RESEARCH LETTER

Relative-Intensity Physical Activity and Its Association With Cardiometabolic Disease

Juned Siddique [iD], DrPH; Whitney A. Welch, PhD; David Aaby [iD], MS; Barbara Sternfeld, PhD; Kelley Pettee Gabriel [iD], PhD; Mercedes R. Carnethon [iD], PhD; Jamal S. Rana, MD, PhD; Stephen Sidney, MD

Aerobic guidelines from the US Department of Health and Human Services recommend at least 150 min/wk of moderate-intensity physical activity, 75 min/wk of vigorous-intensity physical activity, or an equivalent combination of moderate-to-vigorous intensity physical activity (MVPA).[1] MVPA intensity is defined either in terms of *absolute* intensity or *relative* intensity. Absolute intensity refers to the energy required to perform an activity and does not take into account an individual's exercise capacity. Relative intensity is when the level of effort is relative to a person's exercise capacity.[2,3]

For adults aged 18 to 64 years, US Department of Health and Human Services guidelines are based on an absolute-intensity scale. There is limited evidence on whether it is better to assess MVPA on a relative scale to promote and maintain health. Addressing this question has important implications about how individuals should monitor their MVPA intensity, how physicians should prescribe MVPA, and whether current MVPA guidelines should be modified.

Accelerometer-derived MVPA intensity is estimated on an absolute scale. Using data from a large observational study, we investigated the prospective association between relative-intensity MVPA and incident hypertension, incident diabetes mellitus, and waist circumference (WC), and compared our results with those obtained using absolute-intensity MVPA.

Participants were from the CARDIA (Coronary Artery Risk Development in Young Adults) study, an ongoing cohort study of 5115 Black and White men and women aged 18 to 30 years at baseline in 1985 to 1986.[4] In 2005 to 2006 (year 20), an ancillary CARDIA Fitness Study was performed on 2760 participants aged 38 to 50 years who wore accelerometers for 1 week. Previously,[2] we modeled the relationship between accelerometer counts and rating of perceived exertion[3] during the year 20 treadmill test to calculate person-specific accelerometer cut points corresponding to relative-intensity MVPA.

Participants were reexamined in 2010 to 2011 (year 25) and 2015 to 2016 (year 30). Incident hypertension was defined as systolic blood pressure ≥140 mm Hg, diastolic blood pressure ≥90 mm Hg, or use of hypertension medication, at year 25 or year 30. Incident diabetes mellitus was defined as hemoglobin A1c ≥6.5%, fasting glucose ≥126 mg/dL, 2-hour glucose ≥200 mg/dL, or use of diabetes mellitus medication, at year 25 or year 30. We excluded those who did not have accelerometer data (n=399) or who wore the accelerometer <4 days (n=241). Those with missing or prevalent year 20 hypertension (n=395) and diabetes mellitus (n=197) were excluded from the hypertension and diabetes mellitus analyses, respectively. Also excluded were participants with missing outcomes: incident hypertension (n=88), incident diabetes mellitus (n=105), year 30 WC (n=262), or missing year 20 covariates (n=23). The study was approved by the Institutional Review Boards at all sites. Participants provided written informed consent. Data and methods used in this analysis are available on request (http://www.cardia.dopm.uab.edu/contact-cardia).

Analyses were performed using R (version 4.0.3). We used generalized additive models[5] to examine nonlinear relationships of average daily minutes of MVPA with time to hypertension, time to diabetes mellitus, and year 30 WC, stratified by sex. Separate models were fit using MVPA on relative- and absolute-intensity

JAHA is available at: www.ahajournals.org/journal/jaha

scales. Models controlled for age, race (Black/White), year 20 education, year 20 smoking status, and accelerometer wear time. Models for hypertension and diabetes mellitus additionally controlled for year 20 body mass index. Models for year 30 WC additionally controlled for year 20 WC and height. Grouped-time survival models were fit for hypertension and diabetes mellitus using a binomial distribution with a complementary log-log link. As a sensitivity analysis, we reran all our models after imputing missing data.

