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Quantifying physical activity across the midlife: Does consideration of perceived exertion matter?

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ABSTRACT

Many questionnaires ascertain physical activity (PA) frequency, duration, and intensity to benchmark achievement of PA recommendations. However, most scoring algorithms utilize absolute intensity estimates when exertion may be influenced by age or health characteristics. This study quantified PA estimates with and without adjustments for perceived exertion and evaluated if differences were associated with individual-level characteristics. Women ($n = 2{,}711$) in the United States from the Study of Women's Health Across the Nation who completed ≥ 3 Kaiser Physical Activity Surveys (KPAS) across 8 biennial visits were included (baseline age: 46.4 $\pm$ 2.7 years). KPAS responses about activity mode and exertion were converted to metabolic equivalent of a task (METs) using the 2011 Compendium of Physical Activities to estimate absolute and perceived intensity-adjusted METs. Repeated measures (linear mixed effects) regression models were used to examine associations of sociodemographic and health-related characteristics with change in the difference between absolute MET estimates and perceived intensity-adjusted MET estimates. Older age ($p < 0.001$), Chinese ($p < 0.001$) and Japanese ($p = 0.01$) ethnicity, and current smoking ($p = 0.001$) were associated with positive differences between absolute and perceived intensity-adjusted MET estimates, which is suggestive of lower perceived-intensity physical activity. However, for most participants, absolute intensity-based estimates closely approximated perceived intensity-adjusted estimates over time. Traditional PA scoring techniques using absolute intensity estimates only may provide sufficient estimates of PA in longitudinal cohort studies of mid-life and older adult women.

1. Introduction

Insufficient physical activity is a leading risk factor for premature mortality and multiple chronic diseases (Kraus et al., 2019; Tikkanen et al., 2018; Aune et al., 2015; Wahid et al., 2016; Dipietro et al., 2019). Current guidelines for physical activity recommend 150 min of moderate-intensity physical activity or 75 min of vigorous-intensity physical activity; in addition to muscle strengthening activities, each week (United States Department of Health and Human Services, 2018). Yet currently; only one-quarter of adults in the United States are sufficiently active (United States Department of Health and Human Services, 2018; Centers for Disease Control and Prevention, 2008; Centers for Disease Control and Prevention, 2022). Healthy People 2030 goals include reducing the proportion of inactive adults and increasing the proportion of adults engaging in enough aerobic and muscle-strengthening activities to achieve health benefits (Healthy People, 2030).

Continued surveillance of physical activity is needed to monitor progress toward achieving national benchmarks, but physical activity measurement is complex. Considerations for selecting an appropriate physical activity measurement strategy include the primary purpose; study design and hypotheses; physical activity constructs, domains, and parameters; whether information on specific activity type(s) or summary measures are needed; target population; and resources and logistical constraints (Pettee Gabriel et al., 2012; Troiano et al., 2012; Ainsworth et al., 2012). The gold standard physical activity

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measurement technique is direct observation, yet self-reported instruments are widely used in epidemiologic and surveillance efforts because of lower resource requirements and are a valuable approach to behavior assessment (Troiano et al., 2012). Accordingly, Healthy People 2030 benchmarks utilize self-reported physical activity data from the National Health Interview Survey (Healthy People, 2030).

Self-reported physical activity instruments measure multiple dimensions of physical activity, which may include activity type (e.g., walking, running, strength training), frequency (e.g., number of sessions per week), duration of activity bout (e.g., minutes or hours), and intensity or perceived exertion of activity (Pettee Gabriel et al., 2012). Common measurement errors in self-reported assessments include the cognitive burden associated with recalling complex behavior, social desirability, and the incomplete assessment of physical activity across domains (Pettee Gabriel et al., 2012; Adams et al., 2005). Importantly, physical activity intensity includes two distinct constructs: absolute intensity and relative intensity. Absolute intensity is a measure of workload and is typically expressed in metabolic equivalents of a task (METs), which is the rate of metabolic demand compared to sitting at rest (Troiano et al., 2012). Relative intensity is related to cardiorespiratory and muscular fitness, which is a comparison of effort to capacity, and may vary by age, fitness, body size, or other sociodemographic and/or health factors (Troiano et al., 2012).

