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Research Article

Interaction between Physical Activity and Socioeconomic Determinants among Cancer Patients: A Systematic Mapping Review

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Abstract

Socioeconomic factors and physical activity (PA), have been recognized as key factors affecting survival and quality of life of cancer patients. Nevertheless, less is known about their interactions among cancer patients. A mapping systematic review was undertaken to identify gaps in the literature regarding the interactions of socioeconomic factors and PA and the identification of theoretical model to define this relationship. A search for peer-reviewed English articles published between January 2010 and March 2020 in Medline, PsycINFO, Web of Science and SportDiscus databases was realized using three keywords: physical activity, cancer, socioeconomic. Cancer location and time, socioeconomic factor measurement, PA measurement, intervention and theoretical model were analyzed. Of the

5163 articles found, 90 were included (86 observational studies and 4 interventions). While many studies evaluate socioeconomic factors and PA, authors often do not consider their interactions, but test them separately. Socioeconomic factors identified in the studies ranged among 12 categories (age, sex, ethnicity, education, income, occupation, residence, green space exposure, marital status, household, social support, Health insurance). A high diversity of measurements within each category led to a huge variation in the definition of socioeconomic factors and refrained comparison between studies. Similar conclusions could be drawn with regard to the diversity of PA measurements. Only few studies mobilized theoretical models, without considering the interactions between socioeconomic factors and PA. The definition of socioeconomic factors as well as theoretical modeling of how socioeconomic factors interact with PA among cancer patients needs to be clarified.

Keywords: Physical activity; Cancer; Socioeconomic determinant; Mapping systematic review

Abbreviation: PA- physical activity; SES- socioeconomic status

1. Introduction

Every year, 18.1 million new cases of cancer are diagnosed worldwide, and 9.6 million people die of cancer [1]. The most frequently diagnosed cancer types and leading causes of cancer deaths vary across countries and within each country, depending on the degree of economic development and associated social and lifestyle factors [1]. Physical activity (PA) has been recognized as one of the key lifestyle factors increasing cancer survival and quality of life during cancer [2]. PA has been defined as "any bodily movement that results in energy expenditure" [3]. Considered a non-pharmacological intervention, the benefits of PA before [4], during and after cancer treatment [5, 6] have been largely demonstrated. For example, PA improves the quality of life of the person affected by the cancer and reduces the risk of death or recurrence [7, 8], fatigue [9] and depression [10]. Several literature reviews have shown that PA interventions could be effective for well-being and physical, mental and social health [11].

Moreover, evidence-based recommend-dations have been produced and political agendas have considered PA a conditional part of care for all cancer survivors [12]. Despite this evidence regarding both benefits and interventions, people with cancer have a lower PA level than the general population [13, 14], and numerous studies have shown that their PA level decreases after the cancer diagnosis [15], which questions which individual, interpersonal and community factors could support PA practices among cancer patients. In this regard, the literature has shown that PA practice has been associated with the socioeconomic characteristics of the individual, especially different determinants of PA, such as age, sex, income, education, and socioprofessional category [16]. For example, low income has been negatively correlated with recreational PA [17]. Although socioeconomic factors are considered major determinants of PA [18], their definition, as well as their measurement seems a major issue, when looking at their relationships. Indeed, different concepts, such as socio-economic status [19], socioeconomic inequalities [20], socioeconomic background [21] as well as plenty of other indicators (e.g., education, income) have been identified as belonging to socioeconomic factors [18]. An umbrella review analysing correlations between socioeconomic status and PA based the selection of socioeconomic factors on previous studies [17, 22], without justifying the choice of

these indicators. Moreover, in previous literature reviews, the definition of socioeconomic concepts used was missing or too broad [18]. Nevertheless, a previous review showed similar patterns of association with PA among the different indicators of socioeconomic position (e.g., high education level associated with high PA level) [22], but studies of cancer patients are rare [23].

In addition, previous studies of the general population have underlined the need to deeply understand how socioeconomic factors and PA could interact, as well as which mediators and moderators of the relationships could be identified [18]. Recent research has demonstrated that PA could compensate for low socioeconomic status in terms of poor self-related health and low quality of life [24].

To our knowledge, no recent systematic review has summarized results of studies analysing interactions between socioeconomic factors and PA among cancer patients. Expected results could help in developing a theoretical model of interactions between socioeconomic factors and PA among cancer patients. Indeed, theoretical models have been described as being helpful to enable the understanding of behaviour change, especially PA, and serve as strategies in interventions [25]. To achieve these aims, this literature review aimed to identify the association between socioeconomic factors and PA, from the diagnosis to remission. The review aimed to 1) describe indicators of socioeconomic background for cancer patients, 2) identify the relation between this socioeconomic background and PA level before the cancer diagnosis, during treatment and during remission and 3) identify a theoretical model framing the relation between socioeconomic background and PA.

2. Material and Methods

A systematic mapping review was conducted and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [26]. Indeed, the objective of a mapping review is to systematically search for and appraise research evidence and the main gaps in the literature [27].

2.1 Search strategy

The following electronic databases were searched from January 2000 to March 2020: Medline (PubMed), PsycINFO, Web of Science and SPORTDiscus. Electronic databases were searched for each possible combination of the following keywords as well as MeSH terms: physical activity, cancer, socioeconomic factor (see supplementary file 1).

2.2 Inclusion and exclusion criteria

Inclusion criteria were 1) English-written peer-reviewed publications, 2) involving all types of adult cancer patients (18 years and older), and 3) including at least one socioeconomic factor as defined by a previous literature review [18] and one PA domain (measured in terms of frequency, duration or intensity [28]. Only original articles were considered; protocols and reviews were excluded. We excluded studies associating socioeconomic factors and cancer, or PA and cancer only.

2.3 Screening and data extraction

All relevant publications were extracted from databases and imported into Covidence software for title and abstract screening by 2 authors (JMN, AVH). Duplicate records were removed before abstract screening. If there was ambiguity regarding eligibility, a third author (AYO) was consulted.

Any disagreements were resolved by discussion among authors (JMN, AVH and AYO). Then, full texts were retrieved for the retained articles and analysed by one author (JMN), with a random analysis of half of the included studies by AVH.

2.4 Data analysis

The following information was extracted into data tables from each included study: authors, journal, year of publication, country, objectives, inclusion and exclusion criteria, stage and type of cancer, socioeconomic factors and their measurement, PA outcome and its measurement, sample size and population characteristics, type of study and method used, type of association between socioeconomic factors and PA, and theoretical model used. In the results section, "sex" was used for sex and gender, and "ethnicity" for race and ethnicity. To analyse the data, a specific section was dedicated to socioeconomic factor measurement, another to PA measurement, and a section on methods used by selected studies.

3. Results

3.1 Descriptive analysis

Overall, 90 of the 5,163 screened articles were included in this literature review (Figure 1).

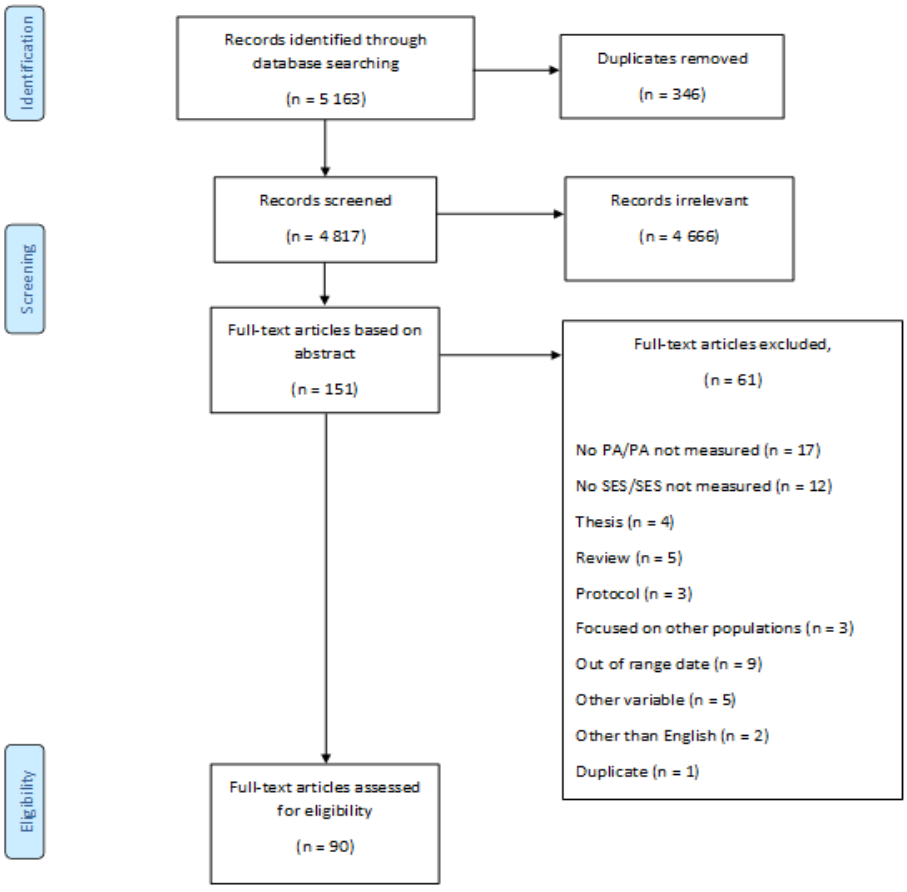

Figure 1: PRISMA diagram.

A rather constant number of publications per year was found, with an increase in the last year. Indeed, one third of the studies (n=29) were published during 2018-2019 and 22 during 2013-2014. Almost half of the studies were performed in North America (37 in the United States and 7 in Canada). The other continents were less represented, with 18 studies conducted in Europe, 9 in Asia, 6 in Oceania, 5 in South America (all in Brazil) and none in Africa. Four multicountry studies were included [29-32].

The most commonly studied cancer locations were breast (n = 48), colorectum (n = 43) and prostate (n = 22). Among the 90 included studies, 45 focused on a single cancer; 16 studies did not mention any cancer location because they principally focused on primary cancer prevention. Forty studies involved before the cancer diagnosis (including primary and secondary prevention), 19 from diagnosis to the end of treatment and 27 cancer survivors. Only one study followed the patients during the cancer [33], 3 investigated both before cancer diagnosis and during remission [34-36] and 2 did not mention when the study took place [37, 38] (see Table 1 for details). We found high diversity with regard to sample size, ranging from 13 to 566 398 participants. Also, participants were 18 to 97 years old.

More than half (n = 56) of the studies included both sexes. Single-sex studies reported different cancer locations. For men, 4 studies included prostate cancer patients [39-42], and one targeted male breast cancer [43]. Studies of women investigated breast (n = 23), cervical (n = 3), colon and rectal (n = 1), epithelial ovarian (n = 1), and gynecologic (n = 1) cancers. Two studies focused on mortality rates due to cancer [37, 38]. Study designs were principally cross-sectional (n = 53), followed by cohort (n = 22), case–control (n = 8), qualitative (n = 2) and mixed methods (n = 1). Four interventional studies were included: 3 randomized controlled trials and one quasi-experimental study. The results of the observational studies will be presented, before dedicating a specific section to interventions.

3.2 Observational studies

3.2.1 PA measurement: Three studies used objective measures (2 studies combining objective and subjective measures) and 83 studies relied on only subjective measurement. The most frequently subjective PA assessment tools used were the International Physical Activity Questionnaire (n=14), the Godin Leisure-Time Exercise Questionnaire [41, 44-47], the Past Year Total Physical Activity Questionnaire [48], the Determinants of Physical Activity Questionnaire [49], the Patient-Centered Assessment and Counseling for Exercise questionnaire [50], and the Leisure-Time Physical Activity questionnaire [49, 51]. Other studies used single-item measures or non-validated scales. Objective measurements used were the GT1M [52, 53] and GT3X actigraph accelerometers [54]. In addition to the diversity of measurement tools and the frequent use of single-item measurement, the recall period ranged from 1 week to up to 3 years before cancer diagnosis. Also, the context of PA measured (global PA vs specific context such as transport, leisure or occupational) and the calculation ranged from “meeting PA guidelines or not” to time spend in minutes per week, which led to high heterogeneity of PA measurement.

3.3 Socioeconomic status variables

The analysis of socioeconomic status variables revealed a large diversity of variables measured, including a broad range of indicators. In total, 71 studies collected multiple socioeconomic variables analysed by PA level, but 16 studies focused on a single socioeconomic variable analysed by PA level (4 focusing on residence, 3 ethnicity, 3 income,

3 education, 2 green space exposure, and 1 occupation). To facilitate the analysis, variables were gathered into the following categories: education, income, occupation, residence, marital status and household, social support, exposure to green areas, lifestyle and Health insurance (see Table 2). The association between the factors in these categories and PA was analysed in terms of time of cancer, type of cancer and pattern tested.

3.3.1 Age: All studies collected age by asking for the date of birth or an age category. The authors of the publications classified age as a demographic, sociodemographic, medical or gynaecologic variable. Only 17 studies analysed the relation between age and PA for a broad range of cancer types. Seven focused on before cancer diagnosis, 5 during treatment, and 5 after cancer treatment. Nine articles demonstrated that older adults (age 65 years and older) frequently had lower PA level, be inactive or be less active than younger people [29, 43, 55-61].

3.3.2 Sex: Mentioned as "sex" or "gender", all studies collected this variable. Although sex can be considered a biological variable and gender a cultural variable, many studies did not differentiate between the two. This variable was solely used as a control variable or analysed according to other socioeconomic variables, not with PA, which disallowed any conclusions on their interactions.

3.3.3 Ethnicity: Ethnicity was mentioned as "ethnicity" or "race" (with only one study distinguishing between "race" and "ethnicity") [51]. The definition of ethnicity in the different publications was rare and depended on authors' decisions in terms of classification, which led to studies defining groups such as "white and non-white" [43, 47, 61, 62], "multiracial reason" [46] or "others" [63, 64]. In most studies focusing on ethnicity, a large sample in the native population was compared with ethnic minority groups. For example, African-American ethnicity members (31.8%) were compared with Caucasian [65], and Danish (n = 152 356) with non-Danish samples (n = 9 927) [66]. Twenty-one studies collected data on PA level and ethnicity, but only 8 considered interactions between ethnicity and PA.

Four studies considered that white participants had a more active lifestyle than black or African-American participants [56, 67-69], but one study demonstrated no significant difference between ethnicities before cervical cancer diagnosis [70]. White cancer survivors were more active than non-white survivors in a Canadian study [47]. Non-Hispanic cancer patients were more engaged in routine PA than were Hispanic patients, specifically during and after treatment [50]. A comparison between Lebanese and American-Lebanese participants for predictors of breast cancer risk showed that the Lebanese-American group exercised more than the Lebanese group [31].

3.3.4 Education: Education was collected in 63 studies, but only 23 examined the relation between education and PA, for a broad range of cancer types. Nine focused on before cancer diagnosis, 3 during treatment, 10 after treatment, and 1 during and after cancer treatment. This variable was the single observed socioeconomic variable in 3 articles [32, 53, 71], 2 demonstrating that people with higher education frequently have a higher chance of meeting PA guidelines [71, 72]. Among the 23 studies analysing PA and socioeconomic status, 15 demonstrated that individuals with high education tended to have a high level of PA or meet PA guidelines, whatever the time of cancer. One study examining factors associated with breast cancer among women before diagnosis showed the reverse association

[30], with high education linked to low PA level. Two studies showed no association between education and PA level among cancer survivors [73, 74].

3.3.5 Income: Income was collected in 44 studies, 14 examining the relation between income and PA, for a broad range of cancer types. Seven studies focused on before cancer diagnosis, 1 during treatment, 5 after cancer, and 1 before diagnosis and after cancer treatment. Three studies specifically focused on the cancer time [75-77]. A study examining change in health promotion behaviour among low-income cancer patients with diverse cancer types after diagnosis showed that they engaged in walking and were interested in learning more behaviours [77]. The second study demonstrated that cancer death rate was predicted by the mean income from the US county where patients resided and that this relation was strongly mediated by physical inactivity, accounting for 12% of the percentage mediated in a multivariable model [76]. The third article demonstrated that income did not affect PA level among Brazilian breast cancer patients during treatment [75]. Of the studies analysing income and PA, including other socioeconomic indicators, 8 demonstrated that individuals with high income tended to have a high level of PA or met PA guidelines, whatever the time of cancer (4 before, 1 during, 2 after and 1 before and after treatment) [36, 46, 48, 53, 70, 78-80].

3.3.6 Occupation: Occupation was collected in 41 studies, 14 examining the relation between occupation and PA, for a broad range of cancer types (4 focusing on before cancer diagnosis, 2 during treatment, 7 after cancer treatment, and 1 before cancer diagnosis and after treatment). Seven articles demonstrated that employed people tended to have a high level of PA or met PA guidelines, whatever the time of cancer [41, 44, 48, 53, 73, 81]. Regarding comple-mentary results, an international study of women with breast cancer showed that women who were unemployed had a high global physical inactivity level [30].

Moreover, mother's employment played a role in women's physical inactivity, whereas father's employment seemed not related to physical inactivity [30]. A second study focusing on variations in PA level between before and after cancer diagnosis showed a significant decrease after diagnosis. This change was detected especially among professionally inactive patients for vigorous PA, with no changes in moderate PA or walking [35]. A third study showed that the odds of being unemployed due to health were appro-ximately 2.5-fold greater for inactive skin cancer survivors (i.e., who did not practice any leisure time aerobic activity lasting at least 10 min per week) [82].

3.3.7 Residence: Residence variables were collected in 32 studies, but only 8 (4 before cancer diagnosis and 4 after cancer treatment) examined the relation between residence and PA, for a broad range of cancer types [29, 30, 37, 38, 42, 52, 55, 83]. Four studies solely analysed this variable [29, 37, 38, 83]. A study comparing adherence to cancer prevention guidelines in 18 African countries showed that adherence to PA guidelines ranged from < 3% in Mauritius to 81% in Zambia for women and from < 5% in Mauritius to 84% in Zambia for men [29]. A second study compared the variation in cancer screening participation by geograp-hic area in Australia, showing insufficient exercise more likely for people living in inner regional areas and outer regional areas than in major cities [83]. Another study showed an increase in colorectal cancer mortality due to PA in Brazil (+0.66%), with a decrease observed in the rest of the world (-0.84%) between 1990 and 2015 [37]. Similar results were

found for women with breast cancer (+0.77% in Brazil and -2.84% worldwide; [38].

3.3.8 Green space exposure: Green space exposure was collected in 2 studies, as a single studied variable, among populations before cancer diagnosis [60, 84]. A study of the association between green space and skin cancer showed that time spent outdoors and time spent in moderate to vigorous PA was higher among people living than not living in greener areas. As compared with people with 0% to 20% green space, for those with >80% green space, the adjusted odds of skin cancer were 9% higher, with only 1.6% of the association mediated by moderate to vigorous PA [84]. A second study showed an association between the presence of urban green areas and reduced risk of breast cancer but did not observe any mediation by PA level [60].

3.3.9 Marital status: Marital status was collected in 41 studies, only 8 studies examining the relation between marital status and PA, for a broad range of cancer types. All studies demonstrated that marital status did not affect PA level, whatever the time of cancer [40, 44, 63, 64, 70, 80, 85, 86].

3.3.10 Household: Only 6 studies collected indicators related to household [74, 81, 87-91], but no study analysed the association of these variables and PA because they were principally considered control variables.

3.3.11 Social support: Six studies collected indicators related to social support, but only 3 [42, 79, 86] examined the relation between social support and PA, for a broad range of cancer types. These articles demonstrated that having good social support is related to high level of PA or meeting PA guidelines, specifically during treatment [42, 79] and after treatment [86].

3.3.12 Health insurance: In total, 13 studies collected indicators related to insurance, but only one study analysed the association of insurance and PA level and showed a positive relation between access to health care and PA [67].

3.4 Theoretical model

Among the observational studies, only 5 reported using a theoretical model. Models cited were the social determinants of health theoretical framework [67], the social cognitive theory-based theory [59, 92, 93], the theory of planned behaviour [45, 59, 94], the population intervention model [95], and the cause of death ensemble model [38].

3.5 Interventions

Among the 90 included studies, 4 were interventional studies, taking place before diagnosis [94] as well as during [93, 96] and after treatment [92] (See Table 3). Three interventions took place in North America, and one in Europe. Two targeted breast cancers (only women) [92, 94], one prostate cancer [93] and the last a broad range of cancer types [96]. Three were randomized controlled trials [92-94] and one was a quasi-experimental trial [96]. The duration of follow-up varied, the shortest intervention lasting 12 weeks [92] and the longest over 1 year [94]. A single theoretical model was used: the social cognitive theory-based model [92].

Intervention strategies were diverse, including a specific training with an average of 200 min of supervised and unsupervised PA per week [94]; encouragement by use of a pedometer provided to count steps and encouragement to walk for at least 30 min per day, completed by a dietary

journal [93]; an email intervention using social cognitive theory targeting PA [92]; and a free community-based exercise program including taking part in 30 weeks of individualized aerobic and resistance training with other participants. Among the 4 interventions, 2 considered PA practice as main outcomes [92, 94], and the 2 others focused on cancer-related fatigue or quality of life [96], BMI and body composition [93].

Results of the exercise intervention showed that 8% of the variance for supervised exercise was explained by cancer location and older age. For unsupervised exercise, 21% of the variance was explained by cancer location, a family history of breast cancer and increased vitality. Residence and age played an important role in PA practice among breast cancer patients [94]. Results of an email intervention showed a post-intervention difference in PA between the experimental and control group for self-reported moderate and vigorous PA among breast cancer patients. This study did not analyse the association of a socioeconomic variable with PA to explore the effect of variables, and the authors mentioned in the limitations section the focus on a single ethnicity and type of cancer [92]. For the dietary and PA intervention, 64% of patients provided a log sheet of daily step counts or time spent walking, but precise results on PA increase or decrease were not presented nor analysed by any socioeconomic variable [93]. In a community exercise intervention, PA was considered only as a predictor of cancer-related fatigue or quality of life, with no effect on either outcome [96]. The relation between socioeconomic status and PA was not tested in this intervention.

Author, Date, Reference	**Country**	**Type of cancer** Time of treatment	**Study design**	**Measured SES**	**PA**	**Theoretical model**
Aarts et al. 2013 [71]	The Netherlands	Breast, colon, lung, prostate After	Prospective Cohort	Education	Subjective	No
Adams et al. 2013 [55]	Australia	Not studied Before	Cross-sectional	Sex, education, before-tax household income, occupation, country of birth, area of residence (metropolitan or regional)	Subjective	No
Advani et al. 2014 [98]	USA	Not studied After	Cross-sectional	Income (financial strain), ethnic group	Subjective	No
Ahmed et al. 2018 [86]	Saudi Arabia	Breast, colorectal, leukemia, lymphomia, others During	Cross-sectional	Age, sex, university degree, marital status, family support, employment status	Subjective	No
Akinyemiju et al. 2014 [29]	18 African countries	Breast, cervical, colorectal, liver, prostate Before	Cross-sectional	Countries	Subjective	No
Akinyemiju et al. 2018 [56]	USA	Breast, colorectal, prostate Before	Prospective cohort	Race	Subjective	No
Akinyemiju et al. 2017 [30]	India, China, Mexico, Russia & South Africa	Breast Before	Cross-sectional	Countries, individual and parental SES (education, employment status), lifecour-se SES (education, employment status)	Subjective	No
Akinyemiju et al. 2017 [68]	USA	Breast, colon, prostate, others Before	Prospective cohort	Race, sex, region	Subjective	No
Alazzeh & Azzeh, 2018 [87]	Saudi Arabia	Colorectal During	Case–control	Employment, family income, educational level, family size	Subjective	No
AlSaeed & Tunio, 2017 [99]	Saudi Arabia	Brain, breast, colon, gastric, leukemia, liver, lymphoma, kidney, ovary, prostate, sarcoma, testicular, thyroid, uterine Before	Cross sectional	Marital status, employment	Subjective	No
Amuta et al. 2018 [78]	USA	Not studied Before	Cross-sectional	Age, income ranges, level of education, marital status, race, sex	Subjective	No
	USA	All cancer	Cohort	Low-income, ethnic population	Subjective	No

Andersen et al. 2016 [100]		Before				
Anderson et al. 2019 [79]	USA	Epithelial Ovarian Cancer (EOC) During	Observational	Individual, social (perceived social support) and societal factors (low family income, low educational attainment and perceived discrimination)	Subjective	No
Andrykowski, 2012 [43]	USA	Male Breast cancer After	Case–control	Age, sex, race and ethnicity, education, martial status, annual household income, employment status	Subjective	No
Aparicio-Ting et al. 2012 [48]	Canada	Not studied Before	Cross-sectional	Age, sex, annual household income, educational attainment, martial status, employment status, social support, urban or rural residence	Subjective	No
Aparicio-Ting et al, 2014 [49]	Canada	Not studied Before	Cross-sectional	Age, sex, annual household income, educational attainment, employment status, marital status	Subjective	No
Asare et al. 2019 [67]	USA	Breast, genitourinary, gynecologic, head, hematologic, lung, neck, other After	Cross-sectional	Race/ethnicity and social determinants of health (SDH; i.e. economic stability, education, access to health care)	Subjective	Social determinants of health (SDH) theoretical framework
Astell-Burt et al. 2014 [84]	Australia	Skin (melanoma and non-melanoma) Before	Cross-sectional	Green space exposure	Subjective	No
Azevêdo et al. 2015 [101]	Brazil	Gastric During	Transversal	Sex, age, origin of residence, income, education, occupation	Subjective	No
Badr et al. 2018 [31]	USA and Lebanon	Breast Before	Cross-sectional	Age, marital status, education, employment, perceived economic status, religion	Subjective	No
Batty et al. 2011 [39]	UK	Prostate During	Prospective	Civil service employment grade, marital status	Subjective	No
Berry et al. 2014 [74]	Australia	Breast, gastrointestinal, prostate, skin, testicular After	Cross-sectional	Education, social environment, work status, family structure, income, first language other than English Socio-Economic Indexes for Areas (SEIFA) score used	Subjective	No
	Norway	Lymphoma			Subjective	No

Bersvendsen et al. 2019 [57]		After	Cross-sectional	Household income, education, paired relationship (married or cohabitant)		
Bifulco et al. 2013 [102]	Italy	Gynecologic During	Cohort	Education, employment	Subjective	No
Bock et al. 2013 [33]	Germany	Breast All time	Cohort	Citizenship, employment, marital status, educational level	Subjective	No
Chatterjee et al. 2015 [103]	USA	Colorectal Before	Cross-sectional	Age, sex, race/ethnicity, health insurance, education, employment, income	Subjective	No
Chipperfield et al. 2013 [40]	Australia	Prostate During	Cross-sectional	Employment status, marital status, education, treatment centre (urban or rural)	Subjective	No
Chouhdari et al. 2019 [104]	Iran	Colorectal Before	Cross-sectional	Age, sex, educational level, job, income, health insurance, employment status	Subjective	No
Cirera et al. 2019 [32]	10 European countries	Pancreatic After	Cohort	Education, Relative index of inequality (RII) used	Subjective	No
Dianatinasab et al. 2018 [88]	Iran	Breast During	Cross-sectional	Age, education, income, marital status, number of children, place of residency	Subjective	No
Diorio et al. 2018 [50]	USA	Acute Lymphocytic Leukemia (ALL), Acute Myeloid Leukemia (AML), Brain tumor, Lymphoma, Solid tumor, Other During and after	Cross-sectional	Age, sex, ethnicity, type of insurance, education	Subjective	Transtheoretical Model for dietary fat, fruit and vegetable intakes and physical activity only measured
Doubeni et al. 2012 [89]	USA	Colorectal Before	Cross-sectional	Education, employment status, ethnicity, jobs, households, marital status	Subjective	No
Ekenga et al. 2015 [105]	USA	Breast Before	Prospective	Employment status	Subjective	No
Fassier et al. 2017 [34]	France	Breast, colon-rectum, prostate, skin, other Before and after	Prospective cohort	Sex, age, living area, employment status, monthly income per household unit, educational level	Subjective	No

Fassier et al. 2016 [35]	France	Breast, colon-rectum, prostate, skin, other Before and after	Prospective cohort	Sex, age, living area, employment status, monthly income per household unit, educational level	Subjective	No
Friis et al. 2018 [66]	Denmark	Bladder, brain, breast, colorectal, gynaecological, kidney, leukaemia, lung, lymphoma, oral, prostate, skin melanoma, testicular, thyroid, other After	Cross-sectional	Social inequality, sex, age, ethnic background, cohabitation status, education	Subjective	No
Goodwin et al. 2020 [83]	Australia	Bowel, breast, cervical, prostate, skin Before	Cross-sectional	Residential location, SES	Subjective	No
Gunes-Bayir et al. 2015 [106]	Turkey	Breast, colon, endometrial, gall bladder, head, liver, lung, neck, ovarian, pancreas, prostate, rectum, soft tissue-bone, stomach, urinary bladder During	Cross-sectional	Age, sex, marital status, education, occupation, living situation (villages, town city, metropolitan), sex, marital status	Subjective	No
Hair et al. 2014 [69]	Australia	Breast After	Cohort study	Race	Subjective	No
Hang et al. 2015 [107]	China	Colorectal During	Retrospective case–control	Sex, age, educational level	Subjective	No
Harrington et al. 2013 [41]	USA	Prostate During	Cross-sectional	Education, partner status, employment, distance of residence from medical center	Subjective	No
Hastert et al. 2016 [108]	USA	Not mentionned Before	Prospective cohort	Area-level SES used	Subjective	No
Howard et al. 2019 [90]	USA	Not mentionned (cancer mortality)	Cross-sectional	Education level, marital status, household size, income, poverty income ratio (ratio of family income to poverty threshold), health insurance	Subjective	No
Hughes et al. 2019 [42]	Australia	Prostate After	Cohort	Education, residence, employment status, marital status, support group participation	Subjective	No
Hvidtfeldt et al. 2013 [72]	Denmark	Breast Before	Cohort	Education	Subjective	Model describing the effect of SEP on breast cancer through alcohol consumption and PA

Inumaru et al. 2012 [109]	Brazil	Breast During	Case–control	Capita income, education level, area of residence	Subjective	No
Ishii et al. 2013 [52]	Japan	Colon Before	Cross-sectional	Sex, age, education level, employment status, marital status, living conditions, household income level	Subjective and Objective	No
Ishii et al. 2011 [53]	Japan	Colon Before	Cross-sectional	Sex, age, education level, employment status, marital status, living conditions, household income level	Subjective and Objective	No
Johannsen et al. 2015 [110]	Denmark	Breast After	Prospective	Marital status, education, personal income, occupational status, household net-wealth	Subjective	No
Kaul et al. 2017 [58]	USA	Breast, cervix, colon or rectum, leukemia, lymphoma or blood, melanoma, ovary, prostate, testicular, thyroid, uterus After	Cross-sectional	Sex, age at survey, race and ethnicity, marital status, insurance status	Subjective	No
Keegan et al. 2014 [111]	USA	Breast After	Case–control	Neighbourhood-level SES	Subjective	No
Khadanga et al. 2016 [36]	USA	Breast Before	Cohort	Education, income, marital status	Subjective	No
Kim et al. 2010 [112]	USA	Colon, rectal Before	Cohort	Neighbourhood-level SES, income, education, occupational status, age, race/ethnicity, close friends	Subjective	No
Kouloulias et al. 2019 [113]	Greece	Breast Before	Observational	Residence, education, income	Subjective	No
Lewis et al. 2014 [65]	USA	Colon During	Cohort	Race, sex	Subjective	No
Lowe et al. 2012 [59]	Canada	Not studied During	Cross-sectional	Sex, age	Subjective	Theory of planned behavior (Social cognitive model)
Meraviglia & Stuifbergen, 2011 [77]	USA	Breast, colon, gallbladder, hematologic, leukemia, lung, myeloma, prostate, uterine Before and after	Qualitative	Income	Subjective	No

Moskowitz et al. 2013 [62]	USA	Breast After	Cross-sectional	Occupation	Subjective	No
Moss et al. 2018 [63]	USA	Not studied Before	Prospective study	Sex, race/ethnicity, marital status, education attainment	Subjective	No
Naik et al. 2016 [47]	Canada	Breast, gastrointestinal, genitourinary, gynecologic, head, neck, thyroid, hematologic, lung, skin, others, unknown After	Cross-sectional	Education, household income, occupation	Subjective	No
Noonan et al. 2016 [85]	USA	Not studied Before	Cross-sectional	Age, marital status, race/ethnicity, annual household income	Subjective	No
O'Callaghan-Gordo et al. 2018 [60]	Spain	Breast Before	Multicase-control study	Urban green areas, agricultural areas, surrounding greenness	Subjective	No
O'Connor et al. 2018 [76]	USA	Not studied Before	Cross-sectional	County-level income (disparity risk index)	Subjective	County Health Rankings conceptual model Models of Mediation
Owusu et al. 2018 [51]	USA	Breast After	Qualitative	Ethnicity	Subjective	No
Park & Strauss, 2019 [61]	USA	Breast, gynecological (cervical, ovarian and/or uterine), prostate, skin (melanoma and/or non-melanoma), uterine, other After	Cross-sectional	Race/ethnicity, marital status, education level, ratio of family income	Subjective	No
Peiró-Pérez et al. 2015 [91]	Spain	Breast Before	Cross-sectional	Age, place of residence, screening centre, level education, self-declared socioeconomic level (SEL) level, related to family burden	Subjective	No
Pena et al. 2014 [75]	Brazil	Breast, malignant and benign breast diseases During	Case–control	Income	Subjective	No
	Lithuania	Cervical			Subjective	No

Petkevicienne et al. 2018 [64]		Before	Cross-sectional	Age, marital status, nationality, education, residence		
Philip et al. 2015 [46]	USA	Lung After	Cross-sectional	Sex, age, education, race/ethnicity, income	Subjective	No
Rawl et al. 2019 [70]	USA	Cervical Before	Cross sectional	Age, sex, race, ethnicity, education, marital status, income, financial security, home ownership, occupational status, place of birth	Subjective	No
Santos-Lozano et al. 2018 [54]	Spain	Breast After	Cross-sectional	Sex, age, educational level, employment situation, care for children	Objective	No
Schootman et al. 2012 [95]	USA	Breast After	Cohort	Age group, race, Hispanic origin, income categories, educational attainment, employment, marital status, home ownership, length at residence in years, income adequacy	Subjective	Population intervention models
Shas et al. 2019 [81]	India	Esopheageal squamous cell carcinoma risk Before	Hospital-based Case–control study	Education level, occupation, professional work intensity, income, house type, place of residence, ownership of several household appliances	Subjective	No
Silva et al. 2018 [38]	Brazil	Breast No specific time	Cohort	SES of brazilian states	Subjective	Cause of Death Ensemble modelling
Silva et al. 2018 [37]	Brazil	Colorectal No specific time	Cohort	Socioeconomic development index of Brazilian states	Subjective	No
Skrzypczak et al. 2012 [114]	Poland	Breast After	Cross-sectional	Education, marital status, place of residence	Subjective	No
Smith et al. 2018 [80]	USA	Breast After	Cross-sectional	Age, education, income, marital status, insurance coverage	Subjective	No
Sözmen et al. 2016 [115]	Turkey	Cervical Before	Cross-sectional	Marital status, educational level, geographical area lived, social security	Subjective	No
Stalsberg et al. 2019 [73]	Norway	Breast	Mixed-methods	Social inequality, level of education, household income, work status	Subjective	No

		After	approach (longitudinal follow-up study)			
Stevinson et al. 2014 [44]	UK	Breast, gastrointestinal, gynaecological, haematological, head, lung, neck, prostate, others After	Cross-sectional	Sex, date of birth, marital status, educational level, employment status, ethnic group, postcode	Subjective	No
Tabaczynski et al. 2020 [45]	Canada	Kidney After	Cross-sectional	Age, sex	Subjective	Theory of Planned Behaviour
Venturelli et al. 2019 [116]	Italy	Breast, cervical, colorectal Before	Cross-sectional	Education, occupational status, perceived economic difficulties, citizenship	Subjective	No
Vidrine et al. 2013 [117]	USA	Not studied Before	Cross-sectional	Sex, age, race/ethnicity, educational attainment, marital status, employment, annual household income, insurance status	Subjective	No
Wang et al. 2016 [118]	USA	Lung Before	Cross-sectional	Sex, age, race, marital status, education	Subjective	No
Weaver et al. 2013 [82]	USA	Breast, colorectal, gynecologic, hematologic, melanoma; prostate, others After	Cross-sectional	Employment, residence (rural-urban)	Subjective	No
Wiedemann et al. 2018 [119]	UK	All cancer Before	Cross-sectional	Age, sex, ethnicity, marital status, educational attainment, occupational status, type of occupation, residential area based-socio-economic	Subjective	No

PA, physical activity; SES, socioeconomic status

Table 1: Characteristics of the included observational studies.

Age	**Age, date of birth**
Sex	Sex, sex
Ethnicity	Ethnic group, ethnic background, race, ethnicity, place of birth, nationality
Education	Education, education level, university degree, level of education, low educational attainment, educational attainment, formal education at 15 years of age, first language other than English
Income	Before-tax household income, financial strain, family income, income ranges, low-income, societal factors low family income, annual household income, monthly income, annual household income, economic stability, perceived economic status, household income, monthly income per household unit, poverty income ratio, capita income, household income level, personal income, county-level income, ratio of family income, financial security, income categories, and income adequacy, house net-wealth, perceived economic difficulties
Occupation	Occupation, occupational status, type of occupation, employment, employment status, type of employment, work status, vocational status, job, professional work intensity, civil service employment grade
Residence	Area of residence, metropolitan or regional, urban residence, rural residence from postal codes, origin or residence, location, place of residence, place of residency, living area, residential location, living situation, area-level SES, residence, living conditions, home ownership, geographical area lived, postcode, residence (rural-urban), residential area based socio-economic, length at residence in years, country, neighbourhood-level SES
Green space exposure	Green space exposure, presence of urban green areas, presence of agricultural areas, and surrounding greenness
Marital status	Marital status, paired relationship, married or cohabitant, partner status
Household	Household, household size, family size, family structure, number of children, cohabitation status, family burden, household appliances
Social support	Family support, individual, social factors, perceived discrimination, social support, social environment, social inequality, support group participation, close friends
Health insurance	Access to health care, insurance status, treatment center, screening center, type of insurance, distance of residence from medical center, insurance coverage, health insurance, social security, care for children

SES, socioeconomic status

Table 2: Category of socioeconomic variables and indicators used for each variable in included studies.

	Brunet et al. 2020 [96]	**Courneya et al. 2012 [94]**	**Hatchett et al. 2013 [92]**	**O'Neill et al. 2015 [93]**
Date, country, cancer, time of treatment	2020, Canada, several cancer type, after	2012, Canada, breast, prevention	2013, USA, breast, after	2015, UK, Prostate, during
Study design	Prospective, quasi-experimental single-group repeated measures design	Randomized controlled trial	Randomized controlled trial	Randomized controlled trial
Population sample	N: 224	N: 160	N: 74	N: 94
	Age: ≥ 18y	Age: 50-74 years	Age: ≥ 18 years	Age: range not precise
	Sex: male and female	Sex: female	Sex: female	Sex: men
	Comparison: no	Comparison: yes	Comparison: yes	Comparison: yes
	Volunteers adults who enrolled in Wellspring Cancer Exercise Program few years ago	Postmenopausal women	Volunteers survivors	Planned to receive a cancer therapy for at least 6 months
		By mails, posters and brochures, media campaigns	By mass email and written letter solicitation	
Intervention strategy	Community exercise program	Exercise program	Email program	Dietary Intake and walking program
PA assessment	Godin Leisure Time Exercise Questionnaire	Weekly minutes of total supervised and unsupervised exercise	7-day physical activity recall questionnaire	7 Day Physical Act-ivity Recall Questi-onnaire; Phone call to monitor compliance
Results	Physical activity practice did not affect cancer-related fatigue or quality of life	Completion of 95% of supervised exerc-ise and 79% of un-supervised exercise	Time spend in moderate to vigorous PA	64% of patients provided a log sheet of daily step counts or time spend walking
Theoretical model	No	No	Social cognitive theory-based email evaluated	No

Table 3: Interventions for physical activity (PA) among cancer patients.

4. Discussion

The present systematic mapping review analysed the interactions between socio-economic factors and PA among cancer patients. The analysis of the 86 observational and 4 intervention studies showed several gaps in the literature. First, despite the data collection of both socioeconomic factors and PA, only a few studies considered their interactions, and often these variables were not crossed in studies, but their effect on a third variable (quality of life, survival, etc.) was tested separately. In other words, the interactions between PA and socioeconomic variables to predict cancer evolution or related variables were not tested. However, most articles described an exploratory model testing a multivariate association between socio-economic variables, PA and other predictors with cancer-related variables, which prevents an understanding of the complexity of PA practice among cancer patients.

Second, studies focused on a single time of cancer — before diagnosis, during treatment or after cancer treatment — which disallows examining the temporal dynamics in the interactions between socioeconomic factors and PA. Because previous studies have shown a decrease in PA practice from diagnosis to remission [15], studies providing evidence for these temporal patterns and their predictors are of primary importance for developing effective and tailored interventions. Third, the diversity of indicators to evaluate socioeconomic factors [18] and lack of definitions thereof are major weaknesses in comparing studies. The indicators varied among education, residence, health insurance, and marital status, and the measurements used among these categories also varied (e.g., country, town, and living area were considered variables in the residence category), which led to a high number of scales or classifications used. The authors' classification of the variables as sociodemographic or socioeconomic or demographic did not help to identify them. Some authors considered this diversity by using a sociodemographic index (i.e., aggregation of scores on different socioeconomic variables), but no consistency was found across studies to calculate such an index, which led to even more variability in the measurement.

Fourth, the paucity of interventions for collecting and analysing socioeconomic factors reveal the difficulty in taking these variables into account when offering programs. Moreover, the use of PA to reduce social inequalities, as shown in a previous intervention for obese adolescents, has not been investigated [97]. Fifth, the lack of a theoretical model used in the observational study disallowed the ability to model and understand the interactions between the studied variables [25]. Sixth, the results, to be interpreted with caution with regard to the low number of studies in each socioeconomic category, demonstrated more similar patterns of association than in the general population, which questions the recurrence of the association patterns between socioeconomic factors and PA among vulnerable populations [18]. Different limitations to this study must be mentioned. First, studies involving a specific sport (i.e., yoga) and not measuring PA practice were not included, which limits the identification of evidence based on specific activities offered to cancer patients. Second, the review does not assess the quality of the studies but rather focuses on gaps in the literature. Third, we were not able to conceptualise a model of interactions between socio-economic factors and PA among cancer patients because of lack of a theoretical model and a path model tested in the literature as well as the diversity of measurement.

5. Conclusion

The identification of interactions between socioeconomic status and PA among cancer patients is at its early stage. The clarification of the definition of socioeconomic factors as well as the variables included in their measurement is highly necessary. Consistency in PA measurement, with use of a validated measurement tool, is needed to move the field forward. Despite finding 90 studies measuring PA behaviour and socioeconomic factors, few studies tested the association between these variables. In addition, the analysis of temporal patterns of PA at all times of cancer by socioeconomic factors is key to the development of an intervention theory adapted to patient profiles because patient compliance with PA post-diagnosis has been identified as weak.

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Conflicts of Interest

Authors declare no conflict of interest.

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