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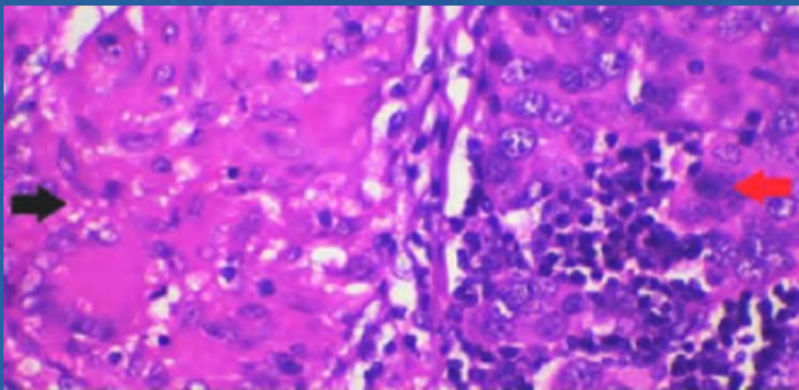
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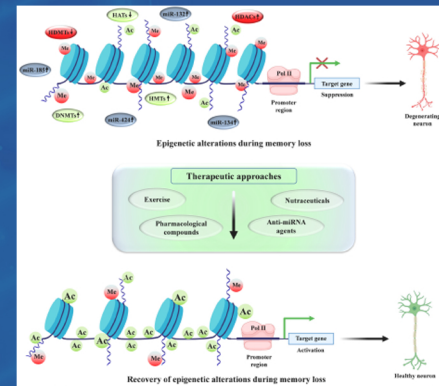
Epigenetics in memory decline during aging

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Review Article

Effect of modifiable lifestyle risk factors on the incidence and prevention of cancer in modern society: A review

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ABSTRACT

Human society has been influenced by modernization, which has altered our pattern of living. It is believed that several environmental and lifestyle factors, including urbanization, employment linked to socioeconomic transition, increased affluence, and altered social and family structures, are partially to be blamed for cancer. Lifestyle changes associated with urbanization such as smoking, alcohol consumption, excessive body weight, and being physically inactive are well-known risk factors for cancer. Anxiety due to stressful events can increase the production of free radicals, which in turn causes oxidative damage and the emergence of cancer. Economic liberty provides more leisure time and inclination toward ready-to-eat food, more screen time, and sedentary habits to some extent. All these factors have a positive impact on cancer initiation and development. Hence, a healthy lifestyle, together with nutritious food and regular exercise should be prioritized for cancer prevention. A healthy lifestyle has been associated with a decreased risk of different types of cancer, involving the lungs, liver, colon, breast, endometrium, and kidney. To outline this review, searches were performed with PubMed and Scopus databases up to August 2022. The lifestyle risk factors for cancer have been described in this review, along with recommendations for improving lifestyle choices for human welfare.

Keywords: Cancer, Lifestyle, Physical Activity, Stress

INTRODUCTION

Over the past few decades, a trend has been observed wherein there is an increase in the incidence of noncommunicable diseases than infectious diseases and the prevalence of noncommunicable diseases such as cardiovascular diseases and cancer has been on the rise mostly in developing countries[1–3] In modern world, our way of living has changed as a result of globalization, increased wealth, altered social and family structures, a lack of physical activity, and anxiety brought on by stressful events.[4] The incidence of cancer has increased greatly due to these lifestyle factors, but it can be prevented by major lifestyle changes.[5] It has been reported that these lifestyle risk factors are related to various types of cancer involving breast, lung, prostate, colon, and stomach.[6]

