Clin Nutr Res. 2020 Apr;9(2):122-133
https://doi.org/10.7762/cnr.2020.9.2.122
pISSN 2287-3732·eISSN 2287-3740

CLINICAL NUTRITION RESEARCH

Original Article

Check for updates

Fructose Feeding and Hyperuricemia: a Systematic Review and Meta-Analysis

Kourosh Sayehmiri,[1] **Iraj Ahmadi**,[2] **Enayat Anvari**[2]

[1]Department of Social Medicine, Faculty of Medicine, Ilam University of Medical Sciences, Ilam 6931851147, Iran
[2]Department of Physiology, Faculty of Medicine, Ilam University of Medical Sciences, Ilam 6931851147, Iran

OPEN ACCESS

Received: Mar 3, 2020
Revised: Apr 11, 2020
Accepted: Apr 16, 2020

Correspondence to
Enayat Anvari
Department of Physiology, Faculty of Medicine, Ilam University of Medical Sciences, Ilam 6931851147, Iran.
E-mail: Anvari_ph@yahoo.com

ORCID iDs
Kourosh Sayehmiri
https://orcid.org/0000-0002-9742-770X
Iraj Ahmadi
https://orcid.org/0000-0001-9065-3088
Enayat Anvari
https://orcid.org/0000-0001-7508-071X

Funding
This work was supported by the deputy of research and technology of Ilam University of Medical Sciences, Ilam, under grant (No. 941015-33).

Conflict of Interest
The authors declare that they have no competing interests.

ABSTRACT

High fructose feeding has been suggested to involve in several features of metabolic syndrome including hyperuricemia (HP). We designed and implemented a study to determine the effect size of fructose intake and the relative risk of HP based on the type of fructose feeding (diet or solution), duration of treatment (2–6, 7–10, and > 10 weeks), and animal race. The required information was accepted from international databases, including PubMed/MEDLINE, Science Direct, Scopus, and etc., from 2009 until 2019 on the basis of predetermined eligibility criteria. The data selection and extraction and quality assessment were performed independently by two researchers. Results were pooled as random effects weighting and reported as standardized mean differences with 95% confidence intervals. Thirty-five studies including 244 rats with fructose consumption were included in the final analysis. The heterogeneity rate of parameters was high (I2 = 81.3%, p < 0.001) and estimated based on; 1) type of fructose feeding (diet; I2 = 79.3%, solution 10%; I2 = 83.4%, solution 20%; I2 = 81.3%), 2) duration of treatment (2–6 weeks; I2 = 86.8%, 7–10 weeks; I2 = 76.3%, and > 10 weeks; I2 = 82.8%), 3) the animal race (Wistar; I2 = 78.6%, Sprague-Dawley; I2 = 83.9%). Overall, the pooled estimate for the all parameters was significant (p < 0.001). The results of this study indicated that a significant relationship between HP and fructose intake regardless of the treatment duration, animal race, fructose concentration and route of consumption.

Keywords: Fructose; Rats; Uric acid; Hyperuricemia; Meta-analysis; Systematic review

INTRODUCTION

Over the past few decades, the mean serum uric acid (UA) level and prevalence of hyperuricemia (HP) appear to have increased in all individuals. The significant increase in sweetened sugary beverages and fructose intake coincides with the secular trend of HP [1]. HP has known as a serious risk factor for metabolic, cardiovascular and renal diseases. It also plays a role in the development of associated disorders with metabolic syndrome including diabetes, coronary artery disease and gout. Furthermore, in some studies it has been linked with premature mortality and its incidence has been rising during the last decades [1,2]. HP or excessive circulating urate concentration (higher or equal to 6.8 mg/dL), the end product

of purine metabolism, is an important risk factor for gout and plays a role in its pathogenesis [3,4]. This abnormality arises by high level formation of UA or reduced its excretion [2].

UA is synthesized in the liver, adipose and muscle tissue and is mostly excreted through the kidney. Several factors, such as high-fructose feeding and the using of xenobiotic and alcohol can be contributed to induction of HP [5].