Often, self-reported physical activity data are coded or categorized using absolute intensity estimates but ascertained within the context of relative intensity. For example, the International Physical Activity Questionnaire (Craig et al., 2003) measures four dimensions of physical activity, starting with intensity categories. First, a prompt describes vigorous-intensity activity. Then, participants recall whether and for how may days during the past week they engaged in any vigorous-intensity activity, and typical duration of activity. The process is repeated to assess frequency and duration of moderate-intensity activity and walking. Multiple physical activity assessments use similar procedures, with recall cues including elements of perceived exertion (Craig et al., 2003; Bull et al., 2009; Godin and Shephard, 1985). The result is that survey questions and scoring algorithms utilize absolute intensity estimates that may be based in part on relative intensity cues (e.g., respiration and/or perspiration), which may be influenced by individual-level factors such as age or health (Troiano et al., 2012).

Unsurprisingly, confusion and discordance are common for absolute and relative intensity estimates from self-reported physical activity data. To address limitations in the estimation of absolute and relative intensity physical activity data, the current study sought to: (Kraus et al., 2019) characterize the relative intensity of physical activity utilizing perceived exertion measures over time; (Tikkanen et al., 2018) compare physical activity estimates with and without adjustments for perceived exertion; and (Aune et al., 2015) determine if sociodemographic or health factors were associated with agreement between absolute intensity-based physical activity estimates and perceived intensity-adjusted physical activity estimates over time.

2. Methods

2.1. Study population

The Study of Women's Health Across the Nation (SWAN) is a prospective, multicenter, multiethnic/racial study of the menopause transition and aging. Sampling and recruitment methods have been described previously (Sowers et al., 2000). Briefly, 3,302 women who were aged 42–52 years at the 1996 baseline visit, pre- or early perimenopausal, and self-identified with site-specific designated race/ethnic groups were recruited for a longitudinal study from seven locations (Boston, MA; Chicago, IL; Detroit-area, MI; Los Angeles, CA; Newark, NJ; Oakland, CA; and Pittsburgh, PA (Sowers et al., 2000). Annual or biennial study visits provided clinical and behavioral data through the most recent follow-up visit 15 in 2016–2017. Study protocols were approved by the Institutional Review Boards at each study site. Participants provided written, informed consent at each visit. The analytic sample for the present study included participants with $\geq$ 3 visits with self-reported physical activity data between baseline and visit 15 (n = 2,711). Compared with the analytic sample, excluded women were similar in baseline age and self-reported physical functioning but had a slightly higher baseline body mass index (BMI) and were significantly more likely to be African American or Hispanic/Latina, and less likely to have a college degree, compared to included women.

2.2. Measures

The Kaiser Physical Activity Survey (KPAS (Ainsworth et al., 2000) was used to assess physical activity in multiple life domains, including planned exercise, at baseline and visits 3, 5, 6, 9, 12, 13, and 15. Participants were asked to report up to two sports or exercise activities performed most frequently over the previous 12 months. Surveys obtained information about the activity type (open-ended), frequency (months in the previous 12 months), and duration (hours per week). Perceived exertion was measured with the question "When you did this activity, did your heart rate and breathing increase?" Response categories included *No*; *Yes, a small increase*; *Yes, a moderate increase*; and, *Yes, a large increase*. Traditionally, the KPAS questionnaire yields ordinal summary scores, which range from 1 to 5 for specific life domain indices (Sternfeld et al., 1999).

