**Name of Journal:** *World Journal of Gastrointestinal Oncology*

**Manuscript NO:** 88815

**Manuscript Type:** ORIGINAL ARTICLE

***Retrospective Cohort Study***

**Chinese herbal medicine decreases incidence of hepatocellular carcinoma in diabetes mellitus patients with regular insulin management**

Lai HC *et al*. Chinese herbal medicine reduced HCC risk

Hsiang-Chun Lai, Ju-Chien Cheng, Hei-Tung Yip, Long-Bin Jeng, Sheng-Teng Huang

**Hsiang-Chun Lai,** Graduate Institute of Chinese Medicine, School of Chinese Medicine, College of Chinese Medicine, China Medical University, Taichung 404328, Taiwan

**Ju-Chien Cheng,** Department of Medical Laboratory Science and Biotechnology, China Medical University, Taichung 404, Taiwan

**Hei-Tung Yip,** Management Office for Health Data, China Medical University Hospital, Taichung 404327, Taiwan

**Long-Bin Jeng,** Organ Transplantation Center, China Medical University Hospital, Taichung 40447, Taiwan

**Sheng-Teng Huang,** Department of Chinese Medicine, China Medical University Hospital; School of Chinese Medicine, China Medical University, Taichung 40447, Taiwan

**Author contributions:** Lai HC contributed to conceptualization, methodology, writing - original draft; Cheng JC contributed to resources, investigation, validation, editing; Yip HT contributed to software, formal analysis, visualization; Jeng LB contributed to resources, supervision, editing; Huang ST contributed to methodology, writing-reviewing and editing, project administration, funding acquisition.

**Supported by** the National Science and Technology Council of Taiwan, No. NSC112-2320-B-039-045-; China Medical University Hospital, No. DMR-111-013, No. DMR-111-195, No. DMR-112-004 and No. DMR-112-177; and Department of Chinese Medicine and Pharmacy and Ministry of Health and Welfare, No. MOHW-112-CMC-03.

**Corresponding author: Sheng-Teng Huang, MD, PhD, Doctor, Professor,** Department of Chinese Medicine, China Medical University Hospital; School of Chinese Medicine, China Medical University, No. 2 Yude Road, North District, Taichung 40447, Taiwan. sheng.teng@yahoo.com

**Received:** October 10, 2023

**Revised:** December 31, 2023

**Accepted:** February 1, 2024

**Published online:**

**Abstract**

BACKGROUND

Type 2 diabetes mellitus (DM) is an independent risk factor for hepatocellular carcinoma (HCC), while insulin is a potent mitogen. Identifying a new therapeutic modality for preventing insulin users from developing HCC is a critical goal for researchers.

AIM

To investigate whether regular herbal medicine use can decrease HCC risk in DM patients with regular insulin control.

METHODS

We used data acquired from the Taiwanese National Health Insurance research database between 2000 and 2017. We identified patients with DM who were prescribed insulin for > 3 months. The herb user group was further defined as patients prescribed herbal medication for DM for > 3 months per annum during follow-up. We matched the herb users to nonusers at a 1:3 ratio according to age, sex, comorbidities and index year by propensity score matching. We analyzed HCC incidence, HCC survival rates, and the herbal prescriptions involved.

RESULTS

We initially enrolled 657144 DM patients with regular insulin use from 2000 to 2017. Among these, 46849 patients had used a herbal treatment for DM, and 140547 patients were included as the matched control group. The baseline variables were similar between the herb users and nonusers. DM patients with regular herb use had a 12% decreased risk of HCC compared with the control group [adjusted hazard ratio (aHR) = 0.88, 95%CI = 0.80–0.97]. The cumulative incidence of HCC in the herb users was significantly lower than that of the nonusers. Patients with a herb use of > 5 years cumulatively exhibited a protective effect against development of HCC (aHR = 0.82, *P* < 0.05). Of patients who developed HCC, herb users exhibited a longer survival time than nonusers (aHR = 0.78, *P* = 0.0001). Additionally, we report the top 10 herbs and formulas in prescriptions and summarize the potential pharmacological effects of the constituents. Our analysis indicated that *Astragalus propinquus* (Huang Qi) plus *Salvia miltiorrhiza Bunge* (Dan Shen), and *Astragalus propinquus* (Huang Qi) plus *Trichosanthes kirilowii* Maxim. (Tian Hua Fen) were the most frequent combination of single herbs. Meanwhile, Ji Sheng Shen Qi Wan plus Dan Shen was the most frequent combination of herbs and formulas.

CONCLUSION

This large-scale retrospective cohort study reveals that herbal medicine may decrease HCC risk by 12% in DM patients with regular insulin use.

**Key Words:** Hepatocellular carcinoma; Diabetes mellitus; Insulin; Herb; Taiwanese National health insurance research database

Lai HC, Cheng JC, Yip HT, Jeng LB, Huang ST. Chinese herbal medicine decreases incidence of hepatocellular carcinoma in diabetes mellitus patients with regular insulin management. *World J Gastrointest Oncol* 2024; In press

**Core Tip:** Type 2 diabetes mellitus (DM) is an independent risk factor for hepatocellular carcinoma (HCC), while insulin is a potent mitogen. In this propensity-score-matched population-based cohort study, we investigated whether regular herbal medicine use can decrease HCC risk in DM patients with regular insulin control. DM patients with regular herb use had a 12% decreased risk of HCC compared to the control group. The cohort with herb use of > 5 years cumulatively exhibited a protective effect against development of HCC. Moreover, among patients who developed HCC, herb users exhibited a longer survival time than non-users (adjusted hazard ratio = 0.78).

**INTRODUCTION**

Hepatocellular carcinoma (HCC) is the fifth most common cancer, and the third-leading cause of cancer-related deaths worldwide[1]. Regional incidence rates of liver cancer are the highest in East Asia [14.8 per 100000 person-years (PY)], more than double the worldwide incidence rate (7.3 per 100000 PY)[2]. This is followed by North Africa (13.2 per 100000 PY) and Southeast Asia (9.5 per 100000 PY)[2]. Treatment strategies for HCC include surgery (resection or liver transplantation), ablation, intra-arterial therapy, radiotherapy, and systemic therapy (such as tyrosine kinase inhibitor). Meanwhile, the Barcelona Clinic of Liver Cancer provides the most commonly applied staging system and guidelines regarding treatment options[3]. Major risk factors for HCC include male sex, chronic hepatitis B virus (HBV), chronic hepatitis C virus (HCV), cirrhosis, alcohol abuse, tobacco use, nonalcoholic fatty liver disease (NAFLD), diabetes mellitus (DM), obesity, and exposure to toxins such as aflatoxins and carbon tetrachloride[4]. In East Asia, chronic HBV infection is the primary risk factor for HCC; however, incidence rates of HBV infection have been decreasing following a universal vaccination policy. HCV infection is a more influential factor in Western Europe and America, where people with HCV have a 15–20-fold increased risk of developing HCC[5]. In terms of treatment, direct-acting antiviral agents have been reported to achieve a higher rate of sustained virological response (SVR) with fewer side effects compared to interferon regimens. More specifically, after treatment with direct-acting antiviral agents, HCV patients with SVR had a 78% decreased risk of HCC occurrence compared with nonresponders[6]. Henceforth, due to the declining role of viral infections, metabolic etiologies have increasingly become the focus of investigations into HCC occurrence.

Type 2 DM (T2DM) is an independent risk factor for both NAFLD and HCC[7]. It is reported that patients with T2DM have a 2.5–4-fold increased risk of developing HCC compared with normal individuals[8]. Treatments for DM include insulin-sensitizing agents, agents stimulating insulin secretion, insulin supplementation, and treatments to reduce gastrointestinal and urinary glucose absorption. While these medications provide adequate control of blood sugar levels, some of them fail to significantly reduce the risk of HCC occurrence. In recent years, studies have demonstrated an elevated risk of HCC incidence in diabetic patients treated with insulin[9]. As insulin is a potent mitogen, it acts to upregulate various growth factors including insulin-like growth factor 1 (IGF-1), thereby increasing HCC risk[8]. As a complementary and alternative treatment option, traditional Chinese medicine (TCM) has been used for centuries in East Asia, while it has more recently been gaining popularity worldwide. Studies have reported that TCM contains many natural compounds, exerting a variety of beneficial therapeutic effects, including anticancer, and balancing blood sugar levels[10,11]. Of particular interest here, TCM indicates that *Astragalus membranaceus* (a synonym of *Astragalus propinquus*) has the effect to tonify qi. In contemporary investigations, *Astragalus membranaceus*, which is rich in antidiabetic compounds including polysaccharides, saponins and flavonoids has presented anti-HCC effects in cell lines[12,13].

Researchers have yet to report on the potential of herbal treatments to decrease HCC risk in DM patients with regular insulin use. In addition, it must be noted that the development of carcinogenesis is a long-term process. Thus, we conducted a population-based retrospective cohort study using data from the Taiwan National Health Insurance Research Database (NHIRD) to investigate the potential of regular herb use to decrease HCC risk in DM patients with regular insulin management. We further analyzed the associated TCM prescriptions to provide both clinical guidance and summarize the potential molecular mechanisms of the herbs and formulas which could act to decrease HCC risk in DM patients with regular insulin management.

**MATERIALS AND METHODS**

***Data source***

In Taiwan, over 99% of residents participate in the single-payer National Health Insurance (NHI) program, which was launched in 1995. The medical claim data are stored in the NHIRD. In addition to demographic characteristics such as sex, birth date and region of residence, the database contains critical information regarding disease diagnosis, medication usage and other treatments received. Diseases in this database are recorded using codes of the International Classification of Diseases, Ninth & Tenth Revision, Clinical Modification (ICD-9 & 10-CM). Here, we utilized the NHIRD to investigate the association between herb use and HCC in DM patients. This study was approved by the Institutional Review Board of China Medical University Hospital Research Ethics Committee, No. CMUH109-REC2-031 (CR-3). All records and personal information were anonymized prior to analysis, thus the requirement for written informed consent was waived.

