Determinants of sleep quality in 5,835 individuals living with and beyond breast, prostate, and colorectal cancer: a cross-sectional survey.

Silje Aronsen[1], Rana Conway[1], Phillippa Lally[1], Anna Roberts[1], Helen Croker[1], Rebecca J Beeken[1*], and Abigail Fisher[1*].

*these authors are joint senior

[1] Research Department of Behavioural Science and Health, University College London, Gower Street, London, WC1E 6BT, UK

Corresponding author

Correspondence to Silje Aronsen (silje.aronsen.19@alumni.ucl.ac.uk)

Declarations

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Conflict of interest

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

Ethics approval

Ethical approval was obtained through the National Research Ethics Service Committee South Central—Oxford B (reference number 14/SC/1369).

Consent to participate and consent for publication

The following statement was provided on the questionnaire:

"By completing this questionnaire you are consenting to your anonymous information being used for research on lifestyle in people diagnosed with cancer."

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors contributions

SA, RC, PL, AR, HC, RB, AF designed the study, RC, AR, HC collected the data, SA, RC, AF analysed the data, SA, RC, PL, RB, AF interpreted the data. SA drafted the manuscript, RC, AF, PL, RB, AR, HC revised it critically for intellectual content and finally approved the version to be submitted.

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Abstract

Purpose: The present study aimed to quantify the level of sleep problems in 5,835 breast, prostate and colorectal cancer survivors, and explore a number of potential determinants of poor sleep quality in the present sample. BMI, diet, and physical activity were of particular interest as potential determinants.

Methods: Participants who completed the "Health and Lifestyle after Cancer" survey were adults who had been diagnosed with breast, prostate or colorectal cancer (mean time since cancer diagnosis was 35.5 months, SD=13.56). Sleep quality was assessed using the Pittsburgh Sleep Quality Index. BMI was calculated from self-reported height and weight. Participants were categorised as meeting/not meeting the World Cancer Research Fund (WCRF) recommendations for fibre, fruit and vegetables, added sugar, red meat, processed meat, fat, alcohol, and physical activity. Analyses accounted for demographic and clinical factors.

Results: 57% of those with sleep data were classified as poor sleepers (response rate 79%). Being female, having a higher number of cancer treatments, more comorbid conditions, and being more anxious/depressed, increased the odds of being a poor sleeper. After adjustment for these factors there were no associations between diet/alcohol/physical activity and sleep. However, BMI was associated with sleep. Individuals in the overweight and obese categories had 22% and 79% higher odds of being poor sleepers than individuals in the underweight/healthy weight category, respectively.

Conclusions: The findings suggest that there may be a need to develop sleep quality interventions for cancer survivors with obesity. Even after adjustment for multiple clinical and demographic factors, BMI (particularly obesity) was associated with poor sleep. Thus, researchers and health professionals should find ways to support individuals with overweight and obesity to improve their sleep quality.

Implications for cancer survivors: The present findings highlight that poor sleep is a common issue in cancer survivors. Interventions seeking to improve outcomes for cancer survivors over the longer term should consider sleep quality.

Keywords: cancer, sleep quality, diet, obesity, physical activity

Introduction

The incidence of cancer is increasing in both developed and developing countries with breast, prostate, and colorectal cancer among the most common cancer types [1]. At the same time, earlier diagnosis and better cancer care have increased the number of people surviving cancer and increased their life expectancy [2]. For example, the percentage of individuals in the UK surviving cancer for 10 or more years has nearly doubled from 24% to 50% in the last 40 years [3]. The World Cancer Research Fund (WCRF) and American Institute for Cancer Research (AICR) [4] recommend that cancer survivors follow guidelines for health behaviours, such as having a healthy diet, and staying physically active, to achieve longer and healthier cancer survivorship. Whilst research has explored how following these guidelines may impact cancer survivors' quality of life and wellbeing [5, 6], there is little research exploring the potential impact of health behaviours on sleep quality in cancer survivors.

Some of the most common health-related issues cancer survivors report are sleep problems, and a study from the USA found that cancer survivors reported 11% more sleep problems than healthy populations [7]. A systematic review including prospective/longitudinal and cross-sectional studies looking at long-term effects of cancer and treatment exposures, showed that sleep disturbance is common in breast, prostate, and rectal/colon cancer survivors, up to several years after completion of primary cancer treatment [8]. Furthermore, existing studies suggest that sleep problems are reported by 37-64% of breast and prostate cancer survivors [9,10]. However, these studies included relatively small samples of each cancer type (n<200), and included some participants still receiving treatment. Furthermore, qualitative research shows that colorectal cancer survivors commonly report disrupted sleep [11], however there is a lack of quantitative research exploring sleep quality in colorectal cancer survivors.

There is evidence of a (bidirectional) relationship between body mass index (BMI) and sleep in non-cancer populations. One longitudinal study followed 11,965 individuals from adolescence to young adulthood and found that high BMI during an earlier developmental stage was associated with shorter sleep duration in the subsequent stage [12]. In addition, research shows that an increase of 6 kg/m^2 in BMI results in a fourfold greater risk of developing obstructive sleep apnoea-hypopnea syndrome, which involves recurring episodes of total obstruction (apnoea) or partial obstruction (hypopnea) of airways during sleep [13]. Therefore, obesity is a major risk factor for developing sleep apnoea, and it is estimated that as many as 45% of individuals with obesity have the sleep disorder [14]. At the same time, research has also explored how sleep may subsequently affect BMI.