When the world's population reaches 8.3 billion in 2030, there are likely to be 21.4 million cases and 13.2 million deaths due to cancer.[7] The increased incidence of cancer has been documented in various studies.[8] Lung cancer is a prominent cause of mortality in males,[9] and breast cancer is prevalent among females.[8] Other common causes of death in males are colorectal cancer (CRC) and prostate cancer.[8] Hepatocellular carcinoma (HCC), affecting all age groups in both males and females is in the sixth position after breast, lung, prostate, colon, and stomach cancer.[8,10] Smoking, alcohol consumption, unhealthy eating habits, and excess body weight are lifestyle risk factors and are responsible for 35% of cancer deaths worldwide.[11] In 2021, Friedenreich *et al.* documented that obesity and sedentary behavior are associated with cancer.[12] While these aspects of lifestyle are not inherently unique to contemporary culture, they have become more prevalent in many societies due to the effect of globalization. Healthy lifestyles may reduce the incidence of cancer morbidity and mortality to a great extent and for cancer prevention, priority should be given to these factors.[13] Among many modifiable risk factors, the most notable are alcohol consumption, smoking, obesity (high BMI, measured in kg/m²), and insufficient physical activity (sufficient physical activity ≥ 30 min/five times/week or minimum 1,600–2,400 calories/day burnt for adult women and 2,000–3,000 calories/day burnt for adult men)[14,15] and 30–40% of cancers are preventable by the transformation of modifiable lifestyle risk factors.[16] A healthy

lifestyle combined with proper diet and exercise should be prioritized for cancer prevention as it negatively impacts lymphoma, myeloma, lung, colon, breast, endometrial, and kidney cancer incidence.

However, it is important to understand that cancer is a complicated illness, and a number of circumstances might lead to its occurrence. Lifestyle factors are just one piece of the puzzle, and it is often difficult to isolate their effects from other factors such as genetics, environmental exposures, and medical history.

REVIEW METHODOLOGY

For this review, searches were conducted in databases such as PubMed, Scopus, and Web of Sciences for all full-text articles up to August 2022 using combinations of various key terms such as "cancer", "lifestyle", "modifiable risk factors", "lung cancer", "liver cancer" or "hepatocellular carcinoma", "melatonin", "sleep deprivation", and "tobacco smoking/adverse effects". The lifestyle factors mainly included tobacco smoking, alcohol consumption, sedentary behavior, overweight/obesity, and diet, while some studies also included green tea consumption, fruit and vegetable consumption, the damaging effect of blue light, sleep deprivation, exposure to indoor air pollution, practicing yoga and physical activity. Besides the reference lists of original studies, reviews and meta-analyses were also scrutinized to identify relevant studies.

Included studies fulfilled the following criteria: (i) prospective cohort studies; (ii) review article; (ii) incident total and site-specific cancer or cancer mortality; (iii) focusing on a single lifestyle factor; (iv) a combination of only two lifestyle factors; and (v) using the combination of lifestyle factors as an exposure variable. Studies were excluded if they were: (i) other publication types (such as protocols, case-control studies) or not peer-reviewed publications (such as editorials and commentaries); (ii) formulation or validation of prediction models; (iii) duplicate reporting from the same cohort studies or duplicate publications; and (iv) studies without necessary or sufficient data.[17]

THE INCIDENCE OF CANCER AND LIFESTYLE FACTORS

Obesity and cancer

Obesity (BMI ≥ 30 kg/m²)[18] is linked to an enhanced risk of cancer of the endometrium, esophagus, colon, kidney, liver, pancreatic tissues, and breast in postmenopausal women, and also poses a threat of malignant melanoma.[19,20]

It has been reported that intentional weight loss among obese women can reduce the risk of endometrial cancer by 54%.[21] Excessive body fat at a young age is linked to the development of eight kinds of cancer in later stages of life.[22] Postmenopausal

breast cancer risk is greater in adult women who have a body mass index > 23.4 kg/m² at 20 years of age.[23] Chronic inflammations, inhibition of apoptosis, and oxidative stress have been observed in carcinogenesis, which is stimulated by obesity.[24]

Sedentary behavior and cancer

Inflammatory factors like tumor-necrosis factor-α, interleukin-6, and leptin might lead to the progression of cancer in the lung and these factors might aggravate due to sedentary behaviors.[25] It has been reported by a meta-analysis that sedentary behavior and television watching are linked to lung cancer, colon cancer, and endometrial cancer.[26]

More than a quarter of the global population is not properly active.[27] An inverse relationship has been found between physical activity and many types of cancer.[28] Obesity-induced carcinogenesis has been linked to oxidative stress, apoptotic suppression, and chronic inflammation.[24] It has been observed that moderate-to-vigorous physical activity (sufficient physical activity ≥ 30 min/five times/week or minimum 1,600–2,400 calories/day burnt for adult women and 2,000–3,000 calories/day burnt for adult men) during leisure time and reduction of television watching has been related to an increase of cancer-free (colorectal, lung, prostate, and postmenopausal breast cancer) life span.[29] It is also reported that television watching is associated with the risk of lung cancer and less television watching especially in smokers might avert lung cancer.[30] Hence, moderate physical activity of 150 minutes or vigorous physical activity of not less than 75 minutes per week has been recommended (sufficient physical activity ≥ 30 min/five times/week or minimum 1,600–2,400 calories/day burnt for adult women and 2,000–3,000 calories/day burnt for adult men).[14,15,28,31] Global action plan of WHO on physical activity 2018–2030 may be implemented by some countries[32] to combat the situation.

