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**Significant Associations Between Sun Exposure and Adiposity
Were Not Observed in Breast and Prostate Cancer Patients
in a Cross-sectional Analysis**

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ABSTRACT

Obesity is a significant health problem worldwide. Exposure to low dose ultraviolet radiation (like that in sunlight) suppresses the development of obesity in mice; however, the nature of the associations between sun exposure and adiposity is not well understood in humans. The present study characterized cross-sectional relationships between sun exposure and adiposity in a convenience cohort of breast (n=269; mean age=58 years) and prostate (n=78; mean age=69 years) cancer patients. Participants were enrolled in a 3-month exercise program in Perth, Australia. Self-reported questionnaires measured time spent outdoors (previous week, winter, and summer), sex, age, treatment received and physical activity levels. Adiposity measures included body mass index, waist-hip ratio, and body fat percentage (measured via DXA). In unadjusted models, greater time spent outdoors across all times was significantly associated with lower waist-hip ratio, while greater time spent outdoors in the last winter was associated with lower body fat percentage, but not when stratified by sex. There were no statistically significant associations between time spent outdoors and adiposity after adjusting for sex, age, treatments received, and physical activity. Longitudinal studies in larger populations may elucidate significant associations not found in our study due to the cross-sectional design and power limitations.

INTRODUCTION

Obesity is prevalent worldwide (1), with an estimated 39% of the adult population overweight or obese (2). This represents a significant clinical and public health problem as obesity is a major risk factor for serious non-communicable diseases, including cardiovascular disease and type-2 diabetes, and internal cancers, including post-menopausal breast cancer (3).

Generally, obesity is attributed to excess energy intake (from foods and drinks) relative to energy expenditure (including physical activity); however, the aetiology is complex and involves both genetic and biopsychosocial factors (4, 5). The role of sun exposure in modulating the development of obesity, and related metabolic pathways, is of emerging interest (6).

Sun exposure is the major source of vitamin D for humans. Recent epidemiological studies indicate there are reduced levels of circulating 25-hydroxyvitamin D (the major circulating form of vitamin D) in individuals with obesity as defined by body mass index (BMI $>30\text{kg/m}^2$), compared to those of normal BMI ($\geq 18\text{kg/m}^2$, $<25\text{kg/m}^2$) (7). However, it is not clear whether obesity causes lower 25-hydroxyvitamin D levels or vice versa (8). A bidirectional Mendelian genetic randomisation study suggested that higher BMI may reduce circulating 25-hydroxyvitamin D levels (9). There could be multiple explanations for this observation, including the hypothesis that blood 25-hydroxyvitamin D levels are diluted by increasing fat mass (10). A further explanation for the inverse relationships between adiposity and vitamin D status could be reduced sun exposure due to a more sedentary indoor lifestyle of people with obesity (6). However, compared with placebo, dietary vitamin D supplementation has demonstrated only small (or no) effects on weight loss (11-13).

There is some evidence for reduced adiposity and risk of metabolic dysfunction in individuals with increased exposure to sunlight or ultraviolet radiation (UVR) (6). For example, in the $>24,000$ female participants of the *Melanoma in Sweden Study*, there was a reduced risk for type-2 diabetes in individuals with active sun exposure habits (14). However, there are inconsistent findings from other observational studies, and only a limited number of clinical trials that have tested the capacity of sun exposure or direct exposure to UVR to affect

adiposity and/or the severity/incidence of type-2 diabetes or metabolic disease (6). We have previously shown in mice fed a high fat diet, that ongoing exposure to UVR suppressed weight gain and symptoms of metabolic syndrome (15). These effects were independent of changes in concentrations of circulating 25-hydroxyvitamin D, with nitric oxide identified as a mediator of some of the effects of UVR (15, 16).

The relationship between sun exposure and obesity has not been explored in cancer patients. Individuals with breast or prostate cancer are at increased risk of developing obesity, compared to the general population (17-19). This may be caused by the modes of action of some cancer treatments, such as chemotherapy, surgery and radiotherapy for breast cancer (19), and hormonal treatments in both breast and prostate cancer (20). The aim of the present study was to examine the relationship between time spent outdoors (as a proxy for sun exposure) and adiposity in a convenience cohort of adults diagnosed with breast or prostate cancer. Based upon our animal experiments (15, 16), we hypothesised that higher sun exposure would be associated with lower adiposity, independent of potential confounders.

