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JSAMS-1601; No. of Pages 6
ARTICLE IN PRESS
Journal of Science and Medicine in Sport xxx (2017) xxx–xxx
Contents lists available at ScienceDirect
Journal of Science and Medicine in Sport
journal homepage: www.elsevier.com/locate/jsams

Original research

The impact of accelerometer wear location on the relationship between step counts and arterial stiffness in adults treated for hypertension and diabetes

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ARTICLE INFO

Article history:
Received 4 August 2017
Accepted 15 August 2017
Available online xxx

Keywords:
Fitness trackers
Wrist
Physical activity
Vascular stiffness
Carotid-femoral pulse wave velocity

ABSTRACT

Objectives: Accelerometer placement at the wrist is convenient and increasingly adopted despite less accurate physical activity (PA) measurement than with waist placement. Capitalizing on a study that started with wrist placement and shifted to waist placement, we compared associations between PA measures derived from different accelerometer locations with a responsive arterial health indicator, carotid-femoral pulse wave velocity (cfPWV).
Design: Cross-sectional study.
Methods: We previously demonstrated an inverse association between waist-worn pedometer-assessed step counts (Yamax SW-200, 7 days) and cfPWV (−0.20 m/s, 95% CI −0.28, −0.12 per 1000 step/day increment) in 366 adults. Participants concurrently wore accelerometers (ActiGraph GT3X+), most at the waist but the first 46 at the wrist. We matched this subgroup with participants from the 'waist accelerometer' group (sex, age, and pedometer-assessed steps/day) and assessed associations with cfPWV (applanation tonometry, Sphygmocor) separately in each subgroup through linear regression models.
Results: Compared to the waist group, wrist group participants had higher step counts (mean difference 3980 steps/day; 95% CI 2517, 5443), energy expenditure (967 kcal/day, 95% CI 755, 1179), and moderate-to-vigorous-PA (138 min; 95% CI 114, 162). Accelerometer-assessed step counts (waist) suggested an association with cfPWV (−0.28 m/s, 95% CI −0.58, 0.01); but no relationship was apparent with wrist-assessed steps (0.02 m/s, 95% CI −0.24, 0.27).
Conclusions: Waist but not wrist ActiGraph PA measures signal associations between PA and cfPWV. We urge researchers to consider the importance of wear location choice on relationships with health indicators.
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1. Background

Accurate and objective measures of physical activity (PA) and sedentary behavior are needed to study relationships with health metrics. Accelerometers are increasingly used to quantify PA levels in free-living settings and are superior to self report.[1]

The recommended and most extensively used accelerometer wear location is the waist, close to the body's center of gravity.[1–3] However, it imposes more participant burden than wrist placement. Waist placement is less convenient with dresses or loosely worn clothing. In recognition of this, the most recently reported cycle (2011–2014) of the National Health and Nutrition Examination Survey (NHANES) switched to placing accelerometers at the wrist.[4] Indeed, preliminary results (2011–2012) from the NHANES study indicated significantly higher adherence rates of 70–80%, compared to 40–70% in previous cycles using waist-worn accelerometers.[4]

Our recent experiences in our Step Monitoring to improve ARTERial health (SMARTER) trial also faced decisions related to a balance between participant burden and accuracy. SMARTER examined the effects of step count prescriptions on arterial health in adults with type 2 diabetes mellitus and/or hypertension.[5,6] The primary PA measure was step counts derived from simple Yamax-200 pedometers worn at the waist (i.e., closing of circuit with hip flexion) and similar devices were used for the intervention. The primary outcome was carotid-femoral pulse wave

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http://dx.doi.org/10.1016/j.jsams.2017.08.011
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Please cite this article in press as: Cooke AB, et al. The impact of accelerometer wear location on the relationship between step counts and arterial stiffness in adults treated for hypertension and diabetes. *J Sci Med Sport* (2017), http://dx.doi.org/10.1016/j.jsams.2017.08.011

velocity (cfPWV), a composite indication of arterial health. Participants also wore an ActiGraph GT3X+ accelerometer to capture PA intensity. The first 46 participants wore the accelerometer at the wrist. However, because of poor correlation between accelerometer step counts and pedometer step counts, the remaining 280 participants wore the accelerometer at the waist. At baseline, we demonstrated an association between pedometer-assessed step counts and cfPWV.[7] These findings are in line with the established association of higher step counts with lower incidence of cardiovascular disease events.[8] SMARTER offers an opportunity to compare wrist and waist accelerometer locations in terms of associations of PA measures with a robust measure of arterial health. cfPWV is considered the "gold-standard" measure of arterial stiffness, and an independent predictor of cardiovascular events and mortality.[9]

While previous studies have compared the impact of wear location (wrist vs. waist) on step counts,[3] activity counts,[10,11] and energy expenditure (EE)[12–14] in free-living and laboratory settings, this is the first study to our knowledge that has considered the impact of wear location on the association between PA and an arterial health indicator.

2. Methods

The present analysis includes a subgroup of participants from the 366 individuals evaluated for the SMARTER trial (Clinicaltrials.gov NCT01475201). Written informed consent was obtained and SMARTER trial procedures were approved by McGill University's Faculty of Medicine Institutional Review Board (A08-M76-11B) and participating institutions (McGill University Health Centre, St. Mary's Hospital, Jewish General Hospital, Institut de recherches cliniques de Montréal).