Smoking and cancer

The smoke of tobacco contains carcinogens that induce somatic mutation as a result of the generation of DNA adducts.[33] Passive smoke is also considered carcinogenic by the International Agency for Research on Cancer (IARC).[34] It has been reported that cigarette smoking caused 48% of all cancer deaths in the United States.[35] The incidence of cancer and cancer death associated with tobacco smoking has been extensively documented in a population-based Australian cohort study.[36] Tobacco smoke causes the development of cancer in different organs throughout the body like the mouth, pharynx, trachea, voice box, lungs, liver, and esophagus [Figure 1]. Carcinogens produced during tobacco smoking are associated with pancreatic, colon, uterine and bladder
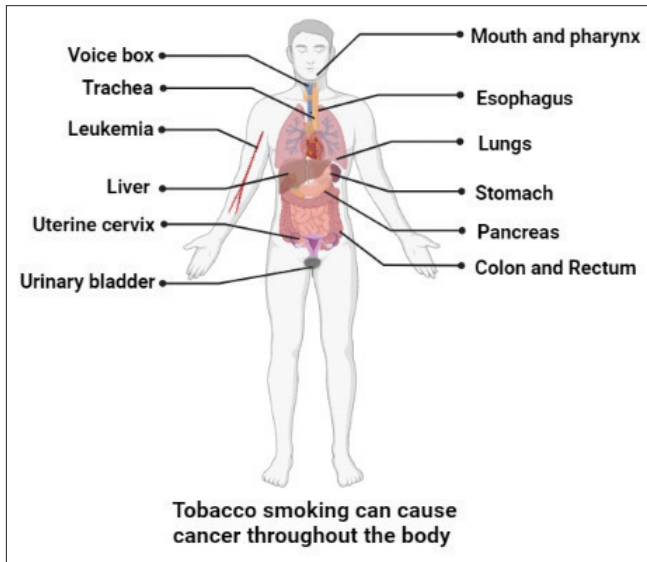
Figure 1: Tobacco smoking can cause cancer throughout the body. Tobacco smoke contains various types of carcinogens which promote the progression of cancer in multiple sites throughout the body, for example, in mouth, pharynx, voice box, trachea, lungs, liver, esophagus, stomach, pancreas, bladder and colon. (Created in Biorender.com)

cancer.[37] Tobacco use is a major factor in the development of cancer; however, obesity and lack of physical activity pose a greater threat to carcinogenesis, which we have described in the previous segment.[38]

Alcohol consumption and cancer

Researchers showed that alcohol consumption is associated with pancreatic cancer.[39] Consumption of alcohol escalates cancers such as of the liver, stomach, colorectal area, mouth, larynx, and pharynx.[19] As alcohol plays a major role in the development of cancer, population awareness regarding the risk of cancer due to alcohol consumption should be increased and alcohol restriction policy measures need to be implemented.[40]

Indoor and outdoor ambient air pollution and cancer

Indoor air pollution due to the use of coal has been associated with lung cancer.[41] Globally, it has been observed that outdoor ambient air pollution is linked to an increased incidence of lung cancer and many lung cancer–related deaths.[42] The carcinogenic potential of outdoor air pollution might be associated with black carbon exposure.[43] Polluted air contains particles as well as gases.[44] Particulate matter ($PM_{2.5}$) has been recognized as a risk factor for lung cancer by IARC.[45]

Air pollution might cause a risk of brain cancer through oxidative stress mediated by neuroinflammatory signaling pathways.[46] The IARC Working Group has reckoned outdoor air pollution and particulate matter as carcinogenic to humans.[47] Long-term exposure to low-level ambient air pollution is also related to cancer incidence in the lung.[48]