Fructose is a simple sugar with 6 carbons similar to glucose, which differs in spatial pattern with glucose and is found in many fruits and vegetables [6]. It can cause several adverse effects including insulin resistance, dyslipidemia, oxidative stress, neuronal loss, and HP when used in high concentrations [7,8].

However, a meta-analysis of isocaloric replacement tests does not support the relationship between fructose and serum UA [9]. The role of fructose in all food sources as a risk factor for incidental HP remains unclear. In addition, there is a significant lack of meta-analysis studies evaluating the role of dietary fructose in the occurrence of metabolism disorders. The purpose of this study was to evaluate the systematic review and meta-analysis of the effect size of fructose intake and the relative risk (RR) of HP based on the route of fructose feeding (diet or solution 10% and 20%), duration of fructose consumption (2–6, 7–10, and > 10 weeks), and race of animal (Sprague-Dawley or Wistar rats).

MATERIALS AND METHODS

Study protocol

Current research is a systematic review and meta-analysis on the relationship between fructose intake and acid uric level by reviewing available studies. This study was conducted according to design of Meta-analysis in Observational Studies in Epidemiology protocol and their results reported according to preferred reporting items for systematic reviews and meta-analyses (PRISMA) guideline [10]. To avoid possible bias, search strategy, article selection, quality assessment and data extraction have been independently done by 2 researchers and agreement was reached on the obtained results with the help of a third researcher.

Search tactic

The required information was accepted from national databases, including Iranian Journal Database or Magiran (http://www.magiran.com/), Barakat Knowledge Network System (http://health.barakatkns.com), Scientific Information Database (http://www.sid.ir), Iranian National Library (http://www.nlai.ir/), Regional Information Center for Science and Technology (http://en.ricest.ac.ir/), Iranian Research Institute for Information Science and Technology (https://irandoc.ac.ir), and also international databases, including PubMed/MEDLINE, Science Direct, Embase, Scopus, Cochrane Library, Web of Science as well as the Google Scholar search engine from 2009 until 2019. To maximize the comprehensiveness of the search, Medical Subject Headings keywords such as “fructose feeding”, “fructose consumption”, “fructose intake”, “fructose”, “high fructose corn syrup” “uric acid”, “hyperuricemia”, “rats”, “humans” “mice” and “uricemia” were used. Previous review researches were also studied to identify other relevant articles. Combined search was performed with “and” and “or”.

https://doi.org/10.7762/cnr.2020.9.2.122

Inclusion and exclusion criteria

Inclusion criteria was done according to Population, Intervention, Comparison, and Outcome [11]: 1) Population: rat, mice and human with or without HP; 2) Intervention: consumption of fructose; 3) Comparison: variable aimed for serum UA level, gender, concentration of fructose intake, methods of consumption (solution or diet), duration of fructose intake and etc.; 4) Outcome: estimating the relationship of HP with fructose consumption.

The exclusion criteria were: 1) Fructose feeding with other sweeteners such as sucrose or glucose and in combination with fat; 2) Irrelevance; 3) Fructose feeding with injecting a drug such as alloxan, streptozotocin and etc. and 4) Review articles, case reports, letter to the editor and comments. For articles that the full text was not available, we requested the author for the full text of it.

Selection of articles

All studies that have been assessed the serum uric acid levels following fructose consumption were screened independently by 2 researchers; a list of titles and abstracts was first developed. Full text of articles submitted to researchers after concealing the characteristics of articles, including author(s) and journal name. Multiple publications from a similar research were considered as a one study. If a study was rejected, the reason was stated. A third researcher judged the article if they disagreed. For articles with incomplete information, we contacted the relevant author to provide information by email.

Quality assessment

Next, the selected research was evaluated using the modified Newcastle Ottawa Scale for non-randomized studies [12]. In the checklist, the lowest acceptable score was considered 4 and the studies that reached this score were included in the study.

Data extraction

All final papers in the study process were ready for extraction through a pre-prepared checklist. The checklist for the selected articles included the author's name, year of publication, location and duration of the study, sample size, concentration of fructose intake, and method of fructose consuming (as solution or diet forms).