At year 20, mean age was 45.2 years (SD=3.6 years), mean body mass index was 28.7 kg/m^2 (SD=6.3 kg/
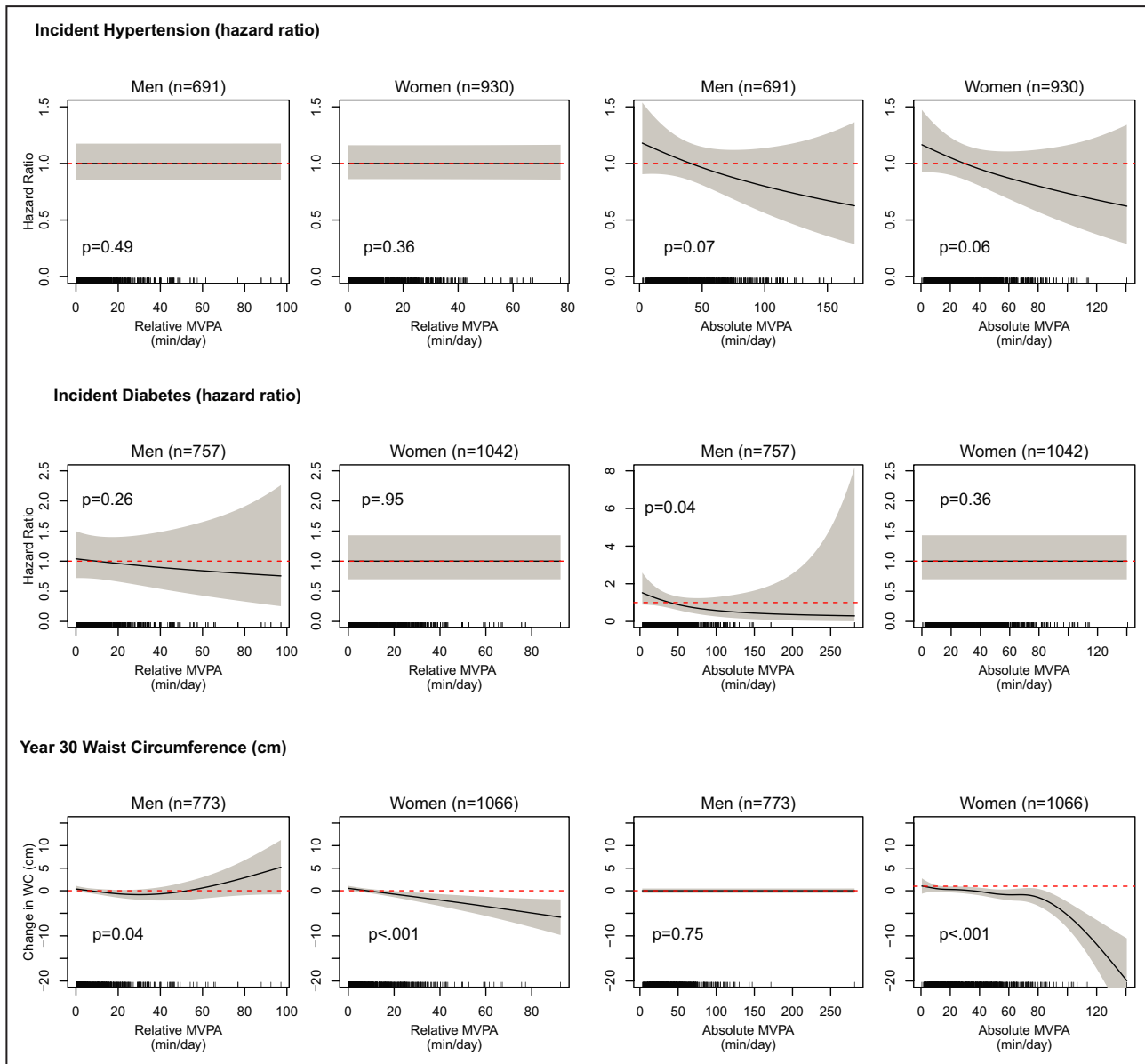
Figure. **Incident hypertension, diabetes mellitus, and waist circumference (WC) as a function of moderate-to-vigorous intensity physical activity (MVPA) on both relative- and absolute-intensity scales, stratified by sex.**
Models were fit using generalized additive models that allow for nonlinear relationships between the outcome and continuous covariates using splines. For hypertension and diabetes mellitus, the *y* axis is the hazard ratio relative to the hazard where MVPA is set to its mean. For WC, the *y* axis is the change in year 30 WC as MVPA deviates from its mean value. The red dotted lines in the panels are drawn at 1 (hypertension and diabetes mellitus) or 0 (WC) to indicate the effect when MVPA is set to its mean. Shaded areas represent 95% CIs around the smoothed effects. When the 95% CI of the physical activity (PA) effect at a given MVPA value includes the red line, the corresponding inference is that the effect of PA is not significant at the 0.05 level. All models controlled for age, race (Black/White), year 20 smoking status, year 20 education, and accelerometer wear time. Models for hypertension and diabetes mellitus additionally controlled for year 20 body mass index. Models for year 30 WC additionally controlled for year 20 WC and height. The tick marks above the *x* axis of each plot correspond to observed MVPA values for each participant.