Our trial protocol is registered,[5] baseline characteristics have previously been described,[7] and the final results have been published.[6] Participants were recruited through McGill- and Université de Montréal-affiliated primary care clinics in Montreal, Quebec. Eligibility criteria included diagnosis of type 2 diabetes mellitus and/or hypertension, body mass index (BMI) between 25 and 40 kg/m^2, age of 18 years or older, and absence of any acute or chronic co-morbid conditions affecting ability to walk.

cfPWV was measured non-invasively using applanation tonometry (Sphygmocor, AtCor Medical, Sydney, Australia). Detailed methods have been described previously.[5] Pedometers (Yamax SW-200, San Antonio, TX, USA) with a concealed viewing window were worn at the waist for the assessment of step counts in all participants. This Yamax SW-200 model uses a coiled spring-suspended lever arm requiring 0.35 g vertical acceleration for step detection. This device was also used for monitoring by participants and physicians in the active arm which included physician-delivered step count prescriptions.

In addition, at baseline, participants wore research-grade accelerometers were used (ActiGraph GT3X+, Pensacola, FL, USA) not only for the assessment of step counts but also for EE, sedentary time, light PA, moderate-to-vigorous PA (MVPA), and activity counts per minute. Participants (n = 46) were initially instructed to wear the accelerometer for 7 consecutive days on the non-dominant wrist at all times (24 h/day). The subsequent 280 participants were instructed to wear the accelerometer for 7 consecutive days on the waist during waking hours. In both cases, participants removed the accelerometer during bathing and water activities.

Analyses were conducted in participants who wore the accelerometer for ≥10 h/day for at least 4 out of the 7 days to ensure accurate assessments. Non-wear time was defined as 60 consecutive minutes of zero activity counts, and the spike tolerance was set to 2 min of >100 activity counts. The Freedson adult 1998 energy estimation equation was applied,[15] and PA levels were classified using cut points previously used in a similar population of older sedentary adults (sedentary: <200 counts/min, light: 200–1999 counts/min, moderate: 2000–3999 counts/min, vigorous: ≥4000 counts per min).[16] The data were processed in 10-s epochs using the ActiLife software version 6.5.4. The low frequency extension (LFE) function was not applied to the data presented herein. While, the LFE function may be useful in elderly populations or individuals with very slow walking speeds, we found it led to much higher estimates of step counts in our population. Step counts recorded with the LFE function were greater than with the default filter by 8017 (SD 1939) steps/day [wrist: 8293 (SD 1603), waist: 7694 (SD 2203)].

The 46 participants who wore the accelerometer at the wrist were individually matched with participants from the larger group (n = 280) who wore the accelerometer on the waist. Specifically, they were first matched based on sex to ensure a similar sex distribution in the two groups. Participants were then matched for walking levels using pedometer-assessed step counts. They were subsequently matched for age and waist circumference (when possible), two correlates of cfPWV in this cohort. When there was more than one potential match, the participant with the closest pedometer-assessed step counts was selected (within 500 steps/day).

Descriptive statistics were used to summarize participant characteristics using mean, standard deviations (SD), number and proportions, as appropriate. Mean differences between wear location (wrist minus waist) for step counts, EE, light PA, MVPA and sedentary time were computed with 95% confidence intervals (CIs). Accelerometer wear time was included as a covariate in the models to account for differences in wear time between the wrist and waist locations. Linear regression models were used to evaluate the association between cfPWV and step counts, as well as other accelerometer-assessed PA measures (EE, light PA, MVPA, sedentary time, and activity counts per minute). Our previous examination of the relationship between pedometer-assessed step counts and cfPWV among the full cohort of 366 SMARTER participants included adjustments for several covariates and possible confounding variables. Taking into consideration the smaller sample size in this study, we have presented unadjusted regression coefficients to allow comparison between the subsample of matched participants and full SMARTER cohort. SAS version 9.3 was used (SAS Institute, Cary, NC, USA). Finally, we examined associations between all available accelerometer-derived PA measures and cfPWV for all participants with an accelerometer placed at the waist.

3. Results

Participants in waist and wrist subgroups were very similar in terms of age, sex, anthropometric measures, and cfPWV (Table 1).

The waist and wrist subgroups had similar pedometer-assessed step counts (worn at the waist in both groups) (Table 1). However, in terms of accelerometer measures, participants who wore the accelerometer at the wrist had higher accelerometer-assessed step counts, total activity counts per minute, light PA, MVPA and EE, compared to the subgroup who wore it at the waist (Table 1). The wrist accelerometer location subgroup also recorded less sedentary time than the waist subgroup (Table 1).

In the full cohort of SMARTER participants, we previously reported that a 1000-step/day increment in walking was associated with a 0.2 m/s (95% CI −0.28, −0.12) decrement in cfPWV in unadjusted analyses, and a 0.1 m/s (95% CI −0.20, −0.02) decrement in cfPWV across models adjusted for several covariates including age, sex, BMI, ethnicity, immigration status, employment, education,

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