Self-reported responses from the KPAS questionnaire were converted to MET-minutes per week. Open-ended responses to primary and secondary sports/exercise activities were categorized into 65 coded groups by the SWAN Coordinating Center. Next, two investigators (K.R.Y. and K.P.G.) assigned an absolute MET value to each of the 65 reported activity groups using the 2011 Compendium of Physical Activities (Ainsworth et al., 2011). Low MET values and high MET values were also assigned using self-reported perceived exertion during activity performance. Low-intensity activity was defined as *none* or *a small increase* in perceived heart rate and breathing; high-intensity activity was defined as *a large increase* in perceived heart rate and breathing. A third investigator (B.S.) adjudicated the absolute, low, and high MET values for each activity. The MET values for the 10 most common physical activities are shown in Supplemental Table 1.

MET values were multiplied by frequency and duration. We calculated two summary measures using this procedure. Absolute MET values were used to calculate absolute intensity-based MET-minutes/week. Low and high MET values, assigned using perceived exertion, were used to calculate perceived intensity-adjusted MET-minutes/week. Finally, we calculated the difference between the two MET values by subtracting intensity-adjusted METs from absolute intensity-based METs. If the absolute intensity-based MET-minutes exceeded the intensity-adjusted MET-minutes, the difference value is positive, indicating that the perceived intensity of exercise was low because the participant reported *none* or *a small increase* in perceived heart rate and breathing. If the intensity-adjusted MET-minutes exceeded the absolute intensity-based MET-minutes, the difference value is negative, indicating that the perceived intensity of exercise was high, because the participant reported *a large increase* in perceived heart rate and breathing.

Sociodemographic characteristics were measured at baseline. Race/ethnicity was self-identified as non-Hispanic White, African American, Hispanic, Japanese, or Chinese. Education was categorized as high-school diploma or General Education Development or less, some college, or a college degree. Self-reported economic strain was determined by the question: "How hard is it to pay for the very basics like food, housing, medical care and heat?" Responses were dichotomized as not difficult vs. somewhat/very difficult. Marital status was categorized as not married or married.

Other time-varying covariates were selected *a priori* based on known associations with physical activity. Age was measured in years. Height was measured without shoes in centimeters by fixed stadiometer and weight was measured in light clothing in kilograms by balance beam scale. BMI was calculated as weight [kg]/height [m^2]. BMI was categorized as underweight/normal (BMI ≤ 24.9 kg/m^2), overweight (BMI 25–29.9 kg/m^2), and obese (BMI ≥ 30 kg/m^2) for non-Hispanic White, African American, and Hispanic women. We used Asian-specific cutpoints to categorize underweight/normal (BMI < 23 kg/m^2), overweight (BMI 23–24.9 kg/m^2), and obese (BMI ≥ 25 kg/m^2) for Japanese and Chinese women (Wee et al., 2010; WHO Expert Consultation, 2004; Woo et al., 2007). Diabetes status was defined as self-report of a physician diagnosis, current use of anti-diabetic medications, and, when available, a fasting blood glucose ≥ 126 mg/dL. Smoking status was defined as current smoker or non-smoker. Depressive symptoms were ascertained using the Center for Epidemiological Studies Depression Scale (CES-D) and categorized as depressive symptoms (CES-D ≥ 16) or no depressive symptoms (CES-D < 16) (Radloff, 1977). Osteoarthritis (yes/no) was determined by self-reported physician diagnosis and/or current pharmaceutical treatment for osteoarthritis. Physical functioning was assessed with the Physical Component Summary measure of the Medical Outcomes Survey Short Form 36 (SF-36) score (Ware and Sherbourne, 1992), with lower scores indicative of poorer perceived physical functioning. Menopause status was determined from questions on bleeding patterns, current hormone use, pregnancy, breastfeeding, hysterectomy, and oophorectomy and categorized as pre-menopausal, *peri*-menopausal (early or late), post-menopausal (including post by bilateral salpingo oophorectomy or natural), or unknown due to hormone therapy use or hysterectomy.

2.3. Statistical analysis

Descriptive statistics included means (±standard deviation) or proportions for all variables. Differences in baseline sociodemographic variables were compared between the analytic sample and excluded participants using appropriate bivariate test statistics.

