Quantifying Recall and Processing Error when Utilizing the Compendium of Physical Activities in Physical Activity Recall Surveys

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Outline

Physical Activity Surveys

Sources of Error

Preliminary Model

Results

Discussion

Physical Activity Surveys

- Physical activity researchers use surveys to assess physical activity level
  - Physical Activity Propensity Questionnaire
  - 24-Hour Recall
- Additional information available: body mass index (BMI), age, income, etc.
- Interested in usual physical activity level
- Do not typically account for all error sources
- Research needed to understand energy expenditure error characteristics

PAMS

The Physical Activity Measurement Survey (PAMS) is a survey designed to obtain information on physical activity patterns of eligible adults.

Who's Eligible?

- 21-70 years of age
- Living in Dallas, Polk, Marshall, or Black Hawk county
- Not pregnant or lactating
- Can complete interview in either English or Spanish
- No physical limitations or medical restrictions preventing the adult from participating in physical activity
- Lives in household with a land line phone

Data Collection

Physical activity on two nonconsecutive days measured via SenseWear Monitor and Physical Activity Recall (PAR)

SenseWear Monitor

- Worn on arm for 24 consecutive hours
- Continuously measures motion, steps, skin temperature, etc.
- Proprietary algorithm converts measures into metabolic equivalent (MET)

- METs express energy cost as a multiple of resting metabolic heart rate
- METs translated into kcals according to resting energy expenditure (REE)

Example Monitor Data

1	STEPS	METS_per_minute	energy_expenditure	fileID	Year	Month	Day	Hour	Minute
2	0	1.27	1.44	1	2009	10	11	23	55
3	0	1.28	1.46	1	2009	10	11	23	56
4	13	1.68	1.90	1	2009	10	11	23	57
5	4	1.62	1.84	1	2009	10	11	23	58
6	4	1.70	1.93	1	2009	10	11	23	59
7	0	1.65	1.87	1	2009	10	12	0	0
8	11	1.81	2.06	1	2009	10	12	0	1
9	9	1.72	1.95	1	2009	10	12	0	2
10	0	1.75	1.99	1	2009	10	12	0	3
11	24	2.03	2.30	1	2009	10	12	0	4
12	6	1.88	2.14	1	2009	10	12	0	5
13	6	1.76	1.99	1	2009	10	12	0	6
14	28	1.96	2.22	1	2009	10	12	0	7
15	18	1.90	2.15	1	2009	10	12	0	8
16	9	1.76	2.00	1	2009	10	12	0	9
17	12	1.80	2.04	1	2009	10	12	0	10
18	25	1.90	2.15	1	2009	10	12	0	11
19	38	1.99	2.26	1	2009	10	12	0	12
20	19	1.97	2.23	1	2009	10	12	0	13
21	0	1.58	1.79	1	2009	10	12	0	14

PAR

- Interview conducted the day following armband wear
- Day partitioned into 6 hour segments (Midnight - 6:00 AM, 6:00 AM-noon, etc.)
- Individuals recall activities and duration of activities engaged in, rounded to the nearest 5 minutes
- Interviewer attaches a numeric code to each activity
- Codes link to the Compendium of Physical Activity
- Energy Expenditure (kcal) $=$ REE $\times$ MET value $\times$ Time

The Compendium

- First published in 1993, updated in 2000 and 2011
- Developed for epidemiologic studies to standardize MET intensities in physical activity questionnaires
- "MET values were assigned to each activity based on the 'best representation' of an intensity level from published lists and selected unpublished data." [1]

1993 Compendium		2000 Compendium		2011 Compendium		Home Repair
Codes	METs	Codes	METs	Codes	METs	Description
06010	3.0	06010	3.0	06010	3.0	airplane repair
06020	4.5	06020	4.0	06020	4.0	automobile body work
06030	3.0	06030	3.0	06030	3.3	automobile repair, light or moderate effort

[1] Ainsworth *et al.* 2000

Compendium Limitation

"The values in the Compendium do not estimate the energy cost of physical activity in individuals in ways that account for differences in body mass, age, sex, efficiency of movement, etc. Thus, individual differences in energy expenditure for the same activity can be large and the true energy cost for an individual may or may not be close to the estimated mean MET level as presented in the Compendium."[2]

[2] Taken from http://prevention.sph.sc.edu/tools/compendium.html

Example PAR Data

1	CaseID	Replicate	TimeBlock	Code	Mets	Minutes	Description
2	11002	1	1	7030	0.9	360	sleeping
3	11002	1	2	7030	0.9	75	sleeping
4	11002	1	2	13030	1.5	45	sit eating
5	11002	1	2	5184	1.9	60	sit child care: dressing, bathing, grooming, feeding
6	11002	1	2	16010	2	10	driving a car or light truck
7	11002	1	2	5090	2	75	laundry, wash clothes, fold/hang clothes - standing
8	11002	1	2	5170	2.5	65	sit play with child, light
9	11002	1	2	5049	2.5	30	food prep (cook, grill, bake, prepare food)
10	11002	1	3	13030	1.5	20	sit eating
11	11002	1	3	5049	2.5	10	food cleanup (wash dishes, put food away, fill dishwasher
12	11002	1	3	5170	2.5	20	sit play with child, light
13	11002	1	3	5184	1.9	30	sit child care: dressing, bathing, grooming, feeding
14	11002	1	3	6040	3	60	carpentry, woodwork (not for work)

