BMJ Open

Cohort profile: the Women's Health Accelerometry Collaboration

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To cite: Evenson KR, Bellettiere J, Cuthbertson CC, *et al*. Cohort profile: the Women's Health Accelerometry Collaboration. *BMJ Open* 2021;**11**:e052038. doi:10.1136/bmjopen-2021-052038

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2021-052038).

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Received 05 April 2021
Accepted 21 October 2021

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ABSTRACT

Purpose This paper describes the Women's Health Accelerometry Collaboration, a consortium of two prospective cohort studies of women age 62 years or older, harmonised to explore the association of accelerometer-assessed physical activity and sedentary behaviour with cancer incidence and mortality.

Participants A total of 23 443 women (age mean 73.4, SD 6.8) living in the USA and participating in an observational study were included; 17 061 from the Women's Health Study (WHS) and 6382 from the Women's Health Initiative Objective Physical Activity and Cardiovascular Health (WHI/OPACH) Study.

Findings to date Accelerometry, cancer outcomes and covariate harmonisation was conducted to align the two cohort studies. Physical activity and sedentary behaviour were measured using similar procedures with an ActiGraph GT3X+ accelerometer, worn at the hip for 1 week, during 2011–2014 for WHS and 2012–2014 for WHI/OPACH. Cancer outcomes were ascertained via ongoing surveillance using physician adjudicated cancer diagnosis. Relevant covariates were measured using questionnaire or physical assessments. Among 23 443 women who wore the accelerometer for at least 10 hours on a single day, 22 868 women wore the accelerometer at least 10 hours/day on ≥4 of 7 days. The analytical sample (n=22 852) averaged 4976 (SD 2669) steps/day and engaged in an average of 80.8 (SD 46.5) min/day of moderate-to-vigorous, 105.5 (SD 33.3) min/day of light high and 182.1 (SD 46.1) min/day of light low physical activity. A mean of 8.7 (SD 1.7) hours/day were spent in sedentary behaviour. Overall, 11.8% of the cohort had a cancer diagnosis (other than non-melanoma skin cancer) at the time of accelerometry measurement. During an average of 5.9 (SD 1.6) years of follow-up, 1378 cancer events among which 414 were fatal have occurred.

Future plans Using the harmonised cohort, we will access ongoing cancer surveillance to quantify the associations of physical activity and sedentary behaviour with cancer incidence and mortality.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The combined prospective cohort will address research questions pertaining to accelerometer-assessed physical activity and sedentary behaviour with cancer outcomes due to similar measurement protocols for the exposures, outcomes and important covariates.
⇒ A variety of sociodemographic, behavioural and medical history were collected over many years prior to accelerometry measurement that allows for control of important confounders.
⇒ Accelerometry was assessed for 1 week and may not represent behaviour during the entire follow-up period.
⇒ A longer follow-up period will be needed to explore the relationships of accelerometry-assessed behaviours with rare cancers.

INTRODUCTION

Cancer is the second-leading cause of death in the USA for women, with an estimated 289 150 cancer-related deaths and 927 910 new cancer cases predicted to occur among women in 2021.[1] The leading types of new cancer cases for women include breast (30%), lung and bronchus (13%), colon and rectum (8%), uterine corpus (7%), skin melanoma (5%) and non-Hodgkin's lymphoma (4%).[1] Cancer risk increases with age; however, certain screening tests are not recommended for adults 75 years or older since the harms outweigh the benefits.[2] This results in cancer that is often diagnosed at a more advanced stage among women 75 years or older than among women under the age of 75 years.

With a rapidly growing older population, there will be an increased demand for cancer-related healthcare. Among women at age 85 years without a history of cancer, the probability of cancer diagnosis in their remaining lifetime is 12.8% and the probability of cancer death is 9.6%.[2] Focusing on risk factors that are modifiable in later life that can help reduce cancer burden, such as physical activity and sedentary behaviour, should be a public health priority.

Observational studies consistently report associations between lower self-reported moderate-to-vigorous leisure-time physical activity and increased risk of several cancer types.[3] In support of this, the 2018 US' Physical Activity Guidelines Advisory Committee (PAGAC),[4] updated in 2019,[5] identified an overall evidence grade of 'strong' comparing the highest to the lowest levels of physical activity on the risk of developing bladder, breast, colon, endometrial, oesophageal adenocarcinoma, renal and gastric cancers, and an overall evidence grade of 'moderate' for lung cancer. However, there was a limited dose response gradient for oesophageal adenocarcinoma, lung and renal cancers. The review indicated limited evidence on physical activity occurring outside of leisure-time, such as transportation, occupational or household activities. The review also found that few studies reported on associations between physical activity and cancer by population subgroups, such as by age, socioeconomic status or race/ethnicity.