Magee & Hale [15] conducted a review of 20 longitudinal studies exploring how sleep duration may be associated with subsequent weight gain, and concluded findings were inconsistent in adult samples.

There is limited research exploring the relationship between BMI and sleep quality after a cancer diagnosis. An observational study of 861 women with breast cancer found that in initial analyses, higher BMI was associated with shorter sleep (less than 6 hours/night), but this was no longer the case after adjustment for multiple confounders [16]. This study did not explore the association between BMI and sleep quality, so research exploring the relationship between sleep and BMI using validated sleep measures is needed.

Sleep might also be associated with energy intake. An experimental fMRI study with 23 healthy young adults showed that insufficient sleep decreases activity in the appetitive evaluation regions in the brain, which subsequently increases desire for food associated with weight gain [17]. Studies have also found associations between maintaining diets in line with healthy eating guidelines and better sleep quality. For example, a cross-sectional study including 172 middle-aged adults found that maintaining a Mediterranean diet is associated with good sleep quality, which may be due to the high content of polyunsaturated fatty acids and phytochemicals reducing inflammatory markers that have a reported negative impact on sleep quality [18]. On the other hand, some research demonstrates contrary findings. For instance, a repeated-measures randomised crossover study, gave 36 healthy young adults a high-protein diet, high-carbohydrate diet, high-fat diet, and a control diet over several days, and found that participants reported best sleep quality after eating a high-fat diet, even with high intakes of saturated fat [19].

Other research also suggests that individual dietary components may affect sleep independently. A cross-sectional study with 243 adults with obstructive sleep apnoea, found that individuals with higher intakes of red meat had three times higher likelihood of having severe obstructive sleep apnoea than those with lower intakes of red meat, after controlling for other diet components [20].

There is extremely limited evidence about whether sleep and diet are associated after a cancer diagnosis. One cross-sectional study with 232 breast cancer survivors found that those reporting healthier dietary patterns had *more* insomnia symptoms than those reporting less healthy dietary patterns ('western dietary pattern') [21]. This finding was unexpected and the authors argued that more research is needed to explain the association between insomnia symptoms and diet in breast cancer survivors. A limitation of the study may be

that the characteristics of the two dietary patterns were not considerably different, and the 'western dietary pattern' was identified based on few characteristics, some of which were also included in the 'healthy dietary pattern', such as a high intake of eggs, seasonings, and dressings.

Furthermore, research also links alcohol intake to poor sleep in some cancer survivors. For instance, one cross-sectional study with 200 breast cancer survivors found that those who reported drinking alcohol were more likely to be poor sleepers than those who did not drink alcohol [10]. Similar findings have also been found in non-cancer populations. A cross-sectional study with 11,905 healthy adults showed that higher alcohol consumption was associated with poor sleep quality and shorter sleep duration [22]. There is a lack of studies exploring the association between alcohol intake and sleep quality in prostate and colorectal cancer survivors.

A considerable number of studies propose a positive impact of physical activity on sleep quality. One systematic review conducted by Mercier and colleagues [23] explored the effect of various exercise interventions on sleep quality in patients with different cancer diagnoses, and found an improvement in sleep in 48% of the studies. However, most of the participants included in the studies in the review were diagnosed with breast cancer [23], and the findings are therefore mostly generalisable to this cancer population. Furthermore, many of the studies exploring the relationship between physical activity and sleep include cancer patients who were still undergoing primary curative treatment, and more research is needed to understand the health effects of physical activity after completing cancer treatment.

The aim of the present study was to explore potential determinants of sleep quality in breast, prostate, and colorectal cancer survivors, with particular focus on BMI, diet, alcohol, and physical activity. In addition, the study aimed to also explore a number of other demographic and clinical characteristics as potential determinants of poor sleep. The present study explored individual dietary components, rather than a dietary pattern, because the study aimed to explore whether adherence to specific dietary guidelines was associated with sleep quality, and highlight specific behaviour changes cancer survivors may benefit from.

Methods

Design

This cross-sectional study used data from the 'Health and Lifestyle After Cancer' survey [24]. The questionnaire included questions about demographics, health, physical activity, diet and nutrition, alcohol, and sleep. Further details of the survey can be found in the protocol paper for the Advancing Survival Cancer Outcomes Trial (ASCOT) [24] as this survey was used to identify potential trial participants.

Procedure

Participants were recruited through ten participating NHS Trusts across London and Essex, through the Clinical Research Network Portfolio. Participating sites mailed letters of invitation, the survey in paper form, and a link to an internet version of the survey to the eligible patients. Participants completed the survey via their preferred method and returned it directly to the research team. Returned questionnaires were accepted between February 2015 and January 2018. Ethical approval was obtained through the National Research Ethics Service Committee South Central—Oxford B (reference number 14/SC/1369).

Participants

The 'Health and Lifestyle after Cancer Survey' included people who were 18 years and older who had received a diagnosis of breast, prostate or colorectal cancer. Participating hospitals were asked to send surveys to anyone diagnosed with breast, prostate or colorectal cancer between 2012-2015. These dates were chosen to make the numbers manageable and in the hope of reaching people who had completed, or were close to completing, primary curative treatment (an inclusion criteria for the ASCOT trial). However, participants who had been diagnosed outside of these dates and returned surveys were still included in the current analysis. Participants were therefore diagnosed with breast, prostate or colorectal cancer between 1994 and 2017 (mean time since cancer diagnosis was 35.5 months, SD=13.56). However, as some participants were diagnosed with a subsequent cancer the range of diagnosis dates for participant's most recent cancer was 2000-2017. Survey inclusion criteria were deliberately broad to reduce burden on hospital sites and because we were interested in the views of anyone living with and beyond breast, colorectal and prostate cancer.

