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RESEARCH PAPER

Associations of Physical Activity and Sedentary Behavior with Optimism and Positive Affect in Older Women

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Abstract
Psychological well-being is linked to healthy aging in older women, but associations with health behaviors are not well understood. Our study aims to evaluate the relationships between objectively-measured physical behavior (including physical activity and sedentary behavior) with optimism and positive affect in a diverse sample of older women. Our cross-sectional study of 4168 American women (aged 63–99) with accelerometer-measured physical behavior from the Objective Physical Activity and Cardiovascular Health Study assessed associations using multiple linear regression. Effect modification by age, race and ethnicity, social support, and number of chronic conditions was examined as well. In unadjusted models, positive associations for physical activity and negative associations for sedentary behaviors were generally linear for optimism and positive affect. In adjusted models, every one-hour increment in weekly moderate-vigorous physical activity was associated with higher optimism by 0.4 score points [Revised 6-item Life Orientation Test, 95% CI = 0.2, 0.6] and positive affect by 0.6 score points [modified Differential Emotions Scale, 95% CI = 0.2, 0.9]. One-hour increments in light physical activity were associated with higher positive affect [0.2 score points; 95% CI = 0.03, 0.33] while one-hour increments in sedentary behavior patterns were associated with lower positive affect [-0.1 score points; 95% CI = − 0.10, − 0.02). Effect modification by age, race and ethnicity, social support, and number of chronic conditions was not observed. In conclusion, associations between physical behavior with optimism and positive affect were modest but suggest greater activity and less sedentary time are associated with greater psychological well-being in older women.

Keywords Psychological well-being · Healthy aging · Accelerometer · Health behaviors · Sitting time · Cross-sectional

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1 Introduction

Women aged 65 years and older represent a large and growing population in the United States projected to exceed 50 million, or 12.5% of the population, by the year 2060 (Vespa et al., 2020). Women live longer, experience higher rates of morbidity, disability, depression, and anxiety compared to men (IHME, 2022; Vespa et al., 2020). Physical health and healthy aging are closely linked to psychological well-being, which includes eudaimonic (life satisfaction and functioning) and hedonic (high positive and low negative emotions) aspects of well-being (Deci & Ryan, 2008). Therefore, understanding factors that improve psychological well-being for the growing population of older women will be essential to reduce future health and economic burdens in the United States and abroad. Although considerable research about psychological well-being exists, our study strives to extend the current knowledge on two particular aspects: (1) optimism – a "thinking" or eudaimonic component; and (2) positive affect – a hedonic component.

Optimism, defined as the expectation of positive future events (Scheier et al., 1994), is associated with lower age-related morbidity and mortality in postmenopausal women (Koga et al., 2022; Tindle et al., 2009). Two recent longitudinal studies reported significant associations between higher optimism and healthy aging in women, suggesting that optimism is not only related to longevity but also to improved health and functioning in older years (James et al., 2019; Kim et al., 2019). Furthermore, studies show that higher levels of optimism are related to health-promoting behaviors including healthier diet and non-smoking behavior in older women (Kim et al., 2019; Progovac et al., 2019). However, little is known about which behaviors predict optimism.

Positive affect, described as the experience of pleasurable emotions, is a modifiable state that is strongly linked with biological and psychological health (Fredrickson, 2013; Pressman et al., 2019). Higher levels of positive affect have been associated with lower morbidity in older adults (Zhang & Han, 2016) and reduced levels of chronic pain in women (Ong et al., 2020). Fredrickson's upward spiral model postulates that the relationship between positive emotions and new positive health behaviors are reciprocal and can reinforce adherence to wellness behaviors through biological and psychological resources (Fredrickson, 2013).

Physical behavior includes *physical activity* and *sedentary behavior*. While it is well-accepted that higher levels of physical activity can reduce the risk of cardiovascular disease, some cancers, cognitive decline, physical disfunction, and mortality in older adults (World Health Organization, 2020), and independent of physical activity, longer sedentary time and bouts are also associated with higher risk of chronic diseases and all-cause mortality (Di et al., 2017; Diaz et al., 2017; Powell et al., 2019); there is also strong evidence that higher amounts of self-reported exercise, or intentional physical activity, is associated with higher optimism (Boehn et al., 2013; Kim et al., 2019; Progovac et al., 2017) and higher positive affect (Arent et al., 2000; Kim et al., 2019). However, the most commonly-used positive affect measures capture active, energetic states. Pressman et al. (2020) confirmed that the overlap with these "active, energetic" items and self-reported exercise scales can lead to overstatement of the size of the associations. Therefore, past research investigating the benefits of positive emotions on health may have been driven partially or primarily by physical activity, not emotion (Petrie et al., 2018). These issues highlight why the use of accelerometer-measured physical activity and validated positive affect measures without the high energy components are needed to advance our understanding of how these constructs are related.

Although it is well-established that more physical activity and less sedentary behavior reduce the risk for depression (Ku et al., 2018; Loprinzi, 2013; Schuch et al., 2020), the relationships between physical behaviors with psychological well-being in older populations have generally been modest or null. In addition to including positive affect measures with high energy components (e.g., Positive and Negative Affect Schedule (PANAS)), most studies with observed associations used constructed categories for optimism and positive affect (e.g., low vs high) and measured physical behavior through self-reported questionnaires (Carriedo et al., 2020; Pasco et al., 2011; Progovac et al., 2017), which tend to be inaccurate for physical behavior measurement because of recall difficulty (LaMonte et al., 2019). Additionally, most studies that measure physical behaviors with accelerometers use different psychological well-being measures, which include one or several combined aspects (e.g., optimism, positive affect, negative affect, quality of life, life satisfaction), making it difficult to compare results (Black et al., 2015; Buman et al., 2010; Chen et al., 2021; Fox et al., 2007). Thus, to better understand the association between physical behavior and optimism and positive affect in older women, studies are needed that use objective measures of physical behavior and validated measures of these two constructs specifically.

These associations also may vary across demographics and psychosocial constructs. Physical activity levels are strongly dependent on age, and notably decline around menopause in women (Champagne et al., 2008; Martin et al., 2014). Physical activity and sedentary behavior also differ by race and ethnicity in older women (LaCroix et al., 2017); the context of physical movement may vary by race and ethnicity because daily life activities are influenced by culture and ethnic heritage. Optimism and positive affect could also differ across race and ethnicity; in past studies, optimism was slightly lower in Latina women than White or Black women (Progovac et al., 2019). Furthermore, systemic racism could have an impact on optimism and positive affect levels, as perceptions of racism and discrimination have been shown to affect positive affect (Ong & Edwards, 2008). Since older women live with different levels of social support and a significant proportion of older women live with chronic diseases (Salive, 2013; Ward & Schiller, 2013), it is important to understand whether and how associations of physical behavior with optimism and positive affect differ by these factors.

This cross-sectional study explored the relationship between accelerometer-measured physical behavior (i.e., moderate-vigorous physical activity, light physical activity, sitting time, and mean sitting bout duration) with optimism and positive affect in older women within the Women's Health Initiative Objective Physical Activity and Cardiovascular Health (OPACH) study. In the present study, optimism and positive affect measures have been previously validated and do not include "active, energetic" items, reducing the likelihood of capturing physical behavior. This is an important and unique aspect of our study; to confirm and extend the current knowledge about these relationships in older women, an understudied population. Previous studies using self-reported physical activity and well-being measures with self-report scales that overlap with physical activity and physical health and do not include low-activated moods may have overstated associations between well-being and physical activity. We hypothesized that higher amounts of accelerometer-measured physical activity and lower amounts of sedentary behavior are associated with higher optimism and positive affect without high energy components in older women. Additionally, we assessed effect modification (by age, race and ethnicity, social support, and number of chronic conditions) on the associations of physical behavior with optimism and positive affect. We hypothesized that associations would be stronger in magnitude among women with higher age, less social support, and higher number of chronic diseases.

2 Methods

2.1 Study Description and Design

Unless stated otherwise, data for this cross-sectional investigation were collected in 2012–2015 from participants enrolled in the Women's Health Initiative (WHI) Objective Physical Activity and Cardiovascular Health (OPACH) ancillary study. Details about WHI have been published elsewhere (WHI Study Group, 1998). Briefly, the WHI enrolled postmenopausal women, aged 50 to 79 years old, from 40 clinical sites across the United States between 1993 and 1998 (WHI Study Group, 1998). The Long Life Study (LLS) was developed as part of the second WHI Extension Study to support healthy aging research and included an in-home assessment of height, weight, physical function, and other measures (LaCroix et al., 2017). Non-Hispanic Black and Hispanic/Latina women were oversampled and comprise half the OPACH cohort of 7875 women. Participants from LLS were also invited to participate in OPACH at the time of consent. OPACH is a prospective study of accelerometer-measured physical activity and chronic disease outcomes that consented 7048 ambulatory, community-dwelling, WHI participants aged 63 to 99 years (LaCroix et al., 2017).