The PAGAC also reported limited evidence on the relationship of sedentary behaviour with cancer incidence and mortality.[4,6] Evidence supporting the PAGAC statements were primarily based on self-reported physical activity and sedentary behaviour data. Self-reported light activity is especially difficult to recall, and is the most common intensity level older adults participate in.[7,8] To date, few studies of older adults have explored accelerometer-assessed physical activity and sedentary behaviour with cancer incidence and mortality.[9–12] The scarcity of evidence is likely due to the need for larger studies with longer follow-up time to investigate cancer outcomes, particularly for the less common tumour sites.

The Women's Health Accelerometry Collaboration will explore the associations of accelerometer-assessed physical activity and sedentary behaviour with cancer outcomes by combining data from two large prospective studies: the Women's Health Study (WHS) and the Women's Health Initiative Objective Physical Activity and Cardiovascular Health (WHI/OPACH) Study. This endeavour requires harmonisation of accelerometry, cancer outcomes and covariates. The study will provide important insights on cancer incidence and mortality among women 62 years and older. The specific aim for this paper is to describe the rationale, methodology, proposed analysis plan and characteristics of the cohort.

COHORT DESCRIPTION

In order to address the scientific gaps, we harmonised two cohort studies of women 62 years and older using similar data collection methodologies to quantify the associations between physical activity and sedentary behaviour with multiple site-specific incident cancers and overall fatal cancers.

Patient and public involvement

Patients and/or the public were not involved in the design, conduct, reporting or dissemination of this research.

WHS

The WHS is a completed randomised trial (1992–2004) testing aspirin, beta-carotene and vitamin E for preventing cardiovascular disease and cancer among 39 876 healthy USA women at least 45 years of age.[13–15] When the trial ended, women were invited to continue in an observational study. Of the 33 682 alive, 89% of women consented, reporting on their health habits and medical history annually on questionnaires. From 2011 to 2014, an ancillary study was conducted to collect accelerometry among participants.[16] In 2011, 29 494 women were alive and 18 289 agreed to participate and were sent an accelerometer, 6931 declined participation, 1456 were ineligible because they were unable to walk outside of the home, and the remaining 2818 did not respond to the invitation. Overall, 17 466 women returned the accelerometers for downloading. All women gave written informed consent.

All of the women in the accelerometer substudy were previously in the pharmacotherapy intervention arms (either active or placebo).[13–15] The pharmacotherapy intervention did not impact cancer incidence or mortality.[13,14] Thus, the interventions are unlikely to impact the associations we seek to investigate, namely the associations of physical activity and sedentary behaviour with cancer outcomes.

Women's Health Initiative Objective Physical Activity and Cardiovascular Health

From 1993 to 1998, the WHI study initially recruited women 50–79 years for either a clinical trial(s) or an observational study from 40 clinical sites throughout the USA. The WHI/OPACH Study[17] is an ancillary study to the WHI Long Life Study,[18] which was a substudy to WHI. The sampling frame of the WHI Long Life Study were all surviving and actively participating women from the hormone therapy trials with age ≥63 years and all Hispanic and African American women in WHI. The WHI/OPACH ancillary study was designed to collect physical activity and sedentary behaviour measured by accelerometry and self-report, and to collect detailed data on incident falls using daily falls calendars collected for up to 13 months. The primary outcomes of the original study included mortality,[19] falls[20] and cardiovascular disease.[21,22] From 2012 to 2014, 9252 US women consented to the WHI Long Life Study. Among those participants, 8618 consented by mail or phone to participate in the WHI/OPACH ancillary study collecting accelerometry. From those who consented, 58 women died before they could be contacted to begin participation, 10 died before receiving the materials, 141 were determined to be ineligible (eg, dementia, residing in a nursing home, not ambulatory), 765 could not be contacted, and 596 declined to participate when contacted. In summary, 7048 women were sent the accelerometer, a sleep log, the OPACH physical activity questionnaire (available in this paper),[17] and 13 falls calendars. Overall, 6489 women returned the accelerometers for downloading.