We determined the proportion of participants who reported any exercise or planned activities, the most frequent primary exercise or planned activity for the total sample by visit and race/ethnic group, and the distribution of perceived exertion of primary exercise or planned activity. We calculated absolute intensity-based MET estimates and perceived intensity-adjusted MET estimates for each visit. We also determined the proportion of the sample that was meeting physical activity recommendations, according to the 450 MET-minute/week threshold (3.0 METs of moderate physical activity * 150 min/week) (United States Department of Health and Human Services, 2018). Next, repeated measures (linear mixed effects) regression models (PROC MIXED) were used to examine associations of changes in health-related characteristics with change in the difference between absolute MET estimates and perceived intensity-adjusted MET estimates. Repeated measures included age, BMI, smoking, diabetes, osteoarthritis, SF-36, and depressive symptoms; time-invariant variables included race/ethnicity, baseline educational attainment, baseline marital status, and baseline economic strain. In the multivariate model, we included all repeated measures and time-invariant variables. Model adequacy (i.e., Goodness of fit) was assessed based on Akaike's and Bayesian information criteria (Singer and Using, 1998; Shen and González, 2021). A repeated statement, with compound symmetry covariance structure within subject, was included to account for the initial differences between participants and for correlations on the participant level among study visits (Singer and Using, 1998). All data analyses were conducted using SAS v9.4 (SAS Institute, Inc., Cary, NC).

3. Results

Participants (n = 2,711) were, on average, aged 46.4 years (±2.7; range 42 – 52 years). Almost half (48.3%) were non-Hispanic white, one-quarter (27.6%) were African American, 9.9% were Japanese, 8.4% were Chinese, and 6.0% were Hispanic. At baseline, 22.3% had a high school degree or less. Mean BMI was 28.1 kg/m^2 (±7.3) and one-third (34.6%) were classified as obese (Table 1).

Approximately three-fourths of participants reported any planned exercise activities or sports during the previous year (visit-specific range 70.7–79.2%; Fig. 1). Perceived exertion of the primary activity was relatively consistent across visits (Fig. 1). Fewer than one in ten reported no increase in perceived heart rate or breathing (range 5.6–9.3%), approximately one-third reported a small increase in perceived heart rate or breathing (range 33.9–38.7%), just under one-half reported a moderate increase in perceived heart rate or breathing (range 41.3–46.4%), and approximately one-eighth reported a large increase in perceived heart rate or breathing (range 10.6–16.3%).

The primary types of reported physical activity or planned exercise are shown in Table 2. Approximately half of all participants reported walking as their primary physical activity, and the high prevalence of walking was consistent across 5 race/ethnic groups. Ten activities (walking, aerobics, bicycling, strength/resistance training, running/jogging, swimming, dance, tennis, golf, and yoga) accounted for more than 85% of all primary activities.

At baseline, participants reported, on average, 407.0 (±527.7) absolute MET-minutes per week; at visit 15, participants reported, on average, 487.4 (±556.8) absolute MET-minutes per week. At baseline, the difference in absolute MET estimates and intensity-adjusted MET estimates was −0.5 MET-minutes (±113.7; median = 0; IQR: 0.0, 12.4); at visit 15, the difference was 15.8 MET-minutes (±121.7; median = 0.0; IQR:0.0, 39.1). We identified sociodemographic and health factors that were associated with this difference over time. In the multivariate longitudinal model (Table 3), age (β = 0.7; 95% confidence interval (CI):0.4,1.0; p < 0.001), race/ethnicity (Chinese, β = 31.1; 95% CI:19.8,42.5; p < 0.001; Japanese, β = 13.7; 95% CI:2.9,24.4; p = 0.01), education (high school or less, β = 10.3; 95% CI:1.6,19.0; p = 0.02; some college, β = 11.6; 95%CI: 4.4,18.8; p = 0.002), marital status (not married, β = 7.2; 95% CI:0.3,14.1; p = 0.04), current smoking (β = 12.9;

Table 1
Baseline sociodemographic and health-related characteristics for SWAN participants, n = 2711.