MATERIALS AND METHODS

Study population. A total of 688 cancer patients and carers from Perth, Western Australia, were enrolled in a 3-month exercise program at the Exercise Medicine Research Institute, Edith Cowan University (21). The participants (aged 17-92 years) were recruited between 2011 and 2014. Each participant provided written informed consent to participate in the study. Self-reported questionnaires were completed prior to participation in the exercise program, which captured participant demographics, sun exposure characteristics, cancer type, presence of co-morbid conditions (hypertension, hypercholesterolaemia, cardiovascular

disease, diabetes and/or osteoporosis), and type of treatment received for their cancer (surgery, radiation therapy, chemotherapy and/or hormone therapy). There was a total of 50 different cancers; however, only breast cancer (n=269) and prostate cancer (n=78) cases were well represented (n>50) in the population. These are the most common cancers in women and men (respectively) worldwide, and in Australia (excluding non-melanoma skin cancer) (22). We thus restricted our analysis to participants with breast or prostate cancer who had answered the sun exposure questionnaires and had their adiposity measures recorded (Figure 1). Data was collected from these participants at their initial appointment (upon recruitment), which occurred throughout the collection period (2011-2014) with data from n=91, n=126, n=56, and n=73 participants collected in spring, summer, autumn and winter (respectively). Ethics approval was obtained from the Edith Cowan University Human Research Ethics Committee (HREC reference number: 6192 CORMIE).

Measuring sun exposure. Sun exposure was determined by self-reported questionnaire. Time spent outdoors in the previous week was used as a proxy for sun exposure as it is significantly correlated with UVR exposure measured via dosimetry ($r^2 \geq 0.45$; $p \leq 0.003$) (23, 24). Participants were asked three questions about their time spent outdoors as a proxy for sun exposure:

1. “On average, how much time did you spend outdoors on each day of the last week?”;
2. “On average, how much time did you spend outdoors on each day of the week last winter?”; and,
3. “On average, how much time did you spend outdoors on each day of the week last summer?”

The answers to each of these questions were recorded as minutes/day and converted to hours/week.

Measuring skin type and skin responses to sun exposure. The following questions were used to assess skin type and skin response to sun exposure for each participant:

- A. “What best describes the colour of the skin on the inside of your upper arm? That is, the colour of your skin without any tanning? (answers: fair, medium, olive/dark, or black)”;
- B. “Imagine you went out in the strong sun for 30 minutes in the middle of the day for the first time in summer, without protecting your skin with sunscreen or clothing. Which of the following would happen to your skin? (answers: not burn, burn a little, burn moderately, or burn badly)”;
- C. “Now, imagine you did spend several weeks outdoors in the sun, without protecting your skin with sunscreen or clothing. Which of the following would happen to you? (answers: not tan, tan lightly, tan moderately, or tan deeply)”;
- D. “How many bad sun burns with pain lasting longer than a day would you guess you have had? (answers: never, once, 2-10 times, more than 10 times, or don’t know)”

Measuring physical activity. The Godin Leisure-Time Exercise Questionnaire (25) was used to assess physical activity levels by measuring how often each participant performed different forms of exercise in an average week, such as different intensities of aerobic exercise and resistance training. Physical activity level was calculated using a combination of the weekly frequency and duration of moderate and vigorous (scaled by a factor of 1.5) intensity aerobic exercise as outlined by the American College of Sports Medicine exercise guidelines for cancer survivors (26).

Measuring adiposity. The reported adiposity outcomes were BMI, waist-hip ratio, and body fat percentage. BMI was calculated as $(\text{mass (kg)}) \div (\text{height (m)})^2$, while waist-hip ratio was calculated as $(\text{waist circumference (cm)}) \div (\text{hip circumference (cm)})$ as detailed previously (21). Body fat percentage was determined for a sub-sample of participants (see Figure 1) using the Hologic Discovery A Dual Energy X-Ray Absorptiometry (DXA) scanner (Waltham, MA).