From the OPACH study, 6489 women returned accelerometers with usable data; data from those with less than 4 days of 10 or more waking hours of wear time ($n=363$) and from one participant with exceptionally high moderate-to-vigorous physical activity ($n=1$) were excluded. Additional exclusions came from participants who did not return the questionnaire measuring optimism and positive affect ($n=982$) or returned the questionnaire with missing data for these measures ($n=975$). See Fig. 1 for more detail. There was a slight temporal difference with optimism and positive affect measurements collected after the accelerometer data. Because of the temporal difference and the original intent to investigate the associations between physical behavior (including physical activity and sedentary behavior) as exposures and the two psychosocial parameters as outcomes, physical behaviors were examined as the study exposures and optimism and positive affect were examined as the study outcomes. However, the study design was considered cross-sectional because data collection occurred reasonably close in time.

For the present study, 4168 participants with adherent accelerometer data and both outcome measures were included in analyses. The Fred Hutchinson Cancer Research Center institutional review board approved protocols for the Long Life Study and OPACH, and UC San Diego's IRB approved subsequent OPACH data analyses. All women provided informed consent either in writing or orally by telephone.

2.2 Measures

2.2.1 Exposure Measurement: Physical Behavior

Physical behavior measures included physical activity and sedentary behavior. Physical activity intensity and duration were operationalized with measures of moderate-vigorous physical activity (MVPA) (mean hours/day) and light physical activity (LPA) (mean hours/day). Sedentary behavior duration and patterns were operationalized with measures of sitting time (mean hours/day) and mean sitting bout duration (MBD) (minutes).

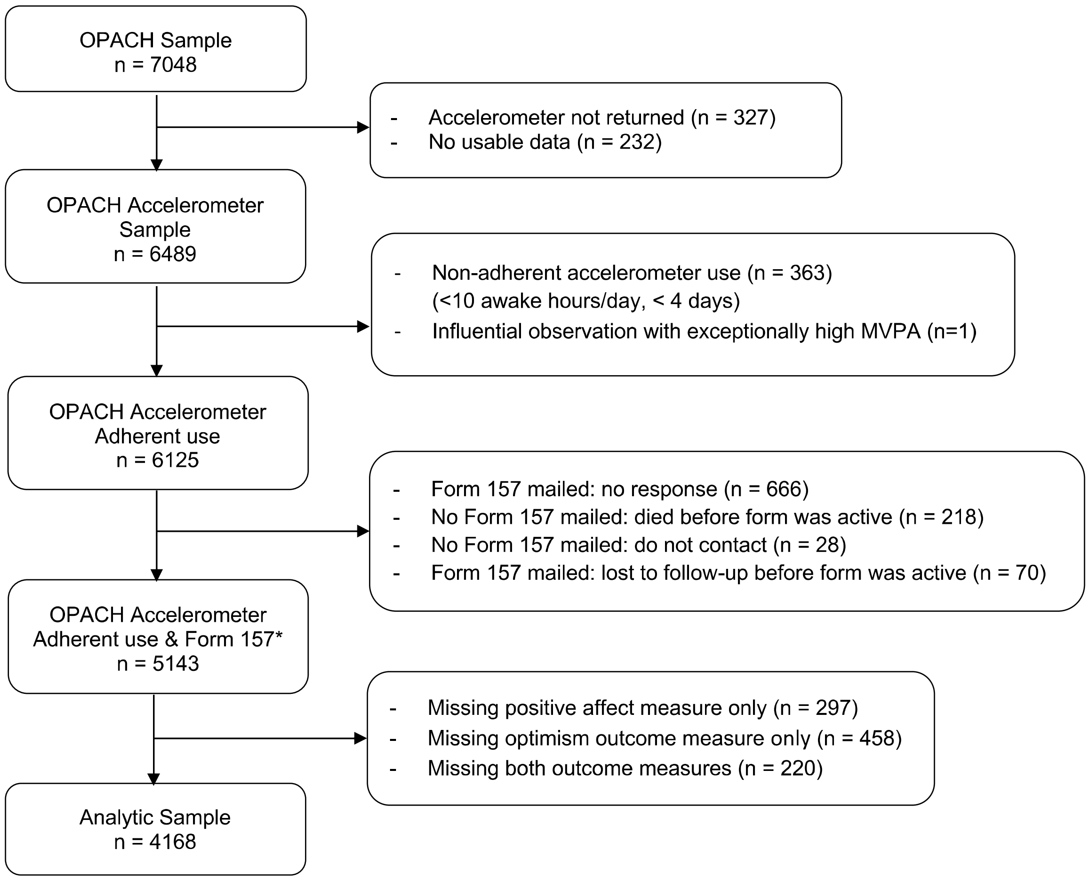

Fig. 1 Strobe Diagram for Physical Activity and Sedentary Behavior Data in OPACH Study (2012–2014) and Optimism, and Positive affect Outcome Measures (2014–2015) in WHI. Form 157 questionnaire included Optimism and Positive Affect Outcome Measures

Physical activity measures included MVPA, LPA, and total physical activity. Between March 2012 to April 2014, the OPACH study provided an ActiGraph GT3X + triaxial accelerometer (ActiGraph Corp; Pensacola, Florida) to be worn over the right hip 24 h per day for 7 days, except when the device could be submerged in water (e.g., bathing, swimming) (LaCroix et al., 2017), and participants concurrently kept sleep logs of their in-bed and out-of-bed times each night. Accelerometer data were originally collected at 30 Hz and then integrated to 15-s epochs using the normal-frequency filter within ActiLife version 6 software (ActiGraphcorp.com). Accelerometer non-wear periods were identified and removed using the Choi algorithm (Choi et al., 2011). Sleep time was removed using reported in-bed and out-of-bed times from sleep logs. Missing bedtimes were imputed using participant-specific mean times or, if all data were missing, the OPACH population mean (Bellettiere et al., 2020). Variation in physical activity time due to differences in accelerometer awake wear time was addressed using the residualized method (Willett & Stampfer, 1986).

Accelerometers were calibrated specifically for older women in a separate laboratory study of 200 women from the same OPACH population (Evenson et al., 2015). MVPA, defined as activity requiring 3.0 or more metabolic equivalents, was measured as the mean number of minutes per day with vector magnitude counts per 15-s epoch of at least 519. LPA was computed as the mean number of minutes per day with sufficient movement that the vector magnitude counts per 15-s epoch were between 19 and 518 (Evenson et al., 2015). Total physical activity is the sum of MVPA and LPA. As recommended, physical activity measures were computed as the mean hours per day using data from days with 10 or more hours of awake wear time (Migueles et al., 2017).

Sedentary behavior included sitting time and sitting patterns (defined as mean sitting bout duration). Sedentary behavior measures were computed using output from machine learning algorithms that were trained among adults specifically to measure sitting behavior. These models were built on our previous work leveraging artificial intelligence along with concurrently collected pictures taken every 10 s and accelerometer data measured 30 times per second to identify sitting, standing, walking, riding a bike, and riding in a vehicle (Ellis et al., 2014). These early models were optimized for use among all adults (Rosenberg et al., 2017), further refined to specifically pinpoint transitions between sitting and standing that enable more accurate measurement of sitting patterns (Greenwood-Hickman et al., 2021; Kerr et al., 2018; Nakandala et al., 2021) and recently retrained using data from over 981 men and women. In a hold-out test sample of 421 adults, the new models exhibited an average sensitivity of 95.3% and specificity of 89.8% for predicting sitting time, when ground truth sitting time was measured using the current standard for ambulatory measurement of sitting (activPAL thigh-worn inclinometer; data not yet published but available upon request). From these data, the average amount of time spent sitting each day was used to measure total sitting time computed as mean hours per day. Consecutive minutes of sitting were classified as sitting bouts (with no minimum requirement and no tolerance) and the mean sitting bout duration was used to measure sitting accumulation patterns.

