Letters

RESEARCH LETTER

Accuracy of Smartphone Applications and Wearable Devices for Tracking Physical Activity Data

Despite the potential of pedometers to increase physical activity and improve health,[1] there is little evidence of broad adoption by the general population. In contrast, nearly two-thirds of adults in the United States own a smartphone[2] and technology advancements have enabled these devices to track health behaviors such as physical activity and provide convenient feedback.[3] New wearable devices that may have more consumer appeal have also been developed.

Even though these devices and applications might better engage individuals in their health, for example through workplace wellness programs,[3] there has been little evaluation of their use.[3-5] The objective of this study was to evaluate the accuracy of smartphone applications and wearable devices compared with direct observation of step counts, a metric successfully used in interventions to improve clinical outcomes.[1]

Methods | This prospective study recruited healthy adults aged 18 years or older through direct verbal outreach at a university. Participants gave verbal informed consent to walk on a treadmill set at 3.0 mph for 500 and 1500 steps, each twice, for no compensation. An observer (M.A.C.) counted steps using a tally counter in August 2014. This study was approved by the University of Pennsylvania institutional review board.

A convenience sample of 10 applications and devices was selected from among the top sellers in the United States. On the waistband, each participant wore the Digi-Walker SW-200 pedometer (Yamax), which has been well validated for research,[6] and 2 accelerometers: the Zip and One (Fitbit). On the wrist, each wore 3 wearable devices: the Flex (Fitbit), the UP24 (Jawbone), and the Fuelband (Nike). In one pants pocket, each carried an iPhone 5s (Apple) simultaneously running 3 iOS applications: Fitbit (Fitbit), Health Mate (Withings), and Moves (ProtoGeo Oy). In the other pants pocket, each carried the Galaxy S4 (Samsung Electronics) running 1 Android application: Moves (ProtoGeo Oy).

At the end of each trial, step counts from each device were recorded. In rare instances that a device was not properly set to record steps (8 of 560 observations), these data were not included. The mean step count and standard deviation for each device was estimated using Excel (Microsoft).

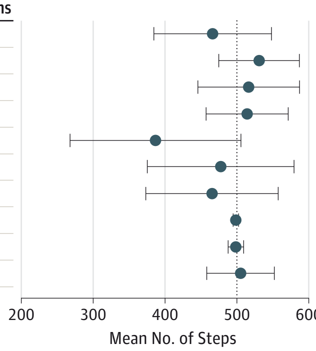
Results | Across all devices, 552 step count observations were recorded from 14 participants in 56 walking trials. Participants were 71.4% female, had a mean (SD) age of 28.1 (6.2) years, and had a mean (SD) self-reported body mass index (calculated as weight in kilograms divided by height in meters squared) of 22.7 (1.5).

Figure 1 shows the results for the 500 step trials by device and **Figure 2** shows the results for the 1500 step trials. Compared with direct observation, the relative difference in mean step count ranged from −0.3% to 1.0% for the pedometer and accelerometers, −22.7% to −1.5% for the wearable devices, and −6.7% to 6.2% for smartphone applications. Findings were mostly consistent between the 500 and 1500 step trials.

Discussion | We found that many smartphone applications and wearable devices were accurate for tracking step counts. Data from smartphones were only slightly different than observed step counts, but could be higher or lower. Wearable devices differed more and 1 device reported step counts more than 20% lower than observed. Step counts are often used to derive other measures of physical activity, such as distance or calories

Figure 1. Device Outcomes for the 500 Step Trials

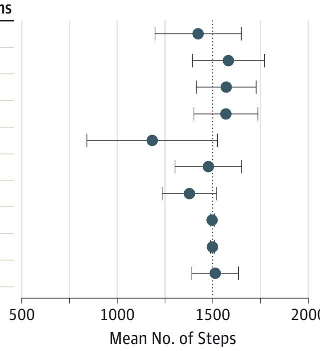
Device	No. of Observations
Galaxy S4 Moves App	27
iPhone 5s Moves App	28
iPhone 5s Health Mate App	28
iPhone 5s Fitbit App	28
Nike Fuelband	28
Jawbone UP24	28
Fitbit Flex	28
Fitbit One	27
Fitbit Zip	27
Digi-Walker SW-200	28



The vertical dotted line depicts the observed step count. The error bars indicate ±1 SD.

Figure 2. Device Outcomes for the 1500 Step Trials

Device	No. of Observations
Galaxy S4 Moves App	28
iPhone 5s Moves App	28
iPhone 5s Health Mate App	27
iPhone 5s Fitbit App	27
Nike Fuelband	28
Jawbone UP24	28
Fitbit Flex	28
Fitbit One	26
Fitbit Zip	27
Digi-Walker SW-200	28



The vertical dotted line depicts the observed step count. The error bars indicate ±1 SD.

burned. Underlying differences in device accuracy may be compounded in these measures.

Our study is limited by being conducted with young, healthy volunteers in a controlled setting with a convenience sample of a small number of applications and devices. Results should be confirmed in other settings and with other devices.

Increased physical activity facilitated by these devices could lead to clinical benefits not realized by low adoption of pedometers. Our findings may help reinforce individuals' trust in using smartphone applications and wearable devices to track health behaviors, which could have important implications for strategies to improve population health.

Meredith A. Case, BA
Holland A. Burwick
Kevin G. Volpp, MD, PhD
Mitesh S. Patel, MD, MBA, MS

Author Affiliations: Perelman School of Medicine, University of Pennsylvania, Philadelphia (Case); Amherst College, Amherst, Massachusetts (Burwick); Center for Health Equity Research and Promotion, Philadelphia VA Medical Center, Philadelphia, Pennsylvania (Volpp, Patel).