Unhealthy diet and cancer

It has been well documented that some dietary and lifestyle factors such as the consumption of red meat has been associated with the incidence of colon cancer.[49] In the Chinese population, processed meat could cause nearly 1% of CRC deaths.[50] According to a study done in the United States of America, a daily increase in the consumption of processed and unprocessed red meat was associated with a 13% rise in cancer mortality.[51] It has been presumed that taking large amounts (determined by the United Nations to be 200 g or more on a daily basis) of red meat is linked to enhanced cancer risk.[52]

Heterocyclic aromatic hydrocarbons, which are hazardous chemicals, might originate during the processing, curing, and preservation of food and red meat.[53] Healthy eating patterns have been recommended by the American Cancer Society for all ages.[54] A healthy lifestyle should be followed to prevent cancer incidence.[55]

Effective role of fish oil in cancer prevention

Omega-3 fatty acids present in fish oil show anti-inflammatory, anti-proliferative, and anti-metastatic potential.[56]

Protective potential of green tea against cancer

Polyphenol present in green tea is epigallocatechin-3-gallate (EGCG), which is a phytochemical and it plays a significant role in various cancers mediated by epigenetic mechanisms.[57] Consumption of green tea along with green leafy vegetables might hinder ovarian cancer.[58] Green tea has been studied for its cancer-fighting properties, and the results are encouraging. EGCG has been linked to cancer prevention.[59] The recent information regarding the anti-cancer effects of green tea extracts in the prevention and treatment of prostate cancer has been reviewed.[60] EGCG has been reported to sensitize cancerous cells to apoptosis caused by antineoplastic drugs, and it can guard noncancerous cells against the dangerous outcome of ultraviolet radiation exposure.[61]

Endocrine-disrupting chemicals and cancer

It has been observed that endocrine-disrupting chemicals (EDCs) has carcinogenic potential.[62] It has been reported that EDCs such as Bisphenol A,[63] Phthalate,[64] Parabens,[65] various personal care products,[66] and other EDCs[67] can act as the triggering factor of cancer.

Mental and physical stress and generation of free radicals

Stress is the altered physiological condition in the body which occurs due to intrinsic or extrinsic stressors, and these affect the homeostasis of the body.[68] The production of free radicals, such as reactive oxygen species and reactive nitrogen species (ROS/RNS) is elevated during stress. Continuous stressful conditions can induce anxiety and depression, thereby producing these free radicals and oxidative damage.[69] Mental and physical stress result in the formation of free radicals and oxidative stress in the human body, which in turn destroy the antioxidant properties of our body, leading to cancer growth. The abundance of free radicals reduces the effectiveness of antioxidant enzymes which eventually increases cancer risk. It has been observed in cancerous and precancerous tissues that elevated ROS level is linked to changes in nucleobases.[70]

The development of HCC has been induced by oxidative stress.[71] The levels of glutathione peroxidase, catalase, and superoxide dismutase, which are potential antioxidant enzymes reduced during stress, are associated with cancer.[72] Increased generation of HO• (hydroxyl radical or hydroxide ion) and other free radicals makes the cells susceptible to DNA mutation and activates oncogenes, which cause initiation and progression of cancer.[73] Several lifestyle factors such as consumption of alcohol, smoking, improper diet, and lack of sufficient exercise play important roles in the development of oxidative stress.[74]

Changes in the sleep cycle and sleep deprivation

People need adequate sleep to function properly. Melatonin, which is required for sleep, is secreted at maximum levels till midnight from the pineal gland and gradually decreases in the morning.[75] People today are becoming more and more addicted to social media and use their electronic devices excessively. It is now established that blue light emitted from electronic gadgets is one of the most important reasons for sleep deprivation.[76] Sleep deprivation influences the generation of free radicals, which induces the development of many types of cancer in the body.[77] The sleep cycle is altered as a result of people sleeping less at night and more in the morning. Melatonin also acts as an antioxidant.[78] Hence, decreased melatonin levels due to sleep deprivation can be considered a cause of cancer.[79]

The damaging effect of blue light on the eye

The human eye may be badly affected by blue light. It is noted that a portion of blue light overlaps with UV which causes skin cancer.[80] Several physiological problems arise due to smartphone light fluxes (SPLF), such as reduction of melatonin secretion, changes in circadian rhythm, and faulty eyesight as (SPLF) spectrum overlaps in UVA (320–410 nm) portion.[81] It is reported that blue light at night produced by electronic devices such as smartphones causes a detrimental effect on the body's physiological activity.[82]