Accelerometry data collection

Both cohorts used the same accelerometer (ActiGraph GT3X+accelerometer (Pensacola, Florida). The triaxial accelerometer was small (4.6×3.3×1.5 cm) and light weight (19 g), with a dynamic range of ±6 G. The WHS women were asked to wear the accelerometer on their right hip, removing it only during sleep, for 7 days. They were also asked to keep a log documenting wear and non-wear days.[16] The accelerometer and log were mailed to participants, with a mailer for return.

The WHI/OPACH women were asked to wear the accelerometer on their right hip for 7 days, including night-time. The WHI/OPACH women were asked to keep a sleep log for in-bed and out-of-bed wear.[23] For women with missing sleep log data, their in-bed and out-of-bed times were imputed using person-specific means, if available, or the sample mean. Using the sleep log, the in-bed wear was removed to make the data congruent across the two cohorts. The accelerometer and log were given to most women at their study visit and were mailed back after completion.

The accelerometer recorded three-dimensional raw acceleration signals at 30 Hz, which were aggregated using ActiLife software (V.6) to counts per 15 s epochs with the normal filter setting. To better detect movement from all directions, vector magnitude (VM) counts were derived by taking the square root of the sum of the three axes squared. Non-wear time was assessed using the validated Choi *et al* algorithm,[24,25] defined as an interval of at least 90 consecutive minutes of zero VM counts/minute, with allowance of up to one 2 min period of nonzero VM counts and requiring that no counts were detected during the 30 min upstream and downstream from that period.

Several metrics were used to describe physical activity and sedentary behaviour from the accelerometer. First, average intensity per day was summarised as average VM/15 s. Second, using WHI/OPACH calibration-study derived accelerometry cutpoints, we defined sedentary behaviour and physical activity from receiver operating characteristic curve analyses that balanced the number of false positives and false negatives.[26] VM/15 s cutpoints were defined as follows: sedentary 0–18, light low 19–225, light high 226–518 and moderate-to-vigorous physical activity ≥519. Third, a moderate-to-vigorous bout was defined as ≥10 min of consecutive moderate-to-vigorous minutes, with allowance for interruptions for up to 20% of the time below the threshold and <5 consecutive minutes below the threshold (to set a maximum time when bouts occur ≥25 min). The bout must start and end with moderate-to-vigorous physical activity.[27,28] Fourth, average steps per day was explored, derived from ActiGraph's proprietary algorithm.

Cancer incidence and mortality outcomes

WHS participants received annual mailed questionnaires which asked about health history, including a diagnosis of cancer. Relevant medical records were obtained for all self-reported cancers (except for non-melanoma skin cancer).

As part of WHI, participants received annual mailed questionnaires which asked about physician diagnosis of new cancer or malignant tumours, hospitalisations, and other health history. Medical records were obtained for all self-reported cancers except non-melanoma skin cancer.[29]

For both studies, physician adjudicators coded cancer using medical record documents such as the pathology report, hospital face sheet, operative report, hospital discharge summary, oncology consultation, radiology report and tumour registry abstract. The date of cancer diagnosis is based on one of the following: microscopically confirmed based on date the tissue that resulted in a positive pathology was removed, not microscopically confirmed based on the date of first hospitalisation for cancer, self-report only based on date reported by participant, and both autopsy-only and death certificate-only based on death date.

For WHS, an Endpoints Committee of physicians blinded to questionnaire exposure data reviewed all medical records using prespecified criteria. A cancer diagnosis was confirmed with histological or cytological evidence. In the absence of these diagnostic tests, strong clinical evidence accompanied by radiologic evidence or laboratory markers was used to confirm cancer occurrence. The histological type, grade and stage of cancer were recorded. The date of cancer diagnosis was based on the earliest date of the relevant evidence (eg, date of histological confirmation). For cancers diagnosed only on death certificates without prior medical records, the date of death was used.