Statistical analysis. Participants with missing data were excluded from the analysis after rechecking original questionnaires for missing records. The analyses focused on the breast and prostate cancer group, as the prevalence of other cancer types were small (<5%). Univariate linear regression modelling was used to examine the associations between each time spent outdoors variable (previous week, last winter, and last summer) and continuous adiposity outcome measures (BMI, waist-hip ratio and body fat percentage), which totaled 9 separate models. Multivariable linear models were used to account for potential confounders, firstly adjusting for only age, cancer treatment received (modelled as yes/no for surgery, radiation, chemotherapy and hormonal therapy), and physical activity level; then adjusting for sex in the subsequent model. Interactions between time spent outdoors and sex were included to determine if associations between time spent outdoors and adiposity was different according to sex. Statistical significance was assumed when $p < 0.05$. Data were analysed using SPSS Statistics 22 (IBM Corporation, 2013 – for Windows).

RESULTS

Cohort characteristics

The distribution of age, education, illness markers, cancer treatment, adiposity measures, and physical activity levels of the cohort, divided by sex/cancer type are described in Table 1. There were substantial differences observed between the male and female participants, whereby the male (prostate cancer) participants were on average >10 years older and reported higher baseline rates of hypertension, hypercholesterolaemia, cardiovascular disease, and diabetes, than the female (breast cancer) participants (Table 1). Higher levels of education and more surgical interventions and chemotherapy were reported in female participants compared to male participants. While BMI was similar for male and female participants, waist-hip ratio was greater in male than female participants, with the opposite observed for body fat percentage. Reported levels of sun exposure were greater for the male compared to the female participants for the previous week, last winter or last summer (Table 1).

Skin type was similar between male prostate cancer and female breast cancer participants (question A); as was skin response after 30 minutes (question B) and after several weeks of sun exposure (question C; Table 1). However, greater proportions of both ‘never’ and ‘more than ten’ previous bad sunburns were reported for the men with prostate cancer compared to women with breast cancer (question D; Table 1).

Time spend outdoors and adiposity by sex/cancer type

In initial logistic regression analyses, men reported significantly greater time spent outdoors compared to women in the past week (coefficient=8.77, 95% CI 5.24 to 12.3; $p<0.001$), last winter (coefficient=10.2, 95% CI 6.24 to 14.08; $p<0.001$), and last summer (coefficient=13.4, 95% CI 8.64 to 18.2; $p<0.001$). In addition, men had higher waist-hip ratio

(coefficient=0.123, 95% CI 0.105 to 0.141; $p<0.001$) and reduced percentage body fat (coefficient=-8.71, 95% CI -10.8 to -6.62; $p<0.001$) compared to women. These coefficients represent a mean difference in hours per week.

Associations between time spent outdoors and adiposity: unadjusted regression models

We found no statistically significant associations between time spent outdoors (all three time points) and BMI for the total population, nor, when the data were stratified by sex (Table 2). Time spent outdoors in the previous week ($p=0.005$; $n=145$), last winter ($p=0.002$; $n=140$), and last summer ($p=0.002$; $n=138$) were positively associated with waist-hip ratio in the total population (Table 2A) but not when data were stratified by sex (Table 2B, C). Time spent outdoors in winter was inversely associated with percentage body fat in the combined analysis (Table 2A, $p=0.016$; $n=63$), but again, not when stratified by sex (Table 2B, C).

Associations between time spent outdoors and adiposity: adjusted regression models

We tested each time spent outdoors variable as a predictor of adiposity, adjusting for potential confounders: firstly including age, treatment received, and physical activity; and then additionally adjusting for sex. In the models adjusted for age, treatment and physical activity, time spent outdoors was not associated with BMI or percentage body fat (data not shown). However, time spent outdoors was significantly associated with waist-hip ratio (time spent outdoors previous week, coefficient=0.002, 95% CI 0.001 to 0.003, $p=0.002$; last winter, coefficient=0.001, 95% CI 0.00005 to 0.002, $p=0.038$; see Table 3 for time spent outdoors

last summer, ‘adjusted model without sex’). When the models were additionally adjusted for sex, time spent outdoors was no longer associated with any of the adiposity measures (Table 3 for time spent outdoors last summer, ‘adjusted model with sex’; data not shown for time spent outdoors previous week and last winter). There were no statistically significant interactions between sex and time spent outdoors (data not shown). In the adjusted models, the only significant predictor of adiposity (WHR and body fat percentage) was sex (see Table 3).