2.2.2 Outcome Measurement: Optimism and Positive Affect

Optimism was assessed between August 2014–2015 using the *Revised 6-item Life Orientation Test (LOT-R)* (Scheier & Carver, 1985; Scheier et al., 1994) composed of six items relating to their expectations of the future (*"In unclear times, I usually expect the best"; "If something can go wrong for me, it will"; "I'm always hopeful about my future"; "I hardly ever expect things to go my way"; "I rarely count on good things happening to me"; and "Overall, I expect more good things to me than bad"*) scored on a five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). The 3 pessimism items were reverse-coded, and all 6 items were summed to generate a summary score that ranged from 6 (low) to 30 (high), with higher scores indicating greater optimism. The scale initially yielded Cronbach's alpha of 0.78, test–retest reliability of 0.79 at 28 months, and good discriminant and convergent validity on a sample of undergraduate students (Scheier et al., 1994). In populations of older post-menopausal women, psychometric assessments demonstrated good internal consistency (Cronbach's alpha = 0.75) (Kim et al., 2019) and test–retest reliability (0.61 over a 4-year period) (Chopik et al., 2015). Further, a recent WHI study, which included this study's participants, also confirmed good reliability and validity (Cronbach's alpha = 0.79) (Posis et al., 2021).

Positive Affect was measured between August 2014–2015 using the 9-item *modified Differential Emotions Scale (mDES)* (Fredrickson, 2013) composed of past 24-h intensity ratings for nine emotions (*amusement, awe, gratitude, hope, interest, joy, love, pride, and serenity*) scored on a five-point Likert scale from 1 (not at all) to 5 (very much). All rated items were summed to generate a summary score that ranged from 9 (low) to 45 (high), with higher scores indicating greater positive affect. Negative affect items of the mDES were not assessed in the WHI-OS. A recent mDES assessment successfully measured positive affect with good reliability and validity (including a Cronbach's alpha = 0.9) in the WHI cohort (Posis et al., 2021).

2.2.3 Covariates

Confounding, effect-modification, and mediating variables were identified a priori based on published literature. Covariates were measured at OPACH baseline or by the WHI questionnaire completed closest to and before the OPACH baseline.

Socio-demographic variables that were associated with physical behavior and well-being measures were controlled for in our study. *Age* at OPACH baseline was computed based on the first day of accelerometer wear. Other covariates were categorized as follows: *race and ethnicity* (Non-Hispanic White, Non-Hispanic Black, or Hispanic/Latina); *highest level of education attained* (≤ high school, some college, or college graduate).

Health-related variables were also controlled for in our study. Behavioral measures included *current smoking* (yes, no) and *alcohol use* (never, < 1 per week, 1–2 per week, 3–4 per week, 5–6 per week, everyday). Mental health-related measures included *live alone* (yes, no), *social support* (Medical Outcomes Study (MOS): range 9 [low] – 45 [high]) (Sherbourne & Stewart, 1991); *sleep disturbance* (range 0 [low] – 20 [high]) (Levine et al., 2003); *pain* (SF-36 pain 2-item construct range 0– 100 [higher score indicates a more favorable health state with respect to pain]) (Ware & Sherbourne, 1992); and *depression symptoms* (8-item Burnam screening instrument): 0–1 range [higher score indicates a greater likelihood of depression] was dichotomized at 0.06 (Burnam et al., 1988). Physical and medical measures were also included. *Body mass index* (BMI), calculated by dividing weight measured by a calibrated analog scale in kg by square of height in meters measured by a stadiometer. The *Short Physical Performance Battery* (SPPB), a measure of lower extremity physical function, assessed through a series of objective physical tests of balance, gait speed, strength, and endurance (Guralnik et al., 1994) were obtained from in-home visits. *Antidepressant use* included 2012 current use of the following medication classes: tetracyclics, monoamine oxidase inhibitors (MAOIS), modified cyclics, selective serotonin reuptake inhibitors (SNRIS), tricyclic agents, and miscellaneous antidepressants. *Number of chronic conditions* at OPACH baseline was characterized using outcomes ascertained by self-report and physician adjudication (0, 1, 2, 3 +, or undetermined categories) including the following 11 chronic conditions that are recognized to be highly prevalent and burdensome to older women: cancer, cerebrovascular disease, cognitive impairment, cardiovascular disease, diabetes, frequent falls, chronic obstructive pulmonary disease, osteoarthritis, depression, urinary incontinence, and sensory impairment. *Multimorbidity* is defined as having at least two chronic conditions and has been operationalized as having two or more chronic conditions from the list of 11 (Rillamas-Sun et al., 2016).

2.2.4 Statistical Analyses

Descriptive data for baseline characteristics were summarized by quartiles of total physical activity. Differences by quartile of total physical activity were evaluated by analysis of variance (ANOVA) for continuous variables and chi-square tests for categorical variables.

To justify reporting single beta (β) coefficients for the entire distribution, we tested linearity by overlaying conditional linear and non-linear polynomial regression models minimally adjusted for age and race and ethnicity with 95% confidence interval (CI) bands on scatterplots for each association. Form, direction, strength, and the presence of outliers between the exposure and outcome variables were visually inspected.

Associations of physical behavior as the independent variable with optimism and positive affect as the dependent variable were tested using multiple linear regression in models that were progressively adjusted as follows: Model 1 included age and race and ethnicity. Model 2 additionally adjusted for socio-economic and lifestyle behavior confounders: educational attainment, current smoking, and alcohol use. Model 3 was the main confounder-adjusted model and included Model 2 covariates and living alone, social support, sleep disturbance, and pain. In addition to Model 3 covariates, Model 4 includes the following measures, which we believe are potential mediators but could also be classified as confounders: BMI, number of chronic diseases, depression symptoms, antidepressant use, and SPPB. Although mediation analysis was not possible in this cross-sectional study, we adjusted for potential mediators to assess their impact on Model 3. To assess potential bias from missing covariate data, we generated results using multiple imputation by chained equations (MICE) implemented with the *mice* package in R based on 15 imputations and 30 iterations (Van Buuren & Groothuis-Oudshoorn, 2011). Residual plots for linearity, constant variance, and normality were reviewed and variation inflation factors were assessed for multicollinearity. No evidence against using multiple linear regression was observed.

Effect modification was tested by including multiplicative interaction terms in the main model (Model 3) between the exposure and each potential effect modifier that was selected a priori based on literature: women <80 and ≥ 80 years old, race and ethnicity, social support <40 and ≥ 40 (median split), and multimorbidity status (no $=$ 0–1 and yes $=$ 2 $+$ chronic conditions). For visualization of differential associations by subgroups, models were repeated, stratified by each potential modifier, and results with p-for-interactions <0.20 were highlighted. All analyses were conducted in RStudio version 3.6.1 (RStudio, Inc. Boston, MA USA) and statistical tests were two-tailed with $\alpha = 0.05$ and 95% confidence intervals.

2.2.5 Sensitivity Analyses

To assess potential selection bias, baseline characteristics were compared among the analytic sample ($n = 4168$) and accelerometer-adherent participants who were missing outcome measures ($n = 1957$) using ANOVA for continuous variables and chi-square tests for categorical variables. To assess potential for bias due to missing covariate data, multiple linear regression results generated by models using multiple imputation were compared to results generated with models using complete case analysis.

We evaluated whether the overall optimism score acted as single bipolar dimension or two separate dimensions by examining the LOT-R optimism and pessimism subscales as outcomes (Carver & Scheier, 2014; Scheier et al., 2021). Results from multivariable linear regression models of physical behavior with each LOT-R subscale were compared to results from models in which the overall optimism score was the outcome.