Coding of cancer type was based on the Surveillance, Epidemiology and End Results programme. Using the International Classification of Diseases for Oncology (ICD-O-3), the morphology code details the type and behaviour of a tumour.[30] The code contained three parts: histology or cell type (four digits), behaviour or the way it acts in the body (one digit) and grade, differentiation or phenotype (one digit). Histology of the primary tumour was ascertained and its behaviour code were ascertained. A behaviour code is defined as 0: benign; (1) uncertain whether benign or malignant; (2) carcinoma in situ; and three or higher: malignant (invasive) primary site. These codes were applied identically across both cohorts; the final classification of cancer by site was limited to behaviour code 3 and is summarised in online supplemental table 1.[3]

Cancer surveillance is currently ongoing in both cohorts. Additionally, we ascertained if women had been diagnosed with a cancer prior to the accelerometer data collection, including type of cancer and time since diagnosis. For both cohorts, deaths were reported by family members or postal authorities, with medical records, interviews with next of kin, and death certificates obtained to confirm the event. The National Death Index was searched periodically for cohort members. The underlying cause of death was classified on the basis of the death certificate, medical records, and other records such as an autopsy report using the ICD 10th edition. The death certificate diagnosis was used when no other records are available. In this paper, we report on cancer diagnosed from study enrolment to the date of accelerometry measurement.

Covariates

Sociodemographics, including age, race/ethnicity and education, were collected at study enrolment. Participants from both cohorts regularly completed mailed questionnaires regarding their health history and health behaviours and we used the measure closest to the time of accelerometer wear. Women identified their general health by answering the question, 'In general, would you say your health is excellent, very good, good, fair or poor?' Women also reported on smoking status, alcohol intake, postmenopausal hormone use and history of diabetes, confirmed coronary heart disease, bilateral oophorectomy and hysterectomy. Height and weight were self-reported in WHS and measured in WHI/OPACH. Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared and defined as underweight (<18.5), normal weight (18.5–24.9), overweight (25.0–29.9) or obese (≥30.0).

Walking speed was collected from self-administered questionnaires. WHS women were asked, 'What is your usual walking pace outdoors?' WHI/OPACH women were asked, 'When you walk at home for more than 10 min without stopping, what is your usual speed?' We harmonised the response options as follows:

1. <2 mph: easy, casual, <2 mph (WHS); casual strolling or walking <2 mph (WHI/OPACH).
2. 2–2.9 mph: normal, average, 2–2.9 mph (WHS); average or normal, 2–3 mph (WHI/OPACH).
3. 3–3.9 mph: brisk pace, 3–3.9 mph (WHS); fairly fast, 3–4 mph (WHI/OPACH).
4. 4 mph or more: very brisk, striding, >4 mph (WHS); very fast, >4 mph (WHI/OPACH).
5. Unknown or does not walk regularly: don't walk regularly (WHS); don't know, rarely or never walks >10 min (WHI/OPACH).

Proposed statistical analysis

We will explore the association of physical activity and sedentary behaviour with cancer incidence and mortality. For site-specific cancer analyses, if participants have a history of the cancer under analysis then they will be excluded. For example, if we analyse lung cancer incidence then we will exclude women who already have a lung cancer diagnosis prior to the accelerometer measurement. For composite cancer (a subset of cancer types combined) and total cancer analyses, we will include women who have a history of cancer prior to accelerometry measurement. For these analyses, we can further explore whether excluding those with cancer impacts the results or whether having prior cancer is a moderator.

Women with a hysterectomy prior to accelerometry measurement will be excluded from investigation of incident endometrial cancer. Similarly, women with bilateral oopherectomy prior to accelerometry measurement will be excluded from investigation of incident ovarian cancer.

We will use stratified Cox regression models to estimate HRs and 95% CIs for various measures of physical activity and sedentary behaviour with cancer incidence and mortality. The stratified model allows the baseline hazards for the two cohorts to differ.[31] However, the hazards of the exposure groups are assumed to be proportional, which will be tested using Schoenfeld residuals. We will censor follow-up time on the date of the cancer diagnosis, the date of death, or the date of last contact. Potential confounders will be the harmonised covariates described in the 'Covariates' section.