DISCUSSION

This study examined the associations between time spent outdoors (as a proxy for sun exposure) and adiposity in women and men with breast and prostate cancer (respectively). In unadjusted models for the combined cancers there were positive associations between time spent outdoors (previous week, last winter or summer) and waist-hip ratio, and an inverse association between time spent outdoors (last winter) and body fat percentage. These associations were not statistically significant in models stratified by sex, and there were no significant associations between time outdoors measures and any measure of adiposity in adjusted analyses. These data support the previously well-described phenomenon of sex differences in adiposity (27), and suggest that time spent outdoors was potentially acting as a proxy for sex in our univariate models. Studies using larger populations are necessary to determine if the loss of these associations post-adjustment we observed was related to study power. Furthermore, longitudinal studies would elucidate the temporality of the associations, which could be assessed in this cross-sectional study.

Our observations suggest that greater time spent outdoors by male participants may have driven the unadjusted positive associations observed between time spent outdoors and waist-hip ratio, with male participants having increased waist-hip ratio, compared to female participants. The unadjusted results of this Western Australian adult population were similar to those of a larger study of the general Korean adult population (n=8,623), in which greater sun exposure over adult life (>5 hours a day) was significantly associated with reduced body fat percentage in men ($p<0.001$), but higher waist circumference in both men ($p=0.046$) and women ($p<0.001$) after controlling for physical activity as a confounder (28). These observations may suggest that metabolic effect(s) of sun exposure are different for men and women. The statistically significant associations between greater sun exposure and adiposity reported by Ohn *et al* (2014) are likely to be due to the longer time frame for measurement of sun exposure (across adulthood, compared to last 12 months), and the greater cohort size (and power) of their analysis (28). A further difference between the current study and that published by Ohn *et al* (2014) was the higher levels of sun exposure observed in the overall healthy South Korean population (28), in which the minimum amount of sun exposure was 14 h/week from 19 years of age (a finding which could be affected by recall bias), compared to the Western Australian-based cancer population examined here, of which one-third of the cohort had ≤ 7 h/week of sun exposure across all seasons.

Chronically sun-damaged skin may contain less fat in subcutaneous tissue than non-damaged skin, possibly due to the production of pro-inflammatory cytokines, which may suppress subcutaneous lipid synthesis (29). These observations may explain the inverse relationships observed between body fat percentage and sun exposure by Ohn *et al* (2014) (28). Other studies have examined the associations between light exposure (in general) and obesity among populations without cancer. When measured using wrist-based actigraphy, increased average daily light exposure (both sun exposure and artificial light) above 500 lux

earlier in the day was associated with reduced BMI in healthy participants from the community (30). These results were linked with the effects of light exposure on circadian rhythm (30). Daily bright light treatment (using light-emitting diodes, between 9 am and 2 pm) combined with a 6-week exercise program caused a greater reduction in body fat, compared with the completion of the exercise program alone, in individuals with obesity (31). In overweight women, three weeks of treatment with bright light in the morning reduced body fat, but not body weight, compared to that observed in the placebo control group (32). In our study, we did not assess the timing of sun exposure (or exposure to other light sources). Further studies are needed to determine whether there are beneficial effects of (morning) sun exposure in mitigating weight loss when incorporated as part of exercise programs.

Men and women living with prostate or breast cancer (respectively) reported differences in their sun exposure behaviour. The effects of (non-skin) cancer diagnosis as an adult on sun exposure behaviours are unknown. Some research has shown that survivors of skin cancer (33) and childhood cancers (34) are more likely to exhibit behaviours that limit their sun exposure compared to control groups, and may modify their sun exposure habits in response to earlier (skin) cancer diagnosis, treatment and survival. The participants in the present study were at different stages of their cancer journey. We had limited capacity to control for differences, such as; time since diagnosis, duration of treatment, and time since last treatment. We also did not have information on whether participants were attempting to improve their general health by participating in lifestyle-based weight loss strategies (e.g. through caloric restriction). The cross-sectional associations were made at one point of time that likely differed for each participant in their cancer journey. Hence, the positive associations between time spent outdoors and adiposity may capture participants at an earlier point in their journey when they have not (as yet) experienced any weight loss.