Data analysis

The variance of the HP was estimated using binomial distribution. The odds ratio (OR) was used to assess the impact of gender (male to female ratio) on HP. According to Cochran's Handbook, heterogeneity between studies was assessed using Cochran Q test and I^2 index. However, for I^2 there are 3 categories: (0%–24% may not matter, 25%–75% shows moderate heterogeneity, and more than 75% indicates high heterogeneity) [13]. For combining data in low and high heterogeneity, were used fixed and random effect models, respectively [14]. Sensitivity analysis was performed with the exception of one study at a time to evaluate the combined strength of OR and 95% confidence interval (CI). To find out the reason for the heterogeneity between studies, subgroup analysis was performed based on duration and concentration of fructose intake, and meta-regression was used between concentration and duration of fructose intake with HP. Egger and Begg's test were used to evaluate the publication bias and was presented in the funnel plot design. Data analysis was done in STATA software version 11.1 and was shown through flowcharts, tables, OR, and funnel plots. A $p < 0.05$ were considered as the significance level.

https://doi.org/10.7762/cnr.2020.9.2.122

RESULTS

Search results

Totally, 1,034 articles were found in the systematic literature assessment. We dismissed 870 articles basis of title and abstract and the rest of studies (n = 164; 153 + 11) due to the following reasons; duplicate papers (n = 7; 164 − 7 = 157 remained), irrelevant records include the review articles, letter to the editor, low quality (n = 103; 157 − 103 = 54 remained), not related to UA measurement (n = 19; 54 − 19 = 35 remained). **Figure 1** shows the PRISMA diagram of our study. Finally, 35 studies entered the final review (**Figure 1**).

The association between the form of fructose intake and HP

The heterogeneity rate was high based on the method of consumed fructose (diet, solution 10% and 20%) (Diet: I^2 = 79.3%, p < 0.001; solution 10%: I^2 = 83.4%, p < 0.001; solution 20%: I^2 = 81.3%, p < 0.001). The overall pooled estimate of the association between fructose feeding and HP was significant (OR, 1.86; 95% CI, 2.38–1.33; p < 0.001) (**Figure 2**).

Sub-category analysis

Also, the heterogeneity rate was estimated based on the duration of fructose intake (2–6, 7–10, and > 10 weeks) (first: I^2 = 86.8%, p < 0.001; second: I^2 = 76.3%, p < 0.001; last: I^2 = 82.8%, p < 0.001). The overall pooled estimate of the association between duration of fructose consumption and HP was significant (OR, 1.86; 95% CI, 2.38–1.33; p < 0.001) (**Figure 2B**).

Finally, the heterogeneity rate was estimated based on the race of animal (Sprague-Dawley or Wistar rats) (Wistar: I^2 = 78.6%, p < 0.001; Sprague-Dawley: I^2 = 83.9%, p < 0.001). The