Age, years (std)	46.4 (2.7)
Race/ethnicity, %	
Non-Hispanic white	48.3
African American	27.6
Hispanic	6.0
Chinese	8.4
Japanese	9.9
Educational attainment, %	
High school or less	22.3
Some college	32.3
College degree	45.4
Marital Status, %	
Never married	13.5
Currently married	67.7
Formerly married	18.8
Difficulty paying for basics, %	
Not difficult	62.6
Somewhat/very difficult	37.4
Body Mass Index, kg/m^2 (std)	28.1 (7.3)
Body Mass Index categories, %	
Underweight or Normal	38.6
Overweight	26.8
Obese	34.6
Smoking status, %	
Never	58.9
Former	25.9
Current	15.2
Diabetes, %	4.5
Depressive symptoms, %	22.9
Osteoarthritis, %	19.6
Physical functioning, SF-36 Role Physical score (std)	75.1 (36.3)
Menopause status, %	
Early perimenopause	44.8
Premenopause	55.2

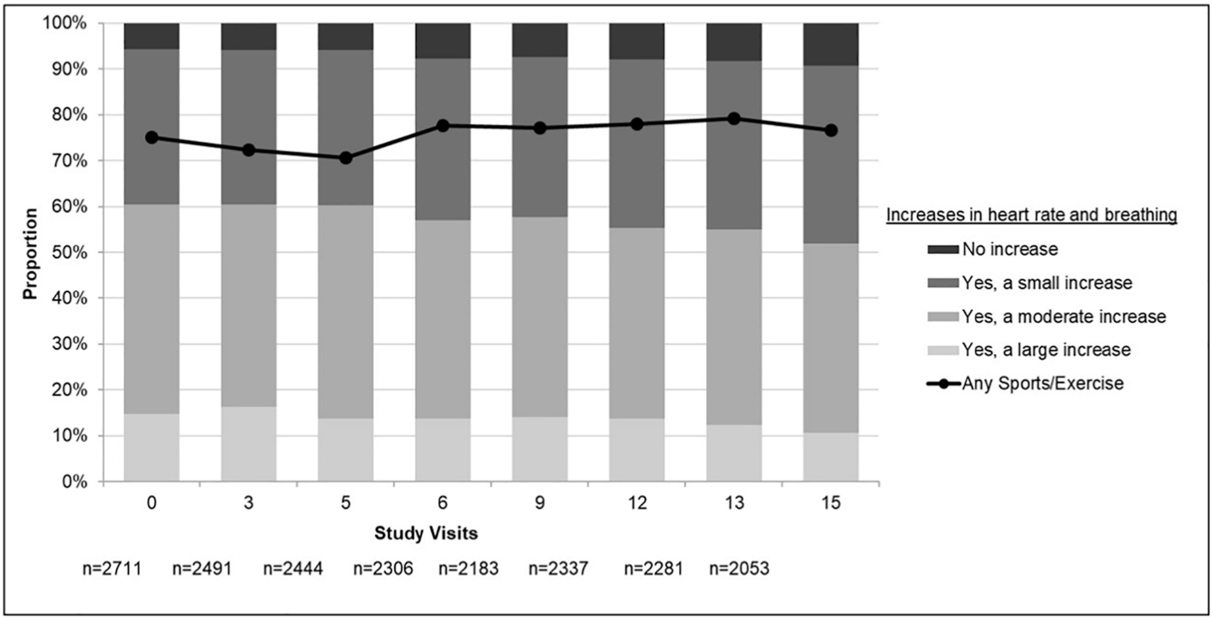

Fig. 1. Perceptions of exertion and proportion of participants who reported any sports/exercise, by study visit.

Table 2
Types of primary planned physical activity at baseline and visit 15 for total sample and by race/ethnic group.