3 Results

Study participants exhibited the following median physical behavior patterns: 0.8 h/day moderate-vigorous physical activity (MVPA), 4.8 h/day light physical activity (LPA), 10.2 h/day sitting time, and 11.8 min mean sitting bout duration (MBD) with median

Table 1 Baseline characteristics by Quartile of Time Spent in Total Physical Activity (2012–2015), Women's Health Initiative (WHI) Objective Physical Activity and Cardiovascular Health ancillary study (OPACH) ($n = 4168$)

Characteristics	Quartiles (Q) of Total Physical Activity[a] (hours/day)				
	Q1 (low)	Q2	Q3	Q4 (high)	*p*-value
Total physical activity[a] (h/d), *mean (SD)*	3.8 (0.6)	5.2 (0.3)	6.1 (0.3)	7.6 (0.8)	NA
Age (years), *mean (SD)*	80.3 (6.5)	78.2 (6.5)	77.6 (6.5)	76.1 (6.1)	< 0.01
Race and Ethnicity, *n (%)*					< 0.01
Non-Hispanic White	651 (62.5)	536 (51.4)	501 (48.1)	424 (40.7)	
Non-Hispanic Black	277 (26.6)	342 (32.8)	335 (32.1)	361 (34.6)	
Hispanic/Latina	114 (10.9)	164 (15.7)	206 (19.8)	257 (24.7)	
Highest education, *n (%)*					0.07
High school or less	180 (17.4)	200 (19.4)	192 (18.6)	211 (20.3)	
Some college	425 (41)	398 (38.6)	364 (35.2)	373 (35.9)	
College graduate or more	431 (41.6)	432 (41.9)	479 (46.3)	455 (43.8)	
Current smoker, *n (%)*	37 (3.8)	25 (2.5)	25 (2.5)	19 (1.9)	0.07
Alcohol consumption, *n (%)*[b]					< 0.01
Never	385 (39.5)	362 (36.7)	326 (32.6)	300 (30.2)	
< 1 per week	358 (36.7)	369 (37.4)	357 (35.7)	327 (32.9)	
≥ 1 per week	232 (23.8)	255 (25.9)	316 (31.6)	367 (36.9)	
Live alone, *n (%)*	531 (55.9)	435 (45.3)	404 (42.5)	365 (38.0)	< 0.01
Social support, *mean (SD)*	36.9 (7.8)	37.8 (7.7)	37.9 (7.5)	38 (7.4)	< 0.01
Sleep disturbance, *mean (SD)*	7.4 (4.7)	7.1 (4.7)	7.3 (4.7)	6.9 (4.5)	0.08
Pain[c], *mean (SD)*	62.3 (27.6)	65.2 (25.5)	68.4 (24.2)	71.8 (22.7)	< 0.01
BMI (kg/m2), *mean (SD)*	30.3 (6.1)	28.8 (5.6)	27.4 (5.3)	26.1 (4.7)	< 0.01
Chronic Conditions[d]					< 0.01
0 or 1	493 (47.5)	562 (54)	575 (55.3)	683 (65.6)	
2 or 3 +	545 (52.5)	478 (46)	464 (44.7)	358 (34.4)	
Depression symptoms[e], *n (%)*	60 (6.4)	54 (5.7)	55 (5.8)	46 (4.8)	0.52
Antidepressant use, *n (%)*	153 (14.7)	122 (11.7)	104 (10)	93 (8.9)	< 0.01
Physical function (SPPB), *mean (SD)*	7.6 (2.6)	8.5 (2.3)	8.8 (2.2)	9.2 (2.2)	< 0.01

$^*p < .05$: ANOVA for continuous variables and chi-squared for categorical variables, [a]Adjusted for accelerometer awake wear time using residuals method. Total Physical Activity is the sum of Moderate-Vigorous Physical Activity and Light Physical Activity, [b]Full variable categorization (never, < 1/week, 1–2/week, 3–4/week, 5–6/week, everyday) used for models and *p*-values, [c]Higher pain score indicates less pain, [d]Sum of cancer, cerebrovascular disease, cognitive impairment, sensory impairment, cardiovascular disease, chronic obstructive pulmonary disease, diabetes, frequent falls, urinary incontinence, depression, and osteoarthritis. Full variable categorization (0, 1, 2, 3 +) used for models and *p*-values., [e]Shortened Center for Epidemiologic Studies Depression Scale (CES-D), ≥ 0.06 categorized as depression symptoms

h/d: hours/day, *SD*: Standard deviation, NA: not applicable, *BMI* body mass index (calculated as weight in kilograms divided by height in meters squared), *SPPB*: Short physical performance battery, WHI: Women's health initiative

optimism scores of 24 (SD = 3.6) and median positive affect scores of 34 (SD = 6.1). Table 1 shows baseline characteristics for our sample of 4168 women [age range 63–99, mean = 78.1 ± 5.7 years] by quartile of time spent in total physical activity. Approximately half the women (50.7%) self-identified as non-Hispanic White, 31.5% as non-Hispanic

Black, and 17.8% as Hispanic/Latina. Women in the highest total physical activity quartile were younger (76.1 ± 6.1) and less likely to self-identify as non-Hispanic White (40.7%), non-drinkers (30.2%) and live alone (38.0%). Those in the highest quartile also had fewer chronic conditions (66% had less than 2), lower BMI (26.1), higher physical function (SPPB scores 9.2), and reported less relative pain (71.8) and anti-depressant use (8.9%).

Results from linear regression models were reported as single beta coefficients for the entire distribution after visual inspection showed that associations of physical behavior with optimism and positive affect were generally linear. For example, overlaying minimally adjusted linear and non-linear (polynomial with three knots) regression models resulted in overlapping 95% CI for each studied relationship (Fig. 2). Positive associations were-observed for MVPA (Pearson's correlation coefficient [$r_{optimism} = 0.11$, $r_{positive\ affect} = 0.08$]) and LPA and ($r_{optimism} = 0.04$, $r_{positive\ affect} = 0.06$), while negative associations were observed for sitting time ($r_{optimism} = -0.04$, $r_{positive\ affect} = -0.05$) and MBD ($r_{optimism} = -0.05$, $r_{positive\ affect} = -0.07$).

Table 2 provides results from progressively adjusted multiple linear regression models for optimism and positive affect separately regressed on each physical behavior. In Model 1, adjusting for age and race and ethnicity, positive associations were observed for MVPA and LPA, and negative associations were observed for sitting time and MBD. MVPA (mean hours/day) associations were stronger than LPA (mean hours/day) associations for optimism with $\beta = 0.6$ (95% CI = 0.42, 0.82) vs $\beta = 0.1$ (95% CI = 0.02, 0.20) and positive affect with $\beta = 0.7$ (95% CI = 0.39, 1.09) vs $\beta = 0.2$ (95% CI = 0.07, 0.38) respectively. Results remain statistically significant after adjustment in Model 2. After main-confounder adjusted Model 3, the LPA-optimism association was no longer statistically significant ($\beta = 0.07$ (95% CI = −0.02, 0.16); however, associations of MVPA with optimism and positive affect and the LPA-positive affect association remained significant. In summary, every one-hour increment in weekly moderate-vigorous physical activity was associated with

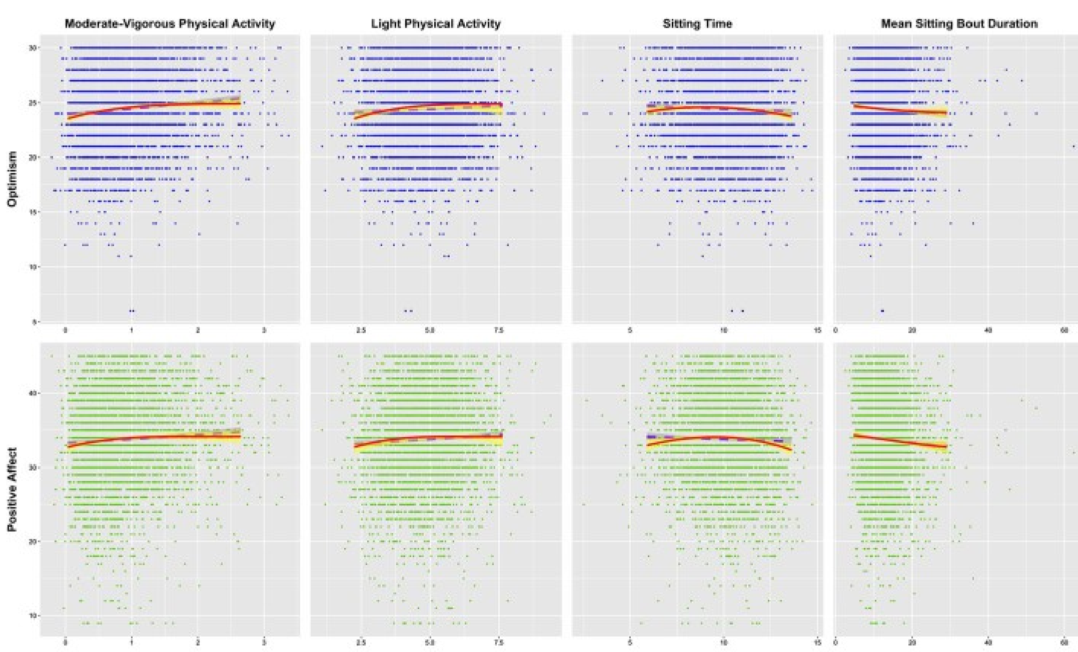

Fig. 2 Association of physical behavior with optimism and positive affect. Scatterplots with smoothed conditional linear and polynomial regression models trimmed at the 1st and 99th percentiles with 95% CI bands. Models were minimally adjusted for age and race and ethnicity

