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Systematic Review

Impact of Lifestyle Modifications on Cancer Mortality: A Systematic Review and Meta-Analysis

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Abstract: *Background and Objectives*: Cancer survival poses significant challenges in oncology, with lifestyle modifications increasingly recognized as crucial in modifying patient outcomes post-diagnosis. This meta-analysis aims to systematically evaluate the impact of various lifestyle interventions on cancer survival across different types of cancer. *Methods*: A comprehensive literature search of electronic databases including PubMed, Scopus and Cochrane was performed to identify relevant studies up to 30 November 2024. Relevant studies were chosen and data were extracted and analyzed using SPSS Version 29.0 software. *Results*: Our systematic review included data from 98 studies involving a total of 1,461,834 cancer patients to evaluate the impact of lifestyle factors on cancer survival. Out of these, 64 studies were included in the meta-analysis. Our meta-analysis demonstrates that adherence to specific dietary patterns significantly improves cancer-specific outcomes. The Healthy Eating Index (HEI) diet was associated with a reduction in cancer-specific mortality (pooled log HR: −0.22; 95% CI: [−0.32, −0.12]; $p < 0.001$). Similar benefits were observed with the Mediterranean diet (aMED), which also reduced cancer mortality and recurrence (pooled log HR: −0.24; 95% CI: [−0.40, −0.07]; $p < 0.001$), and the Dietary Approaches to Stop Hypertension (DASH) diet (pooled log HR: −0.22; 95% CI: [−0.33, −0.12]; $p < 0.001$). Additionally, general dietary improvements were beneficial for breast cancer-specific mortality across 17 cohort studies (pooled log HR: −0.15; 95% CI: [−0.25, −0.06]; $p < 0.001$). Engaging in any form of physical activity post-diagnosis was associated with significant improvements in cancer-specific mortality or recurrence (pooled log HR: −0.31; 95% CI: [−0.38, −0.25]; $p < 0.001$). Participants who ceased smoking after diagnosis exhibited more favorable cancer outcomes (pooled log HR: −0.33; 95% CI: [−0.42, −0.24]; $p < 0.001$), with smoking cessation notably reducing cancer-specific mortality among lung cancer survivors (pooled log HR: −0.34; 95% CI: [−0.48, −0.20]; $p < 0.001$). Additionally, reducing alcohol intake post-diagnosis significantly improved cancer outcomes (pooled log HR: −0.26; 95% CI: [−0.33, −0.19]; $p < 0.001$). Alcohol moderation in gastrointestinal tract cancer survivors specifically decreased both cancer-specific mortality and recurrence (pooled log HR: −0.22; 95% CI: [−0.29, −0.15]; $p < 0.001$). *Conclusions*: Lifestyle modifications after cancer diagnosis significantly improve cancer-specific outcomes. Specific dietary patterns, increased physical activity, smoking cessation, and reduced alcohol intake are

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all associated with lower cancer-specific mortality. Integrating these lifestyle changes into oncology care may enhance patient survival and quality of life.

Keywords: cancer mortality; lifestyle modifications; dietary patterns; physical activity; smoking cessation; alcohol intake

1. Introduction

Cancer remains one of the most formidable public health challenges globally, with its incidence consistently rising and becoming a major cause of morbidity and mortality worldwide. The World Health Organization (WHO) estimates that cancer is the second leading cause of death globally, contributing to approximately 10 million deaths in 2022 alone [1–3]. Cancer survival is a critical aspect of the disease's trajectory, profoundly impacting patient prognosis and quality of life. Survival outcomes are influenced by a variety of factors, including the cancer type, stage at diagnosis, and the efficacy of initial treatment, with some cancers having more favorable survival rates than others [4,5].

Survival outcomes can be further categorized based on whether the cancer remains localized or spreads to other parts of the body. When cancer metastasizes, or spreads to distant sites, it often requires more intensive treatment and presents a greater challenge for long-term survival [4–6]. Amidst these challenges, lifestyle factors have increasingly been recognized as critical elements that can influence cancer survival. Research has consistently shown that certain lifestyle changes, implemented after a cancer diagnosis, can significantly impact overall survival and the quality of life. These factors include dietary habits, physical activity levels, smoking status, and alcohol consumption, each playing a distinct role in the patient's health trajectory post-cancer treatment [7].

Dietary patterns and food choices play a crucial role in modulating cancer risk and recurrence. Diets rich in fruits, vegetables, whole grains, and lean proteins have been associated with a reduced risk of several types of cancer and improved survival rates [8]. Physical activity is another powerful lifestyle factor with a well-documented impact on cancer prognosis. Regular exercise helps reduce body fat, regulate hormone levels, and enhance immune function, all of which can contribute to reduced cancer recurrence rates and better survival [9–11].

Smoking is a well-established risk factor for many types of cancer, and continuing to smoke after a diagnosis can significantly worsen a patient's prognosis. Smoking cessation is, therefore, a critical recommendation for cancer survivors. Studies have shown that quitting smoking at the time of diagnosis can dramatically improve survival rates and reduce the risk of recurrence [12]. Alcohol consumption is another modifiable risk factor that can influence cancer outcomes. Reducing alcohol intake post-diagnosis is advised to enhance health outcomes and reduce the risk of recurrence [13].

Despite the growing body of evidence supporting the impact of lifestyle modifications on cancer outcomes, substantial variability and contradictions exist across studies [14]. This inconsistency poses a challenge for oncologists and other healthcare providers aiming to offer evidence-based lifestyle recommendations to cancer survivors.

To address this, we conducted this systematic review and meta-analysis to evaluate and synthesize the existing research on the impact of different lifestyle modifications on cancer survival. This review analyzes the effects of dietary modifications, physical activity, smoking cessation, and alcohol consumption on cancer survival outcomes.

2. Methods

Our systematic review and meta-analysis was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review is registered with the OSF (https://doi.org/10.17605/OSF.IO/264SC, accessed on 5 February 2025).

2.1. Inclusion and Exclusion Criteria

Studies were selected based on predefined inclusion and exclusion criteria.

2.1.1. Inclusion Criteria

We included in this analysis studies that were cohort studies or case-control studies reporting outcomes related to cancer mortality and that assessed one or more types of lifestyle modifications, such as dietary changes, physical activity, smoking cessation, or alcohol moderation, on the adult population with all cancer types.

2.1.2. Exclusion Criteria

We excluded in the analysis studies that lacked a clear definition of cancer mortality or did not assess long-term survival. We also excluded editorials, letters, comments, or conference abstracts without full data, as well as studies with incomplete data or those that did not report effect sizes and confidence intervals. Additionally, studies focusing on pediatric populations were not included. Studies in languages other than English were excluded.

2.2. Search Strategy

To ensure a comprehensive and systematic collection of data relevant to the effects of lifestyle modifications on cancer mortality, an extensive literature search was conducted across multiple electronic databases. These databases included PubMed, Scopus, and the Cochrane Library. The search was designed to identify all relevant studies published from the inception of each database up to 30 November 2024, which was the cutoff date for study inclusion. This timeframe was selected to capture the most recent evidence while ensuring a thorough review of the available literature.

The search strategy incorporated a combination of MeSH terms and free-text terms to maximize the coverage. The key terms used were “cancer mortality”, “cancer survival”, “long-term survival”, “lifestyle modification”, “dietary intervention”, “physical activity”, “exercise”, “smoking cessation”, and “alcohol consumption”. These terms were used in various combinations with Boolean operators to ensure a comprehensive search. The search was supplemented by hand-searching the reference lists of included studies and relevant reviews to identify additional studies that might have been missed in the initial electronic search.

2.3. Selection Process

The study selection was performed in two phases. After removing the duplicates, the titles and abstracts were screened by two independent reviewers as per the inclusion and exclusion criteria. Following this, full-text articles were assessed for eligibility. Reasons for exclusion were documented. Discrepancies were resolved through discussion or through consultation with the third reviewer. The selection process was documented in a PRISMA flow diagram, detailing the number of studies identified, screened, excluded, and included at each stage (Figure 1).

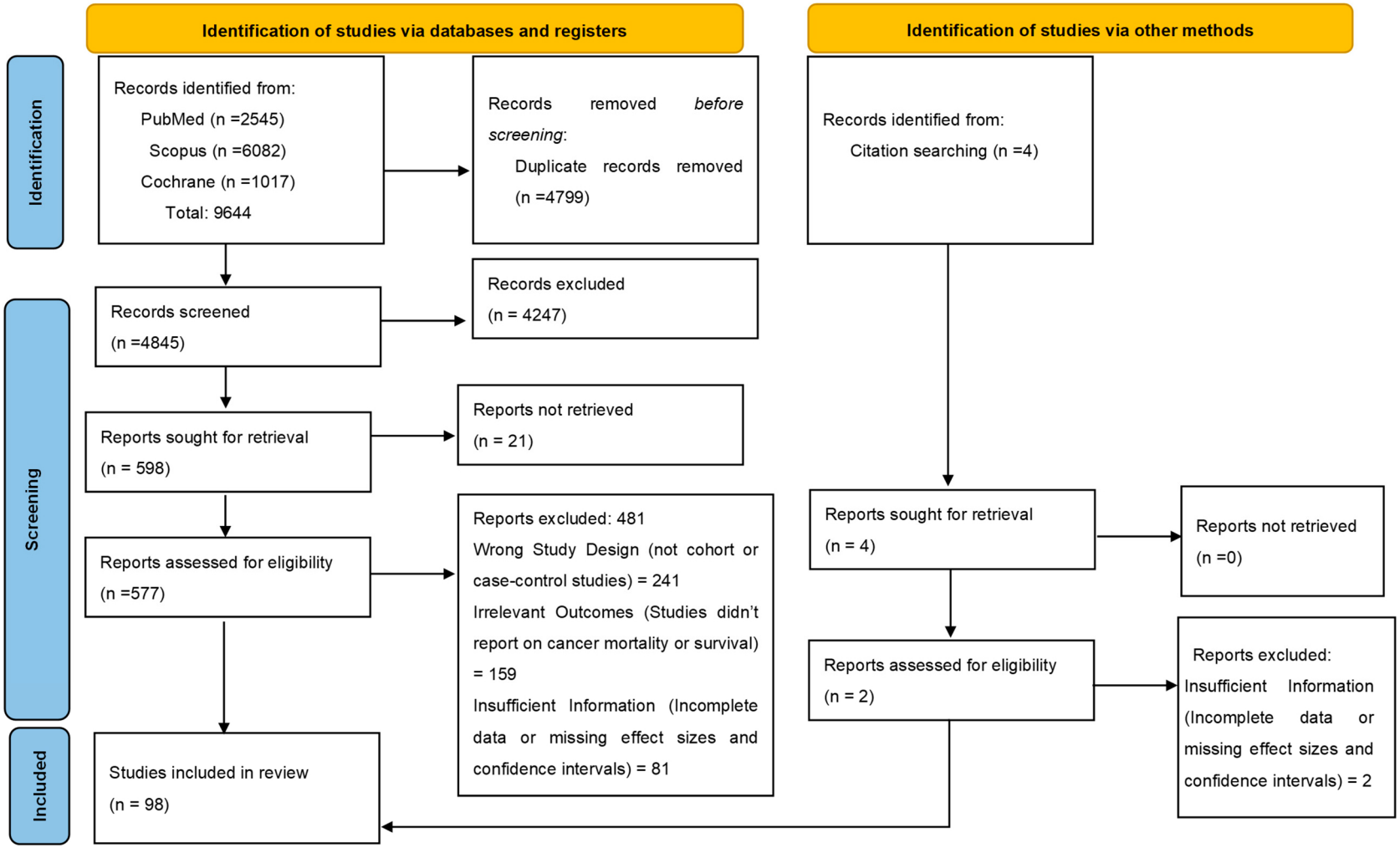


Figure 1. PRISMA flow diagram for the selection of studies.

2.4. Data Extraction

Data from the selected studies were extracted independently by two reviewers using a standardized data extraction form to minimize bias. Discrepancies were resolved through discussion or consultation with a third reviewer when necessary. The extracted data included were study characteristics such as author(s), year of publication, country, and study design. Participant demographics were recorded, including age, sex, cancer type, and stage at diagnosis. We also documented the details of the lifestyle intervention, specifying the type, duration, and intensity of the intervention. The outcomes measured were cancer mortality and survival. Extracted data were entered into an Excel sheet.

2.5. Outcomes

The outcome measures selected for the analysis were cancer-specific mortality and cancer recurrence.

2.6. Quality Assessment

Risk of bias assessment was undertaken independently by two reviewers. Discrepancies were discussed and resolved by consensus or through consultation with other reviewers. The quality and potential bias in individual studies were evaluated using Cochrane Risk of bias in Non-randomized Studies of Interventions. This tool is adaptable for observational studies and evaluates the risks across the following seven domains: confounding, participant selection, classification of interventions (or exposures), deviations from intended interventions (or exposures), missing data, measurement of outcomes, and selection of reported results.

2.7. Statistical Analysis

For this meta-analysis, the statistical analysis was performed with IBM SPSS version 29.0 for the 64 studies. Random-effects models were used throughout the analysis as a strategy to account for the expected heterogeneity across the studies that were included in the meta-analysis. This was aimed at providing more pointed and conservative estimations, knowing that the true effect sizes would not be the same, since the populations, interventions, and designs varied. The primary effect measure was the hazard ratio (HR) for disease-specific mortality as developed by cancer, and the level of confidence intervals (CIs) used to measure the level of accuracy was set at 95%. Studies accepted for the pooled analysis had log-transformed HRs, and their standard errors for the effect point estimates were extracted or calculated from the studies included. Heterogeneity was investigated with the I^2 statistic, where values of 25%, 50%, and 75% were considered as representing low, moderate, and high heterogeneity between the studies, respectively. To evaluate the publication bias, the funnel plot asymmetries were visually examined. A p-value of <0.05 was interpreted as statistically significant in all of the tests. All of the analyses were two-tailed, as lifestyle modification interventions are assumed to work in both directions, affecting either side of the continuum.

This comprehensive methodology ensured that the conclusions drawn from this meta-analysis were robust, reliable, and informative, providing clear guidance for clinical practice concerning the impact of lifestyle modifications on cancer recurrence and survival.

3. Results

3.1. Study Selection

Initially, a comprehensive search across multiple databases yielded a total of 9644 potential studies. Upon closer inspection and the removal of duplicates, we screened 4845 studies by analyzing the titles and abstracts. This screening led to the exclusion of 4247 studies.

We assessed 577 full-text articles for eligibility, of which 481 were further excluded due to reasons such as the wrong study design, irrelevant outcomes, and insufficient information. Ultimately, 98 studies met all of the inclusion criteria and were included in the review. The selection process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, and a flowchart summarizing the study selection process is presented in Figure 1.

3.2. Study Characteristics

The final cohort of 98 studies included a diverse array of research designs, including 94 cohort studies and 4 case-control studies. These studies spanned from 2005 to 2024 and involved a broad geographical distribution, including 48 studies from North America, 25 from Europe, 14 from Asia, and 3 from Australia. Collectively, these studies encompassed a total participant count of 1,461,834, ranging from small-scale studies with 103 participants to large-scale studies involving up to 303,428 participants. The participants were adult cancer survivors. The types of cancer most frequently studied included breast cancer (23 studies), colorectal cancer (23 studies), all cancers (13 studies), lung cancer (9 studies), and prostate cancer (7 studies), among others. The characteristics of the studies included are summarized in Supplementary Tables S1–S4.

3.3. Qualitative Synthesis

The lifestyle interventions analyzed were categorized into the following four main types:

3.3.1. Dietary Changes

Dietary changes were investigated in 43 [15–57] studies, focusing on interventions such as the increased intake of fruits and vegetables, reduced fat consumption, and adherence to specific dietary patterns like the Mediterranean diet. Among the 43 included studies, 10 studies [15–24] utilized the Healthy Eating Index (HEI) as a measure of high food quality. Only three studies [16,20,22] found an inverse relationship between the HEI and cancer-specific mortality. The other seven studies reported no association between the HEI and cancer-specific mortality, overall mortality, or recurrence.

Nine studies [28–31,34–38] employed the Prudent Diet Score as an index for high food quality. Lee et al. [30] identified an inverse relationship between the Prudent Diet Score and cancer-specific mortality. Guinter et al. [29] found that improvements in the DASH and Prudent Diet Scores from pre- to post-diagnosis were inversely associated with colorectal cancer (CRC)-specific mortality. Crowder et al. [31] suggested that adherence to a prudent diet before treatment may reduce the risk of chronic nutrition impact symptoms.

High-quality dietary indices, including the Alternative Healthy Eating Index (AHEI), Alternate Mediterranean Diet (aMED), and Dietary Approaches to Stop Hypertension (DASH), demonstrated mixed but promising associations. Eight studies [15,22,26,28,30,32–34] used the AHEI as an index for high food quality. Six of these studies reported an inverse relationship between the AHEI and cancer-specific mortality, while the remaining two [28,32] did not find a significant correlation. Eight studies [15,16,22,26–28,30,34] assessed the aMED as an index for high food quality. Two studies [15,30] found a significant inverse relationship between the aMED and cancer-specific mortality.

Eight studies [15–17,22,26,29,30,32] utilized the DASH as an index for high food quality. Four studies [15,17,29,30] reported an inverse relationship between the DASH and cancer-specific mortality. Ten studies [25,26,29–31,34,36–39] used the Western Diet Score as an index for low food quality. All of the studies indicated that the adherence to a Western diet was associated with adverse effects on cancer mortality and survival. Crowder et al. [31] found no association between the Western diet and nutrition impact symptoms.

Two studies [40,41] reported on maintaining a plant-based diet for cancer patients using the overall plant-based diet index (PDI), a healthful plant-based diet index (hPDI), and an unhealthful plant-based diet index (uPDI). Anyene et al. [40] reported that a healthful plant-based dietary pattern and unhealthful plant-based dietary pattern may reduce and increase the risk of non-breast-cancer mortality, respectively, whereas Ratjen et al. [41] revealed that the overall plant-based diet index displayed a significant, inverse association with all-cause mortality in colorectal cancer patients. However, Ollberding et al. [42] reported that maintaining a diet rich in fruits, vegetables, and starch after diagnosis of non-Hodgkin lymphoma (NHL) did not have an effect on overall survival.

Four studies reported on the World Cancer Research Fund/American Institute for Cancer Research (WCRF/AICR) recommendations in colorectal cancer patients [43–46]. In Van Zutphen et al. [43] and Romaguera et al. [45], a healthy lifestyle after a CRC diagnosis was associated with a decreased all-cause mortality risk and improved survival among CRC patients, respectively. However, in Song et al. [44], the post-diagnostic WCRF/AICR diet score was not statistically significantly associated with either colorectal cancer-specific or overall mortality. Two studies [47,48] studied the effect of adherence to the Mediterranean diet by using the Mediterranean diet score (MDS) and modified Mediterranean diet score (MMDS) [48] on cancer patients. They all found that maintaining a Mediterranean diet after the diagnosis of prostate, breast, and colorectal cancers, respectively, had a statistically significant association with better long-term overall survival.

Four studies [49–52] investigated the effect of an anti-inflammatory diet using the dietary inflammatory index (DII) [51,52] and energy-adjusted dietary inflammatory index (E-DII) [49,50] on colorectal cancer (CRC), and breast and prostate cancer (PCa) patients. The studies found that the dietary pattern with the most anti-inflammatory potential was associated with a decrease in all-cause mortality among postmenopausal women after diagnosis with CRC [49], a lower risk of cardiovascular mortality [50], and a decrease in the risk of cancer recurrence and overall mortality in patients with breast cancer [51]. However, Zucchetto et al. [52] reported that DII scores were not significantly associated with the all-cause mortality of PCa patients. Three studies [53–55] reported on the effect of a hyperinsulinemic state on cancer survival using the following different indices: the dietary insulin index [55], empirical dietary index for hyperinsulinemia (EDIH) [56], and diabetes risk reduction diet (DRRD) [57]. In colorectal cancer patients, higher dietary insulin scores after colorectal cancer diagnosis were associated with a statistically significant increase in colorectal cancer-specific and overall mortality, indicating poorer survival [53,55], and reduced mortality after breast cancer diagnosis [54].

The relation between diets consistent with the American Cancer Society (ACS) recommendations and cancer outcomes was assessed by McCullough et al. [56], revealing that a diet consistent with ACS recommendations, either pre-diagnosis or post-diagnosis, did not have a statistically significant effect on cancer-specific mortality in patients with breast cancer. Ferrohna et al. [57] evaluated pre-diagnostic dietary patterns in gastric cancer patients, categorizing the intake into the following three groups: Pattern I (high dairy, fruits, and salads/vegetables; low meat/alcohol), Pattern II (low consumption of dairy, fish, produce, and meat), and Pattern III (high in most food groups; minimal vegetable soup). Pattern III demonstrated a statistically significant association with improved prognosis in cases classified as regional spread.

3.3.2. Physical Activity

Physical activity was investigated in 20 studies [10,14,34,58–74], focusing on the relationship between physical activity and cancer survival outcomes across various cancer types. The studies varied in design, participant demographics, and follow-up durations,

yielding valuable insights into how physical activity influences survival rates among cancer patients. Among the included studies, seven studies [34,58,62,67,68,73,74] specifically highlighted the beneficial effects of adhering to physical activity guidelines post-diagnosis. These studies consistently demonstrated that engaging in regular physical activity is associated with improved survival rates in breast, colorectal, ovarian, and other cancer types.

Six studies [14,59,60,65,69,71] explored the association between varying intensities of physical activity and cancer survival. Hamer et al. [60] found that vigorous physical activity significantly reduced the cancer mortality risk compared to mild activity levels. Conversely, Ueshima et al. [14] reported unclear relationships, suggesting that the impact of physical activity may depend on specific cancer types or patient characteristics.

Seven studies [10,14,61,66,70,72,74] assessed the role of sedentary behavior in conjunction with physical activity levels. Cao et al. [70] identified that prolonged sitting combined with low physical activity significantly increased the risk of death from all causes, including cancer. This indicates that reducing sedentary time while increasing physical activity could be crucial for improving survival outcomes.

Five studies [34,63,64,67,73] highlighted the importance of the timing of physical activity in relation to diagnosis. For example, Van Blarigan et al. [34] emphasized that regular physical activity after a stage III colon cancer diagnosis was linked to improved survival, reinforcing the notion that post-diagnosis lifestyle changes can have a substantial impact on outcomes.

Overall, the synthesis of these studies indicates a robust association between physical activity and improved cancer survival, underscoring the need for guidelines promoting physical activity as a modifiable risk factor in cancer care. This is particularly relevant for patients across various cancer types, including breast, colorectal, and ovarian cancers, emphasizing the importance of integrating physical activity into treatment and survivorship plans.

3.3.3. Smoking Cessation

Smoking cessation was evaluated in 19 studies focusing on its impact on survival outcomes in cancer patients [71,74–92]. Among the included studies, six studies [71,75–78,83] highlighted that patients who quit smoking after a cancer diagnosis experienced significantly improved overall survival compared to those who continued smoking. Five studies [77,79,80,82,85,87] reported that ongoing smoking at the time of diagnosis was linked to poorer survival outcomes across various cancer types, including lung and colorectal cancers. Koshiaris et al. [77] indicated that individuals with lung cancer who quit smoking had a lower risk of mortality compared to those who continued smoking.

Five studies [79,84,86,88,91] examined the effects of smoking cessation on specific cancer types, noting that quitting smoking was associated with reduced cancer-related mortality. Four studies [81,89,90,92] investigated the timing of smoking cessation, with findings suggesting that quitting before diagnosis or early in the treatment process significantly correlated with better survival rates. Linhas et al. [90] found that smoking cessation before chemotherapy was associated with improved overall survival in non-small-cell lung cancer patients.

In summary, the evidence strongly supports that smoking cessation is associated with improved survival outcomes in cancer patients, underscoring the importance of quitting smoking at any stage of the disease.

3.3.4. Alcohol Moderation

Alcohol moderation was investigated in 20 studies focusing on the relationship between alcohol consumption and various health outcomes [24,71,93–111], particularly cancer-specific mortality and overall mortality. Among the studies, nine studies [24,71,93,94,97,101–104] identified that light alcohol consumption was associated with a decreased risk of certain cancers, notably breast cancer. Eight studies [94,98–101,105–107] reported that heavy alcohol consumption elevates the risk of overall mortality and specific cancers, such as liver and colorectal cancers. Koyama et al. [101] highlighted that heavy drinkers consuming more than 46 g/day of ethanol faced an increased risk of death compared to non-drinkers.

Six studies [95,102,104,108,110,111] examined post-diagnosis alcohol consumption and its association with increased mortality rates, particularly for prostate cancer. Farris et al. [98] noted that post-diagnosis consumption was linked to higher mortality rates in prostate cancer patients. Five studies [96,98,106,108,109] explored the moderation of alcohol consumption as a protective factor against cancer-related mortality. Jankhotkaew et al. [108] suggested that moderate alcohol intake may mitigate the risks associated with specific cancers, emphasizing the need for moderation in drinking behaviors.

Pre-diagnosis alcohol consumption has a non-linear association with increased breast cancer-specific mortality and may elevate the cancer-specific mortality risk in colorectal cancers. Light alcohol consumption significantly lowers the risk of all-cause mortality. However, heavy drinking before diagnosis is linked to poorer survival rates after a colorectal cancer diagnosis compared to light drinking. The protective benefits of light alcohol consumption might be limited to wine, and could vary based on age and the presence of diabetes mellitus. In contrast, post-diagnosis alcohol consumption is associated with increased mortality, particularly for prostate cancer. Heavy drinkers consuming more than 46 g/day of ethanol have a higher risk of death from oropharyngeal cancers compared to non-drinkers, regardless of gender.

Overall, the evidence suggests a complex relationship between alcohol consumption and health outcomes, with light consumption potentially offering some protective benefits, while heavy consumption remains a significant risk factor for various cancers and overall mortality.

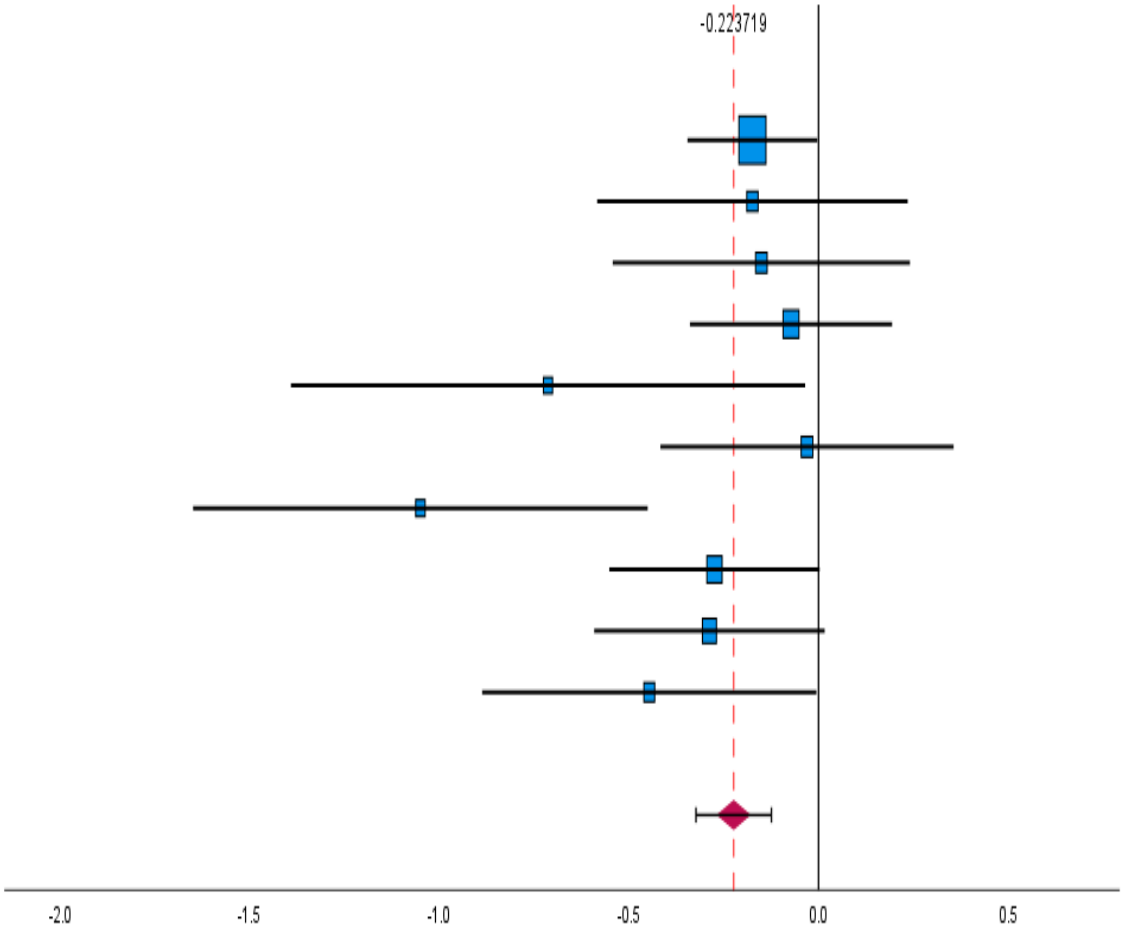
3.4. Quantitative Synthesis

The meta-analysis utilized both fixed-effects and random-effects models to account for variability across studies. The analysis revealed significant associations between lifestyle modifications and cancer outcomes:

3.4.1. Dietary Changes

We conducted an analysis of 10 cohort studies, encompassing a total of 28,650 cancer patients, to investigate the effects of adherence to the Healthy Eating Index (HEI) diet on cancer-specific mortality. The forest plot, which we generated using a random-effects model (Figure 2a), indicated that the adherence to the HEI diet post-cancer diagnosis was associated with significantly improved outcomes in terms of cancer-specific mortality (pooled log HR: −0.22; 95% CI: [−0.32, −0.12]; $p < 0.001$). The heterogeneity among the studies was very low ($I^2 = 0\%$), suggesting a low variability among the studies. Furthermore, the funnel plot (Supplementary Figure S1) demonstrated no signs of publication bias across the studies, as the plot was asymmetric.

ID	Study	LogOR	Std. Error	Lower	Upper	p-value	Weight	Weight (%)	NumberofParticipants
1	Park et al.	-0.17	0.09	-0.35	-0.00	0.05	130.35	33.59	6370
2	Ergas et al.	-0.17	0.21	-0.58	0.24	0.40	22.90	5.90	3660
3	Wang	-0.15	0.20	-0.54	0.24	0.45	24.99	6.44	3450
4	Luo et al.	-0.07	0.14	-0.34	0.19	0.59	53.96	13.90	887
5	Karavasiloglou et al.	-0.71	0.35	-1.39	-0.04	0.04	8.36	2.15	230
6	Sun	-0.03	0.20	-0.42	0.36	0.88	25.68	6.62	2295
7	Deshmukh et al.	-1.05	0.31	-1.65	-0.45	0.00	10.69	2.75	1191
8	Jacobs et al.	-0.27	0.14	-0.55	0.00	0.05	49.85	12.85	4204
9	Thomson et al.	-0.29	0.16	-0.59	0.02	0.06	41.53	10.70	636
10	Pelser et al.	-0.45	0.22	-0.89	-0.01	0.05	19.76	5.09	5727
	Overall	-0.22	0.05	-0.32	-0.12	0.00			



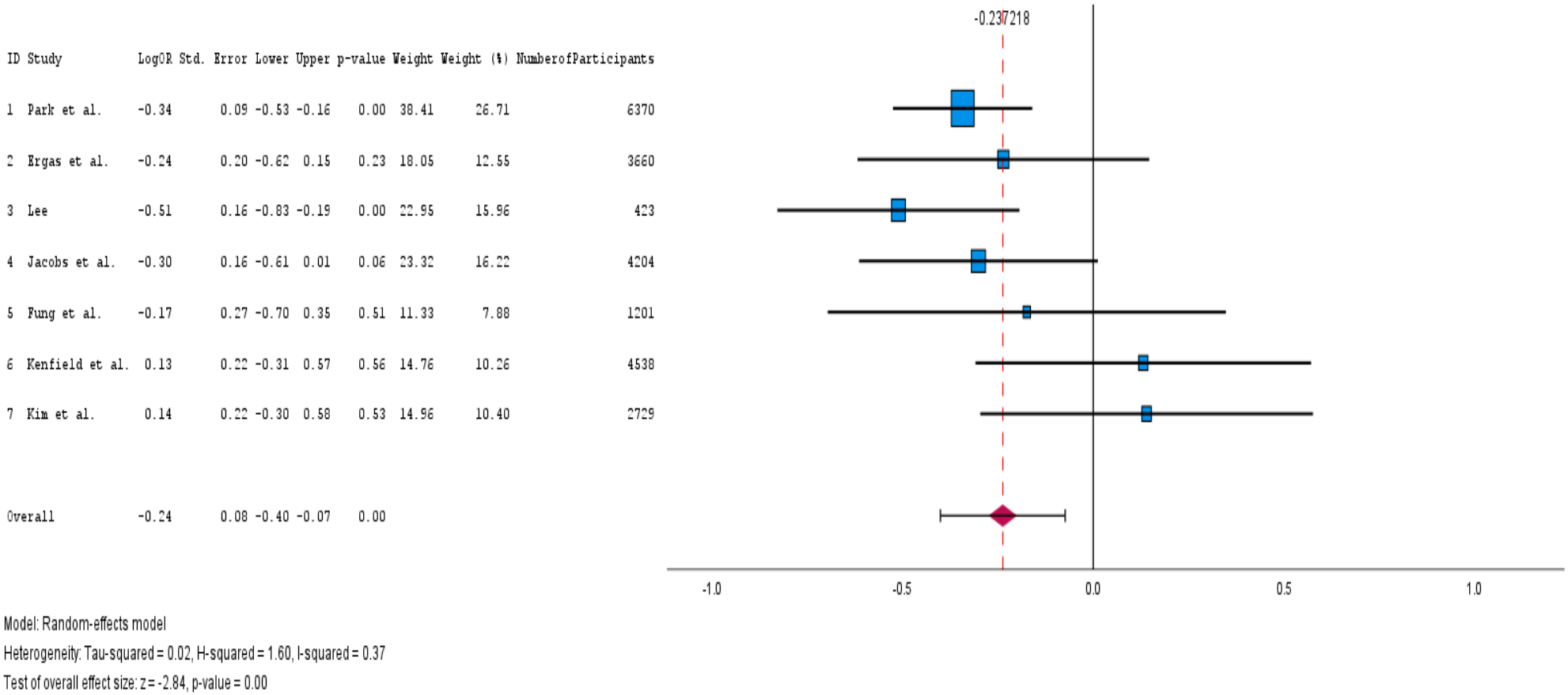
Model: Random-effects model

Heterogeneity: Tau-squared = 0.00, H-squared = 1.00, I-squared = 0.00

Test of overall effect size: z = -4.41, p-value = 0.00

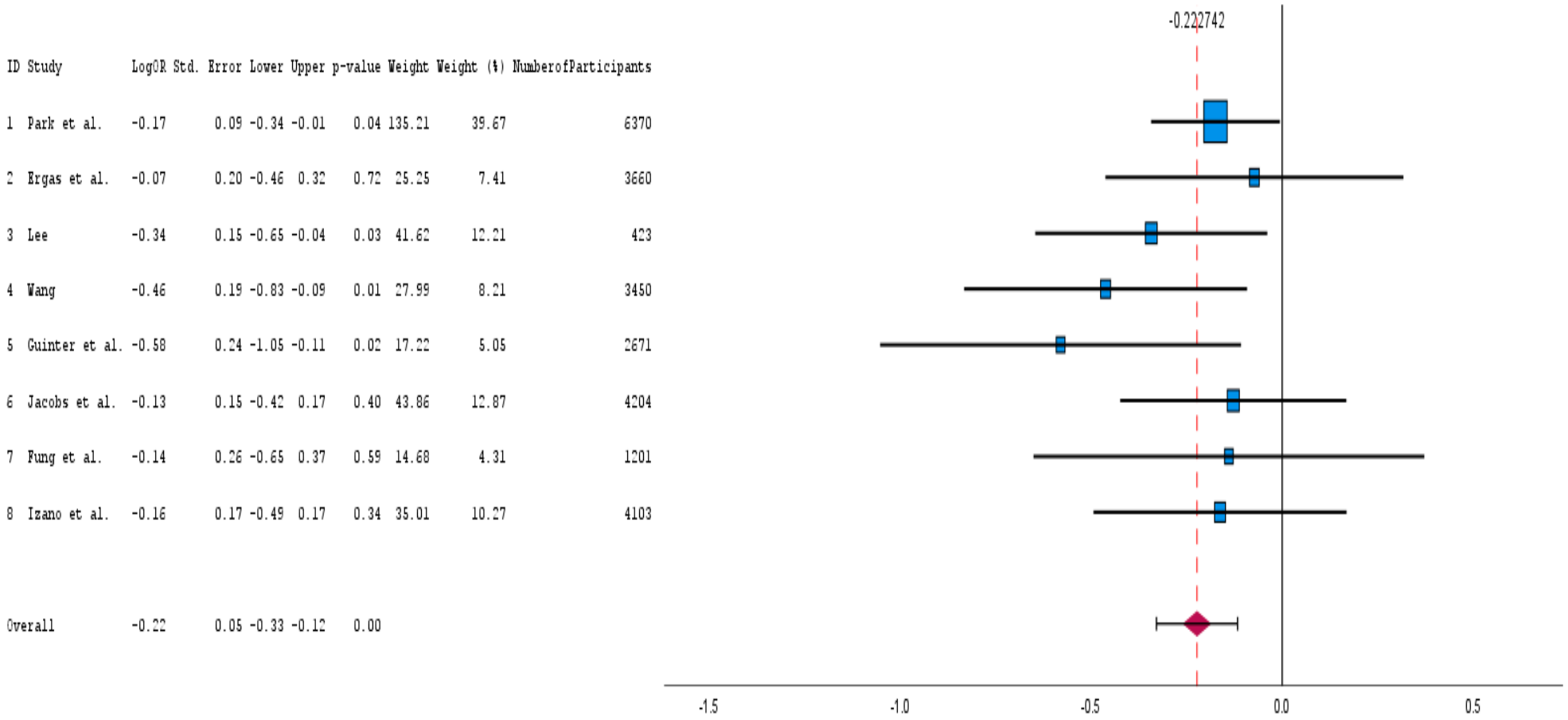
(**a**)

Figure 2. *Cont*.



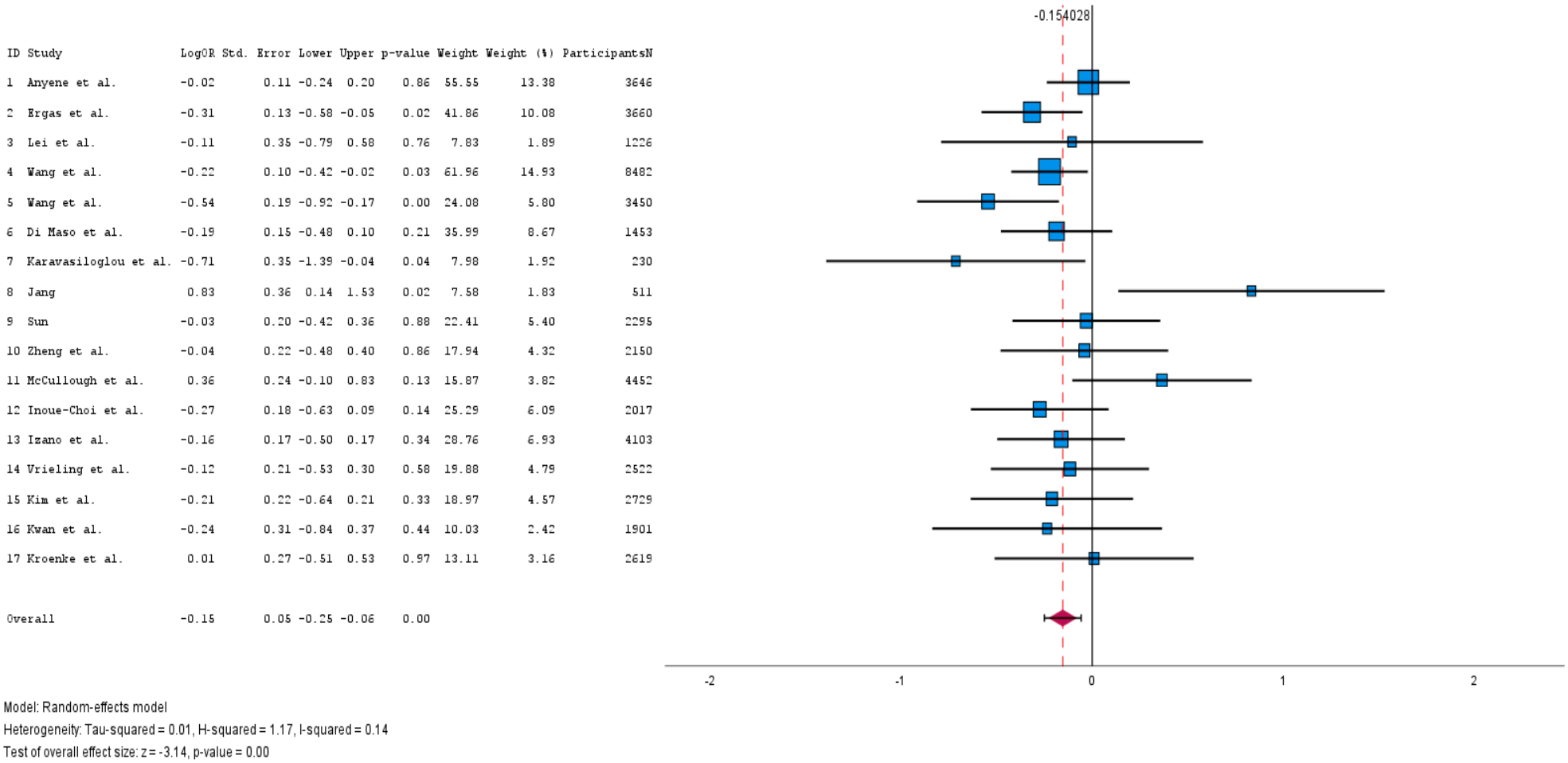
(**b**)

Figure 2. *Cont*.



(**c**)

Figure 2. *Cont*.



(**d**)

Figure 2. (**a**): Forest plots of the HEI diet impact on cancer survival [15–24]. (**b**): Forest plots of the aMED diet impact on cancer survival [15,16,22,26–28,30]. (**c**): Forest plots of the DASH diet impact on cancer survival [15–17,22,29,30,32]. (**d**): Forest plots of the diet (any) impact on breast cancer survival outcomes [16,17,19,20,28,32,37–40,46,47,49,51,56].

We analyzed seven cohort studies, encompassing 23,125 cancer patients, to assess the impact of adherence to the aMED diet on cancer-specific mortality. The forest plot, which we generated using a random-effects model (Figure 2b), demonstrates that following the aMED diet after a cancer diagnosis is associated with better outcomes in terms of cancer-specific mortality and recurrence (pooled log HR: −0.24; 95% CI: [−0.40, −0.07]; $p < 0.001$). The random-effects model showed no heterogeneity ($I^2 = 0\%$), indicating a high consistency among the studies. Additionally, the funnel plot (Supplementary Figure S2) reveals no indications of publication bias across the studies.

We examined eight cohort studies, involving a total of 26,082 cancer patients, to evaluate the effects of adherence to the DASH diet on cancer-specific mortality. The forest plot, which we generated using a random-effects model (Figure 2c), indicates that following the DASH diet after a cancer diagnosis improves outcomes in both cancer-specific and overall mortality (pooled log HR: −0.22; 95% CI: [−0.33, −0.12]; $p < 0.001$). The random-effects model shows a very low heterogeneity ($I^2 = 0\%$), suggesting a high level of consistency across the studies. Moreover, the funnel plot (Supplementary Figure S3) shows no signs of publication bias.

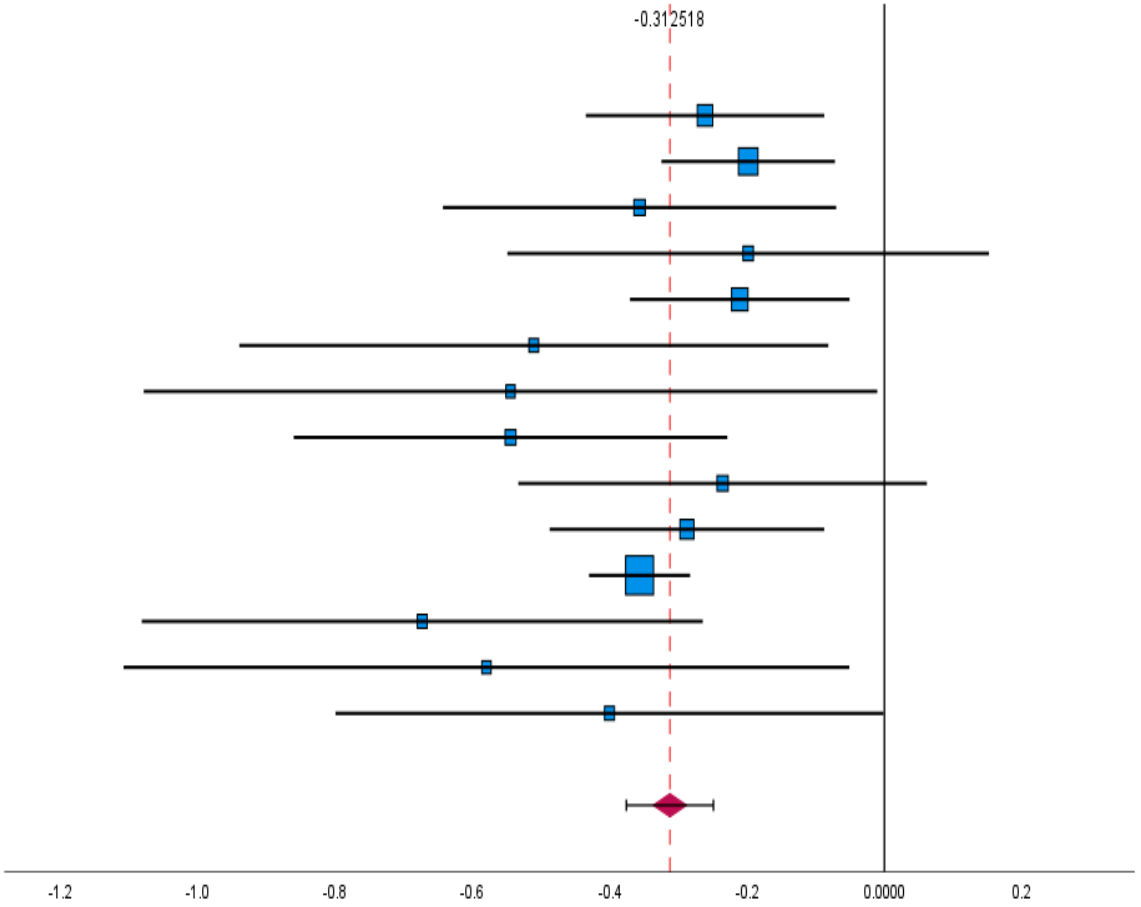
We also generated forest and funnel plots after including 17 cohort studies conducted on the effect of any form of diet on cancer survival in breast cancer patients. The forest plot we created using a random-effects model (Figure 2d) demonstrated that any form of diet had a favorable outcome for breast cancer-specific mortality (pooled log HR: −0.15; 95% CI: [−0.25, −0.06]; $p < 0.001$). The heterogeneity was very low ($I^2 = 14\%$; $p < 0.001$), indicating consistency among the studies. Additionally, the funnel plot revealed symmetry, suggesting the absence of publication bias (Supplementary Figure S4).

3.4.2. Physical Activity

We explored 14 cohort studies, encompassing a total of 898,036 cancer patients, to assess the impact of any form of physical activity on cancer-specific mortality. The forest plot we created using a random-effects model (Figure 3a) shows that any form of physical activity has a favorable outcome for cancer-specific mortality or recurrence (pooled log HR: −0.31; 95% CI: [−0.38, −0.25]; $p < 0.001$). The heterogeneity is very low ($I^2 = 0\%$), indicating consistency across the studies. There seemed to be the presence of publication bias among the different studies included, as shown in Supplementary Figure S5, which suggests that studies with favorable outcomes were published more often.

We also generated forest and funnel plots after including seven cohort studies conducted on the effect of physical activity on cancer-specific mortality for all cancer patients, excluding studies that measured the impact of physical activity on specific cancers. The forest plot we created using a random-effects model (Figure 3b) demonstrated that any form of physical activity had a favorable outcome for overall cancer-specific mortality or recurrence (pooled log HR: −0.24; 95% CI: [−0.33, −0.14]; $p < 0.001$). The heterogeneity was greater ($I^2 = 72\%$), indicating inconsistency among the studies, which may be because of studies which included different cancer types, stages, and treatment regimens, or variation in the types, intensity, and frequency of physical activity across the studies. Additionally, the funnel plot revealed no asymmetry, suggesting the absence of publication bias (Supplementary Figure S6).

ID	Study	LogOR	Std. Error	Lower	Upper	p-value	Weight	Weight (%)	ParticipantsN
1	Palesh O et al	-0.26	0.09	-0.44	-0.09	0.00	98.85	10.35	103
2	Patel AV et al	-0.20	0.06	-0.32	-0.07	0.00	155.71	16.30	69776
3	Hamer M	-0.36	0.15	-0.64	-0.07	0.01	42.32	4.43	7008
4	Ueshima K et al	-0.20	0.18	-0.55	0.15	0.27	29.15	3.05	10385
5	Watts EL et al	-0.21	0.08	-0.37	-0.05	0.01	112.15	11.74	272550
6	Hansen JM et al	-0.51	0.22	-0.94	-0.08	0.02	19.92	2.09	678
7	Van Blarigan EL et al	-0.54	0.27	-1.08	-0.01	0.05	13.06	1.37	992
8	Friedenreich CM et al	-0.54	0.16	-0.86	-0.23	0.00	35.41	3.71	830
9	Di Maso M et al	-0.24	0.15	-0.53	0.06	0.12	39.49	4.13	777
10	Walter V et al	-0.29	0.10	-0.49	-0.09	0.00	78.90	8.26	3121
11	Jee Y et al	-0.36	0.04	-0.43	-0.28	0.00	272.14	28.49	303428
12	Cannioto RA et al	-0.67	0.21	-1.08	-0.26	0.00	21.86	2.29	1340
13	Ammitzbøll G et al	-0.58	0.27	-1.11	-0.05	0.03	13.33	1.40	959
14	Mok Y et al	-0.40	0.20	-0.80	-0.00	0.05	22.85	2.39	226089
	Overall	-0.31	0.03	-0.38	-0.25	0.00			



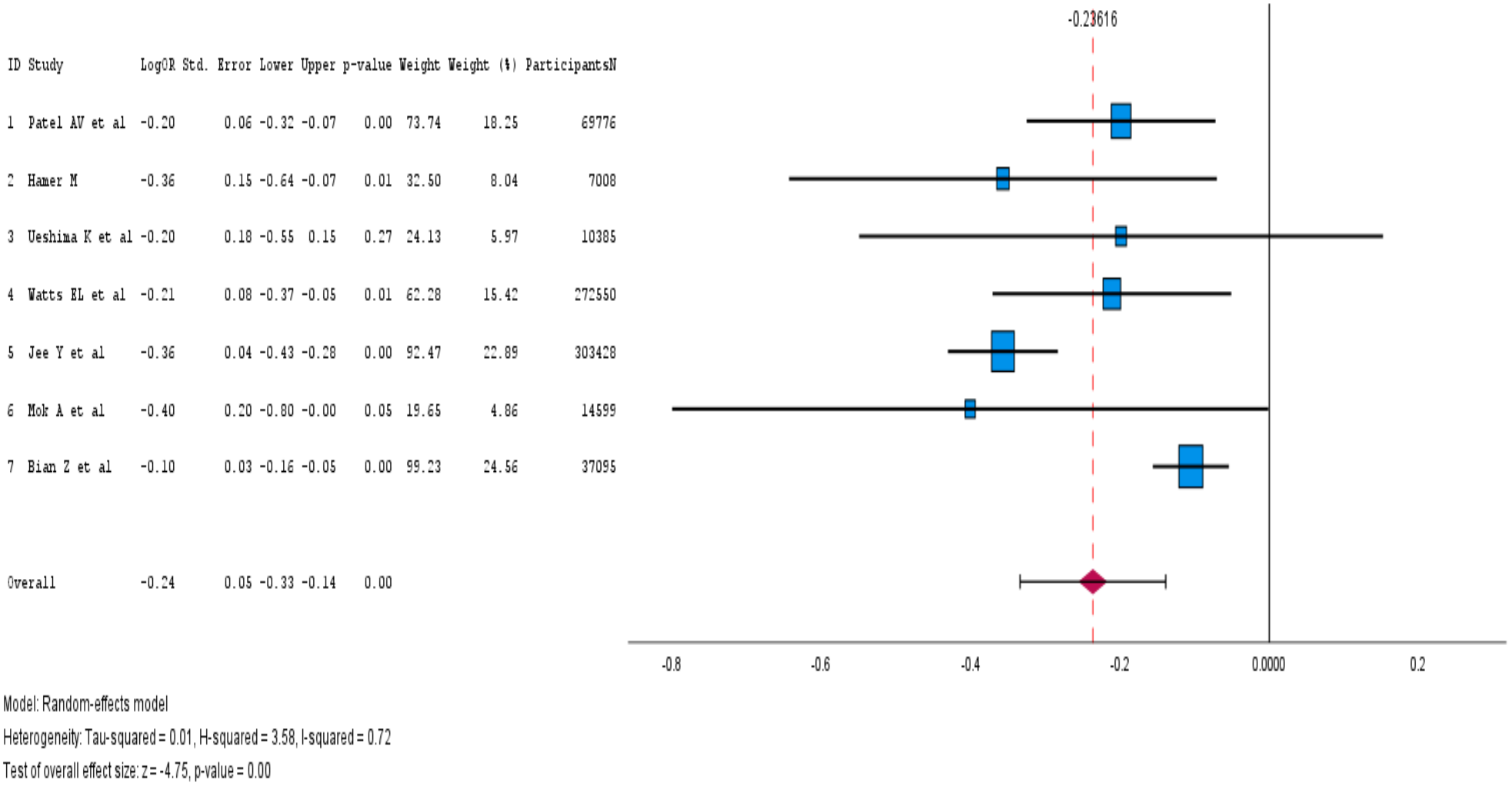
Model: Random-effects model

Heterogeneity: Tau-squared = 0.00, H-squared = 1.21, I-squared = 0.17

Test of overall effect size: z = -9.66, p-value = 0.00

(**a**)

Figure 3. *Cont.*



(**b**)

Figure 3. (**a**): Forest plot of the physical activity impact on cancer survival outcomes [14,34,58–69]. (**b**): Forest plot Physical activity with all cancer survival only [14,59–61,66,69,71].

3.4.3. Smoking Cessation

We identified 15 cohort studies, incorporating a total of 101,576 patients, to assess the impact of smoking cessation on cancer-specific mortality. We generated a forest plot (Figure 4a) including all of these studies, and observed that participants who quit smoking after diagnosis had significantly more favorable cancer outcomes (pooled log HR: −0.33; 95% CI: [−0.42, −0.24]; $p < 0.001$). The results across the studies were moderately consistent ($I^2 = 35\%$). The funnel plot (Supplementary Figure S7) revealed no publication bias among the studies.

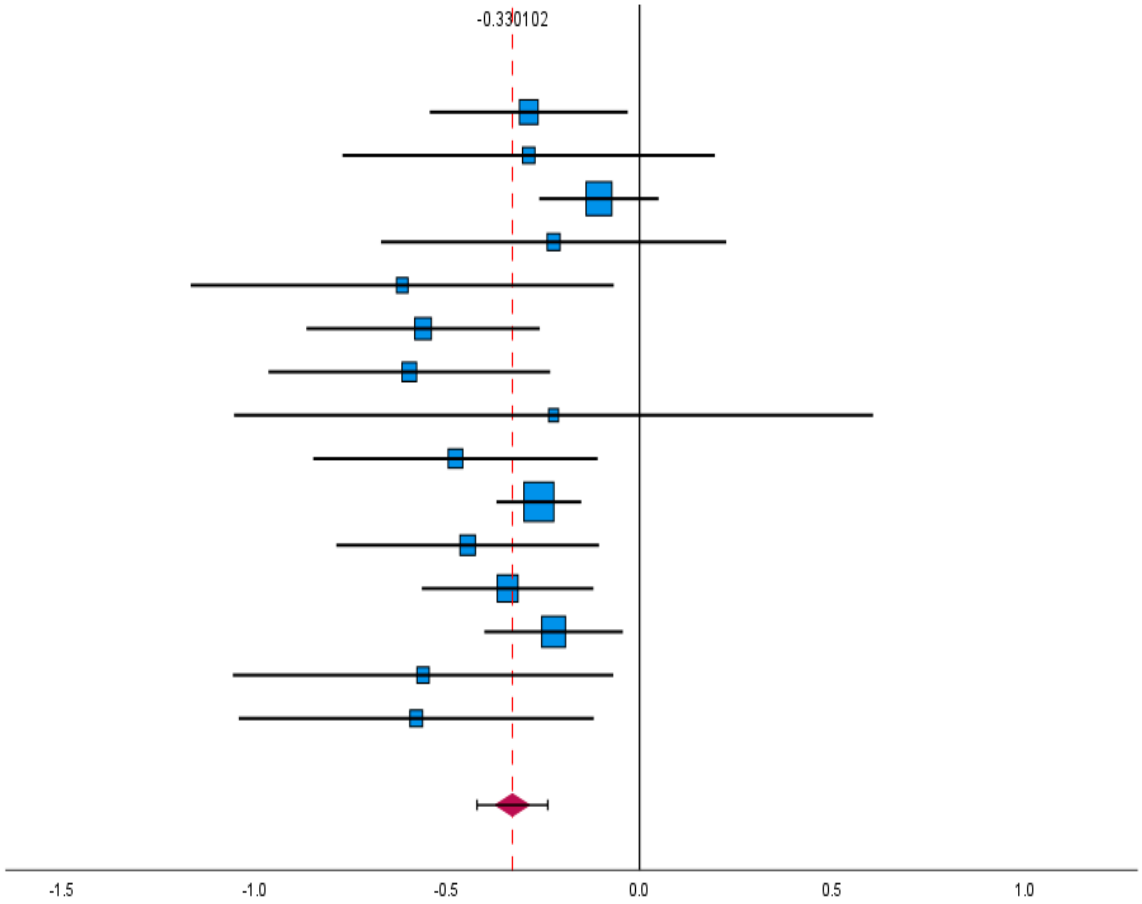
We then focused on nine cohort studies assessing the effect of smoking cessation on cancer-specific mortality in lung cancer survivors, excluding studies focusing on other cancer types. The forest plot (Figure 4b), utilizing a random-effects model, demonstrated that smoking cessation significantly reduced cancer-specific mortality in lung cancer survivors (pooled log HR: −0.34; 95% CI: [−0.48, −0.20]; $p < 0.001$). While the analysis revealed moderate heterogeneity ($I^2 = 42\%$), indicating some variability among the studies, the funnel plot (Supplementary Figure S8) showed signs of symmetry, pointing to a low potential for publication bias.

3.4.4. Alcohol Moderation

We conducted a meta-analysis of 15 cohort studies, involving 365,218 patients, to evaluate the impact of alcohol moderation on cancer-specific mortality. A forest plot (Figure 5a) was constructed using data from these studies, revealing that individuals who reduced their alcohol intake post-diagnosis experience significantly improved their cancer outcomes (pooled log HR: −0.26; 95% CI: [−0.33, −0.19]; $p < 0.001$). The results demonstrated moderate heterogeneity ($I^2 = 40\%$). Additionally, a funnel plot (Supplementary Figure S9) indicated some evidence of publication bias.

Subsequently, we focused on eight cohort studies specifically examining the effects of alcohol moderation on cancer-specific mortality among gastrointestinal tract cancer survivors, excluding studies related to other cancer types. The forest plot (Figure 5b), generated using a random-effects model, showed that alcohol moderation significantly decreased both cancer-specific mortality and recurrence in this group (pooled log HR: −0.22; 95% CI: [−0.29, −0.15]; $p < 0.001$). The analysis indicated a very low heterogeneity ($I^2 = 0\%$), suggesting a high consistency among the studies. The funnel plot (Supplementary Figure S10) displayed symmetry, indicating a low likelihood of publication bias.

ID	Study	LogOR	Std. Error	Lower	Upper	p-value	Weight	Weight (%)	ParticipantsN
1	Sheikh et al	-0.29	0.13	-0.54	-0.03	0.03	37.27	8.21	517
2	Gemini et al	-0.29	0.25	-0.77	0.20	0.24	14.19	3.13	364
3	Koshiaris et al	-0.11	0.08	-0.26	0.05	0.18	62.98	13.87	191
4	Ferketich et al	-0.22	0.23	-0.67	0.23	0.33	16.15	3.56	1863
5	Mahdi Sheikh et al	-0.62	0.28	-1.17	-0.07	0.03	11.34	2.50	212
6	Tse et al	-0.56	0.15	-0.87	-0.26	0.00	29.83	6.57	3202
7	Chen et al	-0.60	0.19	-0.96	-0.23	0.00	22.49	4.95	163
8	Chang et al	-0.22	0.42	-1.05	0.61	0.60	5.30	1.17	1677
9	Kenfield et al	-0.48	0.19	-0.85	-0.11	0.01	22.16	4.88	5366
10	Bian Z et al	-0.26	0.06	-0.37	-0.15	0.00	78.29	17.25	37095
11	Heberg et al	-0.45	0.17	-0.79	-0.11	0.01	25.06	5.52	7841
12	Japuntich et al	-0.34	0.11	-0.57	-0.12	0.00	44.37	9.77	5575
13	Jang D et al	-0.22	0.09	-0.40	-0.04	0.02	55.45	12.21	37079
14	Rades et al	-0.56	0.25	-1.06	-0.07	0.03	13.67	3.01	181
15	Dobson Amato et al	-0.58	0.24	-1.04	-0.12	0.01	15.40	3.39	250
	Overall	-0.33	0.05	-0.42	-0.24	0.00			



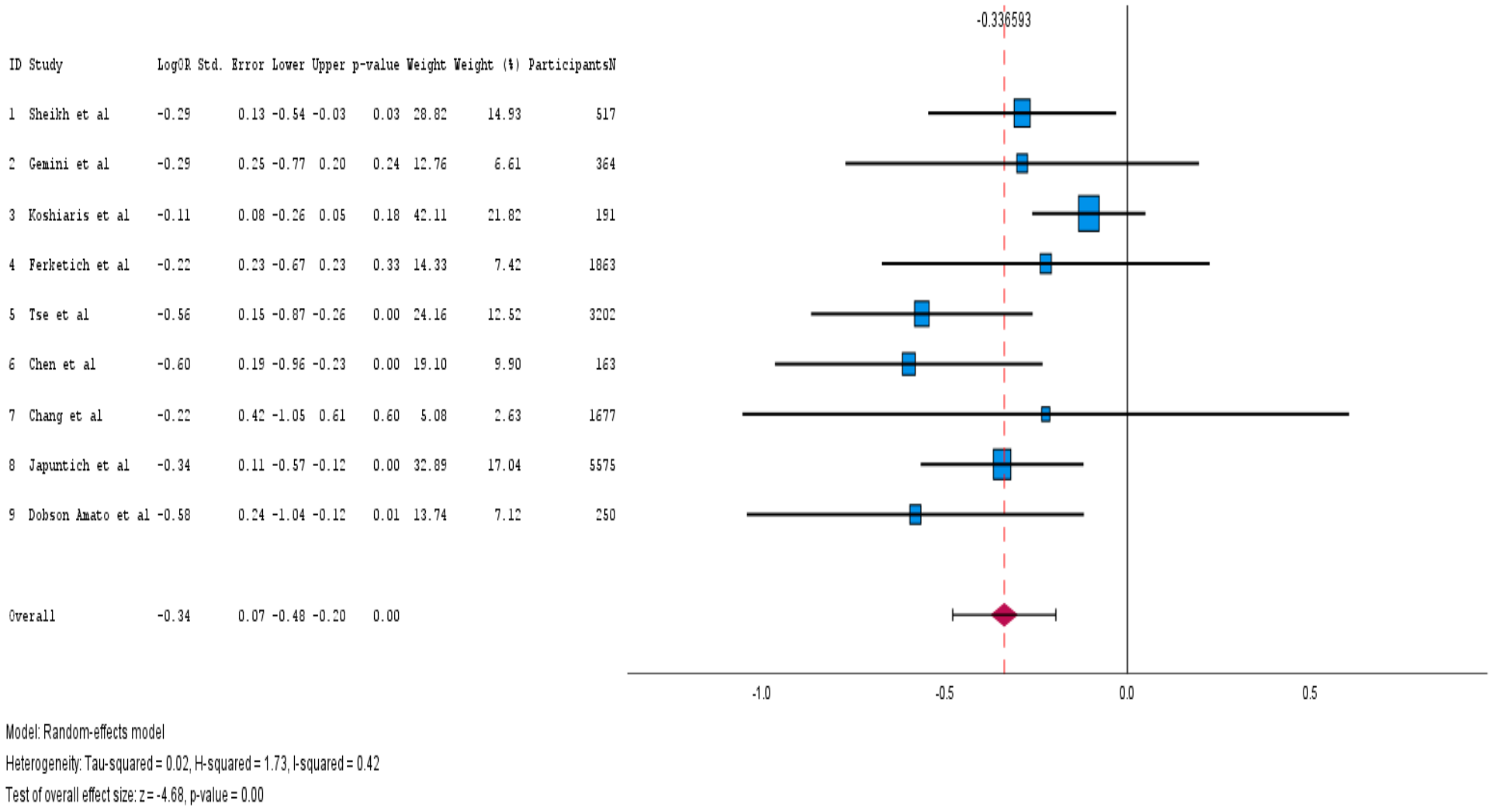
Model: Random-effects model

Heterogeneity: Tau-squared = 0.01, H-squared = 1.54, I-squared = 0.35

Test of overall effect size: z = -7.03, p-value = 0.00

(**a**)

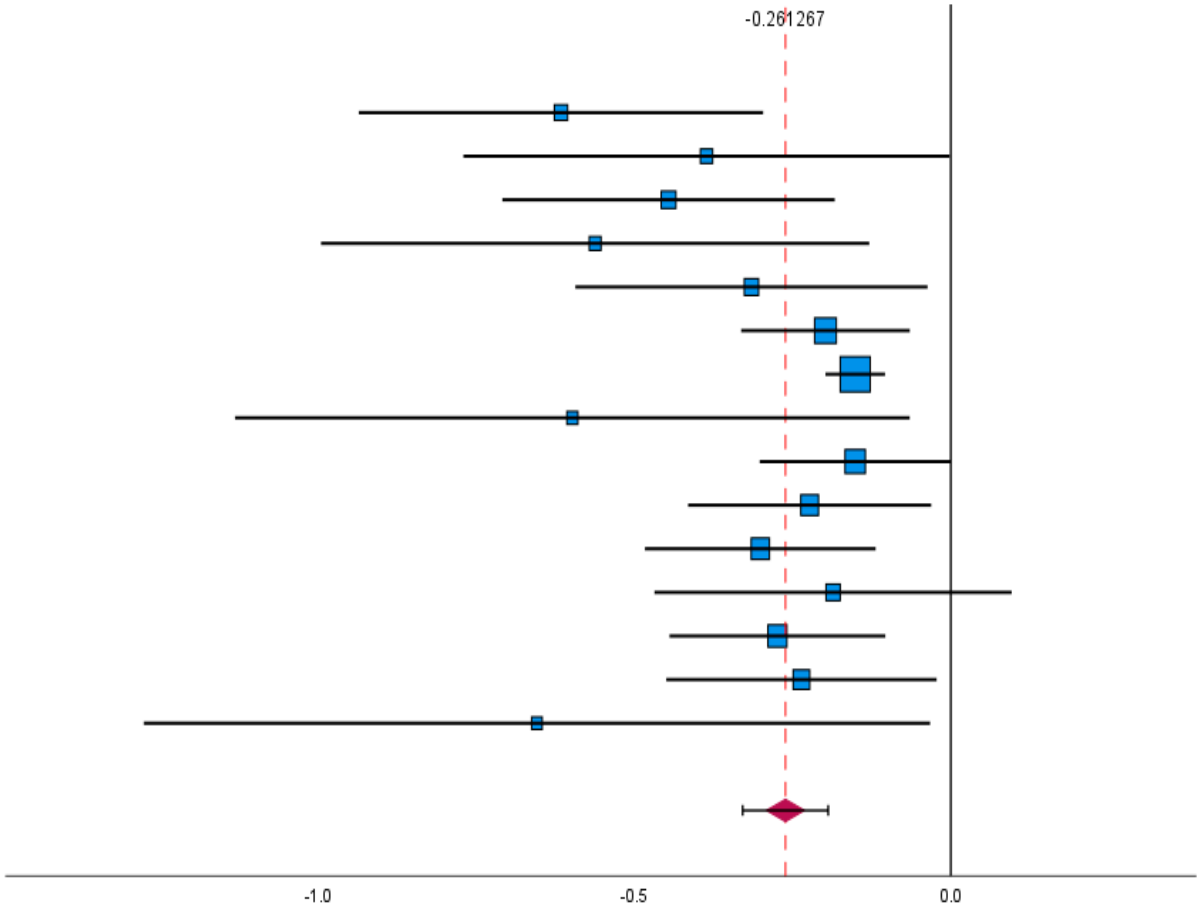
Figure 4. *Cont.*



(**b**)

Figure 4. (**a**): Forest plot of the impact of smoking cessation on cancer survival outcomes [71,75–88]. (**b**): Forest plot for impact of smoking cessation with lung cancer survival only [75–78,80–82,85,88].

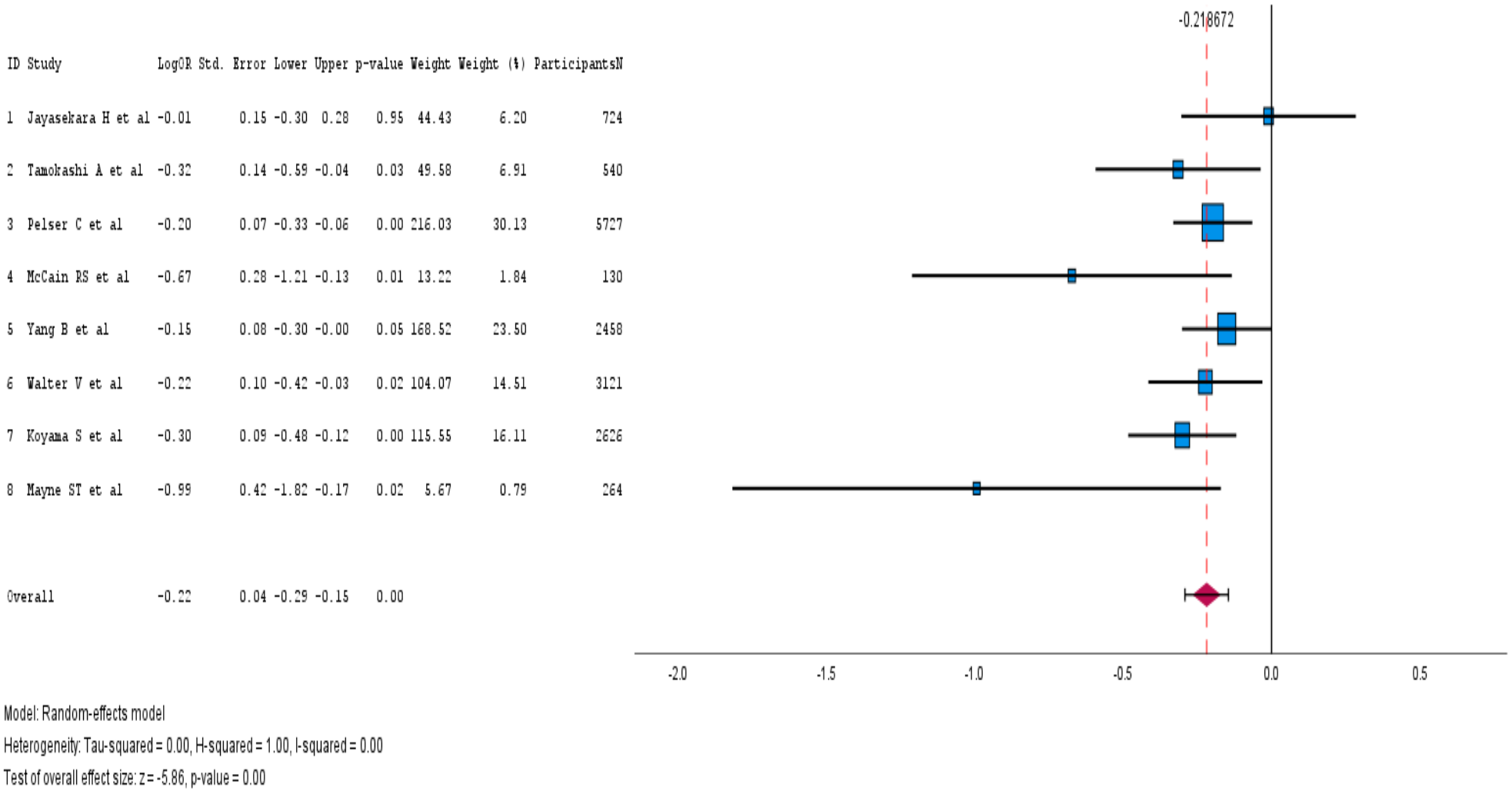
ID	Study	LogOR	Std. Error	Lower	Upper	p-value	Weight	Weight (%)
1	Jung EJ et al	-0.62	0.16	-0.94	-0.30	0.00	31.25	3.72
2	Minami Y et al	-0.39	0.20	-0.77	-0.00	0.05	22.80	2.71
3	Hermans KEPE et al	-0.45	0.13	-0.71	-0.18	0.00	42.75	5.09
4	Vrieling Aet al	-0.56	0.22	-1.00	-0.13	0.01	18.42	2.19
5	Tamokashi A et al	-0.32	0.14	-0.59	-0.04	0.03	39.06	4.65
6	Pelser C et al	-0.20	0.07	-0.33	-0.06	0.00	99.41	11.83
7	Bian Z et al	-0.15	0.02	-0.20	-0.10	0.00	166.34	19.79
8	Farris MS et al	-0.60	0.27	-1.13	-0.06	0.03	12.59	1.50
9	Yang B et al	-0.15	0.08	-0.30	-0.00	0.05	87.99	10.47
10	Walter V et al	-0.22	0.10	-0.42	-0.03	0.02	66.49	7.91
11	Koyama S et al	-0.30	0.09	-0.48	-0.12	0.00	71.00	8.45
12	Benyon RA et al	-0.19	0.14	-0.47	0.10	0.20	38.21	4.55
13	Ramadas K et al	-0.27	0.09	-0.44	-0.10	0.00	76.89	9.15
14	Denissoff A et al	-0.24	0.11	-0.45	-0.02	0.03	57.75	6.87
15	Din N et al	-0.65	0.32	-1.28	-0.03	0.04	9.44	1.12
	Overall	-0.26	0.03	-0.33	-0.19	0.00		



Model: Random-effects model
Heterogeneity: Tau-squared = 0.01, H-squared = 1.66, I-squared = 0.40
Test of overall effect size: z = -7.57, p-value = 0.00

(**a**)

Figure 5. *Cont.*



(**b**)

Figure 5. (**a**): Forest plot of the impact of the reduction in alcohol intake on cancer survival [24,71,93–105]. (**b**): Alcohol moderation on cancer-specific mortality among gastrointestinal tract cancer survivors [24,97,99–101,107,109,111].

4. Discussion

This systematic review and meta-analysis on lifestyle interventions and their impact on cancer outcomes reveals significant insights derived from both qualitative and quantitative syntheses. In the qualitative synthesis, lifestyle interventions were categorized into dietary changes, physical activity, smoking cessation, and alcohol moderation, with each category demonstrating its potential effects on cancer-specific mortality and recurrence.

Numerous studies have independently examined the effects of alcohol moderation, smoking cessation, physical activity, and dietary patterns on cancer-specific mortality and recurrence. For instance, individual studies have consistently demonstrated that reducing alcohol intake post-diagnosis improves cancer outcomes, while smoking cessation has been linked to decreased cancer-specific mortality and recurrence, particularly in lung cancer survivors. Similarly, physical activity has been associated with favorable cancer outcomes, and adherence to healthy dietary patterns, such as the HEI, aMED, and DASH diets, has shown significant benefits in reducing cancer-specific mortality and recurrence. However, our study is unique in synthesizing these four lifestyle factors together, providing a comprehensive overview of their combined impact on cancer outcomes.

Dietary changes were examined across 46 studies, focusing on various dietary patterns, such as the Healthy Eating Index (HEI) and the Mediterranean diet. While only three studies found an inverse relationship between the HEI and cancer-specific mortality, nine studies using the Prudent Diet Score indicated a beneficial association with reduced mortality, particularly in colorectal cancer. Other dietary indices, including the Alternative Healthy Eating Index (AHEI) and the Dietary Approaches to Stop Hypertension (DASH), also showed promising results, reinforcing the importance of high food quality in cancer survival outcomes. Conversely, adherence to a Western diet was consistently linked to poorer outcomes, highlighting the negative impact of low-quality dietary patterns.

Physical activity was evaluated in 20 studies, with 10 studies specifically underscoring the benefits of meeting physical activity guidelines post-diagnosis. Regular physical activity was associated with improved survival rates across multiple cancer types, including breast and colorectal cancer. The analysis revealed that vigorous activity notably reduced the mortality risk compared to mild levels, while sedentary behavior correlated with increased mortality risk, emphasizing the necessity of reducing sedentary time to enhance cancer survival.

Smoking cessation was supported by evidence from 21 studies, which demonstrated that patients who quit smoking after their cancer diagnosis had significantly better survival outcomes. Timing was crucial; quitting before diagnosis or early in the treatment process was associated with improved survival rates, particularly for lung cancer patients.

Lastly, alcohol moderation was investigated in 20 studies, indicating a complex relationship between alcohol consumption and health outcomes. While light alcohol consumption was linked to decreased cancer risk, heavy drinking consistently elevated the mortality risk across several cancer types. Notably, post-diagnosis alcohol consumption correlated with increased mortality rates, particularly in prostate cancer, emphasizing the need for moderation following diagnosis.

In the quantitative synthesis, the meta-analysis results reinforced the findings from the qualitative analysis, revealing significant associations between lifestyle modifications and improved cancer outcomes. For instance, adherence to the HEI diet demonstrated a hazard ratio log HR to be -0.22 for cancer-specific mortality, indicating a decreased risk of mortality in patients adopting this diet. Similarly, the aMED and DASH diets showed log HRs of -0.24 and -0.22, respectively, supporting the role of these dietary patterns in enhancing survival rates.

Physical activity was shown to have a favorable effect on cancer-specific mortality (log HR: −0.31), while smoking cessation yielded a significant reduction in cancer-specific mortality and recurrence (log HR: −0.33). Alcohol moderation also revealed a positive impact, with a log HR of −0.26 for those reducing intake post-diagnosis.

Clinically, our study underscores the importance of a multifaceted approach to cancer survivorship care. By integrating alcohol moderation, smoking cessation, physical activity, and adherence to healthy dietary patterns, healthcare providers can offer more holistic and effective strategies to improve cancer-specific outcomes. Academically, this study fills a critical gap in the literature by providing a consolidated analysis of these lifestyle factors, which were previously studied in isolation. This comprehensive approach not only enhances our understanding of the individual and combined effects of these factors but also sets a foundation for future research to explore synergistic interventions.

One of the primary strengths of our study is the comprehensive nature of the systematic review, which includes a large sample size across multiple cohort studies, thereby increasing the generalizability of our findings. Additionally, the use of random-effects models and the assessment of publication bias through funnel plots add robustness to our analysis.

This comprehensive meta-analysis also has a number of limitations that must be recognized. There is potential publication bias, represented by the asymmetry of the funnel plots, which could mean the over-representation of positive-results studies, especially regarding physical activity, thus inflating the apparent effects of lifestyle interventions. Observational studies often could not be fully adjusted for confounding factors such as socioeconomic status, health behaviors at baseline, and comorbid conditions; thus, biases may arise. High heterogeneity, for instance, in physical activity, is up to $I^2 = 72\%$, reflecting variability in the study designs, populations, and measurement methods, which may affect the generalizability of the findings. Many studies relied on self-reported data for lifestyle behaviors; hence, the results cannot avoid recall and reporting biases. The variation in the timing of interventions, for example, since the diagnosis, was also irregularly analyzed, which can modify the observed associations. These factors together make the case for a cautious interpretation and stronger research in the future.

5. Conclusions

Our systematic review and meta-analysis highlights the significant benefits of alcohol moderation, smoking cessation, physical activity, and adherence to healthy dietary patterns on cancer-specific mortality. These findings advocate for a comprehensive lifestyle modification approach in cancer survivorship care, emphasizing the need for integrated interventions that address multiple lifestyle factors simultaneously.

Healthcare providers should encourage cancer patients to adopt a holistic lifestyle modification strategy that includes reducing alcohol intake, quitting smoking, engaging in regular physical activity, and following healthy dietary patterns. Such an approach has the potential to significantly improve cancer-specific outcomes and enhance overall survivorship quality.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/medicina61020307/s1, Table S1: Characteristics of studies associated with Dietary changes; Table S2: Characteristics of studies associated with Physical Activity; Table S3: Characteristics of studies associated with Smoking Cessation; Table S4: Characteristics of studies associated with Alcohol Moderation; Figure S1: Funnel plots to assess publication bias in studies assessing HEI diet impact on cancer survival; Figure S2: Funnel plots to assess publication bias in studies assessing aMED diet impact on cancer survival; Figure S3: Funnel plots to assess publication bias in studies assessing DASH diet impact on cancer survival; Figure S4: Funnel plots to

assess publication bias in studies assessing diet impact on breast cancer survival; Figure S5: Funnel plot to assess publication bias in studies assessing physical activity impact on cancer outcomes; Figure S6: Funnel plot to assess publication bias in studies assessing physical activity impact on all cancer survival outcomes only; Figure S7: Funnel plot to assess publication bias in studies assessing smoking cessation impact on all cancer survival; Figure S8: Funnel plot to assess publication bias in studies assessing smoking cessation impact on lung cancer survival; Figure S9: Funnel plot to assess publication bias in studies assessing alcohol impact on all cancer survival; Figure S10: Funnel plot to assess publication bias in studies assessing alcohol impact on survival in gastrointestinal tract cancers.

Author Contributions: Conceptualization, S.A.R., M.A.P. and M.E.-T.; methodology, S.A.R., M.A.P., M.E.-T., I.R.R., A.F.W., R.B., S.M.S., Y.E.-T. and A.A.M.S.A.; software, S.A.R., M.A.P. and M.E.-T.; validation, I.R.R.; formal analysis, S.A.R., M.A.P., I.R.R., A.F.W., R.B., S.M.S., Y.E.-T. and A.A.M.S.A.; investigation, S.A.R., M.A.P., M.E.-T., I.R.R., A.F.W., R.B., S.M.S., Y.E.-T. and A.A.M.S.A.; resources, M.E.-T.; data curation, S.A.R., M.A.P., I.R.R., A.F.W., R.B., S.M.S., Y.E.-T. and A.A.M.S.A.; writing—original draft preparation, M.A.P., I.R.R., A.F.W., R.B., S.M.S., Y.E.-T. and A.A.M.S.A.; writing—review and editing, I.R.R., A.F.W., R.B., S.M.S. and Y.E.-T.; visualization, S.A.R., M.A.P., M.E.-T., I.R.R., A.F.W., R.B., S.M.S., Y.E.-T. and A.A.M.S.A.; supervision, M.E.-T.; project administration, M.E.-T.; funding acquisition, not applicable. All authors have read and agreed to the published version of the manuscript.

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