	Total	African American	Non-Hispanic white	Chinese	Hispanic	Japanese
Baseline						
Primary planned physical activity, %						
Walking	49.9	54.6	53.5	41.1	36.6	31.7
Aerobics	9.3	8.2	8.3	11.0	26.8	12.3
Bicycling	7.0	7.2	7.9	4.3	14.6	3.1
Strength/resistance training	5.9	8.2	4.6	7.4	7.3	5.7
Running/jogging	3.5	1.4	3.7	7.4	0.0	5.3
Swimming	3.3	1.2	3.8	3.7	4.9	5.3
Dance	2.4	2.6	2.3	4.3	0.0	1.8
Tennis	2.3	1.0	1.4	3.7	2.4	8.4
Golf	2.2	0.2	1.8	0.6	0.0	10.1
Yoga	1.4	1.0	0.8	3.1	0.0	4.0
Other	12.8	14.4	11.9	13.4	7.4	12.3
Visit 15						
Primary planned physical activity, %						
Walking	51.1	52.3	51.6	44.7	74.5	45.1
Aerobics	6.0	8.5	4.9	3.7	3.9	9.1
Bicycling	5.3	6.1	6.1	4.3	0.0	3.0
Strength/resistance training	8.1	9.1	8.0	6.8	7.8	7.9
Running/jogging	1.2	0.9	1.1	1.9	0.0	1.8
Swimming	3.3	1.2	4.9	3.1	3.9	0.0
Dance	3.5	3.3	2.0	7.5	2.0	6.7
Tennis	1.0	0.3	1.0	0.6	0.0	3.7
Golf	2.2	0.3	2.3	1.9	0.0	6.1
Yoga	5.3	4.0	5.0	8.1	0.0	7.9
Other	13.0	14.0	13.1	17.4	7.9	8.7

95% CI:5.0,20.7; p = 0.001) were positively associated with the longitudinal difference between absolute intensity-based MET estimates and perceived intensity-adjusted MET estimates.

Using absolute intensity-based MET estimates, 34.3% of participants at baseline met aerobic physical activity recommendations for adults; 42.0% at visit 15 met aerobic physical activity recommendations. Across 8 study visits, the proportion meeting aerobic recommendations using absolute intensity MET-estimates ranged from 33.3% to 42.0%. Comparing the absolute intensity-based MET estimates and the perceived intensity-adjusted MET estimates across 8 visits, 96.3% to 97.2% would be classified consistently as meeting or not meeting physical activity recommendation thresholds.

4. Discussion

Increasing dose of physical activity is associated with many health benefits, thereby providing evidence for current physical activity guidelines. However, questions remain about the value of physical activity in preventing some age-related health outcomes – including cognitive decline – given that some, but not all, studies have shown a protective association of physical activity (Greendale et al., 2021; Andel et al., 2008; Aberg et al., 2009). Differences across studies may be due to inadequate measurement and calls for more device-based measurement of physical activity are resounding (Kramer, 2021). Because most physical activity measurement in large epidemiologic studies is based on self-reported assessments, a full understanding of the value of measuring

Table 3
Multivariate associations of health-related characteristics and the difference between absolute MET estimates and perceived intensity-adjusted MET estimates over time (1996–2017) in the Study of Women's Health Across the Nation.

	β (95% CI)	*P*
Intercept	−28.6 (-46.7, −10.4)	0.002
Age, years	0.7 (0.4, 1.0)	<0.001
Race/ethnicity		
Non-Hispanic white	REF	
African American	−0.03 (-7.9, 7.9)	0.99
Hispanic	4.5 (-10.4, 19.5)	0.55
Chinese	31.1 (19.8, 42.5)	<0.001
Japanese	13.7 (2.9, 24.4)	0.01
Education attainment		
High school or less	10.3 (1.6, 19.0)	0.02
Some college	11.6 (4.4, 18.8)	0.002
College degree	REF	
Marital status		
Married	REF	
Not married	7.2 (0.3, 14.1)	0.04
Economic strain		
Not difficult to pay for basics	REF	
Somewhat or very difficult	1.5 (0.3, 14.1)	0.04
BMI, kg/m^2	0.3 (-0.1, 0.7)	0.15
Smoking status		
Non-smoker	REF	
Current smoker	12.9 (5.0, 20.7)	0.001
Diabetes		
No	REF	
Yes	2.1 (-5.6, 9.7)	0.59
Osteoarthritis		
No	REF	
Yes	1.9 (-2.8, 6.6)	0.43
Physical functioning, SF-36	−0.04 (-0.1, 0.1)	0.44
Depressive symptoms		
No	REF	
Yes	2.0 (-3.2, 7.2)	0.45