***Study population and flow chart***

We used data acquired from the Taiwanese NHIRD for the period January 1, 2000 to December 31, 2017. We defined subjects with three or more outpatient visits or one inpatient record of ICD-9-CM code 250 or ICD-10-CM E08-E13 as DM patients. For this cohort study, DM patients with insulin use for > 3 months were the study population. The exposure group in this study included patients with herb use due to DM for > 3 months per annum during the follow-up period. DM patients with insulin use never having received herbal treatment within the study period were defined as the nonexposure group. The index date for the exposure group was set at the first day of herb use after insulin prescription, and we assigned a random date after insulin prescription as the index date for nonexposure patients. The index date for the exposure and nonexposure groups were matched, with both post-indexed > 3 months to account for insulin exposure. Exclusion criteria included patients < 20 years old, with an index date prior to 2000 or after 2017, having any type of cancer aside from HCC, and with HCC diagnosis prior to the index date or within 1 year after the index date. We matched the herb users to nonusers at a 1:3 ratio according to age, sex, comorbidities and index year by propensity score matching. The flow chart illustrating the inclusion process in this study is shown in Figure 1.

***Main outcomes and comorbidities***

The primary outcome of this study was HCC, as defined by the Registry for catastrophic illness patients. Patients with IC Cards for Severe Illness with ICD-9-CM code of 155 or ICD-10-CM code of C220, C228 were the HCC patients. Death or withdrawal from the program prior to the end of the study period (December 31, 2017) was considered as censoring. The related comorbidities included hypertension (ICD-9-CM code 401-405; ICD-10-CM code I10-I15); coronary heart disease (ICD-9-CM code 410-414; ICD-10-CM code I20-I25); ischemic stroke (ICD-9-CM code 433434; ICD-10-CM code I63, I65, I66, I67, I68, G46.3-G46.8); hemorrhagic stroke (ICD-9-CM code 430-432; ICD-10-CM code I60, I61, I62); hyperlipidemia (ICD-9-CM code 272; ICD-10-CM code E78); renal insufficiency (ICD-9-CM code 585, 586, 588.8, 588.9; ICD-10-CM code N18, N19, N25.8, N25.9); cirrhosis (ICD-9-CM code 571.2, 571.5, 571.6; ICD-10-CM code K70.2, K70.30, K70.31, K74.0, K74.1, K74.2, K74.3, K74.4, K74.5, K74.60, K74.69); alcoholic liver damage (ICD-9-CM code 571.0, 571.1, 571.3; ICD-10-CM code K70.0, K70.10, K70.11, K70.40, K70.41, K70.0); NAFLD (ICD-9-CM code 571.8; ICD-10-CM code K74.4, K75.81, K76.0, K76.89); HBV infection (ICD-9-CM code V02.61, 070.20, 070.22, 070.30, 070.32; ICD-10-CM code Z22.51, B16.2, B16.9, B18.1, B19.10, B19.11); and HCV infection (ICD-9-CM code V02.62, 070.41, 070.44, 070.51, 070.54; ICD-10-CM code Z22.52, B17.10, B17.11, B18.2, B19.20, B19.21). In addition, several medications were included in our analysis, including lipid-lowering drugs (statins and non-statins), aspirin, HBV treatments (lamivudine, adefovir, entecavir, telbivudine, tenofovir, Peg-INF α-2a), HCV treatments (sofosbuvir, ledipasvir + sofosbuvir, velpatasvir + sofosbuvir, elbasvir + grazoprevir, glecaprevir + pibrentasvir, ombitasvir + paritaprevir + ritonavir + dasabuvir, daclatasvir, daclatasvir + asunaprevir, interferon + ribavirin), and oral antidiabetic drugs (OADs) [Biguanides, Sulfonamide, alpha glucosidase inhibitors, thiazolidinediones, dipeptidyl peptidase 4 inhibitors, glucagon-like peptide-1 (GLP-1) receptor agonist, sodium-glucose cotransporter 2 (SGLT2) inhibitors and glinides].

***Statistical analysis***

For the categorical variables of baseline characteristics, we represented the number and the percentage. The mean and SD of age were presented. The differences between the two groups were shown by standard mean difference (SMD). A significant difference was shown for SMD > 0.1. We calculated the incidence rate by dividing the number of events for each 1000 PY and the hazard ratio (HR) through the Cox proportional hazard. A 95%CI and *P* value were also indicated. We further illustrated the cumulative incidence curve as calculated by the Kaplan–Meier method and compared by the log-rank test for statistical significance. All analyses were conducted using SAS software, version 9.4 (SAS Institute, Cary, NC, United States). A significance level was set at *P* < 0.05.

**RESULTS**

***Baseline characteristics and comorbidities of study participants***

We enrolled 657144 DM patients with regular insulin between 2000 and 2017. Of these patients, 46849 had used herbal treatments for DM management, while 140547 were included as the matched control group. After propensity matching, the baseline variables were similar between the herb users and nonusers (SMD < 0.1; Table 1). Nearly half of the study patients were > 60 years old. The top three comorbidities identified were hyperlipidemia, hypertension, and coronary heart disease, while the proportions of all comorbidities in the study group and control group were similar. In addition, medications used by the herb users and nonusers demonstrated no differences (Table 1).

***Chinese herbal medicine decreased HCC risk among DM patients with insulin management***

The association between herbal management and HCC is shown in Table 2. The incidence rate of HCC among the herb users was 2.07 per 1000 PY, while it was 1.93 per 1000 PY among nonusers. After adjustment for the variables noted in Table 1, the adjusted HR (aHR) of HCC was 0.88 (95%CI = 0.80–0.97; *P* = 0.001) for herb users compared to the control group. As illustrated in Figure 2A, the cumulative incidence of HCC in herb users was significantly lower than that of the nonusers (*P* = 0.0078), while male patients had a higher risk of HCC relative to female patients (aHR = 1.77; 95%CI = 1.62–1.94; *P* < 0.001). In addition, older patients exhibited an elevated risk of developing HCC. Comorbidities including cirrhosis (aHR = 4.28; 95%CI = 3.80–4.82; *P* < 0.001), NAFLD (aHR = 1.24; 95%CI = 1.09–1.42; *P* < 0.001), HBV infection (aHR = 2.59; 95%CI = 2.32–2.90; *P* < 0.001) and HCV infection (aHR = 4.56; 95%CI = 4.09–5.08; *P* < 0.001) were identified as risk factors of HCC. Similarly, patients with HBV and HCV treatments exhibited increased risks of HCC, by 3.69-fold (95%CI = 3.21–4.25; *P* < 0.001) and 1.47-fold (95%CI = 1.14–1.88; *P* < 0.001) respectively. Of the patients using a GLP-1 receptor agonist and SGLT2 inhibitors, the aHR of HCC was 0.40 (95%CI = 0.24–0.68; *P* < 0.001) and 0.79 (95%CI = 0.64–0.98; *P* = 0.010), respectively.

***Chinese herbal medicine users achieved a longer survival time compared to non-herb users among patients who developed HCC***

By analyzing herb usage during the study period, patients with herb use of > 5 years cumulatively exhibited a protective effect against development of HCC (aHR = 0.82, *P* < 0.05; *P* = 0.003). In patients who used herbs for < 1 year, 1–2.9 years, and 3–4.9 years, the aHR of < 1 for developing HCC failed to reach statistical significance (Table 3). In the cohort of patients who developed HCC, herb users exhibited a longer survival time in days compared to non-users (aHR = 0.78, *P* = 0.0001; Figure 2B).

***The top 10 herbs and formulas of prescriptions***

Data regarding the top 10 single herbs and herbal formulas used by patients, and summaries of the potential pharmacological effects of the constituents are presented in Table 4. Patients with prescriptions of *Rheum palmatum* L. (Da Huang), *Salvia miltiorrhiza Bunge* (Dan Shen), *Trichosanthes kirilowii* Maxim. (Tian Hua Fen), and *Scrophularia ningpoensis* Hemsl. (Xuan Shen) exhibited lower risks of HCC, with statistical significance (aHR = 0.79–0.87; *P* < 0.05). In terms of herbal formulas, patients with prescriptions of Ji Sheng Shen Qi Wan, Liu Wei Di Huang Wan, Shu Jing Huo Xie Tang, Xue Fu Zhu Yu Tang, Qi Ju Di Huang Wan, Bai Hu Jia Ren Shen Tang, and Zhi Gan Cao Tang exhibited lower risks of HCC, with an aHR 0.77–0.86, with statistical significance (*P* < 0.05). The network analysis of the top 30 most prescribed herbs and formulas is presented in Figure 3. The analysis illustrates that *Astragalus propinquus* (Huang Qi) plus *Salvia miltiorrhiza Bunge* (Dan Shen), and *Astragalus propinquus* (Huang Qi) plus *Trichosanthes kirilowii* Maxim (Tian Hua Fen) were the most frequent combination of single herbs. Meanwhile, Ji Sheng Shen Qi Wan plus Dan Shen was the most frequent combination of herbs and formulas.

**DISCUSSION**

Although previous studies have demonstrated that DM patients with insulin management have an increased risk of HCC, this is the first large-scale cohort study indicating the efficacy of herbs at decreasing the HCC risk by 12% among DM patients, after adjusting for sex, age, various drug uses and major comorbidities (aHR = 0.88; 95%CI = 0.8–0.97; *P* = 0.001). Furthermore, among patients who developed HCC during the study period, herbal medicine users exhibited a longer survival time in days compared to non-users (aHR = 0.78, *P* = 0.0001).

Similar to previous reports, our study reveals that males had an elevated risk of developing HCC as compared to females (aHR = 1.77; 95%CI = 1.62–1.94; *P* < 0.001)[14]. Additionally, approximately 50% of our cohort patients were over 60 years of age, noting that HCC risk steadily increases with age. While the diagnosed onset age of HCC varies in different parts of the world, Yang *et al*[4] reported a median onset age above 60 years[4], which is similar to our findings. Our stratified analysis revealed that cirrhosis patients had the highest risk of developing HCC compared to other comorbidities (aHR = 4.28; 95%CI = 3.8–4.82; *P* < 0.001). A study by Fattovich *et al*[15] reported a fourfold elevated risk of developing HCC in cirrhosis patients compared to those with chronic hepatitis[15]. With viral infection or alcohol intake, a damaged liver will undergo regeneration and tissue recovery. The repeated hepatocyte and hepatic stellate cellular proliferation may trigger cancer-related fibroblasts and lead to cirrhosis as well as HCC proliferation[16]. Furthermore, between 15% and 30% of cirrhosis patients develop T2DM due to perturbed glucose utilization and decreased insulin removal by the liver[17]. Hyperglycemia and hyperinsulinemia status may also result in development of HCC. Of note, our study identified HBV and HCV infections as major risk factors of developing HCC. The worldwide incidence of HCV-related HCC is 12–17 per 1000 PY, which is similar to our finding (15.10 per 1000 PY)[5], and the incidence of HBV-related HCC varies by region[15]. In our study, HBV and HCV treatments were adopted in accordance with patient preference and following NHI payment guidelines. HBV treatments were covered for patients with HBV DNA ≥ 2000IU/mL with five-fold elevated liver enzymes or decompensated liver status, while HCV treatments were covered for patients positive for anti-HCV for > 6 months with cirrhosis ≥ F2 or positive for HCV RNA. We hypothesize that the liver status of patients in the HBV and HCV treatment groups were generally more severe, thus causing the elevated risk of HCC incidence noted in our study.