The risk of developing obesity is increased in breast and prostate cancer patients compared to the general population, and may be exacerbated by the effects of cancer treatments (19, 20). Indeed, several studies have reported weight gain as a common phenomenon among breast cancer patients and survivors (19). Suggested causes include the onset of premature menopause during treatment, predisposing women towards weight gain (35). Our results suggest that female participants had lower abdominal obesity (measured by waist-hip ratio), and higher body fat percentage (measured by DXA) compared with male participants, which is consistent with known sex differences in fat distribution between men and women (36, 37), the older age of the men, and the use of androgen-deprivation therapy to treat prostate cancer (20).

A strength of this study is that we used three different methods to measure adiposity. Others have reported limitations when only using BMI as a measure of adiposity. Firstly, the relationship between BMI and percentage of body fat is nonlinear (38). In addition, BMI does not accurately reflect changes in body composition (fat and non-fat mass) that occur with age (39), and may overestimate risk of obesity-related mortality in those aged above 75 years (40). Waist-hip ratio may be a better measure of adiposity in middle-aged persons as it more accurately measures central obesity, and better predicts mortality risk than BMI (40, 41). Waist-hip ratio and body fat percentage (via DXA scan, the most reliable measure for body fat) (42) were likely the more accurate measures of adiposity in our study when considering the older age of the study participants, who had a mean age of 61 years, with 12% over 75 years of age.

Limitations of our study include the convenience sampling method, with data obtained from a community-based exercise program being run for cancer patients. Outcomes observed here may thus not accurately represent findings for the general population. Secondly, sun exposure and physical activity data were collected via self-reported questionnaires, which

may be subject to recall bias. Thirdly, there were considerable numbers of missing sun exposure questionnaire answers and adiposity measures. Body fat percentage measurements were only recorded for some participants due to limitations accessing the DXA scanner. Another confounder not measured, which influences adiposity is caloric intake. Fourthly, the study design did not allow for the directionality of the relationship between sun exposure and adiposity to be determined. Finally, the data did not account for adiposity and sun exposure of patients before their diagnosis of cancer, so the effects of cancer on the associations between sun exposure and adiposity could not be assessed.

In conclusion, in this study of adults with breast and prostate cancer, there were no significant independent associations between time spent outdoors (as a proxy of sun exposure) and adiposity. Further longitudinal studies in larger populations, using dosimeters to accurately quantify sun exposure and accelerometers to accurately measure physical activity, would better characterise the potential effect of sun exposure on adiposity. Emerging research reporting protective effects of sun exposure on breast, prostate and colorectal cancer and non-Hodgkin's lymphoma, which may occur through the modulation of metabolic pathways that contribute towards body weight (43), emphasize the importance of better understanding the associations between sun exposure and adiposity in individuals with cancer. 'Safe' sun exposure could be a cost-effective and accessible tool to reduce adiposity, if integrated as part of lifestyle interventions, especially in sunny countries such as Australia. However, further evidence is needed to demonstrate whether our pre-clinical findings in mice (16, 15) are relevant in people.

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Table 1. Characteristics of participants with prostate (male) or breast (female) cancer.

