**Name of Journal:** *World Journal of Gastroenterology*

**Manuscript NO:** 50861

**Manuscript Type:** MINIREVIEWS

**Severe liver injury due to herbal and dietary supplements and the role of liver transplantation**

Grewal P *et al*. HDS liver injury

Priya Grewal, Jawad Ahmad

**Priya Grewal,** **Jawad Ahmad,** Division of Liver Diseases, Icahn School of Medicine at Mount Sinai, New York, NY 10029, United States

**ORCID number:** Priya Grewal (0000-0001-7820-9769); Jawad Ahmad (0000-0003-1384-2349).

**Author contributions:** All authors contributed to the collection of clinical data, data analysis, and initial and final drafting of the manuscript.

**Conflict-of-interest statement:** Authors declare no conflict of interests for this article.

**Open-Access:** This article is an open-access article which was selected by an in-house editor and fully peer-reviewed by external reviewers. It is distributed in accordance with the Creative Commons Attribution Non Commercial (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: <http://creativecommons.org/licenses/by-nc/4.0/>

**Manuscript source:** Invited Manuscript

**Corresponding author: Jawad Ahmad, FAASLD, FRCP (Hon), MD, Professor,** Division of Liver Diseases, Icahn School of Medicine at Mount Sinai, One Gustave L. Levy Place, New York, NY10029, United States. jawad.ahmad@mountsinai.org

**Telephone:** +1**-**212-2418035

**Fax:** +1**-**212-7317340

**Received:** August 12, 2019

**Peer-review started:** August 12, 2019

**First decision:** September 10, 2019

**Revised:** November 26, 2019

**Accepted:** November 29, 2019

**Article in press:** November 29, 2019

**Published online:** December 14,2019

**Abstract**

Herbal and dietary supplements (HDS) are increasingly used worldwide for numerous, mainly unproven health benefits. The HDS industry is poorly regulated compared to prescription medicines and most products are easily obtainable. Drug induced liver injury (DILI) is a well-recognized entity associated with prescription and over the counter medications and many reports have emerged of potential HDS-related DILI. There is considerable geographic variability in the risk and severity of DILI associated with HDS but the presentation of severe liver injury is similar with a hepatocellular pattern accompanied by jaundice. This type of injury can lead to acute liver failure and the need for liver transplantation. Patients will often fail to mention their use of HDS, considering it natural and therefore harmless. Hence physicians should understand that these products can be associated with DILI and explicitly ask about HDS use in any patient with otherwise unexplained acute liver injury.

**Key words:** Herbal and dietary supplements; Drug induced liver injury; Liver transplantation; Acute liver failure; Geographic variability

**© The Author(s) 2019.** Published by Baishideng Publishing Group Inc. All rights reserved.

**Core tip:** Herbal and dietary supplements (HDS) are used globally for their purported health benefits. Drug induced liver injury (DILI) is a well-recognized entity associated with all types of medications including HDS. There is considerable geographic variability in the use of HDS which is reflected in the risk of DILI associated with HDS. This article reviews severe liver injury due to HDS with an emphasis on geographic differences and injury requiring liver transplantation. Physicians should understand that HDS, despite being described as “natural” remedies and therefore assumed to be safe, can be associated with severe DILI.

Grewal P, Ahmad J.Severe liver injury due to herbal and dietary supplements and the role of liver transplantation**.** *World J Gastroenterol* 2019; 25(46): 6704-6712

**URL:** https://www.wjgnet.com/1007-9327/full/v25/i46/6704.htm

**DOI:** https://dx.doi.org/10.3748/wjg.v25.i46.6704

**INTRODUCTION**

The appeal and use of herbal and dietary supplements (HDS) are increasing worldwide. These supplements come with a promise to improve and maintain many intangible aspects of the overall quality of life including energy, memory, longevity, mood, and self-image. While the proposed health benefits of such products are not supported by scientific data, their harmful effects specifically on the liver are well reported. For the purpose of this review, HDS refers to all products which have previously been named as traditional, alternative or complementary in the West and Unani, Ayurveda, Kampo, and Traditional Chinese Medicine in Africa and Asia. This review will provide an overview of landmark studies on severe drug induced liver injury (DILI) caused by HDS use in various regions of the world. Major trends will be summarized, including issues in interpretation and comparison of global data, liver transplantation (LT) in this population, and the need for physicians to be aware of the possibility of HDS use in patients with unexplained acute liver injury.

