$ 0.2	1.9 $\pm$ 0.3	0.1
Walking: 1.0 mph	113 $\pm$ 16	170 $\pm$ 48	<0.01	2.5 $\pm$ 0.2	2.3 $\pm$ 0.4	0.5
Walking: 1.5 mph	133 $\pm$ 16	196 $\pm$ 52	<0.01	2.9 $\pm$ 0.3	2.7 $\pm$ 0.4	0.3
Walking: 2.0 mph	156 $\pm$ 21	224 $\pm$ 65	0.01	3.4 $\pm$ 0.4	3.1 $\pm$ 0.4	0.1
Walking: 2.5 mph	175 $\pm$ 24	252 $\pm$ 59	0.01	3.8 $\pm$ 0.4	3.5 $\pm$ 0.6	0.2
Walking: 3.0 mph	198 $\pm$ 30	289 $\pm$ 85	0.01	4.3 $\pm$ 0.5	4.0 $\pm$ 0.6	0.3