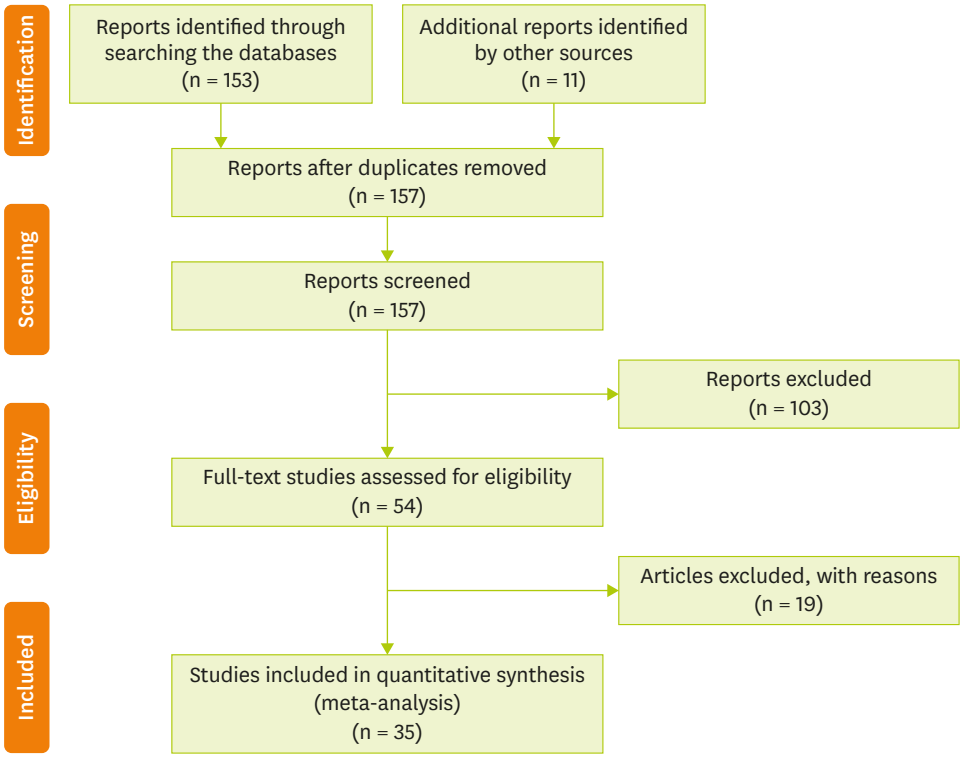

Figure 1. PRISMA flowchart.
PRISMA, preferred reporting items for systematic reviews and meta-analyses.