Analytic sample

In total, 25 337 women were sent an accelerometer, with 18 289 contributing from the WHS cohort and 7048 from the WHI/OPACH cohort (table 1). After excluding those

Table 1 Accelerometer wear overall and by cohort

		Retained	WHS	Retained	WHI/OPACH	Retained
	Total	%	n	%	n	%
Sample invited to substudy	38 746	100	29 494	100	9252	100
Agreed to participate and sent the accelerometer	25 337	65.4	18 289	62.0	7048	76.2
Returned accelerometer	24 429	63.0	17 708	60.0	6721	72.6
Data were downloaded	23 955	61.8	17 466	59.2	6489	70.1
At least one adherent day of wear (≥10 hours)	23 443	60.5	17 061	57.8	6382	69.0
Adherent wear ≥4 days of ≥10 hours/day	22 868	59.0	16 742	56.8	6126	66.2
Removed those with cancer at trial inception*	22 852	59.0	16 726	56.7	6126	66.2

*WHS began as a trial for the primary prevention of cancer and cardiovascular disease; however, postrandomisation, 16 of the 16 742 women were subsequently found to have prevalent cancer and were excluded from this study.
WHI/OPACH, Women's Health Initiative Objective Physical Activity and Cardiovascular Health; WHS, Women's Health Study.

Table 2 Description of sample overall and by cohort

	Overall (n=22 852)		WHS (n=16 726)		Missing	WHI/OPACH (n=6126)		
	%	n	%	n	Missing	%	n	Missing
Age categories								
60–69	35.1	8019	44.2	7392		10.2	627	0
70–79	43.8	10 013	45.2	7565		40.0	2448	
80–89	20.0	4563	10.6	1769		45.6	2794	
≥90	1.1	257	0.0	0		4.2	257	
Race/ethnicity					0			0
White	83.1	18 984	95.3	15 938		49.7	3046	
Black	10.1	2300	1.5	253		33.4	2047	
Hispanic	5.2	1184	0.9	151		16.9	1033	
Unknown or other	1.7	384	2.3	384		0.0	0	
Education					269			41
High school or less	5.5	1237	0.0	0		20.3	1237	
Some college	46.7	10 531	49.7	8182		38.6	2349	
College graduate or more	47.8	10 774	50.3	8275		41.1	2499	
Self-reported or measured near accelerometry measurement								
General health					5			21
Excellent	20.7	4730	24.6	4115		10.1	615	
Very good	47.5	10 842	50.1	8371		40.5	2471	
Good	27.3	6230	22.8	3804		39.7	2426	
Fair or poor	4.5	1024	2.6	431		9.7	593	
Body mass index					3			386
<18.5	1.8	415	2.0	334		1.3	81	
18.5–24.9	39.2	8953	43.1	7215		28.4	1738	
25.0–29.9	33.6	7672	33.6	5624		33.4	2048	
30.0–34.9	14.7	3356	13.5	2263		17.8	1093	
35.0–39.9	5.0	1145	4.1	692		7.4	453	
≥40	2.1	486	1.6	261		3.7	225	
Smoking					1			582
Current	3.4	749	3.5	590		2.9	159	
Former	45.1	10 046	46.0	7695		42.4	2351	
Never	51.5	11 474	50.5	8440		54.7	3034	

Continued

Table 2 Continued

	Overall (n=22 852)		WHS (n=16 726)		Missing	WHI/OPACH (n=6126)		
	%	n	%	n	Missing	%	n	Missing
Alcohol					7			536
Never or rarely	37.9	8445	38.0	6356		37.4	2089	
Monthly	15.9	3558	9.8	1646		34.2	1912	
Weekly	32.9	7340	36.3	6069		22.7	1271	
Daily	13.3	2966	15.9	2648		5.7	318	
Walking speed					4			261
<2 mph	21.5	4906	17.5	2931		32.2	1975	
2–2.9 mph	40.2	9185	42.7	7143		33.3	2042	
3–3.9 mph	20.7	4728	25.5	4271		7.5	457	
≥4 mph	1.5	350	2.0	332		0.3	18	
Unknown or does not walk regularly	15.0	3418	12.2	2045		22.4	1373	
Medical history near accelerometry measurement								
Using postmenopausal hormones	7.9	1812	9.9	1657	6	2.5	155	0
Diabetes history	12.0	2747	9.0	1501	0	20.3	1246	0
Coronary heart disease	5.8	1328	4.3	712	0	10.1	616	0
Oopherectomy, bilateral	21.4	4873	22.2	3718	0	19.2	1155	94
Hysterectomy	41.9	9568	41.6	6957	0	42.6	2611	0
Cancer at accelerometry measurement	11.8	2696	11.9	1982	0	11.7	714	0

WHS and WHI/OPACH categories were compared using X^2 tests. All associations were significant at p<0.0001.
WHI/OPACH, Women's Health Initiative Objective Physical Activity and Cardiovascular Health; WHS, Women's Health Study.

that did not return the accelerometer, did not wear the accelerometer, or experienced accelerometer malfunction, 23 443 (92.5%) and 22 868 (90.3%) women contributed at least one and four adherent days of accelerometry wear, respectively, defined as wearing the device for at least 10 hours during a day while awake. WHS began as a trial for the primary prevention of cancer and cardiovascular disease; however, postrandomisation, 16 women were subsequently found to have prevalent cancer and are excluded from this study. The final sample size for the analyses was 22 852.