m^2), mean education was 15.2 years (SD=2.5 years), 327 (15.5%) participants were current smokers, 880 (41.5%) were Black race, and 907 (42.8%) were men. Mean relative-intensity MVPA was 8.8 min/d (SD=12.1 min/d); mean absolute-intensity MVPA was 33.7 min/d (SD=23.9 min/d).

By year 30, 182 incident hypertension and 56 incident diabetes mellitus events occurred in men. Mean change (from year 20) in WC was 4.2 cm (SD=7.0 cm). Among women, 232 incident hypertension and 72 incident diabetes mellitus events occurred, and mean change in WC was 4.1 cm (SD=7.5 cm). Model results are in the Figure. For men, relative-intensity MVPA was marginally associated with year 30 WC but absolute-intensity MVPA was not. For women, increasing MVPA on both scales was associated with lower year 30 WC. In both men and women, incident hypertension and diabetes mellitus were not significantly related to either relative- or absolute-intensity MVPA, with the exception of a marginal association between incident diabetes mellitus and absolute MVPA in men.

We found no meaningful differences between absolute- and relative-intensity analyses, although there was no formal test to distinguish between these 2 measures. Limitations include a relatively young sample, a single week of measured MVPA, and ≈12% of participants with missing outcomes at year 30 whose absence may result in biased estimates, although analyses after imputing missing data provide similar results to those shown here. The mostly nonsignificant effects of relative-intensity MVPA support current recommendations focusing on accumulating MVPA on an absolute scale for adults aged 18 to 64 years.

REFERENCES

1. US Department of Health and Human Services. *2018 Physical Activity Guidelines for Americans*. 2nd ed. Washington, DC: US Department of Health and Human Services; 2018.
2. Siddique J, Aaby D, Montag SE, Sidney S, Sternfeld B, Welch WA, Carnethon MR, Liu K, Craft LL, Gabriel K, et al. Individualized relative-intensity physical activity accelerometer cut points. *Med Sci Sports Exerc*. 2020;52:398–407. DOI: 10.1249/MSS.0000000000002153.
3. Scherr J, Wolfarth B, Christle JW, Pressler A, Wagenpfeil S, Halle M. Associations between Borg's rating of perceived exertion and physiological measures of exercise intensity. *Eur J Appl Physiol*. 2013;113:147–155. DOI: 10.1007/s00421-012-2421-x.
4. Friedman GD, Cutter GR, Donahue RP, Hughes GH, Hulley SB, Jacobs DR Jr, Liu K, Savage PJ. CARDIA: study design, recruitment, and some characteristics of the examined subjects. *J Clin Epidemiol*. 1988;41:1105–1116. DOI: 10.1016/0895-4356(88)90080-7.
5. Wood SN. *Generalized Additive Models: An Introduction With R*. Boca Raton, FL: CRC Press; 2017.