https://doi.org/10.7762/cnr.2020.9.2.122

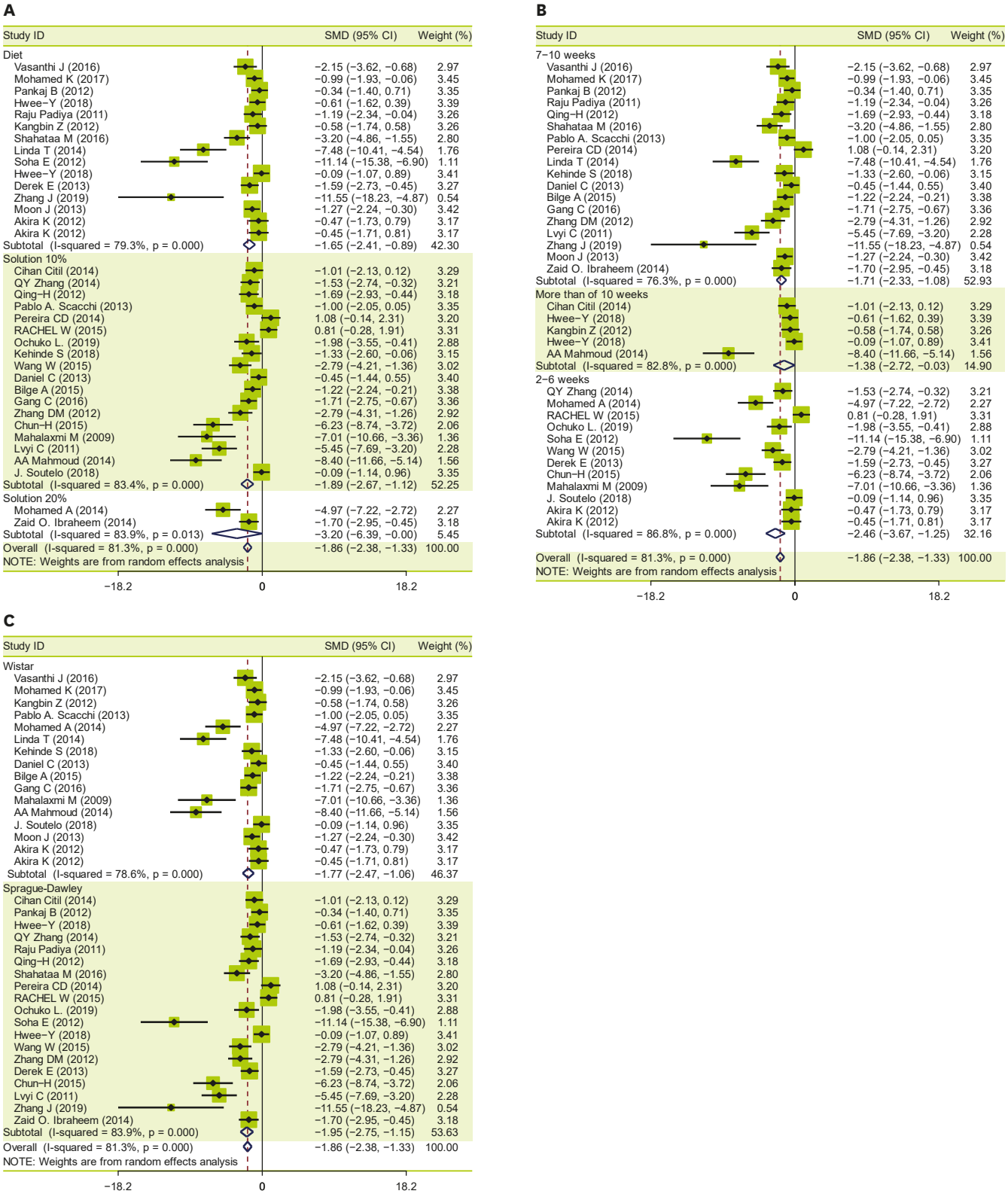

Figure 2. Fructose intake and the relative risk of HP base on the form of fructose feeding (diet, solution 10% and 20%) (A), duration of fructose consumption (2–6, 7–10, and > 10 weeks) (B), race of animals (Sprague-Dawley or Wistar rats) (C). Mean point of each part indicates the estimated OR, and the length of each part displays 95% CI in each study; the rhombic sign shows the OR in each study.
HP, hyperuricemia; OR, odds ratio; CI, confidence interval; SMD, standardized mean difference.

https://doi.org/10.7762/cnr.2020.9.2.122

overall pooled estimate of the association between race of animals and HP was significant (OR, 1.86; 95% CI, 2.38–1.33; p < 0.001) (**Figure 2C**). The cumulative analysis based on the author's name and year of publication also is shown (**Figure 3**).

Relationship between the duration and concentration of fructose treatment with HP using meta-regression

Between duration (p = 0.495) of fructose consumption with HP was not a significant association, while a significant association was observed between fructose concentration (p = 0.029) with HP (**Figure 4**).

Publication bias

Based on Egger's assay test, publication bias of the relationship between fructose consumption and HP was estimated. Visual inspection of the produced funnel design was used to interpret any publication bias between studies to evaluate symmetry. The funnel plot shows that an asymmetry under random-effects model representing the tendency to lower the standardized mean differences (**Figure 5**).

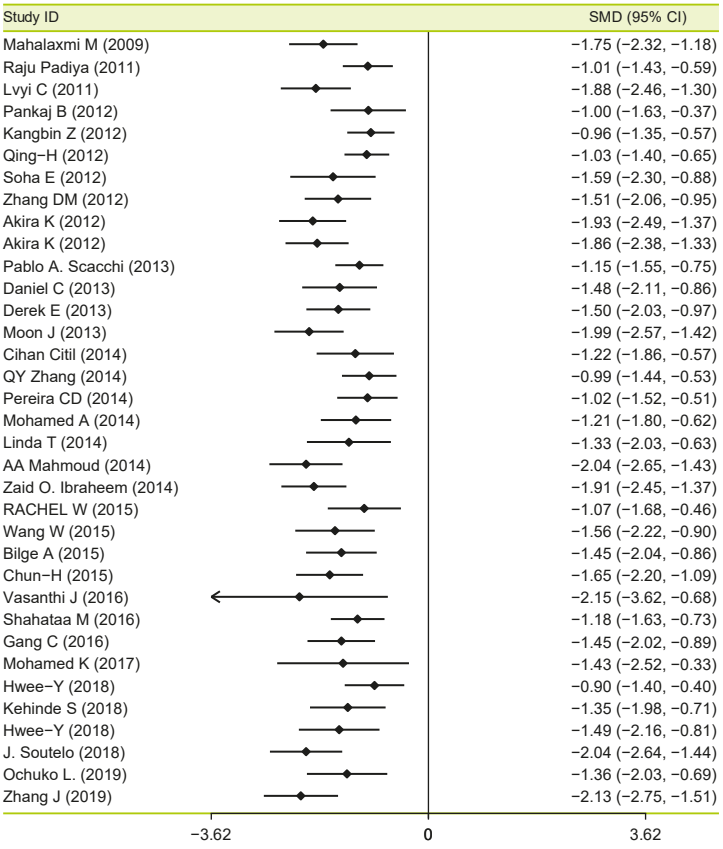

Figure 3. The cumulative analysis with a 95% CI based on the author's name and year of research according to the random effects model. The midpoint of each section shows the hyperuricemia incidence following fructose feeding in rats.
CI, confidence interval; SMD, standardized mean difference.

