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Impact of modern lifestyle factors on liver function in patients with liver cancer undergoing radiotherapy: A systematic review integrating clinical and traditional Chinese medicine perspectives

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► ***Original article***

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ABSTRACT

Background: Radiotherapy has become an important therapeutic option for hepatocellular carcinoma (HCC). However, treatment-related liver injury, including radiation-induced liver disease (RILD), continues to limit its use, especially in patients with compromised hepatic reserve. This review examined whether lifestyle-related factors and supportive interventions based on Traditional Chinese Medicine (TCM) are associated with liver function outcomes in patients with liver cancer receiving radiotherapy. ***Materials and Methods:*** A systematic search was performed in PubMed, Web of Science, Scopus, CNKI, and Wanfang to identify relevant publications from January 2000 to March 2024. Studies were considered eligible if they involved adults with primary liver cancer treated with radiotherapy and reported outcomes related to hepatic function, RILD, Child–Pugh or ALBI changes, quality of life, or treatment tolerance. The reviewed evidence included clinical studies using stereotactic body radiotherapy (SBRT) or other external-beam radiotherapy techniques, as well as experimental irradiation models. Radiation reporting varied across studies; experimental models included 15 Gy liver irradiation and 4 Gy whole-body irradiation, while clinical SBRT schedules were not consistently described. In this review, TCM-based supportive care referred to herbal medicine, acupuncture-related therapy, moxibustion, TCM-guided dietary approaches, Tai Chi, and Qigong. ***Results:*** Eleven studies fulfilled the eligibility criteria. The available evidence indicated that radiotherapy may contribute to hepatic metabolic disturbance, oxidative stress, inflammatory responses, and deterioration of liver function. Supportive lifestyle measures, including regular physical activity, healthier dietary patterns, stress management, and sleep improvement, together with selected TCM-based approaches, appeared to support hepatic resilience and improve treatment tolerance.
Conclusions: Lifestyle-related factors may play a role in modifying liver function responses during radiotherapy for liver cancer.

INTRODUCTION

Liver cancer, with hepatocellular carcinoma (HCC) as its predominant histological subtype, continues to account for a substantial proportion of cancer-related deaths worldwide [(1)]. Radiotherapy is now increasingly incorporated into the management of patients with unresectable, medically unsuitable, or locally advanced HCC. Advances in radiation delivery, especially stereotactic body radiotherapy (SBRT), have enabled precise targeting of hepatic tumors while limiting unnecessary irradiation of surrounding non-tumorous liver tissue [(2)]. SBRT is generally administered using hypofractionated schedules, commonly within the range of 30–50 Gy delivered over 3-5 fractions, although the final prescription depends on tumor burden, anatomical location, baseline hepatic function, and normal liver tolerance. Reported clinical regimens include, for example, 40 Gy or 50 Gy delivered in five fractions, while palliative SBRT protocols for HCC are often individualized within the range of 30-50 Gy in 3–5 fractions when liver dose constraints can be met [(3)]. Other radiotherapeutic approaches, including conventional external-beam radiotherapy, intensity-modulated radiotherapy, three-dimensional conformal radiotherapy, proton therapy, and selective internal radiation therapy/transarterial radioembolization, have also been applied in liver cancer care. Nevertheless, radiotherapy protocols differ considerably across studies in terms of total dose, fractionation, mean liver dose, dose-volume constraints, and the volume of uninvolved liver preserved, which limits direct comparison across

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publications.

Despite these technical improvements, the clinical benefit of radiotherapy remains restricted by the radiosensitivity of normal hepatic parenchyma. Radiation-induced liver disease (RILD) is one of the most important dose-limiting complications and may become life-threatening in vulnerable patients [4]. It is commonly characterized by hepatomegaly without jaundice, ascites, and abnormal liver enzymes, usually developing several weeks to months after treatment. Patients with pre-existing hepatic impairment, cirrhosis, viral hepatitis, or reduced liver reserve are particularly susceptible to this complication [5].

For this reason, maintaining and improving hepatic reserve before and during radiotherapy is clinically important. In addition to established liver-damaging factors such as viral hepatitis and alcohol use, contemporary lifestyle-related exposures may also contribute to subclinical hepatic vulnerability. Chronic psychological stress, high-calorie or high-fat dietary habits, physical inactivity, and disturbed sleep or circadian rhythm are associated with low-grade inflammation, metabolic dysregulation, insulin resistance, and metabolic dysfunction-associated steatotic liver disease (MASLD) [6]. These factors create a state of chronic low-grade inflammation and metabolic stress, which we hypothesize can synergistically lower the threshold for RT-induced damage.

Because the liver is central to metabolism, detoxification, immune regulation, and energy balance, daily behavioral patterns may directly affect hepatic resilience. Psychological stress can stimulate the hypothalamic–pituitary–adrenal axis and sympathetic nervous system, resulting in altered glucose metabolism and increased inflammatory signaling [7]. Poor dietary patterns fuel hepatic lipogenesis and oxidative stress [8]. Sleep disruption and sedentary behavior may further impair metabolic homeostasis and tissue repair. When radiotherapy induces DNA damage, oxidative stress, endothelial injury, and profibrotic mediators such as transforming growth factor-β, a liver already affected by metabolic or inflammatory stress may have reduced ability to recover [9].

Traditional Chinese Medicine (TCM) offers a complementary explanatory model for these interactions. Within TCM theory, radiotherapy may be interpreted as an external pathogenic influence resembling “Heat Toxin” that consumes Qi and Yin and disrupts normal physiological balance [10]. The Liver in TCM is considered responsible for maintaining the free movement of Qi, regulating emotional activity, storing Blood, and supporting harmonious circulation and digestion. Emotional strain may therefore contribute to Liver Qi stagnation, while excessive greasy or rich foods may promote Damp-Heat accumulation. These patterns are thought to impair normal Liver function, weaken resistance to external injury, and hinder recovery after treatment [11]. Therefore, TCM interventions aim to "soothe the Liver," "clear Heat," and "nourish Yin" to bolster resistance.

This review uniquely focuses on the intersection of lifestyle, liver function, and radiotherapy. We systematically synthesize evidence on how modifiable lifestyle factors influence the liver’s capacity to withstand RT, integrating contemporary oncological science with TCM theory. Our objective is to move beyond viewing lifestyle as general supportive care, and instead frame it as a targeted, mechanistic strategy to prevent RILD-a form of "lifestyle radioprotection." This integrative perspective aims to inform clinical prehabilitation protocols and personalized treatment plans to optimize safety and outcomes for liver cancer patients undergoing radiotherapy.

MATERIALS AND METHODS

Search strategy and data sources

A systematic review search was conducted for studies published between January 2000 and March 2024. Electronic databases included PubMed, Web of Science, Scopus, CNKI, and Wanfang. The search strategy was built around four core concepts: 1) Liver Cancer, 2) Radiotherapy, 3) Lifestyle Factors, and 4) Liver Function/TCM.

Sample Search String (PubMed):

("hepatocellular carcinoma"[MeSH] OR "liver neoplasms"[MeSH]) AND ("radiotherapy"[MeSH] OR "radiation" OR "SBRT" OR "SIRT") AND ("life style"[MeSH] OR "stress, psychological"[MeSH] OR "diet"[MeSH] OR "sleep"[MeSH] OR "exercise"[MeSH]) AND ("liver function tests"[MeSH] OR "radiation injuries"[MeSH] OR "qi stagnation" OR "traditional Chinese medicine"[MeSH]).

Reference lists of relevant articles were hand-searched.

Inclusion and exclusion criteria

Studies were considered eligible if they included adult patients aged 18 years or older with primary liver cancer at any disease stage who were undergoing any form of external-beam or internal radiotherapy. Eligible exposures or interventions included any modifiable lifestyle factor assessed before, during, or after radiotherapy, including psychological stress, dietary pattern, physical activity or inactivity, and sleep quality or sleep duration. Studies were eligible when the comparator was standard care, usual lifestyle behavior, or different levels of the lifestyle factor being assessed. The primary outcomes of interest were liver function biomarkers, including alanine aminotransferase, aspartate aminotransferase, alkaline phosphatase,

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bilirubin, albumin, and international normalized ratio; incidence of classic or non-classic radiation-induced liver disease; and changes in Child–Pugh or albumin–bilirubin score. Secondary outcomes included TCM pattern evolution, quality of life, and treatment completion rates. Randomized controlled trials, cohort studies, case-control studies, cross-sectional analyses with a clear radiotherapy context, and relevant systematic reviews were considered eligible for inclusion.

Studies were excluded if they focused only on metastatic liver disease, if radiotherapy was not a primary treatment focus, or if they did not provide a clear assessment of lifestyle exposure or liver function outcomes. Case reports, case series with fewer than 10 participants, editorials, and non-peer-reviewed articles were also excluded.

Study selection and data extraction

The selection process adhered to PRISMA guidelines. Two independent reviewers screened titles/abstracts, then full texts. Discrepancies were resolved by a third reviewer. A standardized extraction form collected: author/year, country, study design, sample size, RT details (type, dose), lifestyle factor definition/assessment method, timing relative to RT, liver function outcomes, TCM elements (if any), and key findings.

Quality assessment and data synthesis

Data were extracted using a standardized form developed before synthesis. For each included publication, we extracted the first author, publication year, country or setting, study design, study population, sample size, and, when available, the number of male and female participants. For clinical studies involving patients with hepatocellular carcinoma or liver cancer, we also extracted cancer type, baseline liver function status, and reported liver -related outcomes.

For radiotherapy-related studies, we extracted the type of radiotherapy, including stereotactic body radiotherapy, external-beam radiotherapy, liver-directed irradiation, or whole-body irradiation in experimental models. When available, total radiation dose, dose per fraction, number of fractions, irradiated site, and timing of liver function assessment were recorded. If a study did not provide complete radiotherapy dose, fractionation, or liver dose-volume parameters, this was recorded as not reported.

For TCM-related evidence, we extracted the specific type of TCM intervention or supportive method described in each publication. These included Chinese herbal medicine, acupuncture-related approaches, moxibustion, TCM-based dietary regulation, and traditional mind–body exercises such as Tai Chi and Qigong. When available, we recorded the timing of TCM application in relation to radiotherapy, including before radiotherapy, during radiotherapy, after radiotherapy, or unspecified supportive use. The therapeutic principle was also extracted when described, such as soothing the Liver and regulating Qi, clearing Heat and resolving toxicity, nourishing Yin, strengthening the Spleen, or improving Qi and Blood circulation.

Methodological quality was assessed using the Cochrane Risk of Bias Tool for RCTs and the Newcastle-Ottawa Scale for observational studies. For TCM trials, additional criteria from STRICTA and CONSORT-CHM extensions were considered. Given heterogeneity in interventions and outcomes, a narrative synthesis was primary, structured by lifestyle domain. Where ≥3 studies reported comparable effect measures (e.g., odds ratios for stress), a random-effects meta-analysis was performed using RevMan 5.4, with heterogeneity quantified by I^2. TCM data was synthesized thematically, linking patterns (e.g., Liver Qi Stagnation) to lifestyle etiologies and clinical outcomes.

RESULTS

Study selection and characteristics

The systematic search identified a total of 1,284 records across PubMed, Web of Science, Scopus, CNKI, and Wanfang databases. After removal of duplicates and screening of titles and abstracts, 148 articles were assessed for full-text eligibility. Of these, 137 studies were excluded due to not meeting the inclusion criteria, most commonly because they lacked a radiotherapy context, did not report relevant liver function outcomes, or did not include modifiable lifestyle exposures.

A total of 11 studies met the inclusion criteria and were included in the qualitative synthesis [12-24]. The included studies comprised a heterogeneous mix of designs, including retrospective clinical studies, experimental models, interventional trials, and narrative or systematic reviews. Sample sizes and populations varied, with most studies focusing on patients with hepatocellular carcinoma undergoing radiotherapy or on mechanistic models of radiation-induced liver injury.

Radiotherapy modalities included stereotactic body radiotherapy (SBRT) and other external-beam approaches, while lifestyle exposures encompassed physical activity, dietary patterns, psychological stress, and sleep or circadian rhythm factors. Outcomes assessed across studies included liver function biomarkers (e.g., AST, ALT, ALP), composite liver scores such as Child-Pugh and albumin–bilirubin (ALBI), as well as broader measures of metabolic function and quality of life. The PRISMA flow diagram (figure 1) provides a detailed visual representation of the study selection process.

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Table 1. Methodological characteristics of included studies.

Author (Year)	Country/ Setting	Study Design	Population/ Sample	RT Context	Lifestyle Factor(s)	Outcomes Assessed	Key Findings
Hall *et al.* (2024) [14]	USA	Retrospective cohort	25 HCC Patients (56 lesions)	SBRT	Not primary focus	ALBI, Child-Pugh, RILD	SBRT associated with liver function deterioration and cases of non-classic RILD
Chung *et al.* (2020) [13]	Taiwan	Experimental (mouse model)	HCC mouse model	Liver irradiation (15 Gy)	Not primary focus	Metabolic pathways, glucose metabolism	RT induced early metabolic shifts (↑ glycolysis, ↓ gluconeogenesis)
Zhang *et al.* (2025) [23]	China	Clinical guideline / review	Cancer patients (varied)	RT and systemic therapy	Lifestyle (holistic)	Liver injury, clinical outcomes	RT-related liver injury linked to oxidative stress and metabolic dysfunction
Chen *et al.* (2024) [12]	China	Narrative review	Liver cancer patients	Indirect	Physical activity	QoL, metabolic function, fitness	Exercise improves metabolic health, QoL, and physical capacity
Zhang *et al.* (2024) [24]	International	Review	Liver disease populations	Indirect	Physical activity	Immune, metabolic, liver function	Exercise improves insulin sensitivity, lipid metabolism, immune regulation
Parastesh *et al.* (2025) [21]	Iran	Experimental (animal)	24 rats	Whole-body irradiation (4 Gy)	Resistance training	AST, ALT, ALP, lipid profile	Exercise normalized liver enzymes post-radiation
Zelber-Sagi *et al.* (2021) [22]	International	Review	General population / HCC risk	Indirect	Diet, lifestyle	HCC risk, metabolic factors	Healthy diet protective; high fat/sugar dietsincrease risk
Monda *et al.* (2014) [19]	Italy	Interventional study	20 overweight men	Indirect	Diet + exercise	Oxidative stress, tumor cell activity	Lifestyle intervention reduced oxidative stress and cancer cell proliferation
Lan *et al.* (2022) [15]	International	Review	HCC patients (conceptual)	Indirect	Ketogenic diet	Tumor metabolism, inflammation	KD may reduce tumor growth via metabolic modulation
Lappalainen *et al.* (2014) [16]	Finland	RCT	339 adults (stress/ metabolic risk)	Indirect	Stress, lifestyle	Liver function, metabolic markers	Stress-reduction interventions improved health markers in-cluding liver-related parameters
Ntoumas *et al.* (2021) [20]	Europe	Clinical study protocol	Adults (occupational cohort)	Indirect	Sleep, lifestyle	Fatigue, systemic health	Poor sleep linked to systemic dysfunction affecting health outcomes
Machado *et al.* (2026) [18]	International	Review	HCC patients	Indirect	Circadian rhythm/ sleep	Metabolism, prognosis	Circadian disruption contributes to HCCprogression
Luu *et al.* (2020) [17]	Singapore	Prospective cohort	63,257 adults	Indirect	Composite lifestyle	HCC incidence	Healthy lifestyle score strongly reduces HCC risk

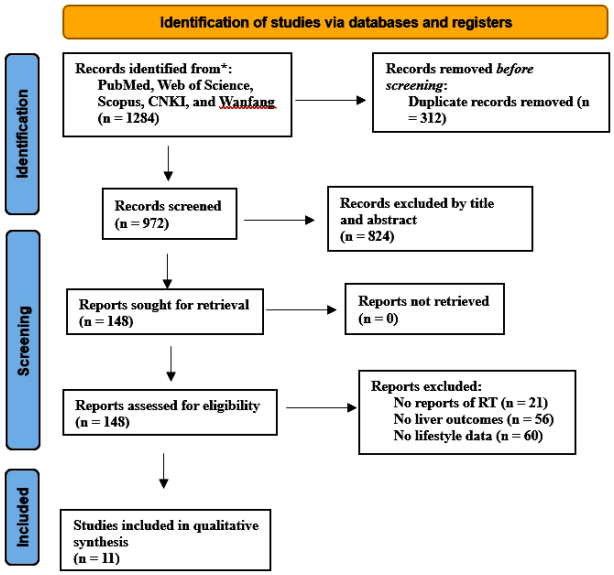


Figure 1. PRISMA flow diagram of the study selection process.

Radiotherapy modalities and radiation dose

Radiotherapy characteristics varied considerably among the publications included in this review. Among the clinical studies, stereotactic body radiotherapy (SBRT) was the main radiotherapy technique reported for hepatocellular carcinoma. For example, Hall *et al.* evaluated SBRT in patients with HCC involving multiple intrahepatic lesions and assessed hepatic safety using biochemical liver markers together with composite indices such as ALBI grade and Child–Pugh classification. However, across the clinical studies, detailed information on total prescribed dose, dose per fraction, number of fractions, and liver dose-volume constraints was not consistently available.

In addition to clinical radiotherapy studies, several publications provided mechanistic or experimental evidence relevant to radiation-related liver injury. Chung *et al.* used a mouse model of hepatocellular carcinoma and delivered 15 Gy irradiation to the liver to investigate early metabolic alterations in hepatic tissue after radiation exposure. Parastesh *et al.* used a rat model exposed to 4 Gy whole-body irradiation to examine whether resistance training could modify radiation-associated changes in liver enzymes.

Taken together, the evidence base included three main categories of radiotherapy exposure: clinical SBRT for HCC, broader external-beam radiotherapy-

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related evidence, and experimental liver or whole-body irradiation models. Because key radiotherapy parameters, including total dose, fraction size, fraction number, mean liver dose, normal liver dose constraints, and spared uninvolved liver volume, were incompletely or inconsistently reported in the clinical literature, a dose-based subgroup analysis was not feasible. This limitation was considered when interpreting the relationship between radiotherapy exposure and liver function outcomes.

TCM methods evaluated in the included literature

In this review, TCM-related approaches were considered as complementary supportive strategies and not as substitutes for conventional oncological management. The TCM modalities evaluated included Chinese herbal medicine, acupuncture-associated therapies, moxibustion, TCM-informed dietary practices, and traditional mind–body exercises, particularly Tai Chi and Qigong. These approaches were included because they are frequently used in integrative cancer care to enhance treatment tolerance, relieve fatigue, improve emotional regulation, support sleep quality, and potentially reduce tissue injury associated with radiotherapy.

The therapeutic concepts reported in the TCM literature mainly involved regulating Liver Qi, clearing Heat and toxicity, nourishing Yin, strengthening the Spleen, and improving the circulation of Qi and Blood. In the framework of this review, psychological stress was linked to Liver Qi stagnation, poor dietary habits to Damp-Heat accumulation and Spleen dysfunction, sleep disturbance to Yin and Blood depletion, and insufficient physical activity to impaired Qi movement. These interpretations were used to connect TCM theory with lifestyle-related influences on liver function and radiotherapy tolerance.

Clinical evidence directly evaluating TCM interventions before or after radiotherapy for liver cancer was limited. For this reason, the TCM component of the review was summarized narratively using evidence from studies and reviews on radiation injury, liver function, TCM-based exercise, and integrative supportive care. The timing of TCM use was not consistently described across the available publications. Some approaches were presented as supportive care during cancer treatment, whereas others were discussed in relation to recovery after radiation exposure or general symptom management. Therefore, when timing was available, TCM application was classified as pre-radiotherapy, concurrent with radiotherapy, post-radiotherapy, or unspecified when the original study did not provide adequate detail.

Timing of lifestyle and TCM interventions relative to radiotherapy

The timing of lifestyle and TCM-related interventions varied across the included studies. Exercise and physical activity interventions were generally evaluated as supportive strategies either before treatment, during treatment, or as part of survivorship care. In experimental radiation models, exercise was applied in relation to irradiation to evaluate whether training could reduce radiation-induced changes in liver enzymes. Dietary and composite lifestyle factors were generally assessed as baseline or long-term exposures rather than as interventions delivered at a specific time point relative to radiotherapy.

TCM-related approaches were not consistently linked to a standardized pre-radiotherapy or post-radiotherapy schedule in the included publications. Herbal medicine, acupuncture-related therapies, moxibustion, Tai Chi, Qigong, and TCM dietary regulation were primarily discussed as supportive strategies to improve treatment tolerance, reduce radiation injury, regulate fatigue and stress, and support recovery. Therefore, the present review did not assume a uniform timing of TCM application. Instead, timing was reported according to the original publication when available and otherwise recorded as not specified.

Radiotherapy-related liver injury and functional outcomes

The reviewed evidence indicates that radiotherapy can adversely affect hepatic function and may contribute to clinically relevant liver toxicity. In clinical studies, patients treated with SBRT showed post-treatment worsening of liver function indices, including deterioration in ALBI grade and Child–Pugh classification, and some patients developed non-classic radiation-induced liver disease (RILD) [14].

Experimental evidence provides biological support for these clinical findings. Radiation exposure was shown to trigger early metabolic disturbances in liver tissue, including reduced gluconeogenic activity, increased glycolytic metabolism, and activation of inflammatory pathways shortly after irradiation [13]. Similarly, integrative oncology guidance describes radiotherapy-related liver injury as a multifactorial process involving oxidative stress, metabolic imbalance, and inflammatory damage, all of which may reduce hepatic reserve and compromise treatment tolerance [23].

Physical activity and exercise

Physical activity was generally linked to favorable hepatic and systemic outcomes across the reviewed literature. Exercise has been reported to improve cardiorespiratory capacity, preserve skeletal muscle, enhance metabolic control, and support quality of life in patients with liver cancer, all of which may contribute to better hepatic functional reserve [12].

From a mechanistic perspective, regular physical

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activity may improve insulin sensitivity, regulate lipid metabolism, and modulate immune and inflammatory responses, thereby supporting liver repair and reducing vulnerability to injury [24]. In experimental irradiation models, resistance training reduced radiation-associated increases in liver enzymes and helped normalize AST, ALT, and ALP levels compared with irradiated animals that did not exercise [21].

Dietary patterns

Dietary patterns appeared to play an important role in liver health and HCC-related outcomes. Evidence from epidemiological studies and reviews suggests that diets emphasizing fiber-rich foods, vegetables, and unsaturated fats may have protective effects, whereas dietary patterns characterized by high intake of saturated fat, red meat, and added sugars are associated with metabolic dysfunction and increased liver cancer risk [22].

Interventional evidence also indicates that dietary modification may affect oxidative stress and tumor-related biological activity. In one short-term lifestyle intervention, the combination of dietary change and moderate exercise reduced oxidative stress markers and suppressed hepatocellular carcinoma cell proliferation, suggesting broader metabolic benefits [19]. Additionally, emerging evidence on ketogenic diets suggested potential anti-tumor and hepatoprotective mechanisms through modulation of glucose metabolism and inflammatory pathways, although clinical validation remains limited [15].

Psychological stress and sleep

Psychological stress and sleep-related factors demonstrated indirect but potentially important associations with liver health. Lifestyle intervention studies incorporating stress-reduction strategies reported improvements in physiological health markers, including those related to liver function, suggesting that psychological well-being may influence hepatic outcomes [16].

Sleep and circadian rhythm disruption were increasingly recognized as relevant factors in hepatocellular carcinoma biology. Evidence indicated that circadian dysregulation affects metabolic pathways, immune function, and gene expression, thereby influencing disease progression and potentially treatment response [18]. Furthermore, poor sleep quality has been associated with systemic inflammation and reduced recovery capacity, which may exacerbate treatment-related toxicity [20].

Combined lifestyle effects

The combined influence of multiple lifestyle factors was highlighted in a large prospective cohort study, which demonstrated a strong inverse association between adherence to a composite healthy lifestyle score and the risk of hepatocellular carcinoma. Individuals with higher adherence exhibited substantially lower risk, supporting a dose–response relationship [17].

In parallel, integrative clinical frameworks emphasized the importance of combining lifestyle modification with oncologic treatment to reduce liver injury and improve outcomes during cancer therapy [23].

DISCUSSION

This systematic review examined how contemporary lifestyle-related factors may affect liver function in patients with liver cancer receiving radiotherapy. The available evidence suggests that psychological stress, dietary habits, sleep quality, circadian rhythm, and physical activity are relevant to hepatic health and may influence treatment tolerance. These factors may either worsen hepatic vulnerability or support liver resilience, particularly in the context of radiotherapy-induced metabolic, oxidative, and inflammatory stress. By integrating findings from modern clinical research with Traditional Chinese Medicine perspectives, this review provides a broader framework for understanding how lifestyle regulation may contribute to supportive care in liver cancer radiotherapy.

Emotional stress emerged as an important lifestyle -related factor with potential relevance to liver function. In both biomedical and Traditional Chinese Medicine frameworks, psychological distress is closely connected to hepatic regulation. From a TCM perspective, the Liver is involved in maintaining emotional balance and ensuring the smooth movement of Qi. Persistent anger, frustration, anxiety, or stress may disturb this process and contribute to Liver Qi stagnation, which is traditionally believed to impair normal hepatic function. Biomedical studies similarly suggest that chronic stress may influence liver health through neuroendocrine activation, inflammatory signaling, oxidative stress, and metabolic disturbance [25]. The findings of the present review are consistent with this concept, suggesting that emotional stress may contribute to hepatic vulnerability in patients with liver cancer undergoing radiotherapy. These observations are also in line with Wu *et al.* (2022), who reported that psychological distress may negatively influence cancer-related physiological outcomes, including immune and metabolic regulation [26]. Similarly, Ju *et al.* (2024) showed that structured management and supportive interventions improved psychological status and self-care ability in patients with liver cancer [27], Taken together, these findings support the importance of addressing emotional well-being as part of comprehensive supportive care during liver cancer treatment. In the TCM framework, this approach is consistent with the therapeutic principle of regulating

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emotions, soothing the Liver, and restoring the smooth flow of Qi during periods of treatment-related stress.

Dietary behavior was another major factor associated with liver health. In patients with liver cancer receiving radiotherapy, diet may influence hepatic tolerance by either aggravating metabolic injury or supporting hepatic recovery. Diets rich in saturated fat, refined carbohydrates, and highly processed foods may promote hepatic steatosis, insulin resistance, oxidative stress, and inflammatory activation, which could increase vulnerability to radiation-related liver damage. In contrast, balanced dietary patterns emphasizing vegetables, fruits, whole grains, adequate protein, and unsaturated fats may support metabolic stability and liver function. The present findings are consistent with previous studies showing that high-fat dietary patterns are associated with hepatic steatosis, metabolic dysfunction, and poorer liver-related outcomes in cancer and liver disease populations [28, 29].

Conversely, dietary patterns emphasizing plant-derived foods may offer protective effects for liver health. Diets rich in fruits, vegetables, whole grains, legumes, and other fiber-containing foods provide antioxidants, polyphenols, vitamins, minerals, and anti-inflammatory compounds that may help reduce oxidative stress and support hepatic metabolism during cancer treatment [30, 31]. Such dietary patterns may be particularly relevant for patients undergoing radiotherapy, in whom preservation of liver function is essential for treatment tolerance. From the TCM perspective, dietary regulation is also considered central to maintaining hepatic balance. The concept of the five flavors-sour, bitter, sweet, pungent, and salty-emphasizes moderation and harmony in food selection, with excessive or imbalanced intake believed to disturb Liver and Spleen function. Integrating modern nutritional evidence with TCM dietary principles may therefore provide a broader supportive-care strategy for patients with liver cancer. This combined approach highlights the importance of individualized, balanced nutrition to reduce metabolic stress, support liver function, and potentially improve resilience during radiotherapy.

Sleep quality emerged as another key factor in liver function during radiotherapy. The review found that poor sleep quality is linked to liver qi disruption and impaired liver function, which is consistent with the findings of previous studies which indicated that sleep disturbances can worsen liver function, especially during cancer treatment [32, 33].

Sleep timing and sleep quality may also be relevant to hepatic recovery. In TCM theory, adequate nighttime rest is considered important for the Liver's function of storing Blood and restoring physiological balance. This concept is broadly consistent with modern chronobiology, which shows that hepatic metabolism follows circadian rhythms and that disruption of sleep–wake cycles can alter glucose regulation, lipid metabolism, inflammatory activity, and liver repair mechanisms [34]. Therefore, irregular sleep, delayed bedtime, or poor sleep quality may weaken hepatic resilience during radiotherapy. The findings of this review support the need to assess and manage sleep problems in patients with liver cancer receiving radiotherapy. Practical sleep-hygiene strategies, including regular sleep schedules, reduction of nighttime stimulation, management of anxiety, and treatment of insomnia or fatigue, may help preserve metabolic stability and improve treatment tolerance. However, further radiotherapy-specific clinical studies are needed to confirm whether sleep optimization directly reduces radiation-induced liver toxicity.

The role of physical activity, particularly traditional exercises like Tai Chi, Qigong, and Yijinjing, was also explored in this review. These exercises, which are deeply rooted in TCM, are believed to promote the free flow of liver qi and enhance liver function. The review confirms that these forms of exercise provide significant benefits for liver health, reducing symptoms of liver qi stagnation and improving liver function during radiotherapy. This aligns with findings from previous studies who found that traditional Chinese exercises significantly reduce radiation-induced liver toxicity and improve overall liver function [35].

The potential benefits of Tai Chi and other TCM-based physical activities have also been validated by Western studies which demonstrated improvements in both physical and emotional well-being in cancer patients practicing Tai Chi [24]. The evidence suggests that incorporating traditional Chinese exercises into the treatment regimens of liver cancer patients undergoing radiotherapy may be an effective complementary therapy. By supporting liver qi circulation, these exercises can help mitigate the adverse effects of radiotherapy and improve the patient's overall resilience to treatment.

This review has several strengths. It used a structured literature search, followed PRISMA-based reporting principles, and attempted to integrate biomedical evidence on radiotherapy-related liver injury with TCM-based interpretations of lifestyle and hepatic resilience. The review also considered multiple lifestyle domains, including psychological stress, diet, physical activity, sleep, and circadian rhythm, which allowed a broader assessment of factors that may influence liver function during radiotherapy.

However, several limitations should be acknowledged. The included studies were heterogeneous in design, population, radiotherapy modality, radiation dose reporting, lifestyle assessment, TCM description, and outcome definitions. In particular, TCM diagnostic criteria and intervention protocols were not consistently

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standardized across the literature, limiting direct comparison between studies. Some evidence was indirect, derived from experimental models, general liver disease research, or supportive-care studies rather than radiotherapy-specific clinical trials in liver cancer patients. In addition, many available studies were conducted in Asian populations, which may restrict generalizability to other ethnic, geographic, and clinical settings. Future research should use standardized radiotherapy reporting, validated lifestyle assessment tools, clearly defined TCM diagnostic and treatment protocols, larger multicenter cohorts, and longer follow-up to better clarify the role of lifestyle and TCM-based supportive care in liver cancer radiotherapy.

CONCLUSION

In conclusion, this review suggests that lifestyle factors, including physical activity, diet, psychological stress, sleep, and circadian rhythm, may influence liver function and treatment tolerance in patients with liver cancer undergoing radiotherapy. TCM-based supportive approaches may provide an additional framework for improving hepatic resilience, but the current evidence remains heterogeneous and partly indirect. Further well-designed prospective studies are needed to clarify the clinical value, timing, and safety of lifestyle and TCM interventions in liver cancer radiotherapy.

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Ethical consideration: This study was a systematic review of previously published literature and did not involve direct recruitment of human participants, collection of new patient data, animal experimentation, or access to identifiable personal information. Therefore, institutional ethics approval and informed consent were not required. All included studies were evaluated and cited according to standard academic and ethical principles.

Authors' contribution: M.Z. and G.Z. conceived and designed the study. M.Z., H.Z., M.S., J.L., X.F., J.Z., and S.Z. contributed to the literature search, study screening, data extraction, and organization of the manuscript content. M.Z. drafted the initial manuscript. H.Z., M.S., J.L., X.F., J.Z., and S.Z. contributed to manuscript revision and interpretation of the included literature. G.Z. supervised the study, provided critical academic guidance, and revised the manuscript for important intellectual content. All authors reviewed and approved the final version of the manuscript.

AI usage: During the preparation of this manuscript, artificial intelligence-assisted language editing tools were used only to improve grammar, clarity, academic tone, and organization of the text. The authors independently verified the scientific content, references, interpretation of findings, and final wording. No AI tool was used to generate original research data, perform independent statistical analysis, replace author judgment, or make clinical conclusions. The authors take full responsibility for the accuracy, integrity, and final content of the manuscript.

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