DM is a metabolic disorder associated with hyperglycemia, hyperinsulinemia and insulin resistance. Due to metabolic disturbances, DM is noted as an independent risk factor for various types of cancer, including breast, colorectal, endometrial, pancreatic, gallbladder, renal, and liver cancers[18]. It has been reported that T2DM patients have a 2.5–4-fold risk of developing HCC compared with normal individuals[8]; the possible underlying mechanism of which is associated with insulin resistance related to hyperinsulinemia. Hyperinsulinemia increases IGF-1, causing IGF-1 and insulin receptor substrate-1 overexpression, thereby activating hepatoma cell proliferation[19]. Insulin supplementation is indicated in T2DM and gestational DM patients; however, although insulin supplements can achieve satisfactory control of blood sugar levels, mounting evidence suggests an elevated risk of HCC in diabetic patients. According to a previous study, both higher daily insulin dosage and longer treatment duration increase the risk of HCC in patients treated with insulin by adjusted odds ratio from 1.9 to 3.73[8]. More specifically, sulfonylureas, which promote insulin secretion, pose a 2.6-fold increased risk of developing HCC[20]. Our report reveals a similar result whereby sulfonylureas increased HCC risk (aHR = 1.08), but without statistical significance.

The biguanide metformin is an oral antihyperglycemic agent that has been identified as a potential hepatoprotective drug against HCC development[21]. Metformin activates adenosine monophosphate-activated protein kinase and inhibits the downstream mammalian target of rapamycin pathway, which plays a key role in preventing hepatocarcinogenesis[22]. Indeed, previous studies have reported a metformin treatment group with a 43%–76% reduced risk of HCC and reduced overall mortality risk[8,9]; however, our subgroup analysis showed no difference between biguanides users and nonusers (aHR = 1.16; 95%CI = 0.84–1.61; *P* = 0.368). Meanwhile, GLP-1 is an insulin secretagogue that ameliorates liver fat accumulation and the inflammatory microenvironment, acting to prevent NAFLD progression to nonalcoholic steatohepatitis (NASH). In our study, GLP-1 receptor agonists decreased HCC risk (aHR = 0.4; 95%CI = 0.24–0.68; *P* < 0.001). Previous studies have demonstrated that GLP-1 receptor agonists induce autophagy *via* elevating the transforming growth factor β1 level and reducing migration *via* suppression of the stress-activated protein kinase/c-Jun N-terminal kinase pathway[23,24], which is further supported by our findings. However, it should be noted that GLP-1 receptor agonists elevate the insulin level in patients, thereby potentially elevating the risk of HCC. Thus, more high-quality clinical evidence is required to clarify the association between GLP-1 receptor agonist and HCC occurrence. In addition, SGLT2 inhibitors are a new class of OAD which act to decrease glucose reabsorption in the renal proximal tubules. SGLT2 has been shown to attenuate the development of NASH and induce cell cycle arrest and apoptosis in an animal model[25]. Our report reveals a decreased HCC risk (aHR = 0.79; 95%CI = 0.64–0.98; *P* = 0.010) in SGLT2 inhibitor users; however, there is a lack of clinical data regarding SGLT2 inhibitors as a protector or inducer of carcinogenesis.

Although many OADs have been developed, insulin continues to play a prominent role in the clinical setting as it is applied to such conditions as chronic DM, type 1 DM, chronic kidney disease, and gestational DM. Thus, identifying a new therapeutic modality is critical to preventing insulin users from developing HCC. As such, many of the herbs applied in TCM contain natural compounds which have been demonstrated to exert both anticancer and antidiabetic effects without causing hyperinsulinemia[10,11]. Table 4 lists and summarizes the possible pharmacological effects of the 10 most-prescribed herbs and formulas identified in our study. Importantly, previous studies have indicated that these herbs and formulas contain active compounds involved in the inhibition of HCC progression. Most of them have been shown to induce apoptosis both *in vivo* and *in vitro* in HCC cell line studies, while *Corydalis yanhusuo*[26] and *Anemarrhena asphodeloides*[27] (present in Zhi Bai Di Huang Wan and Bai Hu Jia Ren Shen Tang) have been noted to induce autophagy. In addition, *Pueraria montana* and *Paeonia lactiflora* (present in Jia Wei Xiao Yao San and Ma Zi Ren Wan) inhibit HCC invasion and metastasis. Aside from *Corydalis yanhusuo,* the other top 10 herbs and formulas have been reported to exert antidiabetic effects, primarily by ameliorating insulin resistance *via* various molecular pathways. As previously reported, *Rheum palmatum*[28], *Astragalus propinquus*[29] and *Magnolia officinalis*[30] prevent pancreatic β-cell death and control blood sugar levels. *Salvia miltiorrhiza*[31,32] and *Magnolia officinalis*[33] inhibit IGF-1, a tumor carcinogen, indicating their potential to inhibit HCC proliferation. Furthermore, *Scutellaria baicalensis*[34]*, Ophiopogon japonicas*[35]and *Anemarrhena asphodeloides*[36] have been demonstrated to modulate gut microbiota in high-fat-diet animal models. Collectively, the present study and previous investigations indicate that the herbs identified herein are associated with both anticancer and antidiabetic effects without causing hyperinsulinemia, although further investigation is warranted.

The NHIRD used in this study provides a large sample size, covering over 99% of Taiwan’s residents with a low loss of follow-up, and provides sufficient power for subgroup analyses to demonstrate convincing outcomes after adjusting for potential confounding factors. However, several limitations need to be considered. First, the NHIRD does not offer information on potential confounding factors such as body mass index, environmental/chemical exposure, alcohol/tobacco consumption, or history of family illness. Thus, we have attempted to adjust for the alcohol confounding factor by considering alcoholic liver disease, revealing no statistical significance between the two cohorts. Second, clinical data were lacking in terms of laboratory data and imaging results, making it difficult to investigate the quality of DM control, and stages of cirrhosis and HCC. Among the demographic characteristics in our patients, the proportion with cirrhosis, alcoholic liver damage and HBV/HCV infection were not significantly different between the groups, suggesting that the background risk of liver cancer occurrence was likely similar for both groups. Third, the NHIRD only records herbal prescriptions manufactured by good-manufacturing-practice-certified pharmaceutical companies; hence, herbs purchased outside of the NHI program were not analyzed in this study. However, self-paid herbs are relatively expensive, at approximately $300 to $400 per month, while we identified patients with > 3 months of herbal prescriptions per annum during the study period; thus, the chance of patients purchasing herbs not covered by NHI should be minimal. Fourth, due to the nature of retrospective cohort studies, bias may exist in our results. More specifically, it is reasonable to suggest that patients with a longer survival time may have received herbal treatment for a correspondingly longer period, thus warranting a prospective study to confirm our results. To minimize these limitations, we defined only patients with long-term (> 3 months) use of insulin and herbs, and patients diagnosed with HCC according to the Registry for Catastrophic Illness Database. We also reviewed the possible mechanisms underlying herbal effects on both anti-HCC and reversal of insulin resistance to bridge our results. Our study reveals several notable findings, while the prescription patterns identified in this large-scale cohort study provide valuable clinical guidance, and warrant further clinical studies and pharmacological investigation.

**CONCLUSION**

As DM patients using insulin have an increased risk of developing HCC, identifying a new therapeutic modality to prevent or mitigate this risk is of importance. This is the first large-scale cohort study to reveal that regular herbal medicine prescriptions can decrease the risk of HCC in DM patients using insulin. Herbal prescriptions may extend the survival time for DM patients with HCC. Future large-scale cohort studies or prospective studies are recommended to further support our results.

**ARTICLE HIGHLIGHTS**

***Research background***

Hepatocellular carcinoma (HCC) is the fifth most commonly occurring cancer globally. Type 2 diabetes mellitus (DM) is independent risk factor for HCC, while insulin is a potent mitogen. Identifying a new therapeutic modality for preventing insulin users from developing HCC is a critical goal for researchers.

***Research motivation***

Previous reports have indicated the potential of herbal treatments to decrease HCC risk in DM patients. However, carcinogenesis is a long-term process. Thus, we conducted a population-based retrospective cohort study using data from the Taiwan National Health Insurance Research Database (NHIRD) to investigate the potential of regular herb use to decrease HCC risk in DM patients with regular insulin management.

***Research objectives***

The objective of this study was to evaluate whether regular herbal medicine use can decrease HCC risk in DM patients with regular insulin control.

***Research methods***

We used data acquired from the Taiwanese NHIRD between 2000 and 2017. We identified patients with DM who were prescribed insulin for > 3 months. The herb group was further defined as patients prescribed herbal medication for DM for > 3 months per annum during follow-up. We analyzed HCC incidence, HCC survival rates, and the herbal prescriptions involved.

***Research results***

We enrolled 657144 DM patients with regular insulin use from 2000 to 2017. Among these, 46849 patients had used herbal treatment for DM, and 140547 patients were included as the matched control group. The baseline variables were similar between the herb users and nonusers. DM patients with regular herb use had a 12% decreased risk of HCC compared to the control group. The cumulative incidence of HCC in herb users was significantly lower than that of the nonusers. Patients with herb use for > 5 years cumulatively exhibited a protective effect against development of HCC. Of patients who developed HCC, herb users exhibited a longer survival time than nonusers. Our analysis indicated that *Astragalus propinquus* (Huang Qi) plus *Salvia miltiorrhiza Bunge* (Dan Shen), and *Astragalus propinquus* (Huang Qi) plus *Trichosanthes kirilowii* Maxim (Tian Hua Fen) were the most frequent combination of single herbs. Meanwhile, Ji Sheng Shen Qi Wan plus Dan Shen was the most frequent combination of herbs and formulas.

***Research conclusions***

This large-scale retrospective cohort study reveals that herbal medicine may decrease HCC risk by 12% in DM patients with regular insulin use. Furthermore, herbal prescriptions may extend the survival time for those DM patients who develop HCC.

***Research perspectives***

Since herbal prescriptions are relatively cheap and commonly used, large-scale cohort studies or prospective studies are required to support our results.

**ACKNOWLEDGEMENTS**

The authors would like to thank James Waddell for the proofreading and revision of our manuscript.