	Males (<i>n</i> =78)	Females (<i>n</i> =269)	Total (<i>n</i> =347)
Age, y, mean (SD)	69.1 (10.0)	58.4 (11.3)	60.8 (11.9)
Education, n (%)	(<i>n</i> =74)	(<i>n</i> =261)	(<i>n</i> =335)
Secondary or less	25 (32)	98 (36)	123 (35)
Trade or diploma	35 (45)	90 (34)	125 (36)
Tertiary	14 (18)	72 (27)	86 (245)
Other	0 (0)	1 (0.4)	1 (0.3)
Co-morbid conditions, n of yes (%)	(<i>n</i> =78)	(<i>n</i> =269)	(<i>n</i> =347)
Hypertension	46 (60)	87 (32)	133 (38)
High cholesterol	36 (46)	91 (34)	127 (37)
Cardiovascular disease	16 (20)	14 (5)	30 (9)
Diabetes	12 (15)	14 (5)	26 (8)
Osteoporosis	6 (8)	24 (9)	30 (9)
Treatment, n of yes (%)	(<i>n</i> =78)	(<i>n</i> =269)	(<i>n</i> =347)
Surgery	34 (44)	248 (93)	282 (81)
Radiation therapy	47 (60)	170 (63)	217 (62)
Chemotherapy	3 (4)	183 (68)	186 (54)
Hormone therapy	50 (64.1)	143 (53)	193 (56)
BMI, kg/m², mean (SD)	28.4 (5.1), <i>n</i> =78	27.6 (5.6), <i>n</i> =268	27.8 (5.5), <i>n</i> =346
Waist-hip ratio, mean (SD)	0.97 (0.07), <i>n</i> =78	0.84 (0.07), <i>n</i> =266	0.87 (0.09), <i>n</i> =344
Body fat percentage, %, mean (SD)	31.0 (5.4), <i>n</i> =37	39.9 (5.7), <i>n</i> =115	37.7 (6.8), <i>n</i> =152
Physical activity, minutes, mean (SD)†	164 (606)	95.5 (162)	110.8 (321)
Time spent outdoors, h (SD)			
1. Previous week	19.9 (12.4), <i>n</i> =39	11.0 (8.4), <i>n</i> =106	13.4 (10.4), <i>n</i> =145
2. Last winter	20.0 (12.6), <i>n</i> =36	10.0 (9.5), <i>n</i> =104	12.6 (11.2), <i>n</i> =140
3. Last summer	26.3 (17.8), <i>n</i> =35	12.8 (10.1), <i>n</i> =103	16.2 (13.8), <i>n</i> =138
A. Skin type, n (%)††	(<i>n</i> =39)	(<i>n</i> =114)	(<i>n</i> =153)
Fair	19 (49)	63 (55)	82 (54)
Medium	12 (31)	41 (36)	53 (35)
Olive/Dark	7 (18)	10 (9)	17 (11)
Black	1 (3)	0 (0)	1 (0.1)
B. Reaction to 30 min of sun exposure, n (%)††	(<i>n</i> =39)	(<i>n</i> =114)	(<i>n</i> =153)
Not burn	4 (10)	6 (5)	10 (6)
Burn a little	19 (49)	39 (34)	58 (38)
Burn moderately	12 (31)	38 (33)	50 (33)
Burn badly	4 (10)	31 (27)	35 (23)
C. Reaction after several weeks of sun exposure, n (%)††	(<i>n</i> =39)	(<i>n</i> =114)	(<i>n</i> =153)
Not tan	2 (5)	10 (9)	12 (8)
Tan lightly	6 (15)	30 (26)	36 (24)
Tan moderately	14 (36)	45 (40)	59 (39)
Tan deeply	17 (44)	29 (25)	46 (30)
D. Bad sunburns in the past, n (%)††	(<i>n</i> =37)	(<i>n</i> =112)	(<i>n</i> =149)
Never	17 (46)	24 (21)	41 (28)
Once	2 (5)	17 (15)	19 (13)
Two to ten times	9 (24)	46 (41)	55 (37)
More than ten times	9 (24)	17 (15)	26 (17)
Don't know	0 (0)	8 (7)	8 (5)

†Physical activity level was calculated using a combination of the weekly frequency and duration of moderate and vigorous (scaled by a factor of 1.5) intensity aerobic exercise

††The proportions (%) reported are for those who answered the skin sensitivity and sun exposure questionnaire (up to 153 individuals)

Table 2. Unadjusted associations for the (A) overall cohort, (B) male prostate cancer, and (C) female breast cancer participants, between sun exposure measures (time spent outdoors in previous week, last winter, or last summer) and adiposity measures (BMI, waist-hip ratio and percentage body fat).

A – Overall

Time spent outdoors	BMI			Waist-hip ratio			Percentage body fat		
	Coefficient (95% CI)†	n	p	Coefficient (95% CI)†	n	p	Coefficient (95% CI)†	n	p
1. Previous week (h)	0.017 (-0.068, 0.102)	14 5	0.694	0.002 (0.001, 0.003)	14 5	0.005 *	-0.137 (-0.297, 0.024)	6 5	0.094
2. Last winter (h)	0.011 (-0.070, 0.091)	14 0	0.796	0.002 (0.001, 0.003)	14 0	0.002 *	-0.211 (-0.382, -0.040)	6 3	0.016 *
3. Last summer (h)	0.043 (-0.023, 0.108)	13 8	0.199	0.002 (0.001, 0.003)	13 8	0.002 *	-0.117 (-0.285, 0.050)	6 0	0.166