Abbreviations: MET, metabolic equivalent of a task; HS, high school; BMI, body mass index; SF, the Medical Outcomes Study Short-Form 36; CI, confidence interval.
Notes: Age is centered at 42 years, the minimum age at baseline. β can be interpreted as change in the difference between absolute MET estimates and perceived intensity-adjusted MET estimates per 1-unit increase in the listed variables. MET values were assigned using the 2011 Compendium of Physical Activities. Intensity-adjusted MET categories were assigned using self-reported perceived exertion, measured with the survey question, *When you did this activity, did your heart rate and breathing increase?*

both behavior and proxies for cardiorespiratory fitness is needed. This manuscript characterized physical activity perceived exertion over time to determine if perceptions of exertion should be used to calculate intensity-adjusted MET estimates to quantify physical activity. For most women in our study, absolute intensity MET estimates and perceived intensity-adjusted MET estimates were concordant over time, particularly when comparing physical activity recommendation thresholds. Our findings suggest that for many epidemiologic samples of mid-life and early old age women, perceived intensity-adjusted MET estimates may not provide estimates that are substantially different from absolute MET estimates obtained from the Compendium of Physical Activities. However, differences in absolute and perceived intensity-adjusted measures may be relevant for some populations – such as Chinese and Japanese women, and women with poor physical functioning – and more work is needed to optimize self-reported measures in these populations.

Most prospective, observational epidemiologic studies measure physical activity on an absolute scale, whereas relative intensity is used in physiologic intervention studies to assign training loads and improve cardiorespiratory fitness (Siddique et al., 2020). In our study, relative intensity of physical activity was estimated using perceived exertion. Perception provides feedback that can alter behavior, and humans have a well-developed evolutionary system for sensing physical effort, strain, and fatigue (Coquart et al., 2014). Physiologic research uses self-reported tools such as the Ratings of Perceived Exertion scale (Borg, 1970; Borg, 1998) to estimate maximal or peak oxygen uptake and approximate cardiorespiratory fitness (Coquart et al., 2014). During the approximately 20 years of follow-up, we expected to observe increases in perceived exertion over time because of aging-related declines in cardiorespiratory fitness and physical functioning. We hypothesized that a substantial proportion of participants with low levels of fitness would report higher perceived exertion over time, and thus their intensity-adjusted MET estimates exceed absolute MET estimates. This hypothesis suggested that age would be significantly associated with a negative difference in MET estimates over time. In our study, we observed a small positive, statistically significant association with age, demonstrating that the difference between absolute intensity-based MET estimates and perceived exertion intensity-adjusted MET estimates increased with age because older adults engaged with increasingly lower-intensity physical activities. However, because mean age was 65.7 years at visit 15, our mid-life and early old age sample may not capture as large of a difference between absolute and perceived intensity-adjusted MET estimates as would studies of much older adults. Additionally, we do not have information about cardiorespiratory fitness and are thus unable to disentangle cardiorespiratory fitness and low-intensity physical activity.

Cardiorespiratory fitness – and thus relative intensity of physical activity – may vary by age, body size, or other sociodemographic or health factors (Troiano et al., 2012). Cardiorespiratory fitness is important for overweight and obese populations since high levels of fitness can attenuate and even eliminate the elevated risk of cardiovascular disease in overweight and obese populations (Lavie et al., 2019). This is particularly important for our study population, since two-thirds were classified as overweight or obese at baseline and many reported some limitations in physical functioning. The fully adjusted model showed that physical functioning and race/ethnicity, but not BMI, were associated with the difference between absolute intensity and perceived intensity-adjusted MET estimates. The complex interplay of perceived exertion and body size may be the result of other sociodemographic variables like race/ethnicity or geographic location, which may dictate norms, personal preference, and/or availability of physical activity opportunities.