https://doi.org/10.7762/cnr.2020.9.2.122

Meta-regression
REML estimate of between-study variance
% residual variance due to heterogeneity
Proportion of between-study variance explained
With Knapp-Hartung modification

Number of objects = 35
τ = 4.53
I^2-res = 81.67%
Adj R-squared = −3.28%

ES	Coef.	SE	t	p > |t|	[95% CI]	
Duration	0.4620148	0.6697704	0.690	0.495	−0.9006433	1.824673
Concentration	−2.954535	1.294889	0.029	0.029	−5.589007	−0.3200632

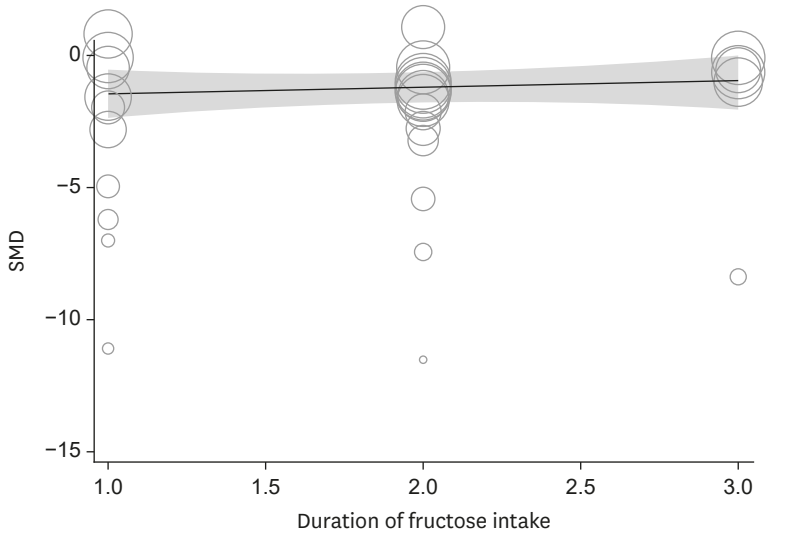

Figure 4. Relationship between the duration and concentration of fructose treatment with HP using meta-regression. It shows that there is no relationship between the duration of fructose feeding and its concentration (A) with HP (p = 0.495, p = 0.029 respectively). The size of the bubbles shows the precision of the studies.
CI, confidence interval; SE, standard error; HP, hyperuricemia; SMD, standardized mean difference; Coef, coefficient.

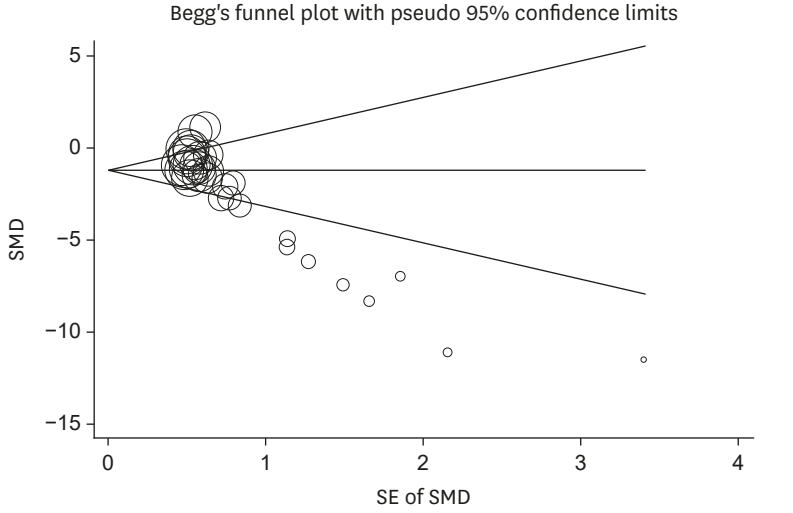

Figure 5. Publication bias in meta-analysis of studies regarding the relationship between hyperuricemia and fructose feeding. Visual inspection of the produced funnel design was used to interpret any publication bias between studies to evaluate symmetry. The funnel plot shows asymmetrical under random-effects model representing the tendency to lower the SMD.
SMD, standardized mean difference; SE, standard error.