**REFERENCES**

1 **Chidambaranathan-Reghupaty S**, Fisher PB, Sarkar D. Hepatocellular carcinoma (HCC): Epidemiology, etiology and molecular classification. *Adv Cancer Res* 2021; **149**: 1-61 [PMID: 33579421 DOI: 10.1016/bs.acr.2020.10.001]

2 **Rumgay H**, Ferlay J, de Martel C, Georges D, Ibrahim AS, Zheng R, Wei W, Lemmens VEPP, Soerjomataram I. Global, regional and national burden of primary liver cancer by subtype. *Eur J Cancer* 2022; **161**: 108-118 [PMID: 34942552 DOI: 10.1016/j.ejca.2021.11.023]

3 **Vogel A**, Meyer T, Sapisochin G, Salem R, Saborowski A. Hepatocellular carcinoma. *Lancet* 2022; **400**: 1345-1362 [PMID: 36084663 DOI: 10.1016/S0140-6736(22)01200-4]

4 **Yang JD**, Hainaut P, Gores GJ, Amadou A, Plymoth A, Roberts LR. A global view of hepatocellular carcinoma: trends, risk, prevention and management. *Nat Rev Gastroenterol Hepatol* 2019; **16**: 589-604 [PMID: 31439937 DOI: 10.1038/s41575-019-0186-y]

5 **Sagnelli E**, Macera M, Russo A, Coppola N, Sagnelli C. Epidemiological and etiological variations in hepatocellular carcinoma. *Infection* 2020; **48**: 7-17 [PMID: 31347138 DOI: 10.1007/s15010-019-01345-y]

6 **Huang P**, Liu M, Zang F, Yao Y, Yue M, Wang J, Fan H, Zhuo L, Wu J, Xia X, Feng Y, Yu R. The development of hepatocellular carcinoma in HCV-infected patients treated with DAA: A comprehensive analysis. *Carcinogenesis* 2018; **39**: 1497-1505 [PMID: 30602007 DOI: 10.1093/carcin/bgy099]

7 **Mantovani A**, Targher G. Type 2 diabetes mellitus and risk of hepatocellular carcinoma: spotlight on nonalcoholic fatty liver disease. *Ann Transl Med* 2017; **5**: 270 [PMID: 28758096 DOI: 10.21037/atm.2017.04.41]

8 **Plaz Torres MC**, Jaffe A, Perry R, Marabotto E, Strazzabosco M, Giannini EG. Diabetes medications and risk of HCC. *Hepatology* 2022; **76**: 1880-1897 [PMID: 35239194 DOI: 10.1002/hep.32439]

9 **Bosetti C**, Franchi M, Nicotra F, Asciutto R, Merlino L, La Vecchia C, Corrao G. Insulin and other antidiabetic drugs and hepatocellular carcinoma risk: a nested case-control study based on Italian healthcare utilization databases. *Pharmacoepidemiol Drug Saf* 2015; **24**: 771-778 [PMID: 26013675 DOI: 10.1002/pds.3801]

10 **Hu B**, An HM, Wang SS, Chen JJ, Xu L. Preventive and Therapeutic Effects of Chinese Herbal Compounds against Hepatocellular Carcinoma. *Molecules* 2016; **21**: 142 [PMID: 26828466 DOI: 10.3390/molecules21020142]

11 **Tran N**, Pham B, Le L. Bioactive Compounds in Anti-Diabetic Plants: From Herbal Medicine to Modern Drug Discovery. *Biology (Basel)* 2020; **9** [PMID: 32872226 DOI: 10.3390/biology9090252]

12 **Zhang K**, Pugliese M, Pugliese A, Passantino A. Biological active ingredients of traditional Chinese herb Astragalus membranaceus on treatment of diabetes: a systematic review. *Mini Rev Med Chem* 2015; **15**: 315-329 [PMID: 25723453 DOI: 10.2174/1389557515666150227113431]

13 **Zang W**, Bian H, Huang X, Yin G, Zhang C, Han LI, Hao P, Ding S, Sun YU, Yang Z, Hoffman RM, Tang D. Traditional Chinese Medicine (TCM) Astragalus Membranaceus and Curcuma Wenyujin Promote Vascular Normalization in Tumor-derived Endothelial Cells of Human Hepatocellular Carcinoma. *Anticancer Res* 2019; **39**: 2739-2747 [PMID: 31177109 DOI: 10.21873/anticanres.13400]

14 **Pinheiro PS**, Medina HN, Callahan KE, Jones PD, Brown CP, Altekruse SF, McGlynn KA, Kobetz EN. The association between etiology of hepatocellular carcinoma and race-ethnicity in Florida. *Liver Int* 2020; **40**: 1201-1210 [PMID: 32087002 DOI: 10.1111/liv.14409]

15 **Fattovich G**, Stroffolini T, Zagni I, Donato F. Hepatocellular carcinoma in cirrhosis: incidence and risk factors. *Gastroenterology* 2004; **127**: S35-S50 [PMID: 15508101 DOI: 10.1053/j.gastro.2004.09.014]

16 **Baglieri J**, Brenner DA, Kisseleva T. The Role of Fibrosis and Liver-Associated Fibroblasts in the Pathogenesis of Hepatocellular Carcinoma. *Int J Mol Sci* 2019; **20** [PMID: 30959975 DOI: 10.3390/ijms20071723]

17 **Schuppan D**, Afdhal NH. Liver cirrhosis. *Lancet* 2008; **371**: 838-851 [PMID: 18328931 DOI: 10.1016/S0140-6736(08)60383-9]

18 **Singh MK**, Das BK, Choudhary S, Gupta D, Patil UK. Diabetes and hepatocellular carcinoma: A pathophysiological link and pharmacological management. *Biomed Pharmacother* 2018; **106**: 991-1002 [PMID: 30119271 DOI: 10.1016/j.biopha.2018.06.095]

19 **Li X**, Wang X, Gao P. Diabetes Mellitus and Risk of Hepatocellular Carcinoma. *Biomed Res Int* 2017; **2017**: 5202684 [PMID: 29379799 DOI: 10.1155/2017/5202684]

20 **Lee JY**, Kim G, Lee YH, Lee BW, Cha BS, Nam CM, Kang ES. Comparison of hepatocellular carcinoma risk between patients treated with glimepiride and gliclazide. *Diabetes Metab* 2019; **45**: 83-85 [PMID: 28778564 DOI: 10.1016/j.diabet.2017.06.007]

21 **Mallik R**, Chowdhury TA. Metformin in cancer. *Diabetes Res Clin Pract* 2018; **143**: 409-419 [PMID: 29807101 DOI: 10.1016/j.diabres.2018.05.023]

22 **Gallagher EJ**, LeRoith D. Diabetes, cancer, and metformin: connections of metabolism and cell proliferation. *Ann N Y Acad Sci* 2011; **1243**: 54-68 [PMID: 22211893 DOI: 10.1111/j.1749-6632.2011.06285.x]

23 **Krause GC**, Lima KG, Dias HB, da Silva EFG, Haute GV, Basso BS, Gassen RB, Marczak ES, Nunes RSB, de Oliveira JR. Liraglutide, a glucagon-like peptide-1 analog, induce autophagy and senescence in HepG2 cells. *Eur J Pharmacol* 2017; **809**: 32-41 [PMID: 28501576 DOI: 10.1016/j.ejphar.2017.05.015]

24 **Yamada N**, Matsushima-Nishiwaki R, Kobayashi K, Tachi J, Kozawa O. GLP-1 reduces the migration of hepatocellular carcinoma cells *via* suppression of the stress-activated protein kinase/c-Jun N-terminal kinase pathway. *Arch Biochem Biophys* 2021; **703**: 108851 [PMID: 33771507 DOI: 10.1016/j.abb.2021.108851]

25 **Kaji K**, Nishimura N, Seki K, Sato S, Saikawa S, Nakanishi K, Furukawa M, Kawaratani H, Kitade M, Moriya K, Namisaki T, Yoshiji H. Sodium glucose cotransporter 2 inhibitor canagliflozin attenuates liver cancer cell growth and angiogenic activity by inhibiting glucose uptake. *Int J Cancer* 2018; **142**: 1712-1722 [PMID: 29205334 DOI: 10.1002/ijc.31193]

26 **Yin X**, Li W, Zhang J, Zhao W, Cai H, Zhang C, Liu Z, Guo Y, Wang J. AMPK-Mediated Metabolic Switching Is High Effective for Phytochemical Levo-Tetrahydropalmatine (l-THP) to Reduce Hepatocellular Carcinoma Tumor Growth. *Metabolites* 2021; **11** [PMID: 34940569 DOI: 10.3390/metabo11120811]

27 **Han FY**, Song XY, Chen JJ, Yao GD, Song SJ. Timosaponin AIII: A novel potential anti-tumor compound from Anemarrhena asphodeloides. *Steroids* 2018; **140**: 125-130 [PMID: 30296545 DOI: 10.1016/j.steroids.2018.09.014]

28 **Cheng FR**, Cui HX, Fang JL, Yuan K, Guo Y. Ameliorative Effect and Mechanism of the Purified Anthraquinone-Glycoside Preparation from Rheum Palmatum L. on Type 2 Diabetes Mellitus. *Molecules* 2019; **24** [PMID: 31013790 DOI: 10.3390/molecules24081454]

29 **Agyemang K**, Han L, Liu E, Zhang Y, Wang T, Gao X. Recent Advances in Astragalus membranaceus Anti-Diabetic Research: Pharmacological Effects of Its Phytochemical Constituents. *Evid Based Complement Alternat Med* 2013; **2013**: 654643 [PMID: 24348714 DOI: 10.1155/2013/654643]

30 **Suh KS**, Chon S, Jung WW, Choi EM. Magnolol protects pancreatic β-cells against methylglyoxal-induced cellular dysfunction. *Chem Biol Interact* 2017; **277**: 101-109 [PMID: 28919305 DOI: 10.1016/j.cbi.2017.09.014]

31 **Wang H**, Su X, Fang J, Xin X, Zhao X, Gaur U, Wen Q, Xu J, Little PJ, Zheng W. Tanshinone IIA Attenuates Insulin Like Growth Factor 1 -Induced Cell Proliferation in PC12 Cells through the PI3K/Akt and MEK/ERK Pathways. *Int J Mol Sci* 2018; **19** [PMID: 30213025 DOI: 10.3390/ijms19092719]