Measures

Dependent variable

Sleep quality was measured using the Pittsburgh Sleep Quality Index (PSQI)[1] [25], which is a 19-item self-rated questionnaire assessing sleep quality and sleep disturbances over a 1-month time interval, with participants scoring above five categorised as poor sleepers. It is widely used in research and previous studies demonstrate strong evidence for its validity and reliability for non-clinical and clinical samples [26].

Independent variables

BMI scores were calculated using self-reported height and weight, and were categorised as underweight/healthy weight (<25), overweight (≥25 and <30), and obese (≥30). The underweight and healthy weight categories were combined because only 1.1% (n=65) of the participants fell into the underweight category.

Daily dietary fibre and fat intakes in grams were assessed using the validated DINE FFQ [27], with some food items changed to reflect food items currently available [24]. Amended items from the DINE FFQ was also used to assess daily intake of red and processed meat in grams [24]. The present survey also included items about daily intake of sugary drinks and fruit juices [28}, and teaspoons of added sugar to estimate daily intakes of free sugar in grams. Two items were included to measure number of daily portions of fruit and vegetables [29]. Alcohol intake was measured using two items adapted from The AUDIT Alcohol Consumption Questions, to estimate the average number of units consumed per week [31].

Physical activity was measured in weekly minutes of moderate to vigorous physical activity (MVPA), using four items from the Godin Leisure-Time Exercise Questionnaire (GLETQ) [30]. To calculate MVPA strenuous minutes are doubled and added to moderate minutes. In the present study, doing ≥150 minutes a week of MVPA was categorised as meeting the recommended guidelines for physical activity, while doing <150 minutes a week of MVPA was categorised as not meeting. The GLTEQ has shown favourable validity and reliability in previous research, compared to objective measures of physical activity [32].

[1] Items 5d and 5j and 10a-e of the PSQI were omitted for the present survey and scoring was adjusted accordingly.

The health guidelines for cancer survivors in the present study were taken from the WCRF/AICR [4] and national UK guidelines as follows: fibre (≥30g/day), fruit and vegetables (≥5 portions/day), added sugar (<30g/day), fat (≤33% daily energy), red meat (<500g/week), processed meat (none). National UK guidelines for alcohol consumption recommend to not exceed more than 14 units of alcohol a week [33]. In addition, the WHO recommends adults to engage in at least 150 minutes of moderate-vigorous physical activity a week [4]. The responses in the present analysis were therefore categorised into "not meeting" and "meeting" the recommended guidelines (see Appendix for cut-off values).

Demographic and clinical characteristics

Age (<55, 55-64, 65-74, and ≥85 years), gender (male or female), racial group (white or non-white), marital status (married/cohabiting or separated/divorced/widowed/single), highest level of education (no formal qualifications, GCSE/Vocational or equivalent, A-level or equivalent, Bachelor's Degree and above or equivalent), number of different types of cancer treatments for their most recent cancer (surgery, hormone therapy, radiotherapy, chemotherapy, biological therapy, plus the number of other treatments received), time since the last cancer treatment (still main treatment, <1 year, >1 year, on active surveillance, don't know), and cancer type (breast, prostate, or colorectal cancer) were assessed. Age was categorised into five age groups which have been used in previous research with individuals living with and beyond cancer [34]. Although participants were asked to report their cancer stage, a very large proportion did not know, so cancer spread, assessed with the question 'Has this cancer spread to any other parts of your body?', was used. Anxiety and depression were assessed using one item from the EQ-5D health-related quality of life questionnaire [35], which has favourable validity in cancer patients [36]. The item asks whether participants are not, slightly, moderately, severely or extremely anxious/depressed, and responses were categorised into not, slightly, and moderately to extremely anxious/depressed for the present analysis.

Number of comorbid conditions were assessed by asking participants if they had any of the health problems listed (osteoporosis, diabetes, asthma, emotional or psychiatric illness, stroke, Parkinson's disease, Alzheimer's disease or dementia, lung disease, arthritis, angina, heart attack, heart murmur, irregular heart rhythm, any other heart trouble, another cancer) or other health problems not on the list. The responses were categorised into 'None', '1', '2', or '≥3'.

Statistical Analysis

For the data analysis, the Statistical Package for the Social Sciences (SPSS) version 25 was used. Descriptive statistics were calculated for the demographic and clinical characteristics and health behaviours. T-tests and Chi-squared tests were used to compare poor and good sleepers on the demographic and clinical characteristics. Covariates included in subsequent analyses (regressions) were selected based on those found to be different between the sleep quality categories. This approach was used to avoid too many covariates which may lead to numerically unstable estimates and large standard errors [37]. However, "cancer type" was not included as a covariate to avoid the problem of multicollinearity, as "cancer type" and "gender" were identical in the breast cancer sample (all female) and prostate cancer sample (all male).

For the cancer spread variable, the response option "don't know" was recoded as missing data. Missing value analysis found that 7.9% of 122,535 values were missing and 66% of 5,835 cases had at least 1 piece of missing data. Little's t-test ascertained that the data was not missing completely at random. Multiple imputation was conducted to account for the missing data, with all the variables planned to be included in the regression analyses included. This provided a sample of 5,835 participants. Multiple imputation was used to reduce the possible bias of missing data [38].