FINDINGS TO DATE

At the time of accelerometry measurement, both cohorts had a mean age above 70 years (78.7 (SD 6.7) WHI/OPACH, 71.5 (SD 5.7) WHS), with a range of 63–97 for WHI/OPACH and 62–89 years for WHS. Both cohorts had a mean BMI in the overweight category (28.1 kg/m^2 (SD 5.7) WHI/OPACH, 26.2 kg/m^2 (SD 5.0) WHS). WHI/OPACH women compared with WHS women had a lower proportion with at least some college education (79.7% vs 100%), very good or excellent general health (50.6% vs 74.7%), drank alcohol daily (5.7% vs 15.9%), used postmenopausal hormones (2.5% vs 9.9%) and walked at least 3 mph (7.8% vs 27.5%) (table 2). At the time of accelerometry measurement, the WHI/OPACH women compared with WHS women included a higher proportion of black (33.4% WHI/OPACH vs 1.5% WHS) and Hispanic (16.9% vs 0.9%) women and had a higher proportion with diabetes (20.3% vs 9.0%) and coronary heart disease (10.1% vs 4.3%). The two cohorts were more similar with regards to never smoking (54.7% WHI/OPACH, 50.5% WHS), cancer (11.7%, 11.9%) and receipt of a bilateral oophorectomy (19.2%, 22.2%) or a hysterectomy (42.6%, 41.6%).

Most women provided at least 4 days of adherent data (defined as 10 hours/day), with 14.9 hours/day of average awake wear time (table 3). The WHS women engaged in a higher mean total volume of physical activity (146 vs 101 average daily VM/15 s) and accumulated more mean steps per day (5489 vs 3573) than WHI/OPACH women. WHS women engaged in approximately 2–3 times more mean moderate-to-vigorous physical activity (91.9 vs 50.4 min/day) and bouts (18.2 vs 6.4 min/day) than WHI/OPACH women. In contrast, mean light high and light low activity were similar. Sedentary behaviour was lower among WHS women compared with WHI/OPACH women (510.6 vs 555.6 min/day). It is important to note that some of the differences in accelerometry measures between cohorts may be due to age, such as indicated in table 4, or due to other potential confounders.

We examined the number of incident and fatal cancers in the cohort, with cancer outcomes documented through 31 December 2019 for WHS and through 30 March 2020

Table 3 Description of accelerometry measures overall and by cohort

	Overall (n=22 852)		WHS (n=16 726)		WHI/OPACH (n=6126)	
	%		%		%	
No of adherent days						
4 days	2.0		1.6		2.9	
5 days	4.4		3.6		6.6	
6 days	18.0		15.0		26.2	
7 days	75.6		79.8		64.3	
No of weekend days						
0 days	1.2		1.0		1.6	
1 day	8.5		7.4		11.3	
2 or more	90.4		91.6		87.0	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Wear time on adherent days, hours/day	14.9	1.3	14.9	1.3	14.9	1.3
Average daily vector magnitude per 15 s	134.0	53.9	146.0	52.8	101.2	42.1
Average daily steps/day	4975.9	2668.8	5489.4	2658.2	3573.1	2142.3
Average minutes/day using vector magnitude						
Sedentary behaviour	522.7	101.0	510.6	98.8	555.6	99.4
Light low	182.1	46.1	179.6	44.2	188.9	50.2
Light high	105.5	33.3	108.2	32.1	98.0	35.5
Moderate to vigorous	80.8	46.5	91.9	45.4	50.4	34.4
Moderate to vigorous bouts	15.0	22.8	18.2	24.6	6.4	13.6

WHI/OPACH, Women's Health Initiative Objective Physical Activity and Cardiovascular Health; WHS, Women's Health Study.