Corresponding Author: Mitesh S. Patel, MD, MBA, MS, University of Pennsylvania, 13th Floor Blockley Hall, 423 Guardian Dr, Philadelphia, PA 19104 (mpatel@upenn.edu).

Author Contributions: Ms Case had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: All authors.
Acquisition, analysis, or interpretation of data: Case, Patel.
Drafting of the manuscript: All authors.
Critical revision of the manuscript for important intellectual content: Case, Patel.
Statistical analysis: Case, Patel.
Administrative, technical, or material support: Case, Burwick, Patel.
Study supervision: Volpp, Patel.

Conflict of Interest Disclosures: The authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Dr Volpp reported receiving research funding from Humana, Merck, Discovery, Weight Watchers, and CVS; consulting income from CVS and VALhealth; and being a principal at VALhealth. No other disclosures were reported.

Funding/Support: This study was funded in part through grant RC4 AG039114-01 from the National Institute on Aging. Dr Patel was supported by the US Department of Veteran Affairs and the Robert Wood Johnson Foundation.

Role of the Funder/Sponsor: The National Institute on Aging, the US Department of Veteran Affairs, and the Robert Wood Johnson Foundation had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

1. Bravata DM, Smith-Spangler C, Sundaram V, et al. Using pedometers to increase physical activity and improve health: a systematic review. *JAMA*. 2007; 298(19):2296-2304.

2. Nieslen website. The US digital consumer report. http://www.nielsen.com/us/en/insights/reports/2014/the-us-digital-consumer-report.html. Accessed November 17, 2014.

3. Patel MS, Asch DA, Volpp KG. Wearable devices as facilitators, not drivers, of health behavior change [published online January 8, 2015]. *JAMA*. doi:10.1001/jama.2014.14781.

4. Bort-Roig J, Gilson ND, Puig-Ribera A, Contreras RS, Trost SG. Measuring and influencing physical activity with smartphone technology: a systematic review. *Sports Med*. 2014;44(5):671-686.

5. Powell AC, Landman AB, Bates DW. In search of a few good apps. *JAMA*. 2014; 311(18):1851-1852.

6. Schneider PL, Crouter S, Bassett DR. Pedometer measures of free-living physical activity: comparison of 13 models. *Med Sci Sports Exerc*. 2004;36(2): 331-335.

COMMENT & RESPONSE

Treating Chronic Knee Pain With Acupuncture

To the Editor In the randomized clinical trial of acupuncture for chronic knee pain,[1] the acupuncture treatment design appeared flawed. Specifically, the acupuncture points were nonstandardized and the study lacked the details necessary to ascertain whether the provided interventions were representative of acupuncture sessions appropriate for chronic knee pain.

First, the acupuncture regimen was not consistent in the study, with some patients receiving less than 1 treatment per week, some patients receiving 1 treatment per week, and others receiving 2 treatments per week for 12 weeks. Dr Hinman and colleagues failed to report how many patients received 1 or 2 treatments per week. The commonly used frequency of acupuncture treatments for chronic knee pain due to osteoarthritis is 2 treatments per week for 8 weeks, followed by 2 weeks of 1 treatment per week, then 4 weeks of 1 treatment every other week, and finally 12 weeks of 1 treatment per month.[2]

Furthermore, no details were provided regarding depth of insertion or whether subjective deqi sensation was experienced by the patient. Deqi has been shown to be important to differential neurophysiological analgesic mechanisms in responders vs nonresponders to acupuncture.[3] Hinman and colleagues also did not provide acupuncture with electrical stimulation, which not only has a dose-dependent effect on the degree of analgesia but also induces differential neurotransmitter responses depending on the electrical frequency used.[2,4]

The only conclusion that can be drawn from this study is that unsystematic acupuncture regimens did not result in significant clinical benefit to patients with chronic knee pain.

Hongjian He, AP, MD, PhD

Author Affiliation: Oriental Family Medicine, Clearwater, Florida.

Corresponding Author: Hongjian He, AP, MD, PhD, Oriental Family Medicine, 901 N Hercules Ave, Clearwater, FL 33765 (drhe@live.com).

Conflict of Interest Disclosures: The author has completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.

1. Hinman RS, McCrory P, Pirotta M, et al. Acupuncture for chronic knee pain: a randomized clinical trial. *JAMA*. 2014;312(13):1313-1322.

2. Berman BM, Lao L, Langenberg P, Lee WL, Gilpin AM, Hochberg MC. Effectiveness of acupuncture as adjunctive therapy in osteoarthritis of the knee: a randomized, controlled trial. *Ann Intern Med*. 2004;141(12):901-910.

3. Asghar AU, Green G, Lythgoe MF, Lewith G, MacPherson H. Acupuncture needling sensation: the neural correlates of deqi using fMRI. *Brain Res*. 2010; 1315:111-118.

4. Han JS. Acupuncture: neuropeptide release produced by electrical stimulation of different frequencies. *Trends Neurosci*. 2003;26(1):17-22.

To the Editor Dr Hinman and colleagues[1] presented a generally well-conducted trial of the effectiveness of acupuncture treatment (stimulation using laser or needles) for pain and function in knee osteoarthritis. However, the authors failed to find any benefit of acupuncture, which is not a surprising outcome—at least for laser acupuncture—given the laser acupuncture treatment parameters used in the trial. These