- Activity: Carpentry
- MET value: 3 METs
- REE: 1.25 kcal
- Time: 60 minutes
- 225 kcals $= 1.25 \times 3 \times 60$

Sources of Error

PAR implementation introduces multiple sources of error:

- **Recall Error:** The individual must accurately recall both the activities and the duration of the activities they engaged in the previous day
- **Interviewer Error:** The interviewer must assign the appropriate Compendium code to the described activity, includes **coding error**
- **Processing Error:** The MET value attached to the code in the Compendium may or may not be a reasonable representation of the individual's true MET value

Goal: Develop methodology to quantify these sources of error

Notation

$\mathbf{R_{ijkt}}$: PAR measurement for person i, on day j, at time period t, administered by interviewer k

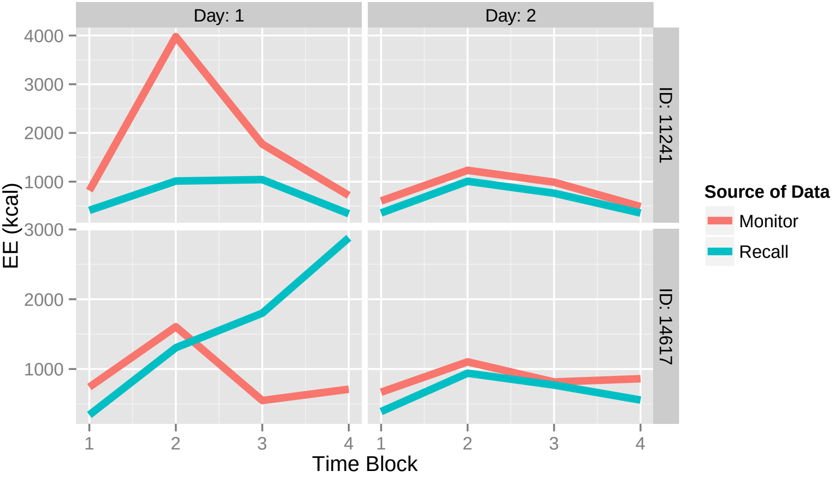
$\mathbf{M_{ijt}}$: monitor measurement for person i, on day j, at time period t

$\mathbf{B_{ijkt}}$: the ratio of PAR relative to monitor PA level, i.e. R_{ijkt}/M_{ijt}

$i \in \{1, 2, \ldots, n\}, \quad j \in \{1, n_i\} \quad n_i \in \{1, 2\} \quad t \in \{1, 2, 3, 4\},$
$k \in \{1, 2, \ldots, K\}$

Note: If M_{ijt} is treated as a gold standard or reference measure, then B_{ijkt} is the ratio of the noisy PAR measurement and “truth”

Example Data



Potential Explanations

$\mathbf{R}_{ijkt} < \mathbf{M}_{ijt}$:

1	CaseID	Replicate	TimeBlock	Code	Mets	Minutes	Description
2324	11241	1	1	7030	0.9	300	sleeping
2325	11241	1	1	13041	2	30	selfcare: dressing/undressing, grooming
2326	11241	1	1	16010	2	10	driving a car or light truck
2327	11241	1	1	16050	3	20	driving a heavy truck or tractor
2328	11241	1	2	16050	3	180	driving a heavy truck or tractor
2329	11241	1	2	13030	1.5	15	sit eating
2330	11241	1	2	16050	3	135	driving a heavy truck or tractor
2331	11241	1	2	13030	1.5	30	sit eating
2332	11241	1	3	16050	3	90	driving a heavy truck or tractor
2333	11241	1	3	13030	1.5	15	sit eating
2334	11241	1	3	16050	3	40	driving a heavy truck or tractor

$\mathbf{R}_{ijkt} > \mathbf{M}_{ijt}$:

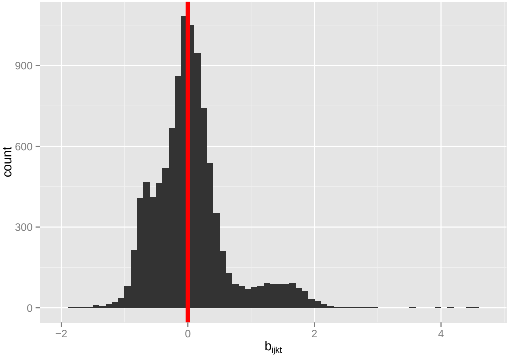
1	CaseID	Replicate	TimeBlock	Code	Mets	Minutes	Description
14192	14617	1	1	7030	0.9	180	sleeping
14193	14617	1	1	7010	1	180	lying down, watching TV, reading
14194	14617	1	2	7010	1	120	lying down, watching TV, reading
14195	14617	1	2	16010	2	5	driving a car or light truck
14196	14617	1	2	11631	5	235	stand/walk heavy work
14197	14617	1	3	11631	5	360	stand/walk heavy work
14198	14617	1	4	11790	8	360	stand/walk very heavy work
14199	14617	2	1	7030	0.9	300	sleeping
14200	14617	2	1	13041	2	60	selfcare: dressing/undressing, grooming
14201	14617	2	2	7020	1	60	sit watching television (TV, DVD, video)
14202	14617	2	2	16010	2	20	driving a car or light truck

Data Summary

- 10282 observations on 1337 individuals
- 564 Males and 773 Females

Variable	Min.	Median	Mean	Max	SD
Age	21	51	50	71	7
BMI	15	29	31	73	12

- Consider the log-scale ratio: $b_{ijkt} = \log(r_{ijkt}/m_{ijt})$



Preliminary Model

$$b_{ijkt} = \mathbf{z}'_{ijt}\boldsymbol{\beta} + \phi_{0i} + \phi_{1i} I_{j=2} + \gamma_k + \epsilon_{ijkt}$$

Data:

b_{ijkt}: observed log-ratio of monitor/recall for individual i, day j, interviewer k, time t

$\mathbf{z}_{ijt}$: covariate vector for person i, day j, time t

Parameters:

$\boldsymbol{\beta}$: covariate parameter vector (compendium bias)

$\boldsymbol{\phi}_i \overset{iid}{\sim} N_2\left(\mathbf{0}, \begin{pmatrix} \sigma_0^2 & \sigma_{01} \\ \sigma_{01} & \sigma_1^2 \end{pmatrix}\right)$: person random effect vector (recall error)

$\gamma_k \overset{iid}{\sim} N(0, \sigma_\gamma^2)$: interviewer random effect (interviewer error)

$\epsilon_{ijkt} \overset{iid}{\sim} N(0, \sigma_\epsilon^2)$: remaining noise (processing error)

Model Variance Structure

$$b_{ijkt} = \mathbf{z}'_{ijt}\boldsymbol{\beta} + \phi_{0i} + \phi_{1i} I_{j=2} + \gamma_k + \epsilon_{ijkt}$$

$$\text{Var}\begin{pmatrix} b_{1111} \\ b_{1112} \\ b_{1211} \\ b_{1212} \end{pmatrix} =$$

$$\begin{pmatrix} \sigma_0^2 + \sigma_\gamma^2 + \sigma_\epsilon^2 & \sigma_0^2 + \sigma_\gamma^2 & \sigma_0^2 + \sigma_{01} + \sigma_\gamma^2 & \sigma_0^2 + \sigma_{01} + \sigma_\gamma^2 \\ & \sigma_0^2 + \sigma_\gamma^2 + \sigma_\epsilon^2 & \sigma_0^2 + \sigma_{01} + \sigma_\gamma^2 & \sigma_0^2 + \sigma_{01} + \sigma_\gamma^2 \\ & & \sigma_0^2 + \sigma_1^2 + 2\sigma_{01} + \sigma_\gamma^2 + \sigma_\epsilon^2 & \sigma_0^2 + \sigma_1^2 + 2\sigma_{01} + \sigma_\gamma^2 \\ \text{Symm.} & & & \sigma_0^2 + \sigma_1^2 + 2\sigma_{01} + \sigma_\gamma^2 + \sigma_\epsilon^2 \end{pmatrix}$$

ϕ_i, γ_k, ϵ_{ijkt} all independent

Results

Fixed Effects:

Parameter	Estimate	(SE)
Intercept	-0.5711	(0.0721)
Age	-0.0017	(0.0010)
BMI	0.0114	(0.0014)
Male	-0.1188	(0.0242)
Time 2	0.3407	(0.0409)
Time 3	0.3998	(0.0409)
Time 4	0.3162	(0.0410)
Time 2×Age	0.0054	(0.0008)
Time 3×Age	0.0054	(0.0008)
Time 4×Age	0.0015	(0.0008)

Sources of Error:

Source		Estimate
Recall	σ_0^2	0.1847
Recall-Day 2	σ_1^2	0.0111
	σ_{01}	-0.0229
Interviewer	σ_γ^2	0.0080
Processing	σ_ϵ^2	0.1253

Known Issues & Future Work

- M_{ijt} is itself a noisy estimate of true physical activity, not even necessarily unbiased
- Incorporate measurement error ideas to relax assumptions on M_{ijt} and calibrate R_{ijkt}
- What is the interpretation of $\mathbf{z}'_{ijt}\beta$? Compendium bias or something more?
- What is the interpretation of ϵ_{ijkt}? It isn't just processing error, but we may have to treat it as if it were.

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