The most common planned exercise activity for our participants was walking. National surveillance data and research also suggest that walking is the most common activity for women and are robust across a range of sociodemographic strata (Brownson et al., 2000; Littman et al., 2005). In 1995; just prior to the beginning of our SWAN cohort baseline survey, the Centers for Disease Control and Prevention and the American College of Sports Medicine promoted brisk walking at 3 to 4 miles per hour as one example of moderate-intensity physical activity (Lee and Buchner, 2008). The 2011 Compendium of Physical Activities includes more than 50 different descriptions and corresponding MET values for walking (Ainsworth et al., 2011). Walking is extremely important for physical activity promotion; particularly for women; yet can be difficult to quantify with self-reported instruments because of its ubiquity. The popularity of moderate perceived exertion and walking in our study may be one reason for the high concordance of absolute intensity-based estimates and perceived intensity-adjusted MET estimates. We suspect many epidemiologic studies of women would find a similar prevalence of moderate exertion and walking, and thus intensity-adjusted MET estimates may not provide estimates that are substantially different from absolute intensity-based MET estimates for midlife women followed over time.

In our study, between baseline and visit 15, participants engaged in increasingly more low-intensity exercise types, and we observed a notable increase in yoga. At baseline in 1996, when participants were aged 42 to 52 years, half of all primary activity was walking and 1.4% of primary activity was yoga. By visit 15 in 2016–2017, when participants were aged 62 to 72 years, the largest change over time in activity type was yoga, which is consistent with national trends showing the growing popularity of yoga over recent decades (Wang et al., 2019). Although the most common planned exercise activity for all race/ethnic groups was walking, some lower-intensity activities like yoga and golf appeared to be more popular among Chinese and Japanese participants. This could partially explain why we observed strong, positive coefficients in the longitudinal model demonstrating that absolute intensity-based estimates exceeded perceived intensity-adjusted estimates for Japanese and Chinese women.

Our work is subject to several limitations. First, we do not have direct measurement of physical activity or cardiorespiratory fitness. Our work relies on self-reports of physical activity and perceived exertion to estimate both absolute intensity and relative intensity physical activity. Self-reported physical activity, while common in large longitudinal epidemiologic studies, is subject to known error; MET estimates may not reflect accurate absolute or relative intensities (Brooks et al., 2004; Kozey et al., 2010). We also focused on planned exercise and did not include occupational or household activity, which may underestimate overall physical activity, particularly for some race/ethnic groups (Ham and Ainsworth, 2010; Marquez et al., 2010). Although SWAN is a race/ethnically diverse sample, all participants were women within 10 years of age, and age and sex are important characteristics which may influence both perceived exertion and the actual energy costs of physical activities. We did not employ corrections for resting metabolic rate and it is possible, and even likely, that MET estimates in our study population are misclassified and our findings may not be generalizable beyond our study population. Our longitudinal study may be subject to selection bias, and more work is needed to understand loss to follow-up in SWAN.

Physical activity measurement is complex. Self-reported physical activity instruments are common in longitudinal epidemiologic studies but often fail to appreciate perceptions of activity exertion. Race/ethnicity and body size are associated with differences between absolute intensity-based estimates and perceived intensity-adjusted physical activity. However, for most participants, absolute intensity-based estimates approximated perceived intensity-adjusted estimates over time. Traditional physical activity scoring techniques may provide sufficient estimates for physical activity in longitudinal cohort studies of mid-life and older adult women, particularly when estimating measures of association with health outcomes.

CRediT authorship contribution statement

Kelly R. Ylitalo: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Funding acquisition. **Carrie A. Karvonen-Gutierrez:** Resources, Writing – review & editing. **Minsuk Oh:** Writing – review & editing. **Barbara Sternfeld:** Supervision, Writing – review & editing. **James Stamey:** Supervision, Writing – review & editing. **Kelley Pettee Gabriel:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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