Logistic regression analyses were conducted to explore factors that were associated with sleep quality. Sleep quality category (poor vs good sleeper) was the dependent variable, and BMI category, and meeting or not meeting guidelines for dietary behaviours (intake of fibre, fruits and vegetables, sugar, red meat, processed meat, fat, and alcohol), and physical activity were the independent variables. First, a series of regressions were run for each of the independent variables individually, with no covariates included in each model. Then, one regression was run including all independent variables and controlling for covariates.

The logistic regression analyses were repeated with completers (N=2,134) to confirm if the pattern of results were similar.

Additional Chi-squared tests were run to explore the association between BMI and the dietary variables, and BMI and physical activity.

Results

Sample characteristics

A total of 5,835 questionnaires were returned from the 13,500 questionnaires that were sent out (43% response rate). Participant characteristics are presented in Table 1. 56% were female, 90% were white, and mean age was 67.4 years. 48% were diagnosed with breast cancer (n=2786), 32% with prostate (n=1839), and 21% with colorectal cancer (n=1210). When those with missing sleep data (21%) were excluded, 57% of those with complete sleep data fell into the 'poor sleeper category'. The method of data collection and ethical approval meant that the research team had no access to data from non-responders.

A number of demographic and clinical factors, reported in Table 1, were associated with sleep quality. The t-tests and the Chi squared tests (when comparing the expected counts and the actual counts) showed that participants who were younger, female, separated/divorced/widowed/single, diagnosed with breast cancer, whose cancer had spread, had a higher number of treatments, were more anxious/depressed, and had a higher number of comorbidities, were associated with poorer sleep quality.

Racial group, educational level, and time since treatment were not associated with sleep quality. The associated variables were included as covariates in the logistic regression analyses. The descriptive statistics for BMI, physical activity and the dietary variables are shown in Table 2.

Table 1: Descriptive statistics, for demographic and clinical characteristics and sleep quality category in breast, prostate, and colorectal cancer survivors.

	Total n=5835	Good sleepers[2] (n=2008, 34.4%)	Poor sleeper[2] (n=2644, 45.3%)	p
Age in years (n, %)				**0.010**
<55	931 (16.0)	232 (15.3)	578 (18.6)	
55-64	1120 (19.2)	299 (19.7)	663 (21.3)	
65-74	2057 (35.3)	575 (37.9)	1097 (35.3)	
75-84	1385 (23.7)	353 (23.2)	640 (20.6)	
≥85	306 (5.2)	60 (3.9)	134 (4.3)	
Missing data	36 (0.6)			
Mean age (mean, SD)	67.4 (11.8)			
Gender (n, %)				**<0.001**
Male	2533 (43.8)	797 (52.4)	1249 (40.0)	
Female	3266 (56.0)	725 (47.6)	1871 (60.0)	
Missing data	36 (0.2)			
Racial group (n, %)				0.165
White	5249 (90.0)	1850 (92.5)	2394 (91.0)	
Non-white	554 (9.5)	151 (7.5)	238 (9.0)	
Missing data	32 (0.5)			
Highest level of education (n, %)				0.573
No formal qualifications	1709 (29.3)	502 (27.6)	691 (28.5)	
GCSE/Vocational	1613 (27.6)	567 (31.1)	797 (32.9)	
A-level	584 (10.0)	194 (10.6)	300 (12.4)	
Degree or higher	1379 (23.6)	559 (30.7)	638 (26.3)	
Missing data	590 (9.4)			
Marital status (n, %)				**0.001**
Married/cohabiting	4037 (69.2)	1503 (75.1)	1839 (69.7)	
Separated/divorced/widowed/ single	1761 (30.5)	499 (24.9)	800 (30.3)	
Missing data	17 (0.3)			
Time since treatment (n, %)				0.172
Still main treatment	490 (8.4)	136 (6.9)	223 (8.6)	
<1 year	495 (8.5)	160 (5.1)	223 (8.7)	
>1 year	4122 (70.6)	1467(75.3)	1914 (74.0)	
On active surveillance	525 (9.0)	201 (10.2)	217 (8.4)	
Don't know	54 (0.9)	10 (0.5)	10 (0.4)	
Missing data	149 (2.6)			
Cancer type (n, %)				**<0.001**
Breast	2786 (47.7)	838 (41.7)	1413 (53.4)	
Prostate	1839 (31.5)	725 (36.1)	736 (27.8)	
Colorectal	1210 (20.7)	445 (22.2)	495 (18.7)	
Cancer spread (n, %)				**0.002**
Yes	558 (9.6)	116 (8.0)	329 (11.3)	
No	4498 (77.1)	1246 (86.2)	2400 (82.2)	
Don't know/Missing	779 (13.2)			
Number of treatments (mean, SD)	1.9 (1.1)	1.85 (1.0)	2.07 (1.1)	**<0.001**
Missing data (n, %)	86 (1.5)			
Anxiety and depression (n, %)				**<0.001**
None	3249 (55.7)	1491 (74.6)	1205 (45.9)	
Slight	1583 (27.1)	409 (20.5)	894 (34.0)	
Moderate to extreme	781 (13.4)	99 (5.0)	525 (24.2)	
Missing data	222 (3.8)			
Number of comorbid conditions				**<0.001**
Mean (SD)	1.3	1.0	1.4	
None (n, %)	1849 (31.7)	790 (39.3)	744 (28.1)	
1	1991 (34.1)	717 (35.7)	867 (32.8)	
2	1120 (19.2)	316 (15.7)	557 (21.1)	
≥3	875 (15.0)	185 (9.1)	476 (18.1)	
Missing	0 (0.0)			

[2] Missing sleep scores for 21% of the total sample.