Table 4 Description of accelerometry measures by cohort stratified by age tertiles*

	Age 60–69 years				Age 70–76 years				Age 77+ years			
	WHS (n=7392)		WHI/OPACH (n=627)		WHS (n=6168)		WHI/OPACH (n=1781)		WHS (n=3166)		WHI/OPACH (n=3718)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Wear time on adherent days, hours/day	15.0	1.2	15.1	1.3	14.8	1.2	15.0	1.3	14.7	1.3	14.8	1.3
Average daily vector magnitude per 15 s	159.7	53.6	125.5	43.7	142.5	50.1	113.8	43.9	120.4	44.6	91.1	37.4
Average daily steps/day	6268.2	2693.7	5045.9	2477.3	5308.5	2499.4	4245.0	2211.0	4023.5	2142.9	3003.2	1811.7
Average minutes/day using vector magnitude												
Sedentary behaviour	499.9	99.1	527.8	99.2	512.9	98.0	538.2	101.3	531.4	96.0	568.6	96.3
Light low	182.7	44.2	200.7	47.2	177.8	43.3	193.9	49.3	176.0	45.6	184.5	50.5
Light high	109.0	31.3	107.5	34.1	108.7	32.4	103.7	34.8	105.8	33.1	93.7	35.5
Moderate to vigorous	105.0	44.9	72.7	36.8	88.8	43.1	61.2	36.3	67.4	39.4	41.4	29.5
Moderate to vigorous bouts	22.3	26.9	11.0	16.8	17.1	23.0	8.8	16.2	10.6	19.5	4.5	11.0

*Age was categorised based on WHAC-specific tertiles: 60–69 years, 70–76 years and 77+ years.
WHAC, Women's Health Accelerometry Collaboration; WHI/OPACH, Women's Health Initiative Objective Physical Activity and Cardiovascular Health; WHS, Women's Health Study.

for WHI/OPACH. During an average of 5.9 (SD 1.6) years of follow-up thus far, 1378 cancer events occurred among which 414 were fatal. The most common cancers were breast (459) and lung (146) cancer.

Strengths and limitations

The Women's Health Accelerometry Collaboration cohort's primary strength is the statistical power to be able to address research questions regarding physical activity and sedentary behaviour with cancer among older women in a cost-efficient manner by using data from existing studies. Cancer outcomes continue to be assessed annually by similar methods, adjudicated and combined systematically across cohorts. Accelerometry was collected by the same device using similar procedures and excellent adherence.

A WHI/OPACH substudy of 200 women participated in a variety of laboratory-based activities while wearing the accelerometer and having oxygen uptake measured. Using these data, accelerometer cutpoints were developed specifically for women 60 years and older.[26] The cutpoint was calibrated to estimate moderate to vigorous activity among older women, which is why the number of minutes may be higher than those reported from other studies that use calibration equations developed in younger samples of adults (ie, what might be a 'light' activity in a younger woman may actually require moderate or higher effort in an older woman).

Raw accelerometry data will allow the research team to develop further measures of physical activity and sedentary behaviour, such as using the activity index[32] and latent class analysis on accelerometry.[33] Using the raw data, we can also apply two machine-learnt algorithms developed specifically for older women; one designed to distinguish sitting, riding in a vehicle, standing still, standing moving and walking,[34] while the other was designed to accurately quantify sitting bouts,[35] which, without the algorithm, are measured with substantial error.[36]

While studies investigating the associations between less common cancer subtypes and physical activity or sedentary behaviour among older women have been limited due to smaller sample sizes and few cancer events, the combined cohorts provide improvement in statistical power, allowing researchers to be better equipped to investigate these associations. In addition to increasing power for the less common cancer outcomes, by including both cohorts we capture more diversity in the population of women in this age range which allows us to better understand these associations in a more heterogeneous population.

The Women's Health Accelerometry Collaboration cohort has several limitations. First, the accelerometer was worn once by participants for 1 week. It is possible that physical activity and sedentary behaviour could change seasonally and over the course of follow-up, and thus, not be represented by the measurement week. To address this concern, the question was explored in a subset of WHS participants that wore the accelerometer up to three times over a period of 2–3 years, the initial measures of physical activity and sedentary behaviour provided a reproducible measure at repeated time points.[37] Adjusting for age, season and BMI, the intraclass correlation coefficients between women indicated moderate to high reproducibility for average VM counts/day (0.83; 95% CI 0.78 to 0.87), sedentary behaviour (0.73; 95% CI 0.66 to 0.80), light activity (0.67; 95% CI 0.59 to 0.74) and moderate-to-vigorous physical activity (0.83; 95% CI 0.78 to 0.87). This indicated that metrics derived from 1 week of accelerometer administration can estimate longer-term patterns of behaviour among women of similar ages.