32 **Wu YT**, Bi YM, Tan ZB, Xie LP, Xu HL, Fan HJ, Chen HM, Li J, Liu B, Zhou YC. Tanshinone I inhibits vascular smooth muscle cell proliferation by targeting insulin-like growth factor-1 receptor/phosphatidylinositol-3-kinase signaling pathway. *Eur J Pharmacol* 2019; **853**: 93-102 [PMID: 30878387 DOI: 10.1016/j.ejphar.2019.03.021]

33 **McKeown BT**, Hurta RA. Magnolol affects expression of IGF-1 and associated binding proteins in human prostate cancer cells in vitro. *Anticancer Res* 2014; **34**: 6333-6338 [PMID: 25368232]

34 **Baradaran Rahimi V**, Askari VR, Hosseinzadeh H. Promising influences of Scutellaria baicalensis and its two active constituents, baicalin, and baicalein, against metabolic syndrome: A review. *Phytother Res* 2021; **35**: 3558-3574 [PMID: 33590943 DOI: 10.1002/ptr.7046]

35 **Chen S**, Li X, Liu L, Liu C, Han X. Ophiopogonin D alleviates high-fat diet-induced metabolic syndrome and changes the structure of gut microbiota in mice. *FASEB J* 2018; **32**: 1139-1153 [PMID: 29084766 DOI: 10.1096/fj.201700741RR]

36 **Yan D**, Fan P, Sun W, Ding Q, Zheng W, Xiao W, Zhang B, Zhang T, Zhang T, Shi J, Chen X, Chen P, Zhang J, Hao Y, Sun X, Pang X, Dong Y, Xu P, Yu L, Ma B. Anemarrhena asphodeloides modulates gut microbiota and restores pancreatic function in diabetic rats. *Biomed Pharmacother* 2021; **133**: 110954 [PMID: 33378992 DOI: 10.1016/j.biopha.2020.110954]

37 **Yang M**, Li X, Zeng X, Ou Z, Xue M, Gao D, Liu S, Li X, Yang S. Rheum palmatum L. Attenuates High Fat Diet-Induced Hepatosteatosis by Activating AMP-Activated Protein Kinase. *Am J Chin Med* 2016; **44**: 551-564 [PMID: 27109162 DOI: 10.1142/S0192415X16500300]

38 **Cao Y**, Chang S, Dong J, Zhu S, Zheng X, Li J, Long R, Zhou Y, Cui J, Zhang Y. Emodin ameliorates high-fat-diet induced insulin resistance in rats by reducing lipid accumulation in skeletal muscle. *Eur J Pharmacol* 2016; **780**: 194-201 [PMID: 27020550 DOI: 10.1016/j.ejphar.2016.03.049]

39 **Tan ZB**, Fan HJ, Wu YT, Xie LP, Bi YM, Xu HL, Chen HM, Li J, Liu B, Zhou YC. Rheum palmatum extract exerts anti-hepatocellular carcinoma effects by inhibiting signal transducer and activator of transcription 3 signaling. *J Ethnopharmacol* 2019; **232**: 62-72 [PMID: 30553869 DOI: 10.1016/j.jep.2018.12.019]

40 **Jia Q**, Zhu R, Tian Y, Chen B, Li R, Li L, Wang L, Che Y, Zhao D, Mo F, Gao S, Zhang D. Salvia miltiorrhiza in diabetes: A review of its pharmacology, phytochemistry, and safety. *Phytomedicine* 2019; **58**: 152871 [PMID: 30851580 DOI: 10.1016/j.phymed.2019.152871]

41 **Naz I**, Merarchi M, Ramchandani S, Khan MR, Malik MN, Sarwar S, Narula AS, Ahn KS. An overview of the anti-cancer actions of Tanshinones, derived from Salvia miltiorrhiza (Danshen). *Explor Target Antitumor Ther* 2020; **1**: 153-170 [PMID: 36046197 DOI: 10.37349/etat.2020.00010]

42 **Li J**, Huang Y, Zhao S, Guo Q, Zhou J, Han W, Xu Y. Based on network pharmacology to explore the molecular mechanisms of astragalus membranaceus for treating T2 diabetes mellitus. *Ann Transl Med* 2019; **7**: 633 [PMID: 31930034 DOI: 10.21037/atm.2019.10.118]

43 **Huang WH**, Liao WR, Sun RX. Astragalus polysaccharide induces the apoptosis of human hepatocellular carcinoma cells by decreasing the expression of Notch1. *Int J Mol Med* 2016; **38**: 551-557 [PMID: 27279598 DOI: 10.3892/ijmm.2016.2632]

44 **Li C**, Pan XY, Ma M, Zhao J, Zhao F, Lv YP. Astragalus polysacharin inhibits hepatocellular carcinoma-like phenotypes in a murine HCC model through repression of M2 polarization of tumour-associated macrophages. *Pharm Biol* 2021; **59**: 1533-1539 [PMID: 34726570 DOI: 10.1080/13880209.2021.1991384]

45 **Lu L**, Peng J, Wan P, Peng H, Lu J, Xiong G. Mechanism of Tripterygium wilfordii Hook.F.- Trichosanthes kirilowii Maxim decoction in treatment of diabetic kidney disease based on network pharmacology and molecular docking. *Front Pharmacol* 2022; **13**: 940773 [PMID: 36386135 DOI: 10.3389/fphar.2022.940773]

46 **Lo HY**, Li TC, Yang TY, Li CC, Chiang JH, Hsiang CY, Ho TY. Hypoglycemic effects of Trichosanthes kirilowii and its protein constituent in diabetic mice: the involvement of insulin receptor pathway. *BMC Complement Altern Med* 2017; **17**: 53 [PMID: 28100206 DOI: 10.1186/s12906-017-1578-6]

47 **Zhao H**, Song L. TKP, a Serine Protease from Trichosanthes kirilowii, Inhibits Cell Proliferation by Blocking Aerobic Glycolysis in Hepatocellular Carcinoma Cells. *Nutr Cancer* 2022; **74**: 333-345 [PMID: 33544002 DOI: 10.1080/01635581.2021.1882508]

48 **Wu K**, Liang T, Duan X, Xu L, Zhang K, Li R. Anti-diabetic effects of puerarin, isolated from Pueraria lobata (Willd.), on streptozotocin-diabetogenic mice through promoting insulin expression and ameliorating metabolic function. *Food Chem Toxicol* 2013; **60**: 341-347 [PMID: 23927877 DOI: 10.1016/j.fct.2013.07.077]

49 **Yang L**, Chen J, Lu H, Lai J, He Y, Liu S, Guo X. Pueraria lobata for Diabetes Mellitus: Past, Present and Future. *Am J Chin Med* 2019; **47**: 1419-1444 [PMID: 31659910 DOI: 10.1142/S0192415X19500733]

50 **Zhou Y**, Xue R, Wang J, Ren H. Puerarin inhibits hepatocellular carcinoma invasion and metastasis through miR-21-mediated PTEN/AKT signaling to suppress the epithelial-mesenchymal transition. *Braz J Med Biol Res* 2020; **53**: e8882 [PMID: 32294699 DOI: 10.1590/1414-431X20198882]

51 **Yan S**, Lu W, Zhou J, Guo X, Li J, Cheng H, Zhu X, Zhao Y, Duan M, Yang H, Zhang Y, Wang Q, Chen L, Zheng T. Aqueous extract of Scrophularia ningpoensis improves insulin sensitivity through AMPK-mediated inhibition of the NLRP3 inflammasome. *Phytomedicine* 2022; **104**: 154308 [PMID: 35792447 DOI: 10.1016/j.phymed.2022.154308]

52 **Ren D**, Shen ZY, Qin LP, Zhu B. Pharmacology, phytochemistry, and traditional uses of Scrophularia ningpoensis Hemsl. *J Ethnopharmacol* 2021; **269**: 113688 [PMID: 33338592 DOI: 10.1016/j.jep.2020.113688]

53 **Fu P**, Du F, Liu Y, Hong Y, Yao M, Zheng S. Wogonin increases doxorubicin sensitivity by down-regulation of IGF-1R/AKT signaling pathway in human breast cancer. *Cell Mol Biol (Noisy-le-grand)* 2015; **61**: 123-127 [PMID: 26638893]

54 **Na HY**, Lee BC. Scutellaria baicalensis Alleviates Insulin Resistance in Diet-Induced Obese Mice by Modulating Inflammation. *Int J Mol Sci* 2019; **20** [PMID: 30744038 DOI: 10.3390/ijms20030727]

55 **Liu D**, Wang Z, Zhong L, Xie C, Huang X, Zhi Y, Zhang Y, Liang J, Shi Z, Huang J, Zhang S, Zhang J, Ding F. Targets and Potential Mechanism of Scutellaria baicalensis in Treatment of Primary Hepatocellular Carcinoma Based on Bioinformatics Analysis. *J Oncol* 2022; **2022**: 8762717 [PMID: 35190740 DOI: 10.1155/2022/8762717]

56 **Wang LY**, Wang Y, Xu DS, Ruan KF, Feng Y, Wang S. MDG-1, a polysaccharide from Ophiopogon japonicus exerts hypoglycemic effects through the PI3K/Akt pathway in a diabetic KKAy mouse model. *J Ethnopharmacol* 2012; **143**: 347-354 [PMID: 22776833 DOI: 10.1016/j.jep.2012.06.050]

57 **Yuan F**, Gao Q, Tang H, Shi J, Zhou Y. Ophiopogonin‑B targets PTP1B to inhibit the malignant progression of hepatocellular carcinoma by regulating the PI3K/AKT and AMPK signaling pathways. *Mol Med Rep* 2022; **25** [PMID: 35169857 DOI: 10.3892/mmr.2022.12638]

58 **Chen JH**, Chiang IT, Hsu FT. Protein Kinase B Inactivation Is Associated with Magnolol-Enhanced Therapeutic Efficacy of Sorafenib in Hepatocellular Carcinoma In Vitro and In Vivo. *Cancers (Basel)* 2019; **12** [PMID: 31905887 DOI: 10.3390/cancers12010087]

59 **Zhang C**, Fan L, Fan S, Wang J, Luo T, Tang Y, Chen Z, Yu L. Cinnamomum cassia Presl: A Review of Its Traditional Uses, Phytochemistry, Pharmacology and Toxicology. *Molecules* 2019; **24** [PMID: 31557828 DOI: 10.3390/molecules24193473]

60 **Moon EY**, Lee MR, Wang AG, Lee JH, Kim HC, Kim HM, Kim JM, Kwon BM, Yu DY. Delayed occurrence of H-ras12V-induced hepatocellular carcinoma with long-term treatment with cinnamaldehydes. *Eur J Pharmacol* 2006; **530**: 270-275 [PMID: 16405947 DOI: 10.1016/j.ejphar.2005.11.053]