Table 2: Descriptive statistics on health characteristics and behaviours and sleep quality category in breast, prostate, and colorectal cancer survivors.

	Total n=5835	Good sleepers[4] (n=2008, 34.4%)	Poor sleeper[4] (n=2644, 45.3%)
Dietary variables[3]			
Fibre (n, %)			
Not meeting	3919 (67.2)	1069 (85.0)	2268 (86.7)
Meeting	668 (11.4)	188 (15.0)	349 (13.3)
Missing	1248 (21.4)		
Fruit and veg (n, %)			
Not meeting	3977 (68.2)	1032 (69.5)	2119 (69.5)
Meeting	1655 (28.4)	453 (30.5)	932 (30.5)
Missing	203 (3.5)		
Added sugar (n, %)			
Not meeting	2673 (45.8)	707 (49.4)	1426 (48.4)
Meeting	2711 (56.5)	725 (50.6)	1522 (51.6)
Missing	451 (7.7)		
Red meat (n, %)			
Not meeting	139 (2.4)	31 (2.2)	71 (2.5)
Meeting	5035 (86.3)	1359 (97.8)	2795 (97.5)
Missing	661 (11.3)		
Processed meat (n, %)			
Not meeting	2861 (49.0)	771 (52.6)	1560 (51.8)
Meeting	2640 (45.2)	694 (47.4)	1451 (48.2)
Missing	334 (5.7)		
Fat (n, %)			
Not meeting	1769 (30.3)	480 (42.1)	1013 (43.3)
Meeting	2303 (39.5)	660 (57.9)	1326 (56.7)
Missing	1763 (30.2)		
Alcohol (n, %)			
Not meeting	714 (12.2)	193 (13.0)	409 (13.5)
Meeting	4848 (83.1)	1286 (87.0)	2612 (86.5)
Missing	273 (4.7)		
Physical activity (n, %)			
<150 mins per week	3161 (54.2)	837 (68.8)	1840 (72.8)
≥150 mins per week	1231 (21.1)	379 (31.2)	686 (27.2)
Missing	1443 (24.7)		
BMI (n, %)			
Underweight/healthy weight	2043 (41.0)	602 (41.4)	1048 (35.0)
Overweight	2247 (38.5)	609 (41.9)	1207 (40.4)
Obese	1209 (20.7)	244 (16.8)	735 (24.6)
Missing	336 (5.8)		

[3] Meeting dietary variables defined as >5 portions of fruit and vegetables/d, ≥30g fibre/d, ≤500g/wk red meat, 0g/d processed meat, ≤33% energy from fat, ≤30g/d added sugar, ≤14units/wk alcohol.

[4] Missing sleep scores for 21% of the total sample

Logistic regression results

Main analysis

Table 3 shows the unadjusted and adjusted results from the logistic regression analyses with the imputed data set. Unadjusted analyses showed that participants who were 65-74 and 75-84 years old had lower odds of being poor sleepers than the youngest age group (<55 years). Furthermore, individuals who were female, separated/divorced/widowed/single, did not meet the physical activity recommendation, had higher BMI, whose cancer had spread, who had a higher number of treatments, a higher number of comorbid conditions, and were more anxious/depressed had greater odds of being a poor sleeper. These findings were also in line with the results from the t-tests and Chi-squared tests.

In the adjusted results, BMI, gender, number of treatments, anxiety/depression, and number of comorbid conditions remained associated with being a poor sleeper, in the same directions as the unadjusted results. Age, marital status, cancer spread, and physical activity were no longer associated.

Specifically, the results showed that participants with a BMI in the overweight and obese categories had 22% and 79% higher odds of being poor sleepers than participants in the underweight/healthy weight category, respectively. Female participants had 25% greater odds of being a poor sleeper than male participants. Furthermore, for every additional type of cancer treatment reported, the odds of being a poor sleeper increased by 17%. Participants with slight anxiety or depression and participants with moderate to extreme anxiety or depression had more than two times greater odds (OR= 2.65) and more than five times greater odds (OR=5.63) of being a poor sleeper than participants with no anxiety or depression, respectively. Those who had 1 comorbid condition did not differ from those with no comorbid conditions. However, individuals with 2 comorbid conditions had 35% greater odds of being a poor sleeper than those who reported no comorbid conditions, and individuals who reported 3 or more comorbid conditions had more than two times greater odds (OR=2.05) of being a poor sleeper.

Table 3: Logistic regression analyses for sleep quality (N=5,835).