B – Males

Time spent outdoors	BMI			Waist-hip ratio			Percentage body fat		
	Coefficient (95% CI)†	n	p	Coefficient (95% CI)†	n	p	Coefficient (95% CI)†	n	p
1. Previous week (h)	0.061 (-0.055, 0.177)	3 9	0.293	0.0004 (-0.002, 0.002)	39 3	0.73	0.015 (-0.205, 0.235)	1 9	0.887
2. Last winter (h)	0.097 (-0.023, 0.217)	3 6	0.108	0.0004 (-0.002, 0.003)	36 1	0.72	0.056 (-0.184, 0.296)	1 7	0.627
3. Last summer (h)	0.050 (-0.039, 0.138)	3 5	0.263	-0.00005 (-0.002, 0.002)	35 4	0.94	0.071 (-0.143, 0.284)	1 7	0.491

C – Females

Time spent outdoors	BMI			Waist-hip ratio			Percentage body fat		
	Coefficient (95% CI)†	n	p	Coefficient (95% CI)†	n	p	Coefficient (95% CI)†	n	P
1. Previous week (h)	-0.046 (-0.175, 0.084)	10 6	0.48	0.0002 (-0.001, 0.002)	10 6	0.76	-0.039 (-0.251, 0.172)	4 6	0.710
2. Last winter (h)	-0.063 (-0.179, 0.053)	10 4	0.28	0.0001 (-0.001, 0.002)	10 4	0.83	-0.172 (-0.411, 0.067)	4 6	0.154
3. Last summer (h)	0.025 (-0.084, 0.134)	10 3	0.65	0.0002 (-0.001, 0.002)	10 3	0.73	-0.052 (-0.289, 0.186)	4 3	0.664

†Estimated difference in adiposity measures per 1 hour increase of time spent outdoors (95% CI, confidence interval). Statistically significant at **p<0.05***

Table 3. Adjusted regression models without sex and with sex, predicting waist-hip ratio for the sun exposure measure, time spent outdoors in previous summer.

Predictors	Adjusted model without sex Coefficient (95% CI) [†]	p-value	Adjusted model with sex Coefficient (95% CI) [†]	p-value
Time spent outdoors last summer (h)	0.001 (0.0003, 0.002)	0.006*	0.0008 (-0.001, 0.001)	0.821
Age (years)	0.001 (0.001, 0.002)	0.002*	0.001 (-0.0002, 0.001)	0.117
Physical activity (h)	-0.00003 (-0.00009, 0.00002)	0.258	-0.00004 (-0.00009, 0.000007)	0.088
Treatment received				
<i>Surgery</i>	-0.042 (-0.064, -0.019)	<0.001*	-0.020 (-0.041, 0.001)	0.060
<i>Hormonal</i>	-0.005 (-0.028, 0.017)	0.658	-0.003 (-0.023, 0.017)	0.792
<i>Radiation</i>	0.015 (-0.007, 0.038)	0.176	0.018 (-0.020, 0.038)	0.072
<i>Chemotherapy</i>	-0.029 (-0.052, -0.006)	0.013*	-0.014 (-0.034, 0.017)	0.185
Sex				
<i>Male</i>			0.092 (0.068, 0.116)	<0.001*
<i>Female</i>			Reference	
Constant	0.816 (0.751, 0.881)	<0.001*	0.828 (0.770, 0.885)	<0.001*

[†]Estimated difference in waist-hip ratio from the reference category of categorical variables or per 1 unit increase of continuous variables. Statistically significant at **p<0.05***

FIGURE CAPTIONS

Figure 1. A flowchart of the inclusion criteria and sample sizes. There were a limited number of participants who received a DXA scan to record body fat percentage compared to the other adiposity measures. The number of individuals with prostate and breast cancer who completed both the sun exposure questionnaire (time spent outdoors in summer) and each adiposity measure (BMI, waist-hip ratio, body fat percentage) are shown.

Figure 1. A flowchart of the inclusion criteria and sample sizes. There were a limited number of participants who received a DEXA scan to record body fat percentage compared to the other adiposity measures. The number of individuals with prostate and breast cancer who completed both the sun exposure questionnaire (time spent outdoors in summer) and each adiposity measure (BMI, waist-hip ratio, body fat percentage) are shown.