**HDS USE**

In the United States, the sale of HDS is a lucrative multibillion-dollar industry with nearly 80000 different supplements sold[1]. The 2-year National Health and Nutrition Examination Survey (2007-2008) revealed that 50% of adult Americans were using HDS[2]. In recent years, HDS use has increased to 64%-69% of the population[3]. In Europe, HDS use was highest in the United Kingdom (41%)[4] but other European countries including Finland, Germany, Romania, Italy, and Spain estimated an overall use of 18.8% with the highest rate in Italy (22.7%) and the lowest in Finland (9.6%)[5] (Table 1). In densely populated regions of the world, such as Africa, Asia and Latin America, nearly 80% of the population uses HDS for their medical ailments[6]. Patients do not disclose HDS use to their physicians, as they assume that they are harmless. As people move across the world, they carry with them their cultural belief in HDS, contributing to the rising prevalence of HDS use in Western countries. These products are very appealing because they are easily accessible through the internet, often cheap and require no prescription or monitoring by a physician.

**WORLDWIDE MAGNITUDE OF SEVERE LIVER INJURY CAUSED BY HDS USE**

While the estimated incidence of severe DILI from HDS use in prospective studies ranges up to 3 individuals per 100000/year in the West the rates are higher in Asia[7] although information on the proportion of patients developing DILI from HDS use is difficult to determine because the actual number of the users is not always clear.

However, data from the Spanish DILI registry over the past 22 years have revealed that the hepatocellular pattern associated with DILI due to HDS use is marked by very high alanine aminotransferase values, predicting severe outcomes including death or need for LT[8]. By the same token, a United States registry study reported higher transplantation rates and lower survival among patients with DILI caused by HDS relative to prescription drugs[9].

**THE EUROPEAN EXPERIENCE**

***Spain***

A decade ago, 2% of DILI cases were attributed to HDS use[10]. More recently, the Spanish DILI registry (1994-2016) reported that HDS use was responsible for 4% of DILI cases, while only 2% were caused by anabolic androgenic steroids. Patients with HDS use were mainly female and usually less than 50 years of age. The pattern of liver injury was predominantly hepatocellular with 78% of the patients presenting with jaundice and 6% progressed to acute liver failure (ALF) (Table 2). Most HDS products were used for weight loss (47%). The most commonly used products were *Herbalife* (multi-ingredient) and green tea extract (GTE). Alarmingly, 9% of the patients inadvertently took the HDS product again because the first instance of hepatoxicity was incorrectly attributed to an innocent bystander drug; consequently, most of these patients were readmitted after the rechallenge[8].

***Iceland***

In a prospective study, the annual incidence of DILI over the 2-year study period (2010-2011) was reported as 19.1 cases per 100,000 inhabitants and 16% of these were attributed to HDS use. Similar to Spain, the most common HDS associated with DILI were *Herbalife* products (33%) and GTE (camellia sinensis) in 27%. The pattern of DILI from HDS was again predominantly hepatocellular. While most patients were symptomatic, only 26% were jaundiced[11].

***France***

Perhaps the most robust data on the incidence of DILI was reported in a French study that used a population based approach where 34 cases of DILI were noted in more than 80000 individuals over a 3 year period, giving a crude annual incidence of 14 per 100000[12]. However, in reviewing the 34 cases, all were from prescription or over the counter medications and there were no cases from HDS. This study was from the late 1990s when DILI from HDS was not as well described. A recent study of 808 patients listed for LT due to ALF noted acetaminophen as the cause in 22% but toxins and other drugs comprised 14% and 28% of all cases were undetermined, undoubtedly some from HDS related DILI[13]. Multiple cases of acute liver injury have been described with the use of various HDS in France[14,15], including green tea extract[16] and germander (Teucrium chamaedrys)[17].

**THE ASIAN EXPERIENCE**

***South Korea***

A prospective study over 2 years (2005-2007) across 17 university hospitals in Korea reported a total of 371 cases of DILI (based on the Roussel Uclaf Causality Assessment Method criteria), with an annual incidence of 12 cases/100000 persons. Whileprescription or non-prescription medications accounted for 27% of cases, the rest were attributed to HDS, including herbal medications, folk remedies and health foods or supplements. The median age of this cohort was 49 years, and the majority of patients were female. The pattern of liver injury was 76.3% hepatocellular, 14.8% mixed, and 8.9% cholestatic. Among the 5 patients (1.8%) who died or underwent LT, 4 were due to HDS. Twenty five cases (21 HDS and 4 medications) were excluded from the study due to missing information on previous HDS and the exact timing of use likely underestimating the actual incidence of DILI from HDS. Hence, the authors proposed that in patients with DILI from HDS a more specific and reproducible tool for causality assessment is necessary[7].

***Japan***

Among the 1676 cases of DILI in Japan from 1997-2006 reviewed retrospectively, 17.1% were related to dietary supplements and Chinese herbal drugs. The diagnostic scale used to adjudicate cases was postulated by the Digestive Disease Week-Japan (DDW-J) 2004 workshop[18]. Most of the patients were middle-aged females with a predominantly hepatocellular pattern of injury. Interestingly, severe liver injury leading to death or LT was rare among HDS users (1.2%), relative to prescription drug users (4.2%)[19].

***India***

A large single center retrospective analysis of 313 DILI cases over a 12-year period (1997-2008) reported an overall mortality of 17.3%, primarily related to use of anti-tuberculosis medications. Only, 1.3% cases were attributed to HDS, mainly Ayurvedic medications. Notwithstanding, half of the patients with HDS related DILI died. The authors postulated that despite the rising popularity of HDS in India, they are increasingly taken after the onset of jaundice from viral hepatitis which may contribute to the increased mortality noted. Also, more so than hepatitis, patients present with constitutional and neurological symptoms due to heavy metal contamination of HDS with lead and arsenic[20].

***China***

A recent review of nearly 26000 confirmed DILI cases; hospitalized from 2012-2014 at approximately 300 medical centers in mainland China were analyzed. Most cases of DILI presented with hepatocellular injury (51%). The major classes of implicated drugs were traditional Chinese medicines (27%) followed by medications for tuberculosis (22%). Only 1% of DILI cases associated with HDS progressed to hepatic failure. However, among the 72 who died only from DILI, HDS was the leading culprit (35%)[21].

A retrospective analysis of 279 studies on DILI involving 24000 patients over a 17-year period (1994-2011) reported that HDS were the second leading cause of DILI (18%) after anti-tuberculosis drugs. Most cases were male (54%), older than 40 years, and 58% had a hepatocellular pattern of injury. The overall mortality in the group was 2.9%. The most frequently implicated drugs were *Xiao He Pian*, Common three-wing-nut root (*Lei Gong Teng*), Polygonum multiflorum (*He Shou Wu*) Radix Trichosanthis (*Tian Hua Fen*) and *Zhuang Gu Guan Jie Wan*[22].

A study from 7 tertiary hospitals in China over 5 years (2007-2012) reported on the etiology of ALF in China with particular focus on cases attributed to traditional Chinese medications. Of the 177 patients with DILI, 112 (63.28%) eventually died. The most common cause of ALF was drug toxicity (43.50%), with traditional Chinese herbs responsible for approximately 26% of cases. No patients in this study underwent LT. The authors concluded that traditional Chinese medicine was an important and under recogonized cause of ALF in China, accompanied by a high mortality[23]. Among the 30 patients with ALF from traditional Chinese medications, most were women (80%) in their 30’s, with hepatocellular pattern of injury and rapid development of hepatic encephalopathy. Nine patients (30%) were using HDS for their skin disorders. More than half the patients eventually died in the absence of LT which was not performed at their treating hospitals[24]. In a review of 145 cases with DILI from Polygonum multiflorum, 23% had underlying liver disease, mainly from alcohol. When compared to patients without preexisting liver disease, these patients had much higher risk of mortality (9.1% vs 0.9%) and likelihood of developing chronicity[25].

**THE UNITED STATES EXPERIENCE**

In earlier studies (1998-2001) from the Acute Liver Failure Study Group (ALFSG), which analyzed 308 ALF cases, 17% had an indeterminate cause of liver failure that the authors speculated was likely related to a drug, possibly HDS not revealed during history, or a hepatotropic virus. This group had a less than 20% transplant free survival rate[26].

A subsequent analysis by the ALFSG group of 1198 cases over a 10.5 year period classified 11.1% as idiosyncratic DILI. Of these, 70% of patients with idiosyncratic DILI were women, of which 27% belonged to minorities. Amongst the DILI cases, 10.6% were determined to be HDS users and continued to show a poor transplant free survival (21.4%)[27].As the awareness of DILI from HDS has increased in recent years, the AFLSG now reports an increasing contribution of HDS as the etiology of ALF, up from 12.4% in the earlier cohort (1998-2007) to 21.1% in the more recent cohort (2007-2015). The predominant HDS were “muscle builders” and “fat burners” hence the patients were mostly male. While the hepatocellular pattern of injury was comparable in all respects to ALF from prescription medications the HDS group had a lower alkaline phosphatase. However significantly more patients in the HDS group needed LT (56% *vs* 32%) and had a lower transplant free survival (25% *vs* 38%). The authors concluded that while the use of HDS is severely underreported, the minority of patients who present with ALF due to HDS tend to have a more severe presentation and higher mortality in the absence of LT and should be referred to a transplant center promptly. Thus, in the United States, patients with HDS use make up about 10%-20% cases of DILI related ALF, do poorly without transplant and end up utilizing this scarce resource[9].

In the United States DILI Network (DILIN), 85 patients with DILI from HDS, excluding body building supplements, were mostly middle-aged females with predominantly hepatocellular pattern of liver injury and marked ALT elevations. There was a higher percentage of HDS patients that underwent LT (13%) compared to 3% in the group that used conventional medications[28].

A review of the Scientific Registry of Transplant Recipients (2003-2015) examining patients transplanted for acute hepatic necrosis of the liver revealed that 21/625 (3%) of DILI was caused by HDS. Most patients were young women transplanted after 2007 with excellent survival. However, 25% of all LT cases (2408) lacked a specific cause for liver failure and 20% of all drug-induced liver failure did not specify the incriminating drug, suggesting that HDS maybe responsible for many more ALF cases needing transplant[29].

**LT FOR HDS RELATED LIVER INJURY**

The role of LT for DILI related to HDS is very similar to other causes of fulminant hepatic failure (FHF) since the presentation is almost always acute and occurs in patients without underlying liver disease. There are scarce reports of chronic DILI due to HDS that can evolve into an injury that ultimately requires LT such as vanishing bile duct syndrome[30]. Although the data is limited, it does appear that severe liver injury due to HDS requiring LT is on the increase.

A recent report examined the characteristics of patients listed for LT in the United States using the status-1 designation which is mainly used for patients with FHF and how it has evolved over time[31]. Interestingly they found that the proportion of LTs performed for status-1 decreased in the period 2009-2015 compared to 2003-2009 although the proportion of DILI related FHF cases did not change. However, there was a more than 2-fold increase in the cases of FHF due to HDS that were listed as status-1 in the later period 2009-2015.

An earlier study looked at FHF due to DILI from a population perspective and noted that it is an uncommon event but it was not generally due to prescription medicines. Of the 32 cases of FHF they found, 18 (56%) were due to acetaminophen, 8 due to prescription medicines (25%) and 6 were due to HDS (19%), but the non-acetaminophen cases were more likely to be fatal or require LT[32].

Several case series have demonstrated the risk of FHF from HDS used for weight loss. The 2 most prominent examples are GTE[33,34] and OxyElite Pro[35,36] which in the latter case led to legal ramifications with 5 individuals and 2 companies pleading guilty to felony charges with the FDA in the United States emphasizing they would continue to aggressively investigate and prosecute companies involved in the sale of mislabeled and potentially unsafe dietary supplements.

The DILIN in the United States described 6 cases of acute liver injury due to “SLIMQUICK”, a line of proprietary weight loss products, comprised of multiple ingredients[33]. All the patients were female and taking the products for weight loss. They all presented with an acute hepatitis and 3 patients were hospitalized with 1 requiring LT. Reviewing the SLIMQUICK preparations, GTE and/or its component catechins were the common ingredient, along with caffeine and extracts of several fruit, vegetable and plant products. The typical presentation of GTE related DILI was also observed in the 19 cases reported by Mazzanti *et al*[34] with the majority women taking the products for weight loss with an acute hepatitis after short or long latency and 4 patients requiring LT.

The case of OxyElite Pro led to investigation by the federal government in the United States and guilty pleas from the manufacturers who admitted to several charges including fraudulent labeling and the finding of 1,3-dimethylamylamine (DMAA) in the product- an additive that was banned by the FDA in 2013[37]. This product was sold as a weight loss and exercise supplement and was associated with multiple cases of FHF all occurring about the same time with multiple fatalities. Independently, the United States military described 7 cases, 2 of which required LT[35]; 8 cases reported in Hawaii with 2 undergoing LT[36], and the DILIN reported 7 cases with 2 requiring LT[38]. All the cases clustered in 2013 and OxyElite Pro was withdrawn from the market (but not before a total of 43 cases of DILI were observed in Hawaii). The actual ingredient that likely caused the liver injury was unclear and may not have been DMAA but rather aegeline, a compound extracted from a plant used in Ayurvedic medicine, Aegle marmelos (bael), with reported beneficial effects on blood sugar and lipids.

The development of FHF has been described with multiple HDS but the need for LT has recently been shown for patients that develop a chronic biliary type injury due to drugs or HDS. The DILIN described 26 patients who developed a vanishing bile duct syndrome associated with DILI with 5 fatalities and another 2 patients requiring LT. The majority of the 26 cases were due to prescription medications but 3 cases were associated with HDS[30].

**KEY TAKEAWAYS**

HDS use is rising across different regions of the world. HDS use in the Far East is upwards of 70% while usage in the West is not far behind. While the HDS contributing to DILI are different, the pattern of injury is usually hepatocellular affecting mostly young women. Approximately 1% of patients will develop severe liver injury leading to death or the need for LT. Acute liver failure study groups across the globe report that 20%-40% of ALF from DILI is a result of HDS use. Information on the proportion of patients developing DILI from HDS use is difficult to determine because the actual number of the users is not always clear.

**BARRIERS TO MAKING GLOBAL COMPARISONS**

Firstly, the regulation of HDS products varies considerably across the world. In the United States, herbs are defined as dietary supplements and undergo less strict regulation relative to prescription drugs. The LiverTox website is a good reference source of reported hepatoxicity related to HDS[39]. Moreover, under the 1994 Dietary Supplement Health and Education Act (DSHEA), 21 herbs are defined as dietary supplements. Unlike conventional drugs, which are required by the Food and Drug Administration to undergo well-designed clinical studies to prove efficacy and safety before marketing, HDS products can be marketed without these requirements.

On the other hand, in Europe, HDS may be labelled either as a dietary supplement or a medicinal product. While the traditional herbal medicinal products are regulated in the European Union, the lack of regulation for “natural” dietary supplemental products, along with the limited awareness among physicians and patients has led to a rise in severe liver injury cases. Additionally, statistics on DILI cases attributable to HDS do no always tell the whole story. For instance, HDS use is much higher in the East, but the reported incidence of severe DILI is not correspondingly that much higher than the rest of the world. This is likely due to the issue of under-reporting and the fact that clinicians are not the sole providers of healthcare. Traditional healers may be an avenue through which patients are receiving not only their HDS but also their medical care. Furthermore, the higher mortality rate in Asia is not necessarily a reflection of greater severity. Rather, it probably reflects lower access to hospitalization and LT.

**CONCLUSION**

HDS use is rising across different regions of the world. HDS use in the Far East is upwards of 70% while usage in the West is not far behind. While the HDS contributing to DILI are different, the pattern of injury is usually hepatocellular affecting mostly young women. Approximately 1% of patients will develop severe liver injury leading to death or the need for LT. Acute liver failure study groups across the globe report that 20%-40% of ALF from DILI is a result of HDS use. Information on the proportion of patients developing DILI from HDS use is difficult to determine because the actual number of the users is not always clear.

Physicians should be aware of the typical clinical presentation of severe DILI from HDS use. It is characterized by a female predominance and an acute hepatocellular injury with markedly elevated serum aminotransferases and bilirubin. Most patients are otherwise healthy, hence HDS use should be suspected particularly in this group. Severe HDS induced liver injury is prone to unintentional re-challenge, and portends a greater risk of death or need for LT. An accurate history of HDS use can be difficult to obtain, in particular in patients that are taking multiple HDS products simultaneously or intermittently. Interactions between common drugs and HDS can also occur, increasing the possibility of toxicity. HDS are also susceptible to adulteration, contamination, rebranding or mislabeling which can further delay the diagnosis and prompt discontinuation of the incriminating HDS product in patients presenting with acute liver injury. Heightened awareness among physicians is crucial in reducing severe liver injury and liver failure from HDS.

**REFERENCES**

1 **FDA Statement: Statement from FDA Commissioner Scott Gottlieb,** M.D., on the agency’s new efforts to strengthen regulation of dietary supplements by modernizing and reforming FDA’s oversight, 2019

2 **Kennedy ET**, Luo H, Houser RF. Dietary supplement use pattern of U.S. adult population in the 2007-2008 National Health and Nutrition Examination Survey (NHANES). *Ecol Food Nutr* 2013; **52**: 76-84 [PMID: 23282192 DOI: 10.1080/03670244.2012.706000]

3 **Dickinson A,** Blatman J, El-Dash N, Franco JC. Consumer usage and reasons for using dietary supplements: report of a series of surveys. *J Am Coll Nutr* 2014; **33**: 176-182 [PMID: 24724775 DOI: 10.1080/07315724.2013.875423]

4 **Posadzki P**, Watson LK, Alotaibi A, Ernst E. Prevalence of use of complementary and alternative medicine (CAM) by patients/consumers in the UK: systematic review of surveys. *Clin Med (Lond)* 2013; **13**: 126-131 [PMID: 23681857 DOI: 10.7861/clinmedicine.13-2-126]

5 **Garcia-Alvarez A**, Egan B, de Klein S, Dima L, Maggi FM, Isoniemi M, Ribas-Barba L, Raats MM, Meissner EM, Badea M, Bruno F, Salmenhaara M, Milà-Villarroel R, Knaze V, Hodgkins C, Marculescu A, Uusitalo L, Restani P, Serra-Majem L. Usage of plant food supplements across six European countries: findings from the PlantLIBRA consumer survey. *PLoS One* 2014; **9**: e92265 [PMID: 24642692 DOI: 10.1371/journal.pone.0092265]

6 **Ekor M**. The growing use of herbal medicines: issues relating to adverse reactions and challenges in monitoring safety. *Front Pharmacol* 2014; **4**: 177 [PMID: 24454289 DOI: 10.3389/fphar.2013.00177]

7 **Suk KT**, Kim DJ, Kim CH, Park SH, Yoon JH, Kim YS, Baik GH, Kim JB, Kweon YO, Kim BI, Kim SH, Kim IH, Kim JH, Nam SW, Paik YH, Suh JI, Sohn JH, Ahn BM, Um SH, Lee HJ, Cho M, Jang MK, Choi SK, Hwang SG, Sung HT, Choi JY, Han KH. A prospective nationwide study of drug-induced liver injury in Korea. *Am J Gastroenterol* 2012; **107**: 1380-1387 [PMID: 22733303 DOI: 10.1038/ajg.2012.138]

8 **Medina-Caliz I**, Garcia-Cortes M, Gonzalez-Jimenez A, Cabello MR, Robles-Diaz M, Sanabria-Cabrera J, Sanjuan-Jimenez R, Ortega-Alonso A, García-Muñoz B, Moreno I, Jimenez-Perez M, Fernandez MC, Ginés P, Prieto M, Conde I, Hallal H, Soriano G, Roman E, Castiella A, Blanco-Reina E, Montes MR, Quiros-Cano M, Martin-Reyes F, Lucena MI, Andrade RJ; Spanish DILI Registry. Herbal and Dietary Supplement-Induced Liver Injuries in the Spanish DILI Registry. *Clin Gastroenterol Hepatol* 2018; **16**: 1495-1502 [PMID: 29307848 DOI: 10.1016/j.cgh.2017.12.051]

9 **Hillman L**, Gottfried M, Whitsett M, Rakela J, Schilsky M, Lee WM, Ganger D. Clinical Features and Outcomes of Complementary and Alternative Medicine Induced Acute Liver Failure and Injury. *Am J Gastroenterol* 2016; **111**: 958-965 [PMID: 27045922 DOI: 10.1038/ajg.2016.114]

10 **García-Cortés M**, Borraz Y, Lucena MI, Peláez G, Salmerón J, Diago M, Martínez-Sierra MC, Navarro JM, Planas R, Soria MJ, Bruguera M, Andrade RJ. [Liver injury induced by "natural remedies": an analysis of cases submitted to the Spanish Liver Toxicity Registry]. *Rev Esp Enferm Dig* 2008; **100**: 688-695 [PMID: 19159172 DOI: 10.18632/oncotarget.7352]

11 **Björnsson ES**, Bergmann OM, Björnsson HK, Kvaran RB, Olafsson S. Incidence, presentation, and outcomes in patients with drug-induced liver injury in the general population of Iceland. *Gastroenterology* 2013; **144**: 1419-1425, 1425.e1-3; quiz e19-20 [PMID: 23419359 DOI: 10.1053/j.gastro.2013.02.006]

12 **Sgro C**, Clinard F, Ouazir K, Chanay H, Allard C, Guilleminet C, Lenoir C, Lemoine A, Hillon P. Incidence of drug-induced hepatic injuries: a French population-based study. *Hepatology* 2002; **36**: 451-455 [PMID: 12143055 DOI: 10.1053/jhep.2002.34857]

13 **Ichai P**, Legeai C, Francoz C, Boudjema K, Boillot O, Ducerf C, Mathurin P, Pruvot FR, Suc B, Wolf P, Soubrane O, Le Treut YP, Cherqui D, Hannoun L, Pageaux GP, Gugenheim J, Letoublon C, Saric J, Di Martino V, Abergel A, Chiche L, Antonini TM, Jacquelinet C, Castaing D, Samuel D; French Liver Transplant Teams. Patients with acute liver failure listed for superurgent liver transplantation in France: reevaluation of the Clichy-Villejuif criteria. *Liver Transpl* 2015; **21**: 512-523 [PMID: 25675946 DOI: 10.1002/lt.24092]

14 **Gaboriau L**, Boursier A, Béné J, Hassinet HR, Gautier S. [Herbal preparations can cause acute hepatitis?]. *Presse Med* 2016; **45**: 545-546 [PMID: 27016852 DOI: 10.1016/j.lpm.2016.02.015]

15 **Langrand J**, Regnault H, Cachet X, Bouzidi C, Villa AF, Serfaty L, Garnier R, Michel S. Toxic hepatitis induced by a herbal medicine: Tinospora crispa. *Phytomedicine* 2014; **21**: 1120-1123 [PMID: 24867504 DOI: 10.1016/j.phymed.2014.04.031]

16 **Gloro R**, Hourmand-Ollivier I, Mosquet B, Mosquet L, Rousselot P, Salamé E, Piquet MA, Dao T. Fulminant hepatitis during self-medication with hydroalcoholic extract of green tea. *Eur J Gastroenterol Hepatol* 2005; **17**: 1135-1137 [PMID: 16148563 DOI: 10.1097/00042737-200510000-00021]

17 **Larrey D**, Vial T, Pauwels A, Castot A, Biour M, David M, Michel H. Hepatitis after germander (Teucrium chamaedrys) administration: another instance of herbal medicine hepatotoxicity. *Ann Intern Med* 1992; **117**: 129-132 [PMID: 1605427 DOI: 10.7326/0003-4819-117-2-129]

18 **Takikawa H**, Onji M. A proposal of the diagnostic scale of drug-induced liver injury. *Hepatol Res* 2005; **32**: 250-251 [PMID: 16099713 DOI: 10.1016/j.hepres.2005.05.007]

19 **Takikawa H**, Murata Y, Horiike N, Fukui H, Onji M. Drug-induced liver injury in Japan: An analysis of 1676 cases between 1997 and 2006. *Hepatol Res* 2009; **39**: 427-431 [PMID: 19207579 DOI: 10.1111/j.1872-034X.2008.00486.x]

20 **Devarbhavi H**, Dierkhising R, Kremers WK, Sandeep MS, Karanth D, Adarsh CK. Single-center experience with drug-induced liver injury from India: causes, outcome, prognosis, and predictors of mortality. *Am J Gastroenterol* 2010; **105**: 2396-2404 [PMID: 20648003 DOI: 10.1038/ajg.2010.287]

21 **Shen T**, Liu Y, Shang J, Xie Q, Li J, Yan M, Xu J, Niu J, Liu J, Watkins PB, Aithal GP, Andrade RJ, Dou X, Yao L, Lv F, Wang Q, Li Y, Zhou X, Zhang Y, Zong P, Wan B, Zou Z, Yang D, Nie Y, Li D, Wang Y, Han X, Zhuang H, Mao Y, Chen C. Incidence and Etiology of Drug-Induced Liver Injury in Mainland China. *Gastroenterology* 2019; **156**: 2230-2241.e11 [PMID: 30742832 DOI: 10.1053/j.gastro.2019.02.002]

22 **Zhou Y**, Yang L, Liao Z, He X, Zhou Y, Guo H. Epidemiology of drug-induced liver injury in China: a systematic analysis of the Chinese literature including 21,789 patients. *Eur J Gastroenterol Hepatol* 2013; **25**: 825-829 [PMID: 23510965 DOI: 10.1097/MEG.0b013e32835f6889]

23 **Zhao P**, Wang C, Liu W, Wang F. Acute liver failure associated with traditional Chinese medicine: report of 30 cases from seven tertiary hospitals in China\*. *Crit Care Med* 2014; **42**: e296-e299 [PMID: 24335449 DOI: 10.1097/CCM.0000000000000136]

24 **Zhao P**, Wang C, Liu W, Chen G, Liu X, Wang X, Wang B, Yu L, Sun Y, Liang X, Yang H, Zhang F. Causes and outcomes of acute liver failure in China. *PLoS One* 2013; **8**: e80991 [PMID: 24278360 DOI: 10.1371/journal.pone.0080991]

25 **Jing J**, Wang RL, Zhao XY, Zhu Y, Niu M, Wang LF, Song XA, He TT, Sun YQ, Xu WT, Yu SM, Wang LP, Guo YM, Bai ZF, Xiao XH, Wang JB. Association between the concurrence of pre-existing chronic liver disease and worse prognosis in patients with an herb- *Polygonum multiflorum* thunb. induced liver injury: a case-control study from a specialised liver disease center in China. *BMJ Open* 2019; **9**: e023567 [PMID: 30782709 DOI: 10.1136/bmjopen-2018-023567]

26 **Ostapowicz G**, Fontana RJ, Schiødt FV, Larson A, Davern TJ, Han SH, McCashland TM, Shakil AO, Hay JE, Hynan L, Crippin JS, Blei AT, Samuel G, Reisch J, Lee WM; U.S. Acute Liver Failure Study Group. Results of a prospective study of acute liver failure at 17 tertiary care centers in the United States. *Ann Intern Med* 2002; **137**: 947-954 [PMID: 12484709 DOI: 10.7326/0003-4819-137-12-200212170-00007]

27 **Reuben A**, Koch DG, Lee WM; Acute Liver Failure Study Group. Drug-induced acute liver failure: results of a U.S. multicenter, prospective study. *Hepatology* 2010; **52**: 2065-2076 [PMID: 20949552 DOI: 10.1002/hep.23937]

28 **Navarro VJ**, Barnhart H, Bonkovsky HL, Davern T, Fontana RJ, Grant L, Reddy KR, Seeff LB, Serrano J, Sherker AH, Stolz A, Talwalkar J, Vega M, Vuppalanchi R. Liver injury from herbals and dietary supplements in the U.S. Drug-Induced Liver Injury Network. *Hepatology* 2014; **60**: 1399-1408 [PMID: 25043597 DOI: 10.1002/hep.27317]

29 **Wong LL**, Lacar L, Roytman M, Orloff SL. Urgent Liver Transplantation for Dietary Supplements: An Under-Recognized Problem. *Transplant Proc* 2017; **49**: 322-325 [PMID: 28219592 DOI: 10.1016/j.transproceed.2016.11.041]

30 **Bonkovsky HL**, Kleiner DE, Gu J, Odin JA, Russo MW, Navarro VM, Fontana RJ, Ghabril MS, Barnhart H, Hoofnagle JH; U.S. Drug Induced Liver Injury Network Investigators. Clinical presentations and outcomes of bile duct loss caused by drugs and herbal and dietary supplements. *Hepatology* 2017; **65**: 1267-1277 [PMID: 27981596 DOI: 10.1002/hep.28967]

31 **Wong LL**, Truong HP, Seto T, Lacar L, Naugler WE. Marked Decrease in Urgent Listing for Liver Transplantation Over Time: Evolution of Characteristics and Outcomes of Status-1 Liver Transplantation. *Transplantation* 2018; **102**: e18-e25 [PMID: 28968354 DOI: 10.1097/TP.0000000000001967]

32 **Goldberg DS**, Forde KA, Carbonari DM, Lewis JD, Leidl KB, Reddy KR, Haynes K, Roy J, Sha D, Marks AR, Schneider JL, Strom BL, Corley DA, Lo Re V 3rd. Population-representative incidence of drug-induced acute liver failure based on an analysis of an integrated health care system. *Gastroenterology* 2015; **148**: 1353-61.e3 [PMID: 25733099 DOI: 10.1053/j.gastro.2015.02.050]

33 **Zheng EX**, Rossi S, Fontana RJ, Vuppalanchi R, Hoofnagle JH, Khan I, Navarro VJ. Risk of Liver Injury Associated with Green Tea Extract in SLIMQUICK(®) Weight Loss Products: Results from the DILIN Prospective Study. *Drug Saf* 2016; **39**: 749-754 [PMID: 27189593 DOI: 10.1007/s40264-016-0428-7]

34 **Mazzanti G**, Di Sotto A, Vitalone A. Hepatotoxicity of green tea: an update. *Arch Toxicol* 2015; **89**: 1175-1191 [PMID: 25975988 DOI: 10.1007/s00204-015-1521-x]

35 **Foley S**, Butlin E, Shields W, Lacey B. Experience with OxyELITE pro and acute liver injury in active duty service members. *Dig Dis Sci* 2014; **59**: 3117-3121 [PMID: 24916713 DOI: 10.1007/s10620-014-3221-4]

36 **Roytman MM**, Pörzgen P, Lee CL, Huddleston L, Kuo TT, Bryant-Greenwood P, Wong LL, Tsai N. Outbreak of severe hepatitis linked to weight-loss supplement OxyELITE Pro. *Am J Gastroenterol* 2014; **109**: 1296-1298 [PMID: 25091255 DOI: 10.1038/ajg.2014.159]

37 “Five Individuals and Two Companies Plead Guilty to Felony Charges in Multimillion Dollar Scheme to Fraudulently Sell Popular Dietary Supplements.” The United States Department of Justice, 13 March 2019, Available from: [www.justice.gov/opa/pr/five-individuals-and-two-companies-plead-guilty-felony-charges-multimillion-dollar-scheme](http://www.justice.gov/opa/pr/five-individuals-and-two-companies-plead-guilty-felony-charges-multimillion-dollar-scheme)

38 **Heidemann LA**, Navarro VJ, Ahmad J, Hayashi PH, Stolz A, Kleiner DE, Fontana RJ. Severe Acute Hepatocellular Injury Attributed to OxyELITE Pro: A Case Series. *Dig Dis Sci* 2016; **61**: 2741-2748 [PMID: 27142670 DOI: 10.1007/s10620-016-4181-7]

39 “Search Livertox Database.” National Institutes of Health, U.S. Department of Health and Human Services, Available from: <http://livertox.nih.gov/>

**P-Reviewer:** Corrales FJ, Nakano H, Nishida T, Sergi C, Shi YJ **S-Editor:** Wang J

**L-Editor:** A **E-Editor:** Zhang YL

**Specialty type:** Gastroenterology and hepatology
**Country of origin:** United States
**Peer-review report classification**
**Grade A (Excellent):** 0
**Grade B (Very good):** B
**Grade C (Good):** C, C, C, C
**Grade D (Fair):** 0 **Grade E (Poor):** 0

|  |  |
| --- | --- |
| **Table 1 Use of herbal and dietary supplements in the United States and Europe (data from references 3-5)** |  |

|  |  |
| --- | --- |
| **Country** | **Estimated percentage of population using HDS** |
| United States | 64-69 |
| United Kingdom | 19.1 |
| Italy | 22.7 |
| Finland | 9.6 |
| Germany | 16.9 |
| Romania | 17.6 |
| Spain | 18.0 |

HDS: Herbal and dietary supplements.

**Table 2 Main herbal and dietary supplements used and their pattern of liver injury across the world**

|  |  |  |
| --- | --- | --- |
| **Country** | **HDS agent** | **Pattern of liver injury** |
| Spain | Herbalife productsGreenTea extract | Hepatocellular |
| Iceland  | Herbalife productsGreenTea extract | Hepatocellular |
| South Korea | Herbal medicationsFolk remedies | Hepatocellular |
| Japan  | Dietary supplementsChinese herbal medications | Hepatocellular |
| India | Ayurvedic medicationsHDS contaminated with arsenic and lead | Hepatocellular |
| China | Common three-wing-nut root, Polygonum multiflorum, Radix Trichosanthis | Hepatocellular |
| United States | Fat burnersSlimquickOxyProlite Pro | Hepatocellular |

HDS: Herbal and dietary supplements.