	Sleep quality (poor sleeper as target group)					
	Unadjusted			Adjusted[5]		
Demographic & health characteristics, and health behaviours	**OR**	**CI**	***p***	**OR**	**CI**	***p***
Age						
<55	1.00	-	-	1.00	-	-
55-64	0.89	0.72-1.09	0.254	1.20	0.92-1.56	0.191
65-74	0.77	0.64-0.92	**0.004**	1.11	0.85-1.45	0.437
75-84	0.73	0.59-0.89	**0.002**	1.15	0.84-1.57	0.401
≥85	0.90	0.64-1.26	0.537	1.10	0.63-1.91	0.733
Gender						
Male	1.00	-	-	1.00	-	-
Female	1.65	1.46-1.86	**<0.001**	1.25	1.00-1.55	**0.048**
Marital status	1.00					
Married/cohabiting	1.00	-	-	1.00	-	-
Separated/divorced/widowed/ single	**1.80**	1.12-.49	**<0.001**	1.12	0.91-1.37	0.287
BMI						
Underweight/healthy weight	1.00	-	-	-	-	-
Overweight	1.13	0.98-1.30	0.086	1.22	1.01-1.48	**0.039**
Obese	1.68	1.41-2.01	**<0.001**	1.79	1.40-2.30	**<0.001**
Cancer spread						
No	1.00	-	-	1.00	-	-
Yes	1.42	1.10-1.82	**0.008**	1.31	0.97-1.76	0.074
Number of treatments	1.22	1.15-1.30	**<0.001**	1.17	1.06-1.27	**0.002**
Anxiety and depression						
None	1.00	-	-	1.00	-	-
Slight	2.96	2.54-3.46	**<0.001**	2.65	2.17-3.23	**<0.001**
Moderate to extreme	7.29	5.50-9.66	**<0.001**	5.63	3.95-8.02	**<0.001**
Number of comorbid conditions						
None	1.00	-	-	1.00	-	-
1	1.24	1.07-1.43	**0.004**	1.19	0.97-1.45	0.094
2	1.69	1.41-2.02	**<0.001**	1.35	1.05-1.75	**0.020**
≥3	2.61	2.10-3.24	**<0.001**	2.05	1.51-2.78	**<0.001**
Fibre						
Meeting	1.00	-	-	1.00	-	-
Not meeting	1.14	0.94-1.38	0.172	1.13	0.89-1.15	0.348
Fruits and vegetables						
Meeting	1.00	-	-	1.00	-	-
Not meeting	0.98	0.87-1.14	0.977	0.99	0.82-1.19	0.898
Added sugar						
Meeting	1.00	-	-	1.00	-	-
Not meeting	0.96	0.85-1.10	0.535	1.03	0.87-1.22	0.710
Red meat						
Meeting	1.00	-	-	1.00	-	-
Not meeting	1.11	0.73-1.71	0.621	0.92	0.53-1.61	0.771
Processed meat						
Meeting	1.00	-	-	1.00	-	-
Not meeting	0.97	0.85-1.10	0.607	1.11	0.93-1.33	0.235
Fat						
Meeting	1.00	-	-	1.00	-	-
Not meeting	1.05	0.91-1.21	0.501	1.03	0.85-1.23	0.789
Alcohol						
Meeting	1.00	-	-	1.00	-	-
Not meeting	1.04	0.87-1.25	0.651	1.148	0.90-1.47	0.272
Physical activity						
≥150 mins per/week	1.00	-	-	1.00	-	-
<150 mins per/week	1.21	1.04-1.42	**0.015**	1.03	0.85-0.24	0.771

[5] the model included age, gender, marital status, BMI, cancer spread, number of treatments, anxiety/depression, number of comorbid conditions, intake of fruits and vegetables, fibre, red meat, processed meat, fat, added sugar, alcohol, and physical activity.

Analysis with original data

The completers analysis is presented in Supplementary Table 1 and showed very similar patterns to the imputed data.

Additional Chi-squared test analyses

A Chi-squared test of the current data showed that all dietary variables, including alcohol, were associated with BMI (all $p<0.001$). When comparing expected counts and actual counts, the results showed that individuals in the highest BMI category were less likely to meet the recommended intake of fibre, fruits and vegetables, red meat, processed meat, fat, and alcohol, than individuals in lowest BMI category. For added sugar intake, individuals with higher BMIs were more likely to meet the recommended guidelines than individuals with lower BMIs.

Furthermore, a Chi-squared test of the current data showed that BMI and physical activity were associated ($p<0.001$), indicating that individuals with higher BMIs were less likely to meet the physical activity guidelines than individuals with lower BMIs.

Discussion

In the present study, 57% of cancer survivors were identified as poor sleepers. Previous research indicated that 23% of the general population reported sleep disturbance compared to 34% of cancer survivors, after the two groups were matched for baseline characteristics [7].

The results show that, after adjusting for covariates, BMI was associated with sleep quality; individuals with overweight or with obesity had greater odds of being poor sleepers than underweight/healthy weight individuals. Diet, alcohol and physical activity were not associated with sleep quality.

The present study is the first to explore if BMI is associated with sleep quality in breast, prostate, and colorectal cancer survivors. Some research has explored the relationship between sleep and BMI in other cancer survivor populations finding similar results to the present study. For example, a study including baseline assessments of 100 stage 1 endometrial cancer survivors with obesity who enrolled in a lifestyle intervention, found that survivors with higher levels of obesity had more sleep disturbances [39]. This study was, like the

present study, cross-sectional. Previous research on non-cancer populations suggest that the sleep and BMI relationship may be bi-directional [12, 15]. Future research should seek to better understand the direction of this relationship in cancer survivors.

Additional research should also explore if intentional weight loss in cancer survivors with a high BMI has a positive impact on sleep quality, and also whether improved sleep quality can influence the effectiveness of weight loss interventions. Randomised controlled trials in non-cancer populations have found that sleep apnoea was improved in individuals taking part in weight loss interventions [40]. Existing research in non-cancer populations also suggests a potential association between good sleep quality and subsequent success in weight-loss interventions. For instance, a randomised controlled trial with 245 women who were affected by overweight or obesity, showed that the women who reported better sleep quality measured by the PSQI at baseline, had a 33% increased likelihood of weight-loss success after 6 months compared to those who reported poor sleep [41]. Sleep hygiene has rarely been included within weight-loss interventions for cancer survivors [42]. Future research may explore the potential bi-directional relationship between sleep and intentional weight-loss success.