Table 2 Association of Accelerometer-measured Physical Behaviors (2012–2014) with Optimism and Positive Affect (2014–2015)[a] among Women's Health Initiative (WHI) Objective Physical Activity and Cardiovascular Health Study (OPACH), (n = 4168)

	MVPA (hours/day)			LPA (hours/day)			Sitting Time (hours/day)			MBD (minutes)		
	β	95% CI	*p*	β	95% CI	*p*	β	95% CI	*p*	β	95% CI	*p*
Optimism												
Model 1[b]	0.62	(0.42, 0.82)	< 0.01	0.11	(0.02, 0.20)	0.02	−0.09	(−0.15, −0.02)	0.01	−0.03	(−0.05, −0.01)	0.01
Model 2[c]	0.53	(0.33, 0.73)	< 0.01	0.11	(0.02, 0.20)	0.01	−0.08	(−0.15, −0.01)	0.02	−0.03	(−0.05, −0.01)	0.01
Model 3[d]	0.38	(0.19, 0.58)	< 0.01	0.07	(−0.02, 0.16)	0.13	−0.03	(−0.10, 0.03)	0.30	−0.02	(−0.04, 0.01)	0.14
Model 4[e]	0.25	(0.05, 0.45)	0.01	0.01	(−0.08, 0.11)	0.76	0.02	(−0.05, 0.09)	0.60	0.00	(−0.02, 0.02)	0.89
Positive affect												
Model 1[b]	0.74	(0.39, 1.09)	< 0.01	0.23	(0.07, 0.38)	0.01	−0.14	(−0.26, −0.03)	0.01	−0.07	(−0.11, −0.03)	< 0.01
Model 2[c]	0.74	(0.39, 1.09)	< 0.01	0.25	(0.09, 0.41)	0.00	−0.15	(−0.27, −0.04)	0.01	−0.08	(−0.11, −0.04)	< 0.01
Model 3[d]	0.55	(0.21, 0.89)	< 0.01	0.18	(0.03, 0.33)	0.02	−0.09	(−0.20, 0.02)	0.10	−0.06	(−0.10, −0.02)	< 0.01
Model 4[e]	0.50	(0.16, 0.85)	< 0.01	0.21	(0.05, 0.37)	0.01	−0.09	(−0.21, 0.02)	0.12	−0.06	(−0.10, −0.02)	< 0.01

[a]Results were generated by models implemented using multiple imputation by chained equations to prevent covariate missing data bias., [b]Model 1: age, race and ethnicity, [c]Model 2: Model 1 covariates, educational attainment, smoking, alcohol use,[d]Model 3 (Main model or confounder-adjusted model): Model 2 covariates, live alone, social support, sleep disturbance, pain, [e]Model 4: Model 3 covariates, BMI, number of chronic diseases, depression symptoms, anti-depressant use, physical functioning (SPPB), $^{*}p < .05$

MVPA: Moderate-vigorous physical activity, *LPA*: Light physical activity, *MBD*:Mean sitting bout duration, *CI*: Confidence interval higher optimism by 0.4 score points [Revised 6-item Life Orientation Test, 95% CI = 0.2, 0.6] and positive affect by 0.6 score points [modified Differential Emotions Scale, 95% CI = 0.2, 0.9]. One-hour increments in LPA were associated with higher positive affect [0.2 score points; 95% CI = 0.03, 0.33]. Associations for these statistically significant relationships (i.e., MVPA with optimism, MVPA and LPA with positive affect) remained after further adjustment with covariates that were hypothesized to be potential mediators and/or confounders (Model 4). For sedentary behavior, sitting time and MBD were associated with lower optimism and positive affect in Model 1, adjusting for age and race and ethnicity. After additional adjustment of Model 3 confounders, the sedentary behavior and optimism associations remain negative, but were no longer statistically significant. For positive affect, a statistically significant negative association remained for MBD ($\beta = -0.06$, 95% CI = −0.10, −0.02), but not for sitting time, after Model 3 adjustments. The inverse MBD-positive affect association remained statistically significant after further adjustment for hypothesized mediators in Model 4.

Table 3 illustrates the magnitude of associations of marginal means from Model 3, which were reported for optimism and positive affect global scores at 25th, 50th, and 75th distribution percentiles for each physical behavior. Each higher increment in quartile of MVPA estimated a 0.1–0.2 higher LOT-R optimism score. Other physical behaviors show virtually no difference in optimism from the 25th to 75th percentiles. For positive affect, each higher increment in quartile of physical activity estimated a 0.1–0.2 higher mDES score, and each higher increment in quartile of sedentary behavior estimated a 0.1–0.2 lower mDES score.

Table 3 Adjusted means of Optimism and Positive Affect at select percentiles of Physical Behavior Metric Distributions

Average	Optimism Score Adjusted Mean (95% CI)	Positive Affect Score Adjusted Mean (95% CI)
MVPA, hours/day		
25th percentile: 0.5	24.9 (24.5, 25.2)	33.4 (32.8, 33.9)
50th percentile: 0.8	25.0 (24.7, 25.3)	33.5 (33.0, 34.0)
75th percentile: 1.2	25.2 (24.9, 25.5)	33.7 (33.2, 34.2)
LPA, hours/day		
25th percentile: 4.0	25.0 (24.7, 25.3)	33.4 (32.9, 34.0)
50th percentile: 4.8	25.0 (24.7, 25.3)	33.6 (33.1, 34.1)
75th percentile: 5.6	25.1 (24.8, 25.4)	33.8 (33.3, 34.3)
Sitting time, hours/day		
25th percentile: 9.0	25.1 (24.8, 25.4)	33.8 (33.2, 34.3)
50th percentile: 10.2	25.1 (24.8, 25.4)	33.6 (33.1, 34.2)
75th percentile: 11.3	25.1 (24.7, 25.4)	33.5 (33.0, 34.0)
MBD, minutes		
25th percentile: 9.2	25.1 (24.8, 25.4)	33.9 (33.3, 34.4)
50th percentile: 11.8	25.1 (24.8, 25.4)	33.7 (33.2, 34.2)
75th percentile: 15.0	25.0 (24.7, 25.3)	33.5 (33.0, 34.0)

MVPA: Moderate-vigorous physical activity, *LPA*: light physical activity, *MBD*: Mean sitting bout duration, *CI*: Confidence interval

Estimates are based on linear regression models that include adjustment for all Model 3 covariates: age, race and ethnicity, educational attainment, smoking, alcohol use, live alone, social support, sleep disturbance and pain

We did not observe statistically significant effect modification by age, race and ethnicity, social support, and number of chronic conditions (Appendix 1). However, when separately reviewing groups with $p < 0.20$ for interactions, we observed β of 0.8 (95% CI = 0.43, 1.09) for those ≥ 80 years old and 0.3 (95% CI = 0.06,0.58) for those < 80 years old for MVPA and optimism (*p*-for-interaction = 0.09), and β of –0.75 (95% CI = −0.42,–0.08) for those ≥ 80 years old and 0.00 (95% CI = −0.17,0.16) for those < 80 years old for the association between sitting time and positive affect (*p*-for-interaction = 0.16).

3.1 Sensitivity Analysis

Women missing data on optimism or positive affect, and therefore excluded from our study, (n = 1957) were older (80.1 ± 6.7 vs 78.1 ± 6.6 years) with lower total physical activity (5.5 ± 1.5 vs 5.7 ± 1.5 mean hours/day) and were more likely to be non-Hispanic Black (37.4 vs 31.5%), have three or more chronic conditions (28.4% vs 18.1%) and use antidepressants (13.5% vs 11.3%) (Appendix 2).

Optimism measure subscale analyses illustrated that neither the optimism subscale or positive affect subscale was driving the association between physical behavior and optimism (Appendix 3). Beta coefficients for the pessimism and optimism subscales separately represented approximately 50% of the full-scale optimism beta coefficient; therefore, we reported results for the full-scale optimism measure and present results for each subscale in the appendix.