It is reported that intensive blue light (400 nm to 440 nm) induces damage to the retina and is associated with the process of photo-bleaching[83,] causing absorption of photons by rhodopsin and increasing the generation of reactive oxygen species which causes oxidative damage due to the accumulation of lipofuscin pigment (the yellow-brown pigment which consists of lipids and proteins and has fluorescent properties) in the retinal pigment epithelium.[75,84] Artificial blue light at night exposure results in a disruption of circadian rhythm, which might enhance breast and prostate cancer risk.[85] Exposure to outdoor blue light that has become enhanced in recent times might pose a threat to producing CRC.[86]

Harmful effects of blue light on circadian rhythm and sleep deprivation can cause oxidative stress

The suprachiasmatic nucleus in the hypothalamus regulates the circadian rhythm and sleep. Blue light emitted by electronic gadgets affects the phase delay of the circadian rhythm as well as causes suppression of melatonin release. Human physiology and mood are largely influenced by exposure to light.[75] Excessive involvement with digital devices at bedtime results in an alteration in the quality and amount of sleep.[87] Sleep deprivation causes oxidative stress.[88] Some chronic and degenerative diseases such as cancer, arthritis, cardiovascular and neurodegenerative diseases, etc., are associated with oxidative stress.[89] Reduced melatonin level is associated with major oxidative damage to DNA.[90]

The beneficial effect of melatonin

It has been reported that melatonin has anti-carcinogenic potentiality as well as antioxidant and immunomodulatory characteristics.[91] Melatonin protects the body from oxidative stress caused by free radicals produced at the time of metabolism.[92] Free radical scavenging activity of melatonin has been documented by many researchers.[93] There are several noteworthy functions of melatonin such as ameliorating sleep quality, decreasing free radicals formation, and restitution of antioxidant enzymes.[94]

Different reviews described anti-carcinogenic potential,[95] therapeutic efficacy,[96] and protective effect of melatonin against oxidative harm to DNA.[92] Melatonin has the potential to reduce breast cancer.[97] Melatonin can alleviate oxidative stress directly through a detoxification mechanism or indirectly by preventing prooxidative enzymes and inducing the body's antioxidant enzymes.[98] Initiation, progression, and metastasis of cancer can be prevented by melatonin.[99] By

combating oxidative damage, melatonin renders protection to proteins, lipids, and DNA.[100]

Detrimental effect of melatonin suppression at night

It has been documented that disruption of the normal secretion of melatonin at night due to exposure to light is associated with cancer risk.[101] Working at night for a long time with exposure to blue light disrupts the circadian rhythm and decreases melatonin secretion and results in sleep deprivation.[102] It is reported that shifting working hours increases the risk of breast cancer in females by 40%.[103] Disruption of circadian rhythm by exposure to light at night during shifting duty and night work may act as triggers of Group 2A carcinogen according to IARC.[104]

DISCUSSION

This review focuses on spreading public awareness about modifiable lifestyle risk factors with the help of scientific literature and evidence of experimental works and aims to overview the impact of changes in these factors to prevent the incidence of cancer. Obesity, smoking, alcohol use, physical inactivity, poor eating habits, disturbed sleep, and oxidative stress are few risk factors that can raise the risk of developing cancer. People who eat diets rich in trans fat, saturated fat, and high calories are generally obese. People who do not exercise regularly may be at increased risk of cancer. Inadequate sleep is reckoned as a vital risk factor for stress, which results in the initiation of cancer. Consumption of green tea along with green leafy vegetables might hinder ovarian cancer. Catecholamines' level increases on account of the inadequacy of sleep; as a result, blood pressure and blood glucose levels increase, causing oxidative stress and injury in the wall of blood vessels. Restoration of good health requires proper sleep at night. Unhealthy lifestyle choices might influence the risk of cancer [Figure 2].