The present study did not ask the respondents of the survey if they had sleep apnoea. Obesity is associated with an increased risk of obstructive sleep apnoea [43]. Future research should explore if sleep apnoea has a mediating effect on the association between obesity and poor sleep quality in cancer survivors.

The lack of associations between the dietary components and sleep quality in the present study is somewhat conflicting with previous studies which have found associations between poorer sleep parameters and unhealthy dietary components, even after adjusting for BMI [19, 20]. However, these previous studies did not include cancer survivors. Nevertheless, the present findings are also not consistent with the study conducted by Kim and colleagues [21] which found that healthy dietary patterns in breast cancer survivors were associated with *more* insomnia symptoms. Furthermore, alcohol intake was also not associated with sleep quality in the present study. Most of the participants (81.1%) met the recommendation for weekly alcohol intake (>14 units), indicating that alcohol misuse may not be very common in cancer survivors.

There may be different reasons why dietary intake was not associated with sleep quality in the present study. The measures used to measure dietary intake may not be precise as they are self-reported and individuals may report intakes that are closer to perceived norms than their actual intake [44]. Previous research suggests

that people tend to overreport intake of fruits and vegetables and underreport food with high fat and sugar contents [45]. Ravelli and Schoeller [46] reviewed existing research on common methods of dietary assessment such as diet recall, diet diaries, and food frequency questionnaires, and identified misreporting in all the methods when comparing them to objective nutrient biomarkers.

Furthermore, another reason why dietary intake was not associated with sleep quality in the present study can be because diet and BMI may be associated, which may obscure a potential independent effect of diet on sleep quality. In the current data, not meeting the guidelines for the dietary variables and alcohol was associated with higher BMIs, except for added sugar intake (which was associated with lower BMIs).

The present study found that not meeting recommended physical activity levels was not associated with poor sleep quality. An explanation for this may be that physical activity is closely connected to BMI [47], and the association between BMI and sleep obscures an association between physical activity and sleep. In the current data, the BMI categories and physical activity (not meeting vs meeting) were associated, indicating that individuals with obesity were less likely to meet physical activity guidelines than individuals in the underweight/healthy weight category.

Secondly, previous studies which have found that physical activity is associated with sleep may have measured physical activity differently to the present study. For instance, a vast amount of research has found that exercise interventions improve sleep quality in cancer patients [23, 48], however the present study only measured self-reported physical activity and did not measure the quality of the exercise that the participants engaged in. It is possible that guided exercise interventions are more efficient and therefore associated with better outcomes for sleep quality. Inaccurate self-reporting of duration and frequency of physical activity may also have influenced the present study findings. Previous studies comparing self-reported physical activity and objective measurements using accelerometers, have shown that individuals self-report higher estimates of physical activity compared to accelerometer numbers [49].

Having more comorbid conditions was associated with poor sleep quality. This is in accordance with previous research which shows that a higher number of medical comorbid conditions is associated with poor sleep quality in cancer patients [50]. In addition, the present findings found that having more reported treatments were associated with poor sleep quality. Moreover, the findings showed that individuals who were

more anxious or depressed had greater odds of being poor sleepers, which is also consistent with previous research on both cancer survivors and healthy populations [51, 52, 53]. The results showed that female participants reported poorer sleep than males, which is consistent with previous research on healthy populations [54]. This association may also have been influenced by cancer type specific side effects, as studies show that poor sleep quality in breast cancer survivors is associated with side effects from hormonal therapy, poor physical functioning, low physical activity levels, depressive symptoms and/or distress [55].

Finally, the present study highlights that sleep is a common issue in breast, prostate, and colorectal cancer survivors, and that more research on sleep interventions for cancer survivors should be conducted. Previous studies also emphasise the importance of conducting sleep research, showing that poor sleep quality is associated with a range of health problems such as diabetes type 2, obesity, and increased risk of Alzheimer's disease [56]. In addition, studies indicate that poor sleep quality in cancer survivors is associated with negative mental health outcomes, such as lower quality of life in breast cancer survivors, and increased depressive symptoms in prostate cancer survivors [57, 10].

Limitations

A limitation of this study is that all included measures were self-reported. However, the majority of the included measures, such as the PSQI and the GLTEQ, have demonstrated high validity and reliability in previous research [26, 32]. Self-reported BMI has also shown good validity in previous research. A cross-sectional study with 100 adults showed that there was a strong correlation between self-reported BMI and direct anthropometric measurements [58] Previous research also shows that self-reported weight using digital home bathroom scales provide accurate and consistent weights for public health research [59]. The dietary components in the present study were estimated based on items from different questionnaires and this combination has not previously been used in research.

A potential additional limitation in the present study is that the participants were 90% white, which means that the findings may not be generalisable to other racial groups. In addition, as the study recruited participants based on a diagnosis of breast, prostate, and colorectal cancer, the findings may also not be generalisable to those living with or beyond other cancer types.

Another potential limitation of the present study is the 21% missing data for the sleep quality variable, which might introduce selection bias and affect internal validity. Multiple imputation was used to reduce the possible bias of missing data [38], and a Little's t-test ascertained that the data was not missing completely at random. In addition, another potential limitation is that sleep apnoea was not explored in the present study.

The present study explored how BMI, diet, alcohol and physical activity are associated with sleep quality, however as the design is cross-sectional the direction of the explored associations cannot be interpreted. Future research should therefore conduct more longitudinal studies to explore the direction of these relationships.

Conclusion

Breast, prostate, and colorectal cancer survivors commonly report poor sleep quality, and a better understanding of the factors that may influence their sleep quality is needed. The present findings emphasise a need for a holistic approach to improve sleep quality in cancer survivors, with a focus on both physical health characteristics such as BMI and individuals' mental health such as anxiety and depression. This study did not find associations between dietary components and physical activity with sleep quality. However, future research may explore if diet and physical activity are mediators in the relationship between BMI and sleep quality. In addition, future research should explore the relationships between health behaviours and sleep quality in non-white cancer survivors and survivors of other cancer types. Researchers and health professionals should work to further identify factors that contribute to poor sleep quality in cancer survivors, to improve the health and wellbeing of this population.

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Appendix

Supplementary table 1

Table 4: Logistic regression analyses for sleep quality with only those with complete data on all variables (N=2,134).

	Sleep quality (poor sleeper as target group)					
	Unadjusted			Adjusted[6]		
Demographic & health characteristics, and health behaviours	**OR**	**CI**	***p***	**OR**	**CI**	***p***
Age						
<55	1.00	-		1.00	-	
55-64	0.89	0.89-1.10	.264	1.12	0.83-1.50	0.470
65-74	0.77	0.77-0.92	**.004**	1.15	0.85-1.55	0.365
75-84	0.73	0.73-0.89	**.002**	1.16	0.80-1.68	0.434
≥85	0.90	0.90-1.26	.529	0.99	0.47-2.08	0.982
Gender						
Male	1.00	-	-	1.00	-	-
Female	1.65	1.46-1.86	**<0.001**	1.25	0.96-1.61	0.090
Marital status	1.00					
Married/cohabiting	1.0000	-	-	1.00	-	-
Separated/divorced/widowed/ single	1.1030	1.13-1.49	**<0.001**	1.12	0.88-1.41	0.367
BMI						
Underweight/healthy weight	1.00	-	-	1.00	-	-
Overweight	1.14	0.99-1.31	0.069	1.21	0.98-1.50	0.083
Obese	1.73	1.45-2.06	**<0.001**	1.75	1.32-2.33	**<0.001**
Cancer spread						
No	1.00	-	-	1.00	-	-
Yes	1.47	1.18-1.84	**0.001**	1.50	1.08-2.07	**0.017**
Number of treatments (continuous)	1.22	1.15-1.30	**<0.001**	1.14	1.02-1.27	**0.024**
Anxiety or depression						
None	1.00	-	-	1.00	-	-
Slight	2.97	2.55-3.46	**<0.001**	2.80	2.22-3.54	**<0.001**
Moderate to extreme	7.45	5.65-9.82	**<0.001**	6.62	4.34-10.08	**<0.001**
Number of comorbid conditions						
None	1.00	-	-	1.00	-	-
1	1.24	1.07-1.43	**0.004**	1.29	1.03-1.62	**0.030**
2	1.69	1.41-2.02	**<0.001**	1.41	1.05-1.90	**0.025**
≥3	2.61	2.10-3.24	**<0.001**	2.05	1.43-2.94	**<0.001**
Fibre	1.00					
Meeting	1.0000	-	-	1.00	-	-
Not meeting	1.1014	0.94-1.38	0.172	1.19	0.89-1.56	0.234
Fruits and vegetables						
Meeting	1.00	-	-	1.00	-	-
Not meeting	0.99	0.87-1.14	0.977	0.97	0.78-1.20	0.757
Red meat						
Meeting	1.00	-	-	1.00	-	-
Not meeting	1.11	0.73-1.71	0.621	0.81	0.41-1.57	0.525
Processed meat						
Meeting	1.00	-	-	1.00	-	-
Not meeting	0.97	0.85-1.10	0.607	1.01	0.82-1.23	0.966
Fat						
Meeting	1.00	-	-	1.00	-	-
Not meeting	1.05	0.91-1.21	0.501	1.02	0.82-1.27	0.848
Added sugar						
Meeting	1.00	-	-	1.00	-	-
Not meeting	0.96	0.85-1.09	0.535	1.07	0.88-1.30	0.513
Alcohol						
Meeting	1.00	-	-	1.00	-	-
Not meeting	1.04	0.87-1.25	0.651	1.23	0.92-1.64	0.162
Physical activity						
≥150 mins p/week	1.00	-	-	1.00	-	-
<150 mins p/week	1.22	1.05-1.41	**0.011**	1.01	0.82-1.25	0.916

[6]: the model included age, gender, marital status, BMI, cancer spread, number of treatments, anxiety/depression, number of comorbid conditions, intake of fruits and vegetables, fibre, red meat, processed meat, fat, added sugar, alcohol, and physical activity.

Dietary cut-off values

Variable	Cut-off points
Fruits and vegetables	Meeting: >5 portions/d Not meeting: <5/d
Fibre	Meeting: ≥30g/d Not meeting: <30g/d
Red meat	Meeting: ≤500g/wk Not meeting: >500g/wk
Processed meat	Meeting: 0g/d Not meeting: >0g/d
Fat	Meeting: ≤33% energy from fat Not meeting: >33% energy
Added sugar	Meeting: ≤30g/d Not meeting: >30g/d
Alcohol	Meeting: ≤14u/wk Not meeting: >14u/wk
BMI	Underweight/healthy weight: <25 Overweight: ≥25 and <30 Obese: ≥30
Physical activity	Meeting: ≥150 minutes MVPA/week Not meeting: <150 minutes MVPA/week