4 Discussion

In this large, ethnically diverse, and well-characterized cohort of older women, higher amounts of MVPA were significantly associated with both higher optimism and higher positive affect independent of confounders. Higher amounts of LPA were associated with higher positive affect, and longer MBD was associated with lower positive affect, both relationships were significant and independent of confounders. However, contrary to our hypothesis, there were null associations for LPA, sitting time, and MBD with optimism and for sitting time with positive affect. Notably, all observed associations were modest in magnitude. Further inclusion of potential mediators (i.e., BMI, chronic disease, depression symptoms, anti-depressant use, SPPB) partially attenuated the full confounder-adjusted results for MVPA and optimism and minimally attenuated positive affect associations, but these associations remained statistically significant, indicating that mediation through these covariates do not fully explain the observed findings. In summary, although limited attenuation of these covariates suggests that higher amounts of MVPA being associated with higher optimism and higher positive affect can be partially explained by mediation, the persistence of an association after adjustment of these covariates indicate other mechanisms may exist.

This study extends the emerging literature on the associations of accelerometer-measured physical behaviors with psychosocial measures of well-being by focusing on older women, an understudied population. Although studies have shown modest to null associations between physical behaviors (typically measured by self-report) and well-being measures in older women, confirmation of these relationships using accelerometer-measured physical behaviors with optimism and positive affect measures without high energy components warranted investigation.

Previous findings on the associations of physical behavior with optimism and positive affect show small or null effects with accelerometer-measured physical behavior (Black et al., 2015;

Buman et al., 2010; Chen et al., 2021; Fox et al., 2007). Consistent with the bulk of the literature, our study demonstrated a mix of modest and null associations between study exposures and outcomes. It is important to note that psychological well-being is often measured differently across studies, and this variation in measurement could be a source of inconsistent findings that are observed in the literature. Psychological well-being measures may include one or several combined aspects of well-being (e.g. optimism, presence of positive affect, absence of negative affect, quality of life, life satisfaction) and may also define and measure the aspects differently; there is currently no standard measure for psychological well-being and researchers should understand the limitations and not assume interchangeability of the various measures.[11] As previously mentioned, two studies that used accelerometer-measured PA in older adults and different measures of well-being came to contradictory conclusions: one found a positive relationship between psychosocial well-being (life satisfaction) and LPA but no relationship with MVPA (Buman et al., 2010). In contrast, another study demonstrated no association for accelerometer-measured LPA, weak positive associations for MVPA, and weak negative associations for sedentary time with measures that included combined aspects of well-being and some measures of positive affect (Fox et al., 2007). Notably, the overall findings of the latter, a randomized control study of older adults, were relatively consistent with our study. Universal acceptance and adoption of a standard psychological well-being measure would be beneficial for comparing results across studies.

Physical behavior assessed with different types of self-report and accelerometer measurements may also be a source of inconsistency in the literature. Self-reported physical behaviors are typically operationalized by activities that are easily recalled (e.g., leisure vigorous activity, commute sitting times); therefore, self-reported physical activity measures may reflect exercise (e.g., vigorous walking, tennis, swimming) and may not reliably capture other common forms of daily life movement (e.g., gardening, cooking, babysitting grandchildren) (LaMonte et al., 2019). Compared to self-reported physical activity, accelerometer-measured physical behavior can more accurately measure a broader suite of physical behaviors, particularly LPA and sitting time, and includes both intentional exercise and all other forms physical activity (LaMonte et al., 2019). However, except for sleep time, accelerometer-measured physical behavior is typically not linked to situational context. As observed by LaMonte et al. (2019), self-reported and accelerometer-measured physical behavior are related but typically capture different aspects of the human movement construct.

Other studies support the likelihood that domains for physical behaviors are an important determinant in the association between physical behavior with optimism and positive affect. Pressman observed that positive affect was positively associated with the frequency in participating in enjoyable leisure activities (e.g., spending quiet time alone, socializing with others, and hobbies) (Pressman et al., 2009). Research also suggests that intentional exercise and non-exercise physical activity may convey independent well-being benefits. For example, Whitehead and Blaxton (2017) found that among older adults, duration of purposeful exercise was linked to daily positive affect, and although non-exercise physical activity was also associated with positive affect, the association was less and did not depend on activity time. The situational context of physical behaviors has an impact on psychosocial well-being and could help explain inconsistencies in evaluating physical behaviors and positive well-being measures.

In the present study, LPA was positively associated, and sedentary behaviors were negatively associated with positive affect but these physical behavior exposures were not associated with optimism. The differences in associations between physical behavior with positive affect and optimism may be attributed to the more modifiable nature of the positive affect compared to optimism, particularly as personality is typically considered to be more stable in older adulthood (Roberts et al., 2006). As observed in previous studies, significant life transitions and intense interventions may modify optimism (Carver et al., 2010). Our results lead to speculation that more intense physical activity (e.g., MVPA) may be needed to change optimism, whereas less intense physical behavior changes (e.g., more LPA, less sitting time) may be sufficient to increase positive affect (Fredrickson, 2013)—future studies are needed to test these hypotheses.

Despite the fact that associations between physical behavior with optimism and positive affect were small, it is important to consider the longer-term power of the upward spiral effect of healthy behaviors on positive emotions and the reciprocal nature of positive emotions on healthy behaviors. The upward spirals of positive emotions reinforce lifestyle change with increased positive health behaviors for better health and more resilience through a range of biologically and psychological resources, which protect against negativity (Fredrickson, 2013). As explanation for the mechanism behind the upward spiral effect, behavioral neuroscience postulates that increases in positive affect can create a "liking" of the positive health behavior which unconsciously becomes desire to increase the health behavior (Fredrickson, 2013). Similar to Fredrickson's (2013) broaden and build theory, Chopik et al. (2015) hypothesizes that increases in optimism may affect health and health behavior with a similar upward spiral mechanism. This is critical in older women, particularly among the oldest-old, because aging-related processes (e.g. declining health, fewer social connections, and the declining material resources) (Chopik et al., 2015), mortality-related processes (e.g. low levels of cognitive and physical functioning) (Chopik et al., 2015), and the "sobering up theory," which posits that older adults tend to lower expectations as they perceive death is approaching (Sweeny & Krizan, 2013), can lead to declines in optimism and well-being (Chopik et al., 2015).

4.1 Limitations

While the cross-sectional nature of this study prevented disentangling the complicated and likely bidirectional relationship between physical behavior with optimism and positive affect, measurement of physical behavior one to two years, on average, prior to optimism and positive affect measurement may lessen overestimation due to reverse causality. Evidence supporting a bidirectional relationship between physical behaviors and positive affect exists. For example, Gibbs et al. (2021) observed mid-life bidirectionality for associations between MVPA and mental component scores (MCS), which included several positive affect measures; baseline MCS had a stronger impact on 10-year change in MVPA compared to baseline MVPA's effects on 10-year change in MCS. It is also possible that a bidirectional relationship between physical behavior and optimism exists.

Although exposure and outcome measures were captured at one period of time, single time measurements can effectively and efficiently represent usual physical behaviors, optimism, and positive affect. Physical behavior measured with a single, 7-day accelerometer monitoring period has been shown to be a reliable measure of two- to three-year usual physical activity and sedentary behavior patterns in older women (Keadle et al., 2017). However, having a single measure of PA prevented us from evaluating how changes in PA, which may represent a major life change, could be associated with changes in optimism and positive affect. Future studies of these relationships warrant repeated measures of PA. Studies also demonstrate that participant optimism levels are relatively stable (Carver et al., 2010) over a few weeks to 10 years with relatively high test–retest reliability ranging from 0.58 to 0.79 (Atienza et al., 2004; Matthews et al., 2004). Finally, research supports that state positive affect demonstrates statistical overlap with trait positive affect (Pressman et al., 2019).

There is mixed evidence that CES-D may vary by race and ethnicity (Mohebbi et al., 2018; Perreira et al., 2005), which means our confounding adjustment for depressive symptoms might be problematic. However, a strength of our study is that we not only include the CES-D short form but also include anti-depressant use, an indicator clinical depression.

4.2 Strengths

The OPACH study included a large cohort of postmenopausal women from multiple sites, races and ethnicities, and socioeconomic backgrounds, and this diversity expands the generalizability of our findings. Another strength of our study was the comprehensive inclusion of age-relevant, validated, and objective measures of physical behavior with 7-day accelerometer data. Notably, after robust adjustment with many confounders, associations persisted. Our study evaluated psychosocial well-being by using optimism and positive affect, specific outcome measures that were validated in the studied population, instead of broad definitions of well-being that may not be easily comparable across studies. Optimism measured by LOT-R is clearly defined and evaluated as a single bipolar measure and as two separate unidimensional measures of optimism and pessimism. Positive affect measured by mDES in our study overcomes limitations of other commonly used positive affect measures (e.g., PANAS, POMS, CES-D) by providing a balanced, wide range of positive emotions, not exclusively focusing on high arousal emotions (e.g., alert, excited, lively, energetic), and not including non-emotions items (e.g., strong, determined, active, self-esteem). Furthermore, our study measured a 24-h rating of positive affect, and research supports that 24-h ratings of positive affect are more accurate than recall of average and usual emotions (Fredrickson, 2013). Finally, to address potential selection bias due to covariate missingness, we used multiple imputation for missing data and compared associations generated with multiple imputed data to those generated using the complete-case analysis (Table 7), and minimal differences were observed. Given the relatively consistent associations, this suggests that the impact from selection bias was limited.

5 Conclusions

In summary, we observed small cross-sectional associations of MVPA with optimism, and of MVPA, LPA and MBD with positive affect. Future studies investigating associations of significant physical behavior changes in older women should measure physical behaviors at multiple time points with both objective measures and domains of physical behavior. Until physical behavior measures can simultaneously and accurately capture duration, intensity, patterns, and domain, our understanding of its impacts on psychosocial well-being will be incomplete. Although associations between physical behavior with optimism and positive affect were modest, older women should be encouraged to participate in higher levels of physical activity and lower levels of sedentary behavior because of general health benefits and potential beneficial associations with psychological well-being.

Appendix

See Tables 4, 5, 6, 7

Table 4 Stratified Models of Accelerometer-measured Physical Behaviors (2012–2014) with Optimism and Positive Affect (2014–2015), WHI OPACH

	MVPA (hours/day)				LPA (hours/day)				Sitting Time (hours/day)				MBD (minutes)			
	β[a]	95% CI	N	*p*-int	β[a]	95% CI	N	*p*-int	β[a]	95% CI	N	*p*-int	β[a]	95% CI	N	*p*-int
Total sample	0.41	(0.21, 0.62)	3444	-	0.03	(-0.06, 0.13)	3444	-	-0.02	(-0.09, 0.05)	3355	-	-0.01	(-0.04, 0.01)	3355	-
Optimism																
Age*				0.09				0.27				0.23				0.25
< 80	0.32	(0.06, 0.58)	1877		-0.01	(-0.15, 0.12)	1877		0.02	(-0.08, 0.12)	1828		0.00	(-0.03, 0.04)	1828	
≥ 80	0.76	(0.43, 1.09)	1567		0.11	(-0.02, 0.24)	1567		-0.08	(-0.18, 0.01)	1527		-0.03	(-0.06, 0.00)	1527	
Race/Ethnicity				0.46				0.42				0.45				0.77
White	0.42	(0.12, 0.71)	1768		0.08	(-0.05, 0.21)	1768		-0.06	(-0.15, 0.03)	1724		-0.02	(-0.05, 0.01)	1724	
Black	0.22	(-0.16, 0.60)	1073		0.01	(-0.15, 0.18)	1073		0.04	(-0.08, 0.17)	1042		0.00	(-0.04, 0.04)	1042	
Hispanic	0.77	(0.28, 1.26)	603		-0.09	(-0.34, 0.16)	603		-0.04	(-0.22, 0.14)	589		-0.02	(-0.10, 0.06)	589	
Social Support				0.49				0.15				0.89				0.58
Low	0.34	(0.04, 0.65)	1710		-0.04	(-0.18, 0.09)	1710		0.01	(-0.08, 0.11)	1661		-0.01	(-0.04, 0.02)	1661	
High	0.40	(0.10, 0.69)	1734		0.10	(-0.03, 0.24)	1734		0.01	(-0.09, 0.10)	1694		-0.02	(-0.05, 0.02)	1694	
Number of Chronic Conditions	0.37				0.37				0.26				0.54			

Table 4 (continued)

	MVPA (hours/day)				LPA (hours/day)				Sitting Time (hours/day)				MBD (minutes)			
0–1	0.27	(0.02, 0.53)	1943		0.07	(-0.05, 0.19)	1943		-0.05	(-0.13, 0.04)	1903		-0.02	(-0.05, 0.01)	1903	
2+	0.57	(0.21, 0.94)	1495		-0.04	(-0.19, 0.11)	1495		0.05	(-0.06, 0.16)	1446		0.00	(-0.03, 0.03)	1446	
Positive Affect	0.51	(0.15, 0.87)	3444	-	0.22	(0.08, 0.39)	3444	-	-0.11	(-0.23, 0.01)	3355	-				-
Age*				0.25				0.27				0.16				0.51
< 80	0.34	(-0.12, 0.79)	1877		0.11	(-0.12, 0.33)	1877		0.00	(-0.17, 0.16)	1828		-0.04	(-0.10, 0.02)	1828	
≥ 80	0.92	(0.34, 1.51)	1567		0.37	(0.13, 0.60)	1567		-0.25	(-0.42, -0.08)	1527		-0.08	(-0.13, -0.03)	1527	
Race/Ethnicity				0.44				0.29				0.14				0.54
White	0.77	(0.24, 1.29)	1768		0.36	(0.13, 0.59)	1768		-0.23	(-0.40, -0.07)	1724		-0.08	(-0.13, -0.03)	1724	
Black	0.21	(-0.43, 0.85)	1073		0.04	(-0.24, 0.33)	1073		0.01	(-0.20, 0.22)	1042		-0.02	(-0.09, 0.05)	1042	
Hispanic	0.40	(-0.44, 1.25)	603		0.14	(-0.29, 0.57)	603		0.05	(-0.26, 0.36)	589		-0.05	(-0.18, 0.08)	589	
Social Support				0.62				0.97				0.82				0.70
Low	0.33	(-0.23, 0.90)	1710		0.29	(0.04, 0.54)	1710		-0.11	(-0.29, 0.06)	1661		-0.06	(-0.12, -0.01)	1661	
High	0.38	(-0.10, 0.87)	1734		0.29	(0.06, 0.51)	1734		-0.07	(-0.24, 0.09)	1694		-0.07	(-0.12, -0.01)	1694	

Table 4 (continued)

	MVPA (hours/day)			LPA (hours/day)			Sitting Time (hours/day)			MBD (minutes)		
Number of Chronic Conditions[b]	0.19			0.63			0.35			0.67		
0–1	0.24	(-0.20, 0.68)	1943	0.17	(-0.04, 0.37)	1943	-0.03	(-0.18, 0.12)	1903	-0.05	(-0.10, 0.01)	1903
2+	0.90	(0.26, 1.53)	1495	0.30	(0.04, 0.57)	1495	-0.21	(-0.41, -0.02)	1446	-0.08	(-0.13, -0.02)	1446

WHI: women's health initiative, *OPACH*: Objective physical activity and cardiovascular health study, *MVPA*: Moderate-vigorous physical activity, *LPA*: Light physical activity, *MBD*: Mean sitting bout duration, *CI*: Confidence interval, *p-int* p-for-interaction

[a]Model 3: age, race and ethnicity, educational attainment, smoking, alcohol use, live alone, social support, sleep disturbance, pain, [b]Sum of cancer, cerebrovascular disease, cognitive impairment, sensory impairment, cardiovascular disease, chronic obstructive pulmonary disease, diabetes, frequent falls, urinary incontinence, depression, and osteoarthritis. To obtain p-for-interaction, the number of Chronic diseases variable was forced into Model 3 as a main effect and interaction term, *p-for-interaction $< .05$

Table 5 Comparison of baseline characteristics between Analytic Sample ($n=4168$) and Sample with Missing mDES or LOT-R Outcome Measures (n = 1957), WHI OPACH

	Analytic sample	Missing outcome	
Characteristic	($n=4168$)	($n=1957$)	*P*
Total physical activity[a] (h/d), *mean (SD)*	5.7 (1.5)	5.5 (1.5)	< 0.01
Age (years), *mean (SD)*	78.1 (6.6)	80.1 (6.7)	< 0.01
Race/ethnicity, *n (%)*			< 0.01
Non-Hispanic White	2112 (50.7)	933 (47.7)	
Non-Hispanic Black	1315 (31.5)	732 (37.4)	
Hispanic/Latina	741 (17.8)	292 (14.9)	
Education, *n (%)*			< 0.01
High school or less	783 (18.9)	454 (23.4)	
Some college	1560 (37.7)	789 (40.6)	
College graduate or more	1797 (43.4)	701 (36.1)	
Current smoker, *n (%)*	106 (2.7)	53 (3.3)	0.28
Alcohol use, *n (%)*			< 0.01
Never	1373 (34.7)	716 (43.8)	
< 1 per week	1411 (35.7)	501 (30.6)	
≥ 1 per week	1170 (29.6)	418 (25.5)	
Live alone, *n (%)*	1735 (45.4)	749 (48.6)	0.04
Social support, *mean (SD)*	37.7 (7.6)	36.3 (8.2)	< 0.01
Sleep disturbance, *mean (SD)*	7.2 (4.7)	7.3 (4.7)	0.56
Pain[b], *mean (SD)*	66.9 (25.3)	64.1 (26.6)	< 0.01
BMI (kg/m2), *mean (SD)*	28.1 (5.7)	28 (5.8)	0.35
Chronic conditions[c]			< 0.01
0 or 1	2313 (55.6)	839 (43.3)	
2 or 3 +	1845 (44.3)	1100 (56.8)	
Depression symptoms[d], *n (%)*	215 (5.6)	130 (8.5)	< 0.01
Antidepressant use, *n (%)*	472 (11.3)	264 (13.5)	0.02
Physical function (SPPB), *mean (SD)*	8.5 (2.4)	7.6 (2.6)	< 0.01

WHI: Women's health initiative, *OPACH*: Objective physical activity and cardiovascular health study, *h/d*: hours/day, *SD*: Standard deviation, *NA*: Not applicable, *BMI*: Body mass index (calculated as weight in kilograms divided by height in meters squared), SPPB: Short physical performance battery

[a]Adjusted for accelerometer awake wear time using residuals method. Total Physical Activity is the sum of MVPA and LPA, [b]Higher pain score indicates less pain, [c]Sum of cancer, cerebrovascular disease, cognitive impairment, sensory impairment, cardiovascular disease, chronic obstructive pulmonary disease, diabetes, frequent falls, urinary incontinence, depression, and osteoarthritis, [d]Shortened Center for Epidemiologic Studies Depression Scale (CES-D), ≥ 0.06 categorized as depression symptoms

Table 6 Association of Accelerometer-measured Physical Behaviors (2012–2014) with LOT-R Optimism Subscale and LOT-R Pessimism Subscale (2014–2015)[a], WHI OPACH ($n=4168$)

	MVPA (hours/day)			LPA (hours/day)			Sitting Time (hours/day)			MBD (minutes)		
	β	95% CI	*p*	β	95% CI	*p*	β	95% CI	*p*	β	95% CI	*p*
LOT-R optimism subscale												
Model 1[b]	0.28	(0.16, 0.40)	<0.01	0.06	(0.00, 0.11)	0.04	−0.04	(−0.08, 0.00)	0.04	−0.01	(−0.03, 0.00)	0.04
Model 2[c]	0.27	(0.15, 0.39)	<0.01	0.07	(0.01, 0.12)	0.01	−0.04	(−0.08, −0.01)	0.02	−0.02	(−0.03, 0.00)	0.01
Model 3[d]	0.21	(0.09, 0.33)	<0.01	0.04	(−0.01, 0.10)	0.10	−0.02	(−0.06, 0.01)	0.24	−0.01	(−0.02, 0.00)	0.12
Model 4[e]	0.17	(0.05, 0.29)	0.01	0.04	(−0.02, 0.09)	0.21	−0.01	(−0.05, 0.03)	0.62	−0.01	(−0.02, 0.01)	0.31
LOT-R pessimism subscale												
Model 1[b]	−0.34	(−0.47, −0.22)	<0.01	−0.05	(−0.11, 0.01)	0.09	0.04	(0.00, 0.09)	0.04	0.01	(0.00, 0.03)	0.04
Model 2[c]	−0.25	(−0.38, −0.13)	<0.01	−0.05	(−0.10, 0.01)	0.11	0.03	(−0.01, 0.07)	0.11	0.01	(0.00, 0.03)	0.07
Model 3[d]	−0.17	(−0.29, −0.05)	0.01	−0.02	(−0.08, 0.03)	0.41	0.01	(−0.03, 0.05)	0.63	0.01	(−0.01, 0.02)	0.45
Model 4[e]	−0.08	(−0.21, 0.04)	0.20	0.02	(−0.04, 0.08)	0.50	−0.03	(−0.07, 0.02)	0.21	−0.01	(−0.02, 0.01)	0.46

WHI: Women's health initiative, *OPACH*: Objective physical activity and cardiovascular health study, *MVPA*: Moderate-vigorous physical activity, *LPA*: light physical activity, *MBD*: Mean sitting bout duration, *CI*: Confidence interval

[a]Results were generated by models implemented using multiple imputation by chained equations to prevent covariate missing data bias. [b]Model 1: age, race and ethnicity, [c]Model 2: Model 1 covariates, educational attainment, smoking, alcohol use, [d]Model 3 (Main model or confounder-adjusted model): Model 2 covariates, live alone, social support, sleep disturbance, pain, [e]Model 4: Model 3 covariates, BMI, number of chronic diseases, depression symptoms, anti-depressant use, physical functioning (SPPB), $^{*}p<.05$

Table 7 Association of Accelerometer-measured Physical Behavior (2012–2014) with Optimism and Positive Affect (2014–2015)[a], WHI OPACH ($n = 4168$)

	MVPA (hours/day)			LPA (hours/day)			Sitting Time (hours/day)			MBD (minutes)		
	β	95% CI	*p*	β	95% CI	p	β	95% CI	p	β	95% CI	*p*
Optimism												
Model 1[b]	0.62	(0.42, 0.82)	< 0.01	0.11	(0.02, 0.20)	0.02	−0.08	(−0.15, −0.02)	0.01	−0.03	(−0.05, −0.01)	0.02
Model 2[c]	0.53	(0.32, 0.73)	< 0.01	0.10	(0.01, 0.19)	0.04	−0.08	(−0.15, −0.01)	0.02	−0.02	(−0.05, 0.00)	0.04
Model 3[d]	0.41	(0.21, 0.62)	< 0.01	0.03	(−0.06, 0.13)	0.49	−0.02	(−0.09, 0.05)	0.59	−0.01	(−0.04, 0.01)	0.27
Model 4[e]	0.32	(0.08, 0.55)	0.01	0.01	(−0.09, 0.12)	0.81	0.01	(−0.07, 0.09)	0.82	−0.01	(−0.04, 0.02)	0.39
Positive affect												
Model 1[b]	0.74	(0.39, 1.09)	< 0.01	0.23	(0.07, 0.38)	< 0.01	−0.13	(−0.25, −0.02)	0.02	−0.06	(−0.10, −0.03)	< 0.01
Model 2[c]	0.76	(0.40, 1.12)	< 0.01	0.26	(0.10, 0.43)	< 0.01	−0.16	(−0.28, −0.04)	0.01	−0.07	(−0.11, −0.03)	< 0.01
Model 3[d]	0.51	(0.15, 0.87)	0.01	0.22	(0.06, 0.39)	< 0.01	−0.11	(−0.22, 0.01)	0.08	−0.06	(−0.10, −0.02)	< 0.01
Model 4[e]	0.44	(0.03, 0.84)	0.03	0.23	(0.04, 0.41)	0.02	−0.13	(−0.27, 0.01)	0.06	−0.06	(−0.11, −0.01)	0.01

WHI: Women's Health Initiative, *OPACH*: objective physical activity and cardiovascular health study, *MVPA*: moderate-vigorous physical activity, *LPA*: light physical activity, *MBD*: mean sitting bout duration, *CI*:confidence interval

[a]Results were generated with complete case analysis, [b]Model 1: age, race and ethnicity, [c]Model 2: Model 1 covariates, educational attainment, smoking, alcohol use, [d]Model 3: Model 2 covariates, live alone, social support, sleep disturbance, pain, [e]Model 4: Model 3 covariates, BMI, number of chronic diseases, depression symptoms, anti-depressant use, physical functioning (SPPB), *$p < .05$, ANOVA for continuous variables and chi-squared for categorial variables

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Declarations

Conflicts of interest The authors have no conflicts of interest to declare that are relevant to the content of this article.

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