https://doi.org/10.7762/cnr.2020.9.2.122

DISCUSSION

The aim of the present study was to assess the relationship between the effect size of fructose intake and the RR of HP based on several parameters including; the method of fructose feeding, duration of fructose treatment, and animal race (**Table 1**). After searching the related databases, 35 articles were entered in the final analysis with the overall OR of the relationship between fructose feeding and HP which was estimated 1.86 (95% CI, 1.33–2.38; p <0.001), representing the higher risk of HP following fructose intake (**Figure 2**). Rate of heterogeneity in our research was high (I^2 = 81.3%; p <0.001), which it may be related to the different duration of treatment and concentration of fructose intake; therefore, subgroup analysis was performed based on duration and concentration of fructose intake. In meta-regression analysis, was estimated the relationship between duration and concentration of fructose treatment with HP. Between duration (p = 0.495) of fructose consumption with HP was not a significant association, while a significant association was observed between fructose concentration (p = 0.029) with HP (**Figure 4**). It seems that an unknown defect may be the cause of this event.

Table 1. Detailed characteristics of 35 studies included in the systematic review on the fructose feeding and UA level measurement

Study	Year	Place	Concentration of fructose	Method of use	Duration in week	UA_c	UA_t	Sample size	Race	Sex
Zhang et al. [15]	2019	China	60	Diet	8	1.41 ± 0.07	2.97 ± 0.06	4	SD	M
Erukainure et al. [16]	2019	South Africa	10	Solution	2	2.46 ± 0.1	3.48 ± 0.31	5	SD	M
Ng et al. [17]	2018	Taiwan	60	Diet	13	0.72 ± 0.43	0.81 ± 0.24	8	SD	M
Ng et al. [17]	2018	Taiwan	60	Diet	21	0.72 ± 0.43	1.72 ± 0.69	8	SD	M
Olaniyi and Olatunji [18]	2018	Nigeria	10	Solution	8	3 ± 0.25	3.9 ± 0.3	6	Wis.	F
Soutelo et al. [19]	2018	Argentina	10	Solution	5	1.02 ± 0.03	1.03 ± 0.05	7	Wis.	F
Jayakumar et al. [20]	2016	India	60	Diet	8	12.05 ± 1.5	22.9 ± 2.48	6	Wis.	M
Chen Jia [21]	2016	China	10	Solution	8	2.4 ± 0.16	3.35 ± 0.19	10	Wis.	M
Shahata et al. [22]	2016	Egypt	60	Diet	8	1.41 ± 0.12	4.2 ± 0.45	7	SD	M
Ma et al. [23]	2015	China	10	Solution	4	2.98 ± 0.08	4.82 ± 0.12	8	SD	M
Wilson and Islam [24]	2015	South Africa	10	Solution	2	2.71 ± 0.41	1.9 ± 0.34	7	SD	M
Aygen et al. [25]	2015	Turkey	10	Solution	9	1.06 ± 0.1	1.64 ± 0.2	9	Wis.	M
Bernasconi et al. [26]	2013	Argentina	10	Solution	10	1.2 ± 0.3	2.2 ± 0.4	8	Wis.	M
Essawy et al. [27]	2014	Egypt	60	Diet	4	2 ± 0.1	8 ± 0.25	8	SD	M
Citil et al. [28]	2014	Turkey	10	Solution	13	6.8 ± 1.25	9.9 ± 1.07	7	SD	M
Ibraheem et al. [29]	2014	Malaysia	20	Solution	8	0.19 ± 0.02	0.28 ± 0.02	7	SD	M
Tran et al. [30]	2014	Canada	60	Diet	9	3.86 ± 0.17	9.41 ± 0.33	8	Wis.	M
Jung et al. [31]	2013	Korea	65	Diet	8	0.55 ± 0.018	0.64 ± 0.026	10	Wis.	M
Cardinali et al. [32]	2013	Argentina	10	Solution	8	1.7 ± 0.1	1.9 ± 0.2	8	Wis.	M