61 **Bhattamisra SK**, Koh HM, Lim SY, Choudhury H, Pandey M. Molecular and Biochemical Pathways of Catalpol in Alleviating Diabetes Mellitus and Its Complications. *Biomolecules* 2021; **11** [PMID: 33672590 DOI: 10.3390/biom11020323]

62 **Chao JC**, Chiang SW, Wang CC, Tsai YH, Wu MS. Hot water-extracted Lycium barbarum and Rehmannia glutinosa inhibit proliferation and induce apoptosis of hepatocellular carcinoma cells. *World J Gastroenterol* 2006; **12**: 4478-4484 [PMID: 16874858 DOI: 10.3748/wjg.v12.i28.4478]

63 **Wang K**, Cao P, Shui W, Yang Q, Tang Z, Zhang Y. Angelica sinensis polysaccharide regulates glucose and lipid metabolism disorder in prediabetic and streptozotocin-induced diabetic mice through the elevation of glycogen levels and reduction of inflammatory factors. *Food Funct* 2015; **6**: 902-909 [PMID: 25630053 DOI: 10.1039/c4fo00859f]

64 **Cheng Y**, Zhou J, Li Q, Liu Y, Wang K, Zhang Y. The effects of polysaccharides from the root of Angelica sinensis on tumor growth and iron metabolism in H22-bearing mice. *Food Funct* 2016; **7**: 1033-1039 [PMID: 26757699 DOI: 10.1039/c5fo00855g]

65 **Nasiri K**, Akbari A, Nimrouzi M, Ruyvaran M, Mohamadian A. Safflower seed oil improves steroidogenesis and spermatogenesis in rats with type II diabetes mellitus by modulating the genes expression involved in steroidogenesis, inflammation and oxidative stress. *J Ethnopharmacol* 2021; **275**: 114139 [PMID: 33894286 DOI: 10.1016/j.jep.2021.114139]

66 **Yang F**, Li J, Zhu J, Wang D, Chen S, Bai X. Hydroxysafflor yellow A inhibits angiogenesis of hepatocellular carcinoma *via* blocking ERK/MAPK and NF-κB signaling pathway in H22 tumor-bearing mice. *Eur J Pharmacol* 2015; **754**: 105-114 [PMID: 25720342 DOI: 10.1016/j.ejphar.2015.02.015]

67 **Ma Z**, Chu L, Liu H, Wang W, Li J, Yao W, Yi J, Gao Y. Beneficial effects of paeoniflorin on non-alcoholic fatty liver disease induced by high-fat diet in rats. *Sci Rep* 2017; **7**: 44819 [PMID: 28300221 DOI: 10.1038/srep44819]

68 **Lee SM**, Li ML, Tse YC, Leung SC, Lee MM, Tsui SK, Fung KP, Lee CY, Waye MM. Paeoniae Radix, a Chinese herbal extract, inhibit hepatoma cells growth by inducing apoptosis in a p53 independent pathway. *Life Sci* 2002; **71**: 2267-2277 [PMID: 12215374 DOI: 10.1016/s0024-3205(02)01962-8]

69 **Ma X**, Zhang W, Jiang Y, Wen J, Wei S, Zhao Y. Paeoniflorin, a Natural Product With Multiple Targets in Liver Diseases-A Mini Review. *Front Pharmacol* 2020; **11**: 531 [PMID: 32410996 DOI: 10.3389/fphar.2020.00531]

70 **Masci A**, Carradori S, Casadei MA, Paolicelli P, Petralito S, Ragno R, Cesa S. Lycium barbarum polysaccharides: Extraction, purification, structural characterisation and evidence about hypoglycaemic and hypolipidaemic effects. A review. *Food Chem* 2018; **254**: 377-389 [PMID: 29548467 DOI: 10.1016/j.foodchem.2018.01.176]

71 **Zhao XQ**, Guo S, Lu YY, Hua Y, Zhang F, Yan H, Shang EX, Wang HQ, Zhang WH, Duan JA. Lycium barbarum L. leaves ameliorate type 2 diabetes in rats by modulating metabolic profiles and gut microbiota composition. *Biomed Pharmacother* 2020; **121**: 109559 [PMID: 31734581 DOI: 10.1016/j.biopha.2019.109559]

72 **Feng M**, Liu F, Xing J, Zhong Y, Zhou X. Anemarrhena saponins attenuate insulin resistance in rats with high-fat diet-induced obesity *via* the IRS-1/PI3K/AKT pathway. *J Ethnopharmacol* 2021; **277**: 114251 [PMID: 34052350 DOI: 10.1016/j.jep.2021.114251]

73 **Kang JH**, Song KH, Woo JK, Park MH, Rhee MH, Choi C, Oh SH. Ginsenoside Rp1 from Panax ginseng exhibits anti-cancer activity by down-regulation of the IGF-1R/Akt pathway in breast cancer cells. *Plant Foods Hum Nutr* 2011; **66**: 298-305 [PMID: 21748437 DOI: 10.1007/s11130-011-0242-4]

74 **Ding L**, Yang Q, Zhang E, Wang Y, Sun S, Yang Y, Tian T, Ju Z, Jiang L, Wang X, Wang Z, Huang W, Yang L. Notoginsenoside Ft1 acts as a TGR5 agonist but FXR antagonist to alleviate high fat diet-induced obesity and insulin resistance in mice. *Acta Pharm Sin B* 2021; **11**: 1541-1554 [PMID: 34221867 DOI: 10.1016/j.apsb.2021.03.038]

75 **Bai L**, Gao J, Wei F, Zhao J, Wang D, Wei J. Therapeutic Potential of Ginsenosides as an Adjuvant Treatment for Diabetes. *Front Pharmacol* 2018; **9**: 423 [PMID: 29765322 DOI: 10.3389/fphar.2018.00423]

76 **Qu Y**, Wang Z, Zhao F, Liu J, Zhang W, Li J, Song Z, Xu H. AFM-detected apoptosis of hepatocellular carcinoma cells induced by American ginseng root water extract. *Micron* 2018; **104**: 1-7 [PMID: 29049926 DOI: 10.1016/j.micron.2017.10.003]

77 **Jafari F**, Jafari M, Moghadam AT, Emami SA, Jamialahmadi T, Mohammadpour AH, Sahebkar A. A Review of Glycyrrhiza glabra (Licorice) Effects on Metabolic Syndrome. *Adv Exp Med Biol* 2021; **1328**: 385-400 [PMID: 34981491 DOI: 10.1007/978-3-030-73234-9\_25]

78 **Chen J**, Jin X, Chen J, Liu C. Glycyrrhiza polysaccharide induces apoptosis and inhibits proliferation of human hepatocellular carcinoma cells by blocking PI3K/AKT signal pathway. *Tumour Biol* 2013; **34**: 1381-1389 [PMID: 23580179 DOI: 10.1007/s13277-013-0746-7]

**Footnotes**

**Institutional review board statement:** This study was approved by the Institutional Review Board of China Medical University Hospital Research Ethics Committee, No. CMUH109-REC2-031 (CR-3).

**Informed consent statement:** In the study, all available data were extracted from NHIRD. All records and personal information were anonymized prior to analysis, thus the requirement for written informed consent was waived.

**Conflict-of-interest statement:** All the authors report no relevant conflicts of interest for this article.

**Data sharing statement:** The datasets generated for this study are available upon request by the corresponding authors at sheng.teng@yahoo.com.

**STROBE statement:** The authors have read the STROBE Statement-checklist of items, and the manuscript was prepared and revised according to the STROBE Statement-checklist of items.

**Open-Access:** This article is an open-access article that was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution NonCommercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: https://creativecommons.org/Licenses/by-nc/4.0/

**Provenance and peer review:** Unsolicited article; Externally peer reviewed.

**Peer-review model:** Single blind

**Peer-review started:** October 10, 2023

**First decision:** December 6, 2023

**Article in press:**

**Specialty type:** Oncology

**Country/Territory of origin:** Taiwan

**Peer-review report’s scientific quality classification**

Grade A (Excellent): 0

Grade B (Very good): B

Grade C (Good): C, C

Grade D (Fair): 0

Grade E (Poor): 0

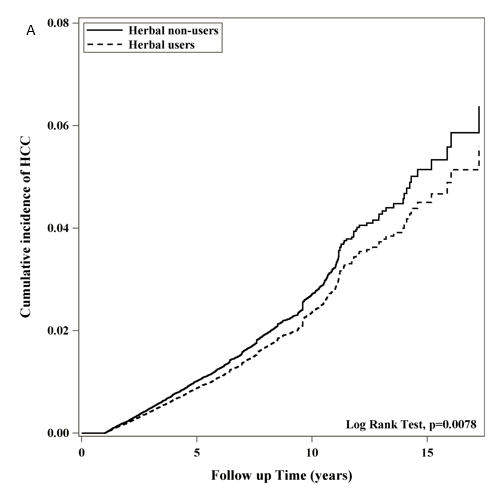
**P-Reviewer:** Li YW, China; Shi YJ, China; Yang ZG, China **S-Editor:** Li L **L-Editor:** Kerr C **P-Editor:**

**Figure Legends**

图示

描述已自动生成

**Figure 1 Flow chart of study enrolment.** NHIRD: National Health Insurance Research Database; HCC: Hepatocellular carcinoma; DM: Diabetes mellitus.

 图表, 图示

描述已自动生成

**Figure 2** **Kaplan–Meier analysis.** A: Kaplan–Meier analysis shows lower cumulative incidence of liver cancer in regular herb users compared to nonusers in diabetes mellitus patients with insulin management during follow-up; B: Kaplan–Meier analysis shows longer survival in regular herb users compared to nonusers in diabetes mellitus patients with insulin control who had hepatocellular carcinoma in our study population. HCC: Hepatocellular carcinoma.

图示

描述已自动生成

**Figure 3 Network analysis of the top thirty most prescribed herbs and formulas.** The spot size indicates the frequency of Chinese herbal product prescription, and the line width indicates the combination frequency between two Chinese herbal products.

**Table 1 Baseline characteristics and comorbidities for herb nonusers and herb users in diabetes mellitus patients with regular insulin management in Taiwan between 2000 and 2017**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variables** | **DM patients with regular insulin use** | | | | **SMD** |
| **Herb non-users, *n* = 140547** | | **Herb users, *n* = 46849** | |
| ***n*** | **%** | ***n*** | **%** |
| Sex |  |  |  |  | 0.014 |
| Female | 71872 | 51.14 | 24288 | 51.84 |  |
| Male | 68675 | 48.86 | 22561 | 48.16 |  |
| Age, yr |  |  |  |  |  |
| 20-40 | 11623 | 8.27 | 4160 | 8.88 | 0.022 |
| 40-60 | 55239 | 39.30 | 18684 | 39.88 | 0.012 |
| > 60 | 73685 | 52.43 | 24005 | 51.24 | 0.024 |
| Mean (SD) | 59.47 (13.25) | | 59.11 (13.38) | | 0.027 |
| Comorbidities |  |  |  |  |  |
| Hypertension | 107255 | 76.31 | 35223 | 75.18 | 0.026 |
| Coronary heart disease | 60016 | 42.70 | 19862 | 42.40 | 0.006 |
| Ischemic stroke | 32117 | 22.85 | 10366 | 22.13 | 0.017 |
| Hemorrhagic stroke | 3418 | 2.43 | 1146 | 2.45 | 0.001 |
| Hyperlipidemia | 114028 | 81.13 | 37707 | 80.49 | 0.016 |
| Renal insufficiency | 24394 | 17.36 | 7823 | 16.70 | 0.018 |
| Cirrhosis | 4952 | 3.52 | 1847 | 3.94 | 0.022 |
| Alcoholic liver damage | 10313 | 7.34 | 3386 | 7.23 | 0.004 |
| Nonalcoholic fatty liver disease | 12398 | 8.82 | 4178 | 8.92 | 0.003 |
| HBV infection | 9560 | 6.80 | 3472 | 7.41 | 0.024 |
| HCV infection | 5770 | 4.11 | 2107 | 4.50 | 0.019 |
| Medication |  |  |  |  |  |
| Lipid-lowering drug |  |  |  |  |  |
| Statin | 8217 | 5.85 | 2766 | 5.90 | 0.003 |
| Non-statin | 13990 | 9.95 | 4299 | 9.18 | 0.026 |
| Aspirin | 4890 | 3.48 | 1559 | 3.33 | 0.008 |
| HBV treatment | 1947 | 1.39 | 696 | 1.49 | 0.008 |
| HCV treatment | 451 | 0.32 | 192 | 0.41 | 0.015 |
| OAD |  |  |  |  |  |
| Biguanides | 9142 | 6.50 | 3054 | 6.52 | 0.001 |
| Sulfonamide | 8855 | 6.30 | 2914 | 6.22 | 0.003 |
| AGI | 22759 | 16.19 | 7829 | 16.71 | 0.014 |
| Thiazolidinediones | 20022 | 14.25 | 7325 | 15.64 | 0.039 |
| DPP4 inhibitors | 14313 | 10.18 | 5648 | 12.06 | 0.060 |
| GLP-1 receptor agonist | 2982 | 2.12 | 1359 | 2.90 | 0.050 |
| SGLT2 inhibitors | 8376 | 5.96 | 3639 | 7.77 | 0.072 |
| Glinide | 25298 | 18.00 | 8886 | 18.97 | 0.025 |
| Insulin dose (mg), mean (SD) | 9449.92 (135.59) | | 8248.88 (115.34) | | 0.071 |

AGI: α-Glucosidase inhibitors; DPP4: Dipeptidyl peptidase 4; GLP-1: Glucagon-like peptide-1; HBV: Hepatitis B virus; HCV: Hepatitis B virus; OAD: Oral antidiabetic agents; DM: Diabetes mellitus; SGLT2: Sodium-glucose co-transporter 2; SMD: Standard mean difference.

**Table 2 Incidence rates of liver cancer, stratified by sex, age, comorbidities and medications, and comparing herb nonusers with herb users in diabetes mellitus patients with insulin management**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variables** | **HCC** | | | **cHR** | **(95%CI)** | ***P* value** | **aHR1** | **(95%CI)** | ***P* value** |
| ***n*** | **PY** | **IR** |
| Herb non-users | 1487 | 771295 | 1.93 | 1.00 | (Ref.) |  | 1.00 | (Ref.) |  |
| Herb users | 639 | 309158 | 2.07 | 1.04 | (0.94, 1.14) | 0.461 | 0.88 | (0.80, 0.97)b | 0.001 |
| Sex |  |  |  |  |  |  |  |  |  |
| Female | 799 | 573926 | 1.39 | 1.00 | (Ref.) |  | 1.00 | (Ref.) |  |
| Male | 1327 | 506527 | 2.62 | 1.93 | (1.77, 2.10)c | < 0.001 | 1.77 | (1.62, 1.94)c | < 0.001 |
| Age, yr |  |  |  |  |  |  |  |  |  |
| 20-40 | 24 | 100697 | 0.24 | 1.00 | (Ref.) |  | 1.00 | (Ref.) |  |
| 40-60 | 777 | 469199 | 1.66 | 7.01 | (4.67, 10.52)c | < 0.001 | 5.59 | (3.71, 8.40)c | < 0.001 |
| > 60 | 1325 | 510557 | 2.60 | 11.80 | (7.90, 17.73)c | < 0.001 | 11.19 | (7.43, 16.86)c | < 0.001 |
| Comorbidities |  |  |  |  |  |  |  |  |  |
| Hypertension | 1653 | 798612 | 2.07 | 1.29 | (1.16, 1.43)c | < 0.001 | 1.10 | (0.98, 1.23) | 0.046 |
| Coronary heart disease | 954 | 443562 | 2.15 | 1.19 | (1.09, 1.29)c | < 0.001 | 1.07 | (0.97, 1.17) | 0.052 |
| Ischemic stroke | 457 | 217351 | 2.10 | 1.14 | (1.02, 1.26)a | 0.016 | 0.98 | (0.88, 1.09) | 0.948 |
| Hemorrhagic stroke | 45 | 20459 | 2.20 | 1.21 | (0.90, 1.62) | 0.210 | 1.09 | (0.81, 1.48) | 0.400 |
| Hyperlipidemia | 1502 | 875554 | 1.72 | 0.57 | (0.52, 0.62)c | < 0.001 | 0.67 | (0.61, 0.74)c | < 0.001 |
| Renal insufficiency | 300 | 146465 | 2.05 | 1.15 | (1.01, 1.30)a | 0.030 | 0.92 | (0.81, 1.04) | 0.326 |
| Cirrhosis | 574 | 29944 | 19.17 | 14.20 | (12.91, 15.65)c | < 0.001 | 4.28 | (3.80, 4.82)c | < 0.001 |
| Alcoholic liver damage | 264 | 67522 | 3.91 | 2.24 | (1.97, 2.55)c | < 0.001 | 1.08 | (0.94, 1.25) | 0.165 |
| Nonalcoholic fatty liver disease | 244 | 90700 | 2.69 | 1.42 | (1.25, 1.63)c | < 0.001 | 1.24 | (1.09, 1.42)b | < 0.001 |
| HBV infection | 647 | 68514 | 9.44 | 6.61 | (6.03, 7.25)c | < 0.001 | 2.59 | (2.32, 2.90)c | < 0.001 |
| HCV infection | 592 | 39215 | 15.10 | 10.60 | (9.68, 11.71)c | < 0.001 | 4.56 | (4.09, 5.08)c | < 0.001 |
| Medication |  |  |  |  |  |  |  |  |  |
| lipid-lowering drug |  |  |  |  |  |  |  |  |  |
| Statin | 108 | 63427 | 1.70 | 0.85 | (0.70, 1.04) | 0.112 | 0.88 | (0.70, 1.11) | 0.313 |
| Non-statin | 169 | 106674 | 1.58 | 0.78 | (0.67, 0.92)b | 0.002 | 0.86 | (0.73, 1.01) | 0.124 |
| Aspirin | 64 | 35231 | 1.82 | 0.93 | (0.73, 1.20) | 0.590 | 0.75 | (0.56, 1.01) | 0.050 |
| HBV treatment | 324 | 13557 | 23.90 | 14.70 | (13.05, 16.54)c | < 0.001 | 3.69 | (3.21, 4.25)c | < 0.001 |
| HCV treatment | 71 | 3899 | 18.21 | 9.20 | (7.26, 11.66)c | < 0.001 | 1.47 | (1.14, 1.88)b | 0.012 |
| OAD |  |  |  |  |  |  |  |  |  |
| Biguanides | 168 | 68930 | 2.44 | 1.27 | (1.08, 1.48)b | 0.003 | 1.16 | (0.84, 1.61) | 0.368 |
| Sulfonamide | 166 | 66481 | 2.50 | 1.30 | (1.11, 1.52)b | 0.001 | 1.08 | (0.78, 1.50) | 0.676 |
| AGI | 379 | 175908 | 2.15 | 1.12 | (1.00, 1.25) | 0.052 | 0.93 | (0.83, 1.06) | 0.475 |
| Thiazolidinediones | 344 | 161421 | 2.13 | 1.09 | (0.97, 1.23) | 0.134 | 1.07 | (0.95, 1.21) | 0.197 |
| DPP4 inhibitors | 289 | 119437 | 2.42 | 1.26 | (1.11, 1.42)c | < 0.001 | 1.15 | (0.99, 1.32) | 0.085 |
| GLP-1 receptor agonist | 14 | 27416 | 0.51 | 0.25 | (0.15, 0.42)c | < 0.001 | 0.40 | (0.24, 0.68)c | < 0.001 |
| SGLT2 inhibitors | 88 | 76062 | 1.16 | 0.56 | (0.45, 0.69)c | < 0.001 | 0.79 | (0.64, 0.98)a | 0.010 |
| Glinide | 418 | 195582 | 2.14 | 1.11 | (1.00, 1.24) | 0.051 | 0.93 | (0.82, 1.04) | 0.222 |

a*P* < 0.05.

b*P* < 0.01.

c*P* < 0.001.

1adjusted by variables in Table 1.

AGI: α-Glucosidase inhibitors; aHR: Adjusted hazard ratio; cHR: Crude hazard ratio; DPP4: Dipeptidyl peptidase 4; GLP-1: Glucagon-like peptide-1; HBV: Hepatitis B virus; HCC: Hepatocellular carcinoma; HCV: Hepatitis B virus; IR: Incidence rate per 1000 person-years; N: Number of events; OAD: Oral antidiabetic agents; PY: Person-years; SGLT2: Sodium-glucose co-transporter 2.

**Table 3 Risk of hepatocellular carcinoma stratified by the duration of herb use compared with nonherb use**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Variables** | **HCC** | | | **cHR** | **(95%CI)** | ***P* value** | **aHR1** | **(95%CI)** | ***P* value** |
| ***n*** | **PY** | **IR** |
| Herb non-users | 1487 | 771295 | 1.93 | 1.00 | (Ref.) |  | 1.00 | (Ref.) |  |
| Herb users |  |  |  |  |  |  |  |  |  |
| < 1 yr | 181 | 89349 | 2.03 | 1.04 | (0.89, 1.22) | 0.610 | 0.88 | (0.76, 1.03) | 0.074 |
| 1-2.9 yr | 171 | 81924 | 2.09 | 1.05 | (0.9, 1.24) | 0.514 | 0.92 | (0.78, 1.08) | 0.169 |
| 3-4.9 yr | 87 | 39932 | 2.18 | 1.09 | (0.88, 1.35) | 0.450 | 0.94 | (0.76, 1.17) | 0.436 |
| ≥ 5 yr | 200 | 97953 | 2.04 | 0.99 | (0.86, 1.15) | 0.943 | 0.82 | (0.71, 0.95)a | 0.003 |

a*P* < 0.05.

1adjusted by variables in Table 1.

AHR: Adjusted hazard ratio; cHR: Crude hazard ratio; HCC: Hepatocellular carcinoma; IR: Incidence rate pre 1000 person-years; *n*: Number of events; PY: Person-years.

**Table 4 Possible pharmacological effects of the ingredients in the top 10 herbs and formulas**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Possible pharmacological effects of the ingredients** | **Average daily dose (g)** | **No. of persons-dosage** | **Frequency (%)** | **aHR1** | **(95%CI)** | ***P* value** |
| Single Herbs: Pin-yin name/Latin name |  |  |  |  | 1.00 | (Ref.) |  |
| Da Huang/*Rheum palmatum L* | Reduces oxidative stress, inhibits β-cell apoptosis and improves β-cell function[28]; Activates AMP-Activated Protein Kinase and improves glucose tolerance[37]; Ameliorates insulin resistance *via* reducing FATP1-mediated skeletal muscle lipid accumulation[38]; Inhibits HCC *via* inhibiting STAT 3 signaling pathway[39] | 1 | 1060286 | 109102 (15.25) | 0.83 | (0.7, 0.98)a | 0.013 |
| Dan Shen/*Salvia miltiorrhiza Bunge* | Reduces oxidative stress and inhibits apoptosis and inflammation *via* the regulation of Wnt/β-catenin, TSP-1/TGF-β1/STAT3, JNK/PI3K/Akt, TGF-β1/NF-κB, AMPK/ACC, signaling pathways in DM model[40]. Inhibits IGF-1[31,32]. Inhibits HCC *via* modulating PI3K/Akt, MAPK and JAK/STAT3 signaling pathways[41] | 1.9 | 2162061 | 107301 (15.00) | 0.87 | (0.76, 1.00)a | 0.0123 |
| Huang Qi/*Astragalus propinquus* | Protects pancreatic β cells from apoptotic death[29]. Regulates resistin (an insulin-resistance protein)[29]. Ameliorates insulin resistance[42]. Induces apoptosis in HCC *via* decreasing the expression of Notch 1[43]. Inhibits HCC *via* repression of M2 polarization of tumor-associated macrophages[44] | 2.2 | 2188885 | 94799 (13.25) | 0.87 | (0.75, 1.01) | 0.0183 |
| Tian Hua Fen/*Trichosanthes kirilowii Maxim* | Ameliorates insulin resistance *via* decreasing the expression of PTGS2, NF-κB, JNK, and AKT[45]. Stimulates insulin receptor kinase activity and enhances glucose clearance[46]. Inhibits HCC cell proliferation *via* blocking PKM2-dependent glycolysis[47] | 2.2 | 1787396 | 77376 (10.81) | 0.83 | (0.71, 0.97)a | 0.0027 |
| Yan Hu Suo/*Corydalis yanhusuo* | Induces autophagy in HCC *via* activating the AMPK-mTOR-ULK1 and the ROS-JNK-ATG cascade and impairing the ERK/AKT signaling pathway[26] | 1.8 | 925275 | 62808 (8.78) | 0.89 | (0.77, 1.03) | 0.0496 |
| Ge Gen/*Pueraria montana var. lobata* | Elevates insulin expression and enhances insulin sensitivity index[48]. Ameliorates insulin resistance[49]. Inhibits HCC invasion and metastasis *via* miR-21-mediated PTEN/AKT signaling pathway[50] | 1.8 | 1032475 | 62061 (8.67) | 0.86 | (0.73, 1.00) | 0.0128 |
| Xuan Shen/*Scrophularia ningpoensis Hemsl* | Improves insulin sensitivity *via* AMPK-mediated NLRP3 inflammasome inhibition[51, 52] | 2.2 | 1099700 | 52418 (7.33) | 0.79 | (0.67, 0.94)b | 0.002 |
| Huang Chin/*Scutellaria baicalensis Georgi* | Regulates IGF-1R/AKT signaling pathway[53]. Ameliorates insulin resistance *via* inhibiting macrophage-mediated inflammation[54]. Elevates AMPK expression[34]. Modulates gut microbiota[34]. Inhibits HCC *via* affecting p53 signal pathway, MAPK signal pathway, apoptosis pathway, T cell receptor pathway, and macrophage-mediated tumor immunity[55] | 1.9 | 852156 | 50546 (7.06) | 0.93 | (0.80, 1.09) | 0.2098 |
| Mai Men Dong/*Ophiopogon japonicus (Thunb.) Ker Gawl* | Ameliorates insulin resistance *via* InsR/IRS-1/PI3K/Akt/GSK-3/Glut-4 signalling pathway[56]. Modulates gut microbiota[35]. Inhibits HCC *via* downregulating PTP1B expression, thereby inactivating the PI3K/AKT pathway and activating the AMPK pathway[57] | 2.3 | 1064080 | 49974 (6.98) | 0.88 | (0.75, 1.04) | 0.0429 |
| Hou Po/*Magnolia officinalis* | Decreases IGF-1 and IGFBP-5[33]. Protects pancreatic β-cells[30]. Inhibits HCC *via* AKT inhibition[58] | 2.1 | 946453 | 49148 (6.87) | 0.84 | (0.70, 1.01) | 0.0232 |
| Herbal Formula: Pin-yin name/Latin name |  |  |  |  |  |  |  |
| Ji Sheng Shen Qi Wan | Ameliorates insulin resistance[59]. Inhibits HCC development[60] | 6.9 | 6239325 | 87687 (15.62) | 0.82 | (0.71, 0.96)a | 0.0026 |
| Liu Wei Di Huang Wan | Ameliorates insulin resistance *via* antioxidative effect and supressing inflammation[61]. Induces apoptosis in HCC[62] | 8.6 | 6803688 | 78029 (13.90) | 0.83 | (0.72, 0.96)a | 0.0022 |
| Shu Jing Huo Xie Tang | Ameliorates insulin resistance[63]. Inhibits HCC *via* regulating iron metabolism[64] | 7.8 | 3550686 | 56106 (10.00) | 0.86 | (0.74, 1.00)a | 0.0152 |
| Xue Fu Zhu Yu Tang | Ameliorates insulin resistance, inflammation and oxidative stress[65]. Inhibits angiogenesis in HCC *via* blocking ERK/MAPK and NF-κB signalling pathway[66] | 6.4 | 3466030 | 55091 (9.81) | 0.80 | (0.68, 0.94)b | 0.0025 |
| Jia Wei Xiao Yao San | Ameliorates insulin resistance[67]. Induces apoptosis in HCC[68]. Inhibits invasion and metastasis in HCC[69] | 7.7 | 3823372 | 51350 (9.15) | 0.92 | (0.78, 1.08) | 0.1529 |
| Qi Ju Di Huang Wan | Ameliorates insulin resistance[70]. Modulates gut microbiota[71]. Inhibits HCC *via* inducing p53-mediated apoptosis and inhibiting proliferation[62] | 7.7 | 4309801 | 50271 (8.96) | 0.83 | (0.68, 1.00)a | 0.0219 |
| Ma Zi Ren Wan | Reduces oxidative stress, inhibits β-cell apoptosis and improves β-cell function[28]. Inhibits HCC *via* AKT inhibition[58] | 5 | 2609093 | 50100 (8.93) | 0.87 | (0.70, 1.08) | 0.1288 |
| Zhi Bai Di Huang Wan | Ameliorates insulin resistance *via* IRS-1/PI3K/AKT pathway[72]. Modulates gut microbiota[36]. Induces autophagy and apoptosis in HCC[27] | 7.1 | 3557458 | 46284 (8.25) | 1.05 | (0.89, 1.23) | 0.9271 |
| Bai Hu Jia Ren Shen Tang | Inhibits IGF-1R/Akt pathway[73]. Ameliorates insulin resistance[74,75]. Induces apoptosis in HCC[76] | 8.4 | 4051247 | 43451 (7.74) | 0.79 | (0.65, 0.96)a | 0.0043 |
| Zhi Gan Cao Tang | Decreases blood glucose[77]; Ameliorates insulin resistance[77]; Induces apoptosis and inhibits proliferation in HCC *via* blocking PI3K/AKT signal pathway[78] | 5.9 | 2423303 | 42951 (7.65) | 0.77 | (0.63, 0.93)b | 0.0042 |

a*P* < 0.05.

b*P* < 0.01.

1adjusted by variables in Table 1.

ACC: Acetyl-CoA carboxylase; aHR: Adjusted hazard ratio; AMP: Adenosine monophosphate; AMPK: Adenosine monophosphate-activated protein kinase; ERK: Extracellular signal-regulated kinase; FATP1: Fatty acid transport protein 1; GLUT-4: Glucose transporter type 4; IGF-1: Insulin-like growth factor 1; IGFBP-5: Insulin-like growth factor binding protein-5; IRS-1: Insulin receptor substrate 1; JAK: Janus-activated kinase; JNK: C-Jun N-terminal kinases; MAPK: Mitogen-activated protein kinase; mTOR: Mammalian target of rapamycin; NF-κB: Nuclear factor kappa B; NLRP3: NLR family pyrin domain containing 3; Notch 1: Neurogenic locus notch homolog protein 1; PI3K: Phosphatidylinositol-3-kinase; PKM2: Pyruvate kinase M2; PTEN: Phosphatase and tensin homolog; PTGS2: Prostaglandin-endoperoxide synthase 2; PTP1B: Protein-tyrosine phosphatase 1B; ROS: Reactive oxygen species; STAT3: Signal transducer and activator of transcription 3 ; TGF-β1: Transforming growth factor beta-1; TSP1: Thrombospondin-1; ULK1: Unc-51-like kinase 1; HCC: Hepatocellular carcinoma; DM: Diabetes mellitus.