Second, there will need to be a longer follow-up period or other cohorts to address the relationships of accelerometry-assessed behaviours with rare cancers. Third, women that could not walk without assistance outside of their home were excluded due to the development of existing accelerometer algorithms on ambulation. More effort is needed to understand how to interpret accelerometry from non-ambulatory individuals in order to include them in studies of this kind.[38] Fourth, while WHS initially mailed accelerometers and used an awake only protocol, in contrast WHI/OPACH provided most of the accelerometers in-person at the home visit and used a 24-hour wear protocol. Despite these differences, there did not appear to be differential impact on accelerometer awake wear time between the cohorts (table 3). Fifth, most potential confounders were similarly measured across the two cohorts. However, height and weight assessed near the time of accelerometry measurement were self-reported in WHS and measured in WHI/OPACH.

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Acknowledgements The authors thank Chris Moore and Fang Wen for their analytic support, and Steve Moore for assistance with the cancer outcome coding. We acknowledge the WHI investigators listed at the following link: https://www-whi-org.s3.us-west-2.amazonaws.com/wp-content/uploads/WHI-Investigator-Short-List.pdf.

Contributors KRE conceived of and drafted the manuscript and GW conducted the data analysis. I-ML, EJS and RD were involved in study design, accelerometry acquisition and/or analysis of the WHS. AZL, KRE, I-ML, CD, BTS and JB were involved in the study design, accelerometry acquisition, and/or analysis for the WHI/OPACH Study. In addition, CCC, AGH, HP and GW provided critical interpretation of the data harmonisation and analysis for this work. All authors (KRE, JB, CCC, CD, RD, AGH, HP, BTS, EJS, GW, I-ML and AZL) reviewed the manuscript critically and approved the final version. KRE is responsible for the overall content as the guarantor.

Funding The study was supported by the National Institutes of Health (NIH) 5R01CA227122: National Cancer Institute, Office of the Director, Office of Disease Prevention, and Office of Behavioral and Social Sciences Research. WHS is funded by NIH grants CA154647, CA047988, CA182913, HL043851, HL080467 and HL099355. The WHI programme is funded by NIH, National Heart, Lung and Blood Institute (NHLBI) #75N92021D00001, 75N92021D00002, 75N92021D00003, 75N92021D00004, 75N92021D00005 and grant R01HL105065. CCC was supported by an NHLBI National Research Service Award (T32-HL007055). HP was supported by the National Cancer Institute (K01 CA234317), the SDSU/UCSD Comprehensive Cancer Center Partnership (U54 CA132384 & U54 CA132379), and the Alzheimer's Disease Resource Center for Advancing Minority Aging Research at the University of California San Diego (P30 AG059299). EJC was supported by the Intramural Research Program at the NIH National Institute on Aging.

Disclaimer The content is solely the responsibility of the authors and does not necessarily represent the official views of the NIH.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval The secondary data analysis was reviewed and approved by the University of North Carolina Institutional Review Board. All study protocols were approved by the Brigham and Women's Hospital Institutional Review Board for WHS and the Fred Hutchinson Cancer Research Center Institutional Review Board for WHI. All women gave informed consent.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are accessible through the established data sharing policies for the Women's Health Study at https://www.ncbi.nlm.nih.gov/projects/gap/cgi-bin/study.cgi?study_id=phs001964.v1.p1 and http://whs.bwh.harvard.edu/. Similarly, data are accessible through the established data sharing policies for the Women's Health Initiative at https://www.whi.org/page/working-with-whi-data. Interested researchers can write to the study to clarify data access. Due to data sharing agreements, the Women's Health Accelerometry Collaboration data are not directly available. Data are available for the Women's Health Study at https://www.ncbi.nlm.nih.gov/projects/gap/cgi-bin/study.cgi?study_id=phs001964.v1.p1 and for the Women's Health Initiative OPACH Study at https://www.whi.org/page/working-with-whi-data. Researchers using the data are required to follow the terms designed to protect the privacy of the participants.

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