Erion et al. [33]	2013	USA	67	Diet	4	2.18 ± 0.21	3.02 ± 0.16	8	SD	M
Kitagawa et al. [34]	2012	Japan	60	Diet	4	0.19 ± 0.01	0.21 ± 0.025	5	Wis.	M
Kitagawa et al. [34]	2012	Japan	60	Diet	6	0.19 ± 0.01	0.2 ± 0.01	5	Wis.	M
Padiya et al. [35]	2011	India	65	Diet	8	1.9 ± 0.2	3.1 ± 0.5	7	SD	M
Chen et al. [36]	2011	China	10	Solution	8	2.21 ± 0.07	3.63 ± 0.11	8	SD	M
Hu et al. [37]	2012	China	10	Solution	8	2.33 ± 0.19	3.9 ± 0.46	7	SD	M
Mohan et al. [38]	2009	India	10	Solution	6	2.42 ± 0.07	3.96 ± 0.12	5	Wis.	M
Bagul et al. [39]	2012	India	65	Diet	8	1.9 ± 0.25	2.5 ± 0.9		SD	M
Kelany et al. [40]	2017	Egypt	65	Diet	8	1.81 ± 0.28	5.28 ± 1.54	10	Wis.	M
Zhou et al. [41]	2012	Canada	60	Diet	13	0.2 ± 0.03	0.7 ± 0.5	6	Wis.	M
Pereira et al. [42]	2014	Portugal	10	Solution	8	6.14 ± 0.66	4.72 ± 0.37	6	SD	M
Ibrahim et al. [43]	2014	Egypt	20	Solution	6	3.39 ± 0.27	7.43 ± 0.34	7	Wis.	M
Wang et al. [44]	2015	China	10	Solution	6	2.44 ± 0.19	4.11 ± 0.23	8	SD	M
Zhang et al. [45]	2012	China	10	Solution	8	1.94 ± 0.04	2.85 ± 0.17	7	SD	M
Zhang et al. [46]	2014	China	10	Solution	6	1.85 ± 0.24	3.7 ± 0.6	7	SD	M
Mahmoud and Elshazly [47]	2014	Egypt	10	Solution	12	0.37 ± 0.07	2.42 ± 0.1	8	Wis.	M

Data are shown as mean ± standard error or number (%).
SD, Sprague-Dawley; M, male, F, female; Wis., Wistar; UA_c, uric acid in control group; UA_t, uric acid in fructose treated group.

https://doi.org/10.7762/cnr.2020.9.2.122

Based on the egger's test and funnel plot in our study, was found an asymmetry under random-effects model and a considerable effect for publication bias, suggesting that several studies may not have been published with significant effect yet (**Figure 5**).

The present data was in consistent with the results of a meta-analysis by Jamnik et al. [3] that had shown the effect of fructose consumption on HP in human. Their report were includes two studies with 125299 participants and 1533 incident gout cases. In that study, the correlation between fructose feeding with gout was evaluated in a 17-year follow-up, showed that an enhancement in the risk of gout (RR, 1.62; 95% CI, 1.28–2.03; p <0.001).

In line with the present study, Ebrahimpour-Koujan et al. [48] also showed the effect of sugar sweetened beverages (SSB) and fructose feeding with the risk of HP in adult humans. It showed that the SSB intake was associated with 35% greater odds of HP (summary effect size, 1.35; 95% CI, 1.19–1.52).

Also, Bomback et al. [49] reported a relationship between sugar-sweetened soda intake and prevalence of HP, but not significant. This inconsistency might be due to the difference in research population, study design and gender of subjects [49].

It is known that fructose feeding could induce UA synthesis through increasing of ATP decomposition as a precursor of UA. ATP depletion can also occur due to the conversion of fructose into fructose mono phosphate and subsequent activation of AMP deaminase, nucleotