Measure for Measure: Thoughts on the Why and How of Physical Activity Assessment

Richard P. Troiano, Ph.D.

CAPT, USPHS (retired)

Session Objective

Provide (my) perspective on evolution of thinking about utility and interpretation of device-based measures.

Disclosures: None (retired USPHS officer)

Our doubts are traitors
And make us lose the good we oft might win
By fearing to attempt.

W. Shakespeare.
Measure for Measure, Act I, Scene IV

Bona Fides

- National Health and Nutrition Examination Survey (NHANES) (CDC, NCHS)
  - Redesigned physical activity questionnaire, developed cardiovascular fitness (treadmill) test component
- Risk Factor Assessment (NCI)
  - Led inclusion of accelerometers in NHANES 2003-2006, 2011-2014
  - Program Director for research on measurement of physical activity
- Physical Activity Guidelines
  - Led development of 2008 Physical Activity Guidelines for Americans
  - Co-lead for 2nd edition (2018)
  - Member of development group for WHO 2020 Guidelines on Physical Activity and Sedentary Behaviour

Wherefore Today?

1. Evolving thoughts about device measures and historical milestones
2. Benefits of device-based measures
3. Features and gaps with device-based measures
4. Forecast from a public-health perspective

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NATIONAL CENTER FOR HEALTH STATISTICS
WHEN WE MEASURE, WE KNOW BETTER
www.cdc.gov/nchs
CDC
inch
cm

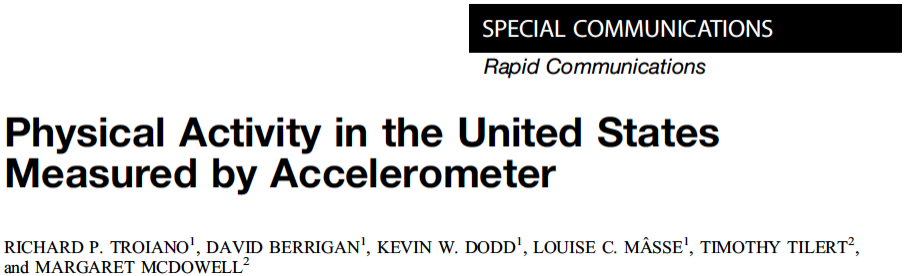
Devices in NHANES Motivation

- NCHS desire for better PA assessment for youth

- Jim Sallis – “It’s time, Rick…”
  - International Physical Activity and Environment Network (IPEN)

Right Place and Time

- NCI had resources and was willing (with other NIH endorsement)
- Analytic choices needed to be made



SPECIAL COMMUNICATIONS

Rapid Communications

Physical Activity in the United States Measured by Accelerometer

RICHARD P. TROIANO[1], DAVID BERRIGAN[1], KEVIN W. DODD[1], LOUISE C. MÂSSE[1], TIMOTHY TILERT[2], and MARGARET MCDOWELL[2]

Med Sci Sports Exerc, 2008

Impact of NHANES Accelerometer Data


- Publicly available data were analyzed my many researchers with a variety of associated endpoints (54 pubs by December 2011)
- The first NHANES accelerometer publication (Troiano et al., 2008) was among the 5 most highly cited articles in field of physical activity and health research

Review Article

Mapping the historical development of physical activity and health research: A structured literature review and citation network analysis☆

Andrea Ramirez Varela[a,*], Michael Pratt[b], Jenine Harris[c], Jesse Lecy[d], Deborah Salvo[e], Ross C. Brownson[c,f], Pedro C. Hallal[a]

Preventive Medicine 111 (2018) 466-72.

Key Meetings (and results)

ADDS 2024

Highlighted Meetings (and supplements)

- Objective Monitoring of Physical Activity: Closing the Gaps in the Science of Accelerometry. - University of North Carolina, 2004

  Med Sci Sports Exerc. 2005 November; 37(suppl):S487-S588.

- Objective Measurement of Physical Activity: Best Practices and Future Directions. - NIH, 2009

  Med Sci Sports Exerc. 2012 January; 44(suppl 1):S1-S89.

- Measurement of Active and Sedentary Behaviors: Closing the Gaps in Self-Report Methods. - NIH, 2010

  J Phys Act Health. 2012 January;9(suppl):S1-S92.

Context

A Look-Back and Flash-Forward

Device-based Measures Situation in Early 2000s

Objective Measurement of Physical Activity: Closing the Gaps in the Science of Accelerometry - University of North Carolina, December 2004

- Cited 1999 Cooper Research Institute meeting on PA measurement:

  "… objective motion sensors were not practical for large scale studies because of high cost, uncertain reliability, and difficulties in the interpretation of data."

Changing Times

From the 2005 supplement

“physical activity” OR exercise AND acceleromet*

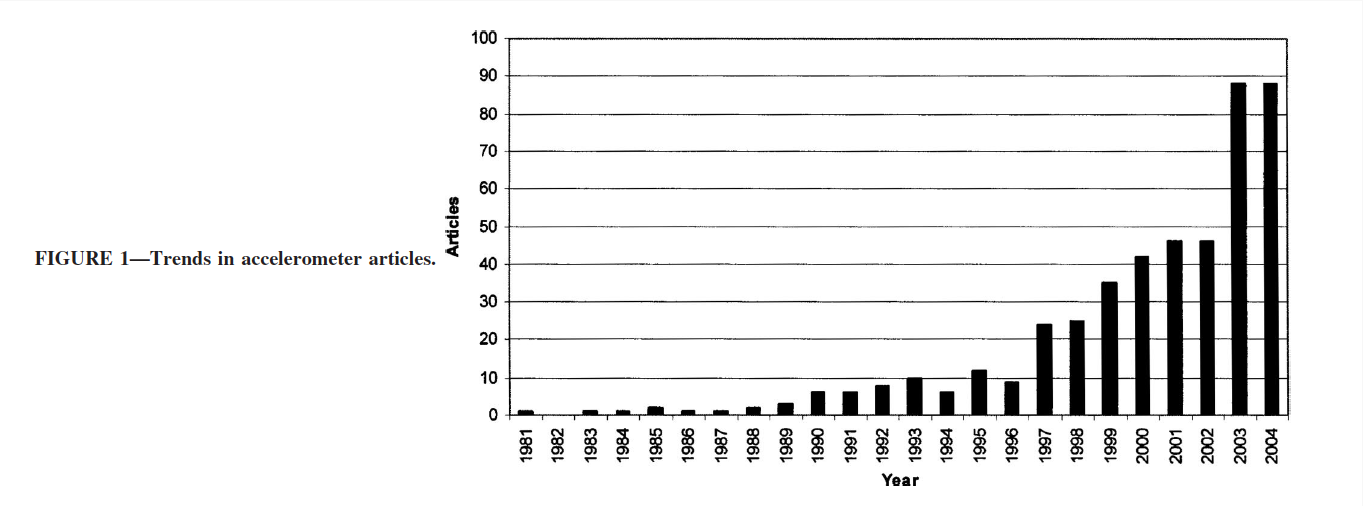


FIGURE 1—Trends in accelerometer articles.

Changing Times

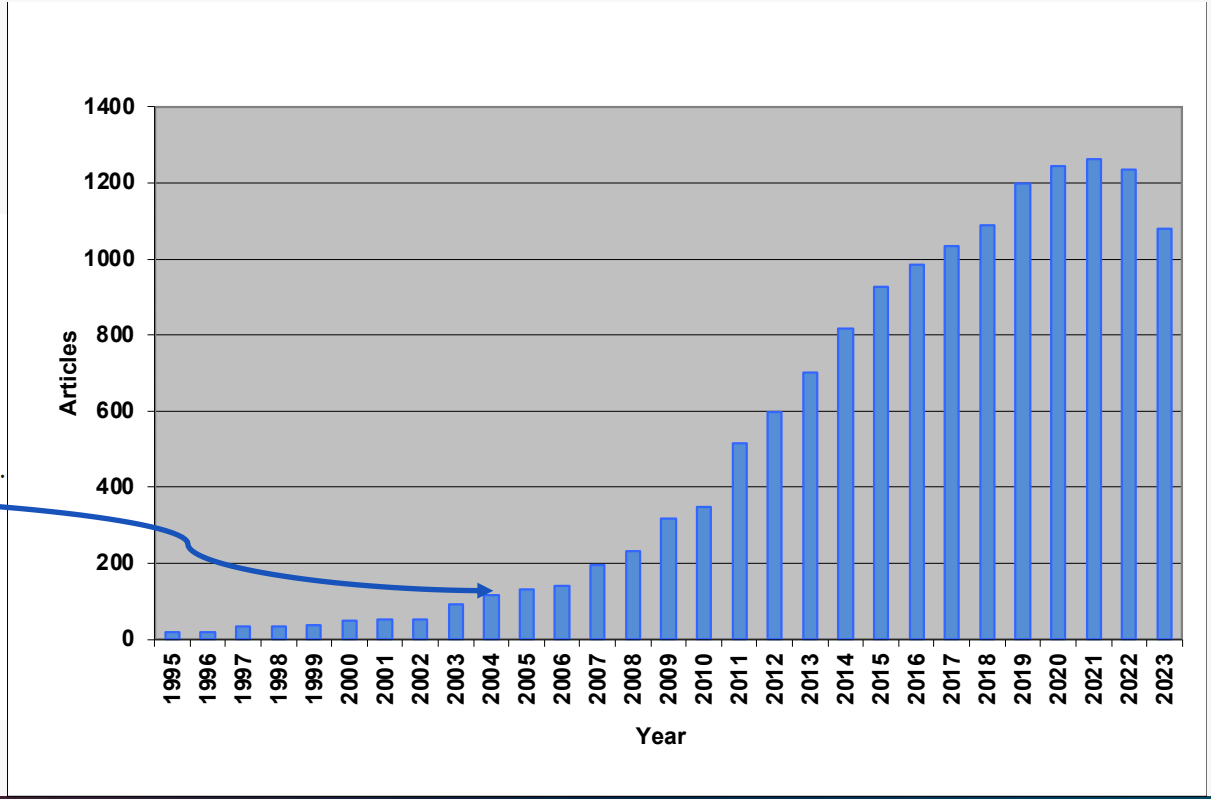


FIGURE 1—Trends in accelerometer articles.

Selected 2004 Recommendations

✓Encourage open-source technology to enhance comparability

✓Tap into cell phone technology

~Develop core set of activities to employ in calibration studies

❖Avoid wrist placement (oops)

2009 Device Meeting Recommendations

- ✓"Monitor data should be collected and saved as raw signals with post-processing used for data transformation."
- ✓"Organiz[e] multi-disciplinary teams … to develop tools, process data, and perform calibration/validation studies…"
- ✓"… discontinue development and use of cutpoint methods to define intensity categories…"

2009 Device Meeting Recommendations

- ✓“Monitor data should be collected and saved as raw signals with post-processing used for data transformation.”
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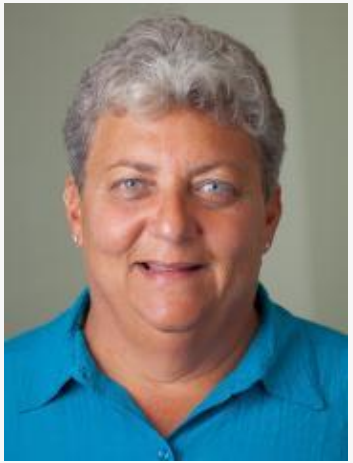
- ✓“… discontinue development and use of cutpoint methods to define intensity categories…”



Conceptual Evolution

How (My) Thinking About Device & Report Measures Changed

My Thinking in 2008

The Korean Journal of Measurement and Evaluation in Physical Education and Sport Science. 2008, 10(2), 31-42

Differences between Objective and Self-Report Measures of Physical Activity. What do they Mean?

Richard P. Troiano · Kevin W. Dodd
National Cancer Institute, National Institutes of Health

Skeptic’s View of Self-Report

Dr. Gregory House, M.D.

Everybody lies.

I’ve found when you want to know the truth about someone, that someone is probably the last person you should ask.

Category Agreement: Men Ages 20-59 y

Accel. Categ	*Category Based on Self-Report*						
	0	**1**	**2**	**3**	**4**	**5**	**Total**
0	***4.89***	9.43	7.70	5.11	6.64	5.42	39.20
1	1.60	***1.95***	2.51	2.32	1.98	1.75	12.12
2	1.43	2.03	***1.96***	2.59	1.58	2.51	12.09
3	0.94	2.03	2.31	***2.10***	2.65	2.21	12.23
4	0.58	1.44	2.07	2.97	***2.58***	2.47	12.11
5	0.76	0.89	1.57	2.49	2.92	***3.62***	12.25
Total	10.22	17.77	18.12	17.58	18.35	17.98	100.0

17.1 % agree

Values are weighted percent within each cell

Category Agreement: Men Ages 20-59 y

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Total	10.22	17.77	18.12	17.58	18.35	17.98	100.0

48.6 % agree
+/- 1 category

Values are weighted percent within each cell

Category Agreement: Men Ages 20-59 y

Accel. Categ	*Category Based on Self-Report*						
	0	**1**	**2**	**3**	**4**	**5**	**Total**
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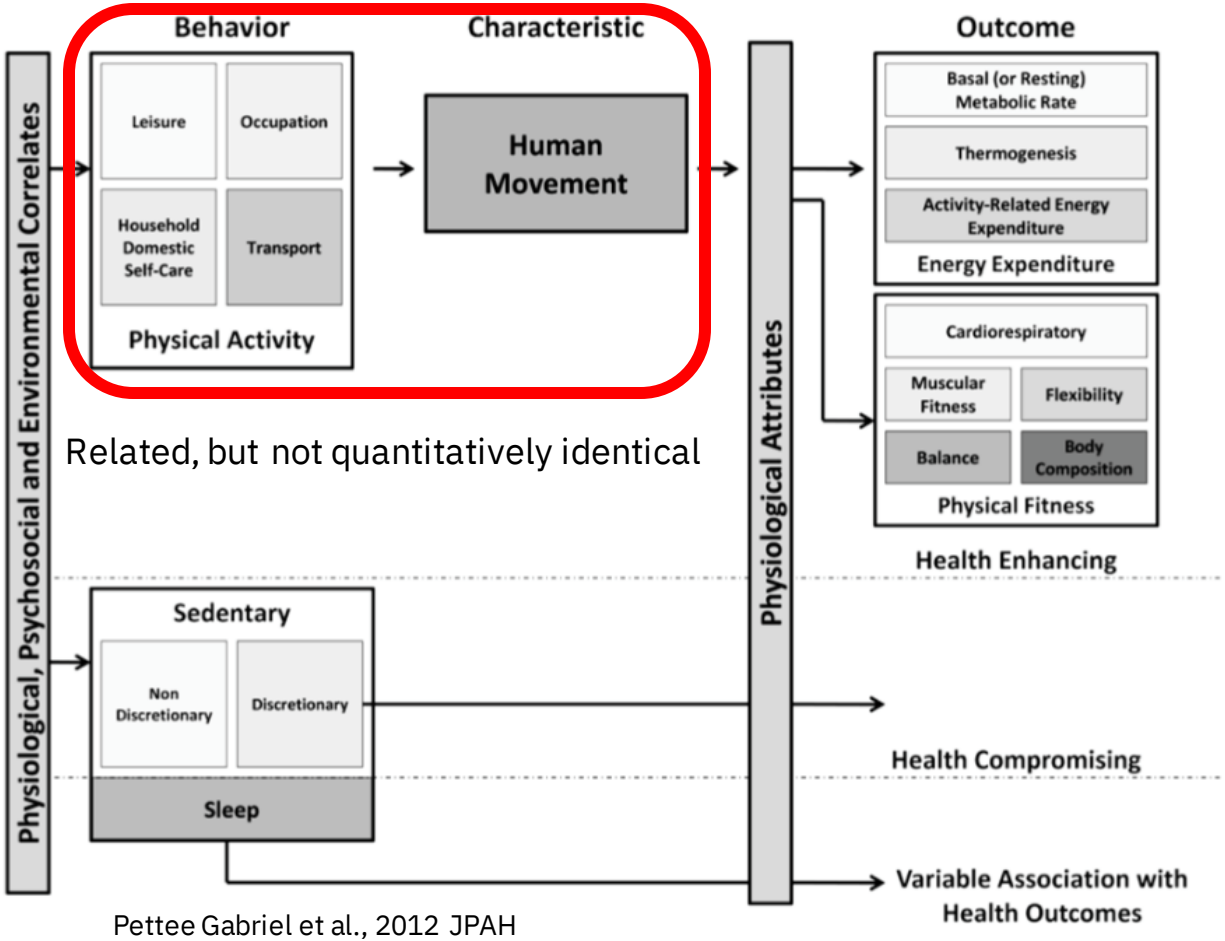
Note distribution across accelerometer categories for low active individuals

Values are weighted percent within each cell

2010 Self-Report Methods Meeting

- ✓Provided framework for PA as a complex and multi-dimensional behavior.
- ✓Called for standardized, precise, consistent terminology and definitions.
- ✓Recognized distinct measurements obtained by accelerometer-based devices and self-report.



Pettee Gabriel et al., 2012 JPAH

Value of Report Measures

Reported Physical Activity and Sedentary Behavior: Why Do You Ask?

Richard P. Troiano, Kelley K. Pettee Gabriel, Gregory J. Welk, Neville Owen, and Barbara Sternfeld

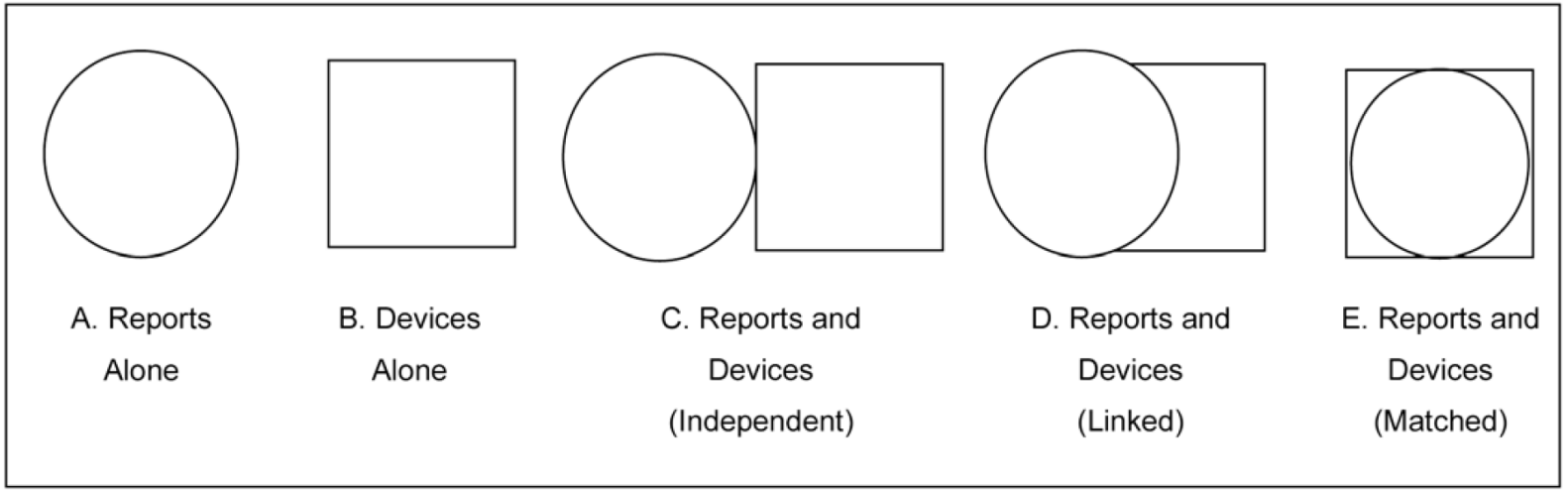


Figure 2 — Approaches to assessing physical activity and sedentary behavior by report and devices.

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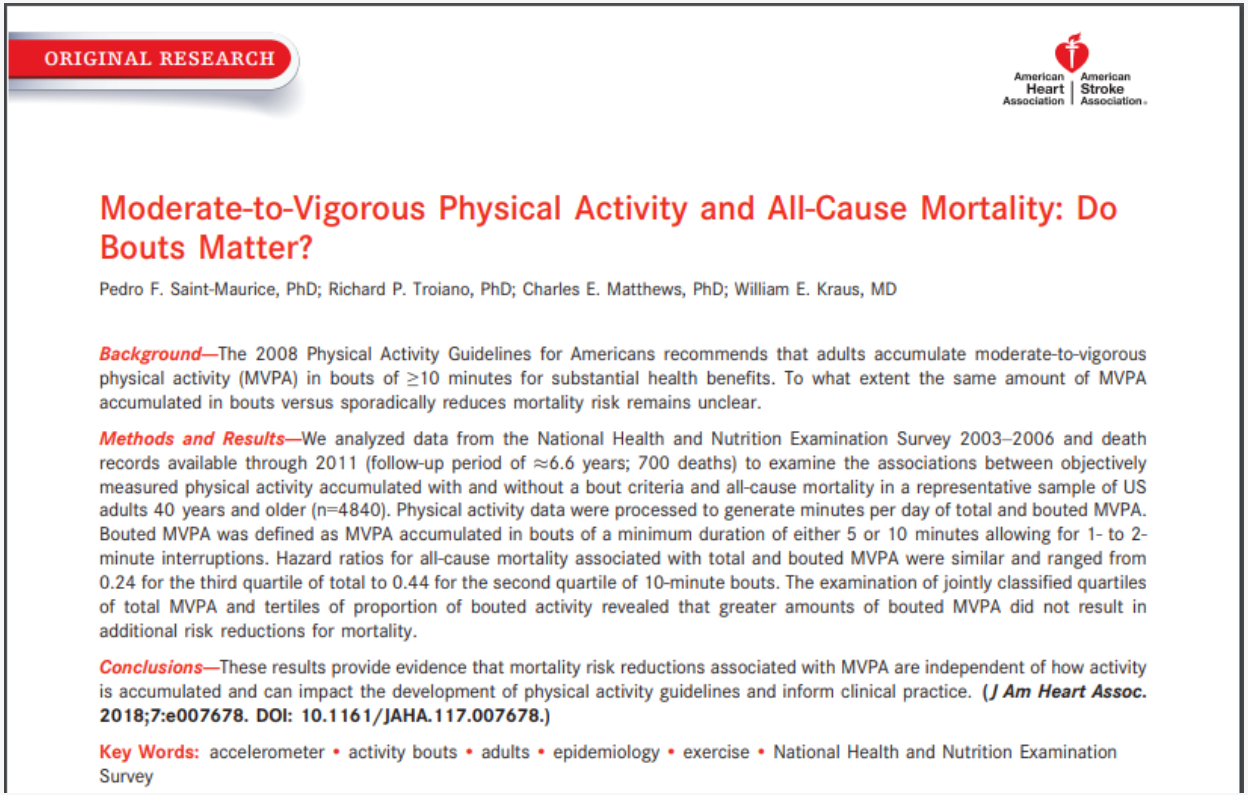
Precise Time Resolution



ORIGINAL RESEARCH

American Heart Association | American Stroke Association

Moderate-to-Vigorous Physical Activity and All-Cause Mortality: Do Bouts Matter?

Pedro F. Saint-Maurice, PhD; Richard P. Troiano, PhD; Charles E. Matthews, PhD; William E. Kraus, MD

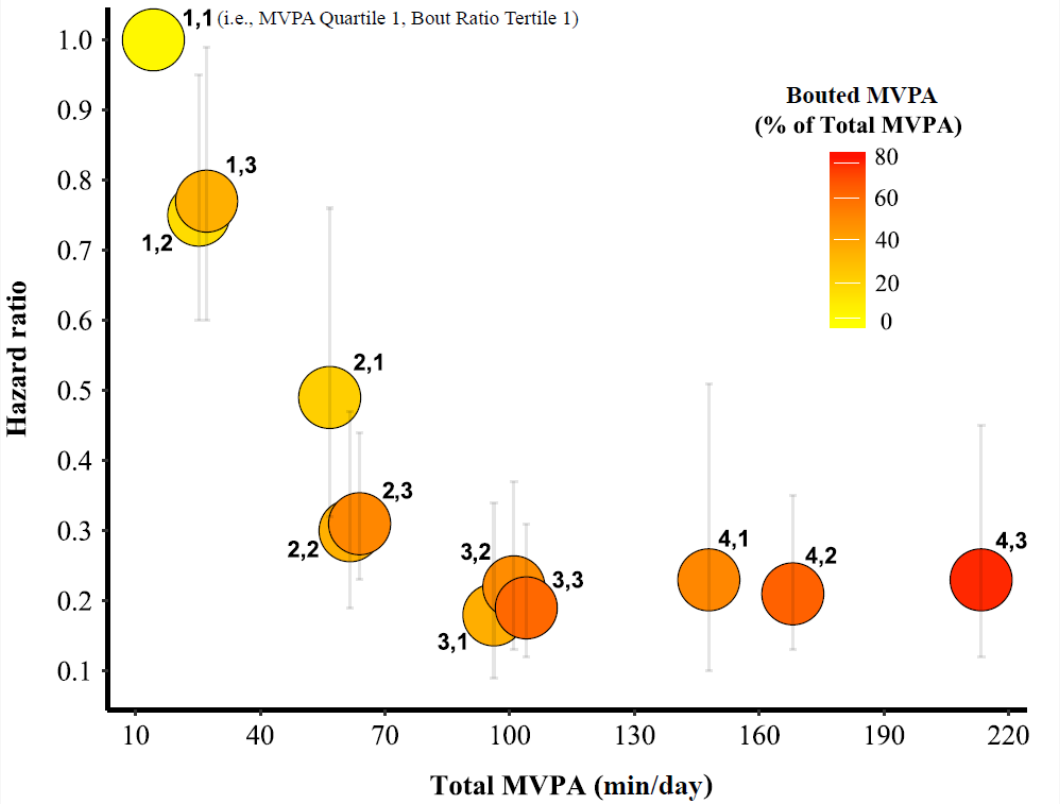
Background—The 2008 Physical Activity Guidelines for Americans recommends that adults accumulate moderate-to-vigorous physical activity (MVPA) in bouts of ≥10 minutes for substantial health benefits. To what extent the same amount of MVPA accumulated in bouts versus sporadically reduces mortality risk remains unclear.

Methods and Results—We analyzed data from the National Health and Nutrition Examination Survey 2003–2006 and death records available through 2011 (follow-up period of ≈6.6 years; 700 deaths) to examine the associations between objectively measured physical activity accumulated with and without a bout criteria and all-cause mortality in a representative sample of US adults 40 years and older (n=4840). Physical activity data were processed to generate minutes per day of total and bouted MVPA. Bouted MVPA was defined as MVPA accumulated in bouts of a minimum duration of either 5 or 10 minutes allowing for 1- to 2-minute interruptions. Hazard ratios for all-cause mortality associated with total and bouted MVPA were similar and ranged from 0.24 for the third quartile of total to 0.44 for the second quartile of 10-minute bouts. The examination of jointly classified quartiles of total MVPA and tertiles of proportion of bouted activity revealed that greater amounts of bouted MVPA did not result in additional risk reductions for mortality.

Conclusions—These results provide evidence that mortality risk reductions associated with MVPA are independent of how activity is accumulated and can impact the development of physical activity guidelines and inform clinical practice. **(*J Am Heart Assoc.* 2018;7:e007678. DOI: 10.1161/JAHA.117.007678.)**

Key Words: accelerometer • activity bouts • adults • epidemiology • exercise • National Health and Nutrition Examination Survey

Contribution of MVPA Bouts to Mortality Benefit



≥ 5 min bouts,
760 cpm
(Matthews) cutpoint

Saint-Maurice, et al. 2018. JAHA

Stronger Biomarker Associations

Biomarker	Self-report		Accelerometer	
	Beta (SE)	Adj. Wald F	Beta (SE)	Adj. Wald F
SBP	0.01 (0.03)	0.23	-0.43 (0.14)	8.89**
BMI	-0.04 (0.01)	14.95***	-0.77 (0.08)	86.71****
HDL (mg/dL)	0.10 (0.03)	8.54**	1.41 (0.27)	27.77****
Glycohemoglobin	-0.004 (0.001)	7.91**	-0.05 (0.01)	47.11****
Glucose	0.01 (0.07)	0.06	-1.67 (0.30)	30.77****
Insulin (μU/mL)	-0.08 (0.03)	10.15**	-1.11 (0.12)	81.53****

** $p < 0.01$
*** $p < 0.001$
**** $p < 0.0001$

Minutes in bouts, Beta per 10 min unit

Atienza et al., 2011 MSSE

Potential to Flummox Reviewers

JAMA. 2020;323(12):1151-60

Research

JAMA | Original Investigation

Association of Daily Step Count and Step Intensity With Mortality Among US Adults

Pedro F. Saint-Maurice, PhD; Richard P. Troiano, PhD; David R. Bassett Jr, PhD; Barry I. Graubard, PhD; Susan A. Carlson, PhD; Eric J. Shiroma, ScD; Janet E. Fulton, PhD; Charles E. Matthews, PhD

Supplemental content

IMPORTANCE It is unclear whether the number of steps per day and the intensity of stepping are associated with lower mortality.

OBJECTIVE Describe the dose-response relationship between step count and intensity and mortality.

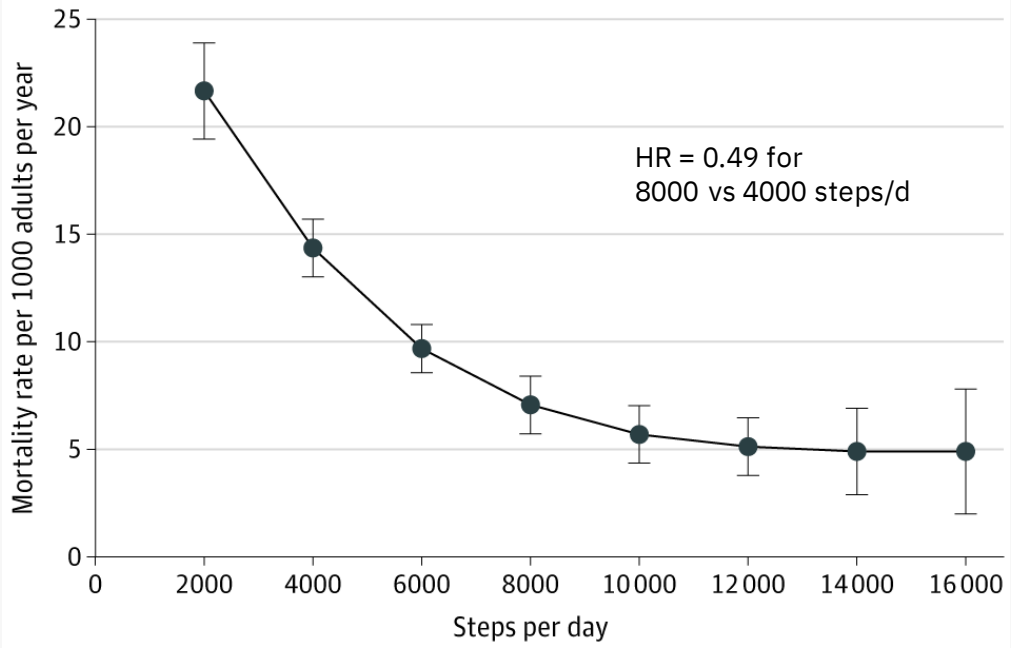
DESIGN, SETTING, AND PARTICIPANTS Representative sample of US adults aged at least 40 years in the National Health and Nutrition Examination Survey who wore an accelerometer for up to 7 days (from 2003-2006). Mortality was ascertained through December 2015.

EXPOSURES Accelerometer-measured number of steps per day and 3 step intensity measures (extended bout cadence, peak 30-minute cadence, and peak 1-minute cadence [steps/min]). Accelerometer data were based on measurements obtained during a 7-day period at baseline.

MAIN OUTCOMES AND MEASURES The primary outcome was all-cause mortality. Secondary outcomes were cardiovascular disease (CVD) and cancer mortality. Hazard ratios (HRs), mortality rates, and 95% CIs were estimated using cubic splines and quartile classifications adjusting for age; sex; race/ethnicity; education; diet; smoking status; body mass index; self-reported health; mobility limitations; and diagnoses of diabetes, stroke, heart disease, heart failure, cancer, chronic bronchitis, and emphysema.

Unbelievable Mortality Reduction

Steps per Day and All-Cause Mortality in a Study of the Association of Daily Step Count and Step Intensity With Mortality Among US Adults Aged at Least 40 Years



Reviewer:
"It is not clinically plausible that an increased step count is independently associated with a 50-70% reduction in mortality risk. There is either a significant problem in the study design or analysis, or the study has a very high level of residual confounding. …"

Potential Confounder or Effect Modifier in Clinical Trials

Association between change in daily ambulatory activity and cardiovascular events in people with impaired glucose tolerance (NAVIGATOR trial): a cohort analysis

Thomas Yates, Steven M Haffner, Phillip J Schulte, Laine Thomas, Kim M Huffman, Connie W Bales, Robert M Califf, Rury R Holman, John J V McMurray, M Angelyn Bethel, Jaakko Tuomilehto, Melanie J Davies, William E Kraus

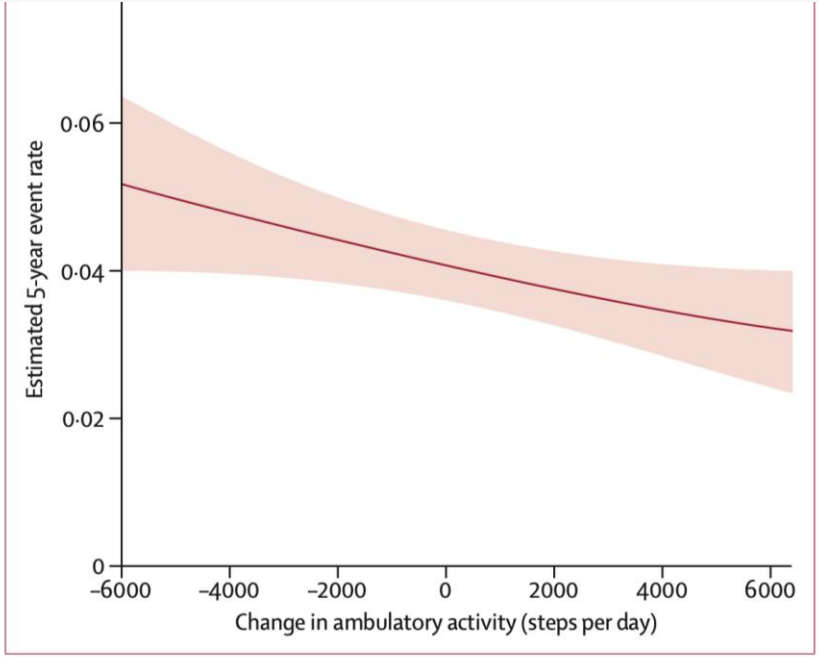
Summary

Background The extent to which change in physical activity can modify the risk of cardiovascular disease in individuals at high cardiovascular risk is uncertain. We investigated whether baseline and change in objectively-assessed ambulatory activity is associated with the risk of a cardiovascular event in individuals at high cardiovascular risk with impaired glucose tolerance.

Lancet 2014; 383: 1059–66

Published Online
December 20, 2013
http://dx.doi.org/10.1016/S0140-6736(13)62061-9

Steps Protect in Pharma Trial



… every 2000 step per day increment in ambulatory activity at baseline (roughly equivalent to 20 min a day of moderately-paced walking activity) was associated with a 10% lower risk of a cardiovascular event. Moreover, each 2000 step per day change from baseline to 12 months was associated with an additional 8% difference in the cardiovascular event rate.

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US Population-referenced Percentiles for Wrist-Worn Accelerometer-derived Activity

SPECIAL COMMUNICATIONS

BRITNI R. BELCHER[1], DANA L. WOLFF-HUGHES[2], ERIN E. DOOLEY[2], JOHN STAUDENMAYER[3], DAVID BERRIGAN[2], MARK S. EBERHARDT[4], and RICHARD P. TROIANO[2]

[1]Department of Population and Public Health Sciences, Keck School of Medicine, University of Southern California, Los Angeles, CA; [2]Division of Cancer Control and Population Sciences, National Cancer Institute, Bethesda, MD; [3]Department of Mathematics and Statistics, University of Massachusetts, Amherst, Amherst, MA; and [4]US Public Health Service (retired), Silver Spring, MD

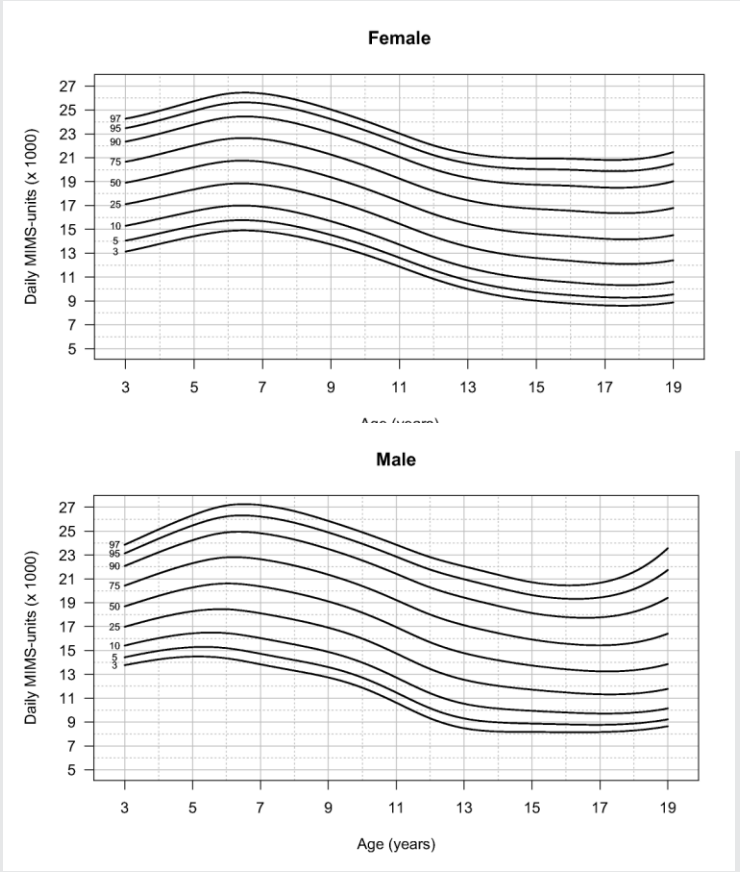
ABSTRACT

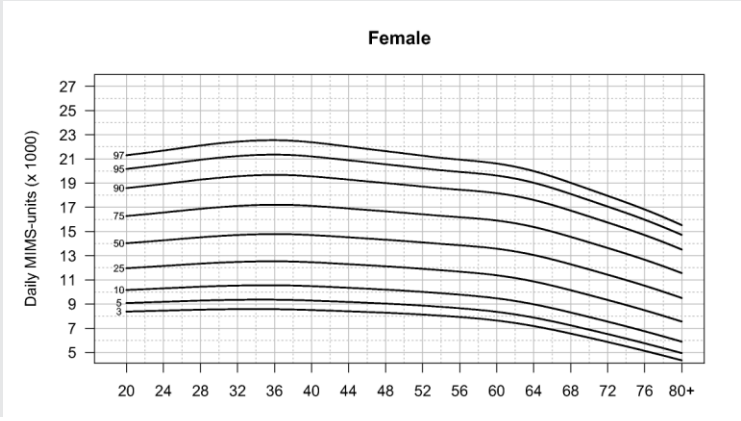
BELCHER, B. R., D. L. WOLFF-HUGHES, E. E. DOOLEY, J. STAUDENMAYER, D. BERRIGAN, M. S. EBERHARDT, and R. P. TROIANO. US Population-referenced Percentiles for Wrist-Worn Accelerometer-derived Activity. *Med. Sci. Sports Exerc.*, Vol. 53, No. 11, pp. 2455–2464, 2021.

Purpose: This study aimed to present age- and sex-specific percentiles for daily wrist-worn movement metrics in US youth and adults. This metric represents a summary of all recorded movement, regardless of the purpose, context, or intensity. **Methods:** Wrist-worn accelerometer data from the combined 2011–2014 National Health and Nutrition Examination Survey cycles and the 2012 National Health and Nutrition Examination Survey National Youth Fitness Survey were used for this analysis. Monitor-Independent Movement Summary units (MIMS-units) from raw triaxial accelerometer data were used. We removed the partial first and last assessment days and days with ≥5% nonwear time. Participants with ≥1 valid day were included. Mean MIMS-units were calculated across all valid days. Percentile tables and smoothed curves of daily MIMS-units were calculated for each age and sex using the Generalized Additive Models for Location Shape and Scale. **Results:** The analytical sample included 14,705 participants age ≥3 yr. The MIMS-unit activity among youth was similar for both sexes, whereas adult females generally had higher MIMS-unit activity than did males. Median daily MIMS-units peaked at age 6 yr for both sexes (males, 20,613; females, 20,706). Lowest activity was observed for males and females 80+ yr of age: 8799 and 9503, respectively. **Conclusions:** Population referenced MIMS-unit percentiles for US youth and adults are a novel means of characterizing total activity volume. By using MIMS-units, we provide a standardized reference that can be applied across various wrist-worn accelerometer devices. Further work is needed to link these metrics to activity intensity categories and health outcomes. **Key Words:** NHANES, NNYFS, MONITOR-INDEPENDENT MOVEMENT SUMMARY UNITS, MIMS-UNITS, PHYSICAL ACTIVITY, SURVEILLANCE, YOUTH, ADULTS

MSSE 53; 2455-2464, 2021

Daily MIMS-units Percentiles by Age





Important Points

Total daily activity metric

- Represents PA from all sources, contexts, and intensities
- Does not quantify PA by intensity → MIMS ≠ Actigraph counts
  - No consensus on cutpoints across ages

Percentile values

- Can be used to predict outcomes
- Provide reference data for other studies
- May apply to other device data if converted to MIMS

Device Measures Overview

Activity monitor (primarily accelerometer-based)

+ Removes cognitive aspect
+ Includes all activity contexts, intensities, and durations
+ Time-stamped data
+ Can provide sleep metrics

– No specific contextual information
– Primarily measures movement of the limb on which it is attached

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Progress, not Perfection

Good News

- Raw data availability
- Moved beyond cutpoints
- Behavioral ID algorithms
- Devices for surveillance reduce reliance on self-report for quantification

Still Waiting

- Interpretation consensus
- See above, still care about intensity
- Ditto above
- Need to bridge historical epi to device data

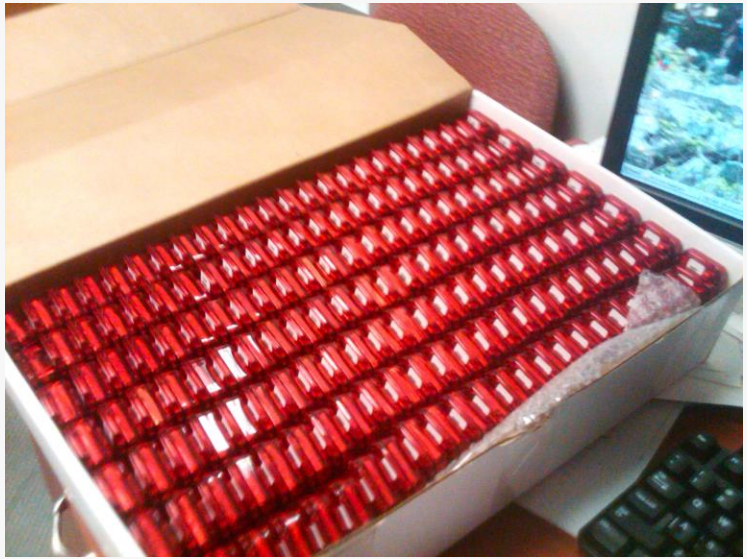
Next Steps?

Challenges and opportunities:

- Algorithm development and/or metric consensus
  - Data pooling
  - Harmonization/standards development

Multi-disciplinary teams and collaborative efforts are key!

Questions?



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Thank You for Your Time.

contact. troianor@mail.nih.gov