RECOMMENDATIONS TO REDUCE THE RISK OF CANCER

Stop smoking

Consuming tobacco in any form (smoking or chewing) is linked to cancer of the mouth, larynx, throat, lung, pancreas, kidney, bladder, and cervix.[105–108] Passive smoking also triggers the risk of lung cancer.[34]

Avoid alcohol consumption

According to a report by World Cancer Research Fund International (WCRF), alcohol intake raises the risk of many forms of cancers, including those of esophagus, breast, colorectum, stomach, liver, mouth, pharynx, and larynx.[19]
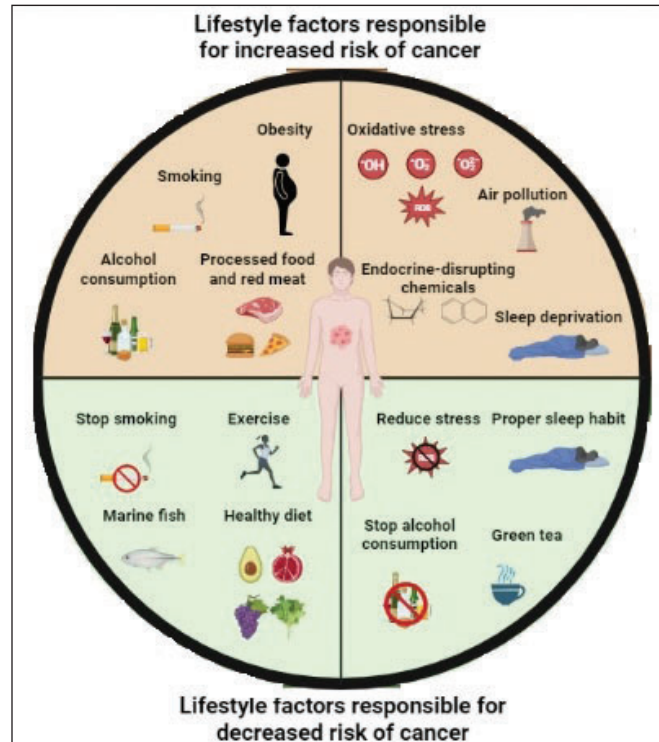
Figure 2: Cancer incidence and prevention are significantly impacted by changes in lifestyle risk factors. Among many risk factors, the most important are alcohol, processed food and red meat consumption, smoking, obesity, changes in circadian rhythm, excessive stress, air pollution and endocrine-disrupting chemicals and are responsible for different human malignancies. However, 30–40% of these cancers can be prevented by avoiding these lifestyle risk factors and maintaining a healthy lifestyle. (Created in Biorender. com)

Drinking alcohol is a significant lifestyle risk factor for cancer.[40]

Avoid red meat consumption

Avoid eating red meat to prevent colon and liver cancer development. Replacement of red meat with foods such as legumes, soy, nuts, poultry, and fish would decrease the threat of cancer and reduce levels of cholesterol.[109]

Take a healthy diet

Fruits and vegetables have a possible anti-carcinogenic effect. Eating an abundance of fruits and vegetables with dietary fiber reduces the risk of CRC and liver cancer in males.[110] Bacteria reside in the colon and produce products through the fermentation of dietary fibers, having anti-proliferative potentiality.[111] Less quantity of vegetable and fruit consumption is ascribable to the burden of diseases worldwide, and available recommendations for the intake of fruit and vegetables should be followed.[112] Follow the WCRF/American Institute for Cancer

Research (AICR) recommendation to take a diet that consists of plenty of whole grains, beans, vegetables, and fruits to prevent cancer as well as various chronic diseases.[113] The Mediterranean diet, which contains fruits, vegetables, legumes, nuts, and grains, is considered to be an effective anti-cancer diet.[114]

Consume plenty of fish

Oily fish such as herring, salmon, and mackerel contain omega-3 fatty acid, and the effective role played by omega-3 fatty acids found in various types of cancer has been extensively reviewed.[115]

Drink green tea

It contains catechins, a large group of flavonoids which are polyphenolic compounds with antioxidant characteristics. The principal type of catechin is EGCG, which has strong chemopreventive, anti-obesity, anti-cancer, and immune modulatory effects.[116] Intake of green tea might be propitious for oral, esophageal, lung, ovarian, and endometrial cancer and cardiovascular disease.[117] EGCG could control the activity and restrain the cell cycle by inducing kinase-mediating apoptosis pathways and impeding cell division, which result in cell death.[118]

Maintain a healthy body weight and avoid obesity

Eat lighter and stick to a low-fat diet because it has been discovered that proper weight management is linked to a decrease in the risk of cancer. High-calorie foods such as fat from animal sources and processed meat intake should be restricted. Sugar intake should also be restricted.[113] When the consumption of non fried food increases, it reduces the risk of cancer of the pancreas.

Engage in physical activity

It will reduce the risk of cancer of the lung, prostate, kidney, colon, and breast. One must have physical activity of at least 30 minutes in the daily schedule. Higher levels of physical activity reduce the risk of several types of cancer.[28] Leisure-time physical activity reduces the risk of bladder cancer by 13%. Physically active women had a reduction of breast cancer by 12–21% compared to those of the least active. Both in premenopausal and postmenopausal women, physical activity has been linked to similar reductions in the risk of breast cancer.[119] In postmenopausal women, weight reduction due to physical exercise led to plummeting levels of C-reactive protein and estradiol, resulting in decreased risk of endometrial and breast cancer. According to the report of World Cancer Research Fund International, physical activity could reduce the risk of endometrial, breast, and colon cancer. World Health Organization provided guidelines that described the importance of physical activity.[120] It has been established that cancers that are related to obesity could be decreased by physical activity.[121] Exercise has also been beneficial for cancer survivors and the strength of cancer patients.[122] Recommended amounts of activity, i.e., 7.5–15 metabolic equivalent task [MET] hours/week in leisure time is correlated with reduced risk of seven different types of cancers including colon, breast, endometrium, kidney, myeloma, liver, non-Hodgkin lymphoma.[123]

Avoid exposure to outdoor and indoor air pollution

Lung cancer due to short-term and long-term exposure to indoor and outdoor air pollutants has been described earlier.[124,125] So try to avoid exposure to outdoor and indoor air pollution.

Avoid endocrine-disrupting chemicals

EDCs should be avoided as these can induce cancer.[126-128]

Consider maintaining a healthy lifestyle

Perform adequate physical exercise and practice yoga for a relaxed and healthy life. Smoking, drinking a large amount of alcohol, physical inactivity, and an unhealthy diet which are regarded by researchers as lifestyle and environmental factors are associated with pancreatic cancer.[129] Approximately 12% of pancreatic cancer is estimated to be caused by obesity and 29% are linked to smoking.[130] Yoga shows promising effects in decreasing the level of pro-inflammatory cytokines and upgrading the quality of human lives.[131] Yoga is good for people because it reduces the Nuclear factor kappa-light-chain-enhancer of activated B cells (NF-κB) pathway, a transcription factor that increases the production of inflammatory genes in response to chronic stress.[132] A proper, healthy lifestyle regimen must be followed in order to reduce the cancer burden.[121]

Keep living a stress-free life

The effect of stress on the progression of cancer has been extensively reviewed. Mravec *et al.* described the importance of treatment with β-blocker and psychotherapy on the survival of cancer patients.[133] Animal studies showed the mechanisms through which cancer progression has been expedited by stressful conditions. Hence, stress management interventions could decrease repetitiveness and death in cancer.[134]

Sleep well and sufficiently

Since circadian rhythm, quantity, and quality of sleep are affected by blue light,[87] it is recommended to restrict oneself from using electronic gadgets before bedtime.[135]

Individuals should exercise daily and have a healthy lifestyle to prevent cancer

The American Cancer Society recommends physical activity of 150–300 minutes with moderate intensity or physical activity of 75–150 minutes with vigorous intensity per week in adults to reduce cancer risk.[54] Recommendations regarding lifestyle for cancer prevention have been advised.[55]

CONCLUSION

The comprehensive analysis of this review gives prominence to the effect that modifiable lifestyle risk factors exert on the incidence and prevention of cancer. As this review discusses, dietary habits, physical activity levels, tobacco use, and alcohol use are important factors in cancer prevention and mitigation. Incorporating a healthy diet while minimizing processed foods and red meat intake, coupled with regular exercise, substantially reduces the risk of cancer development. Furthermore, strategies aimed at smoking cessation and limiting alcohol consumption are imperative in mitigating cancer risk, prioritizing the critical role of behavioral modifications in preventive efforts. Equally significant is the maintenance of a healthy body weight, as obesity not only escalates cancer risk but also worsens prognosis.

Ethical approval

Institutional Review Board approval is not required.

Declaration of patient consent

Patient's consent not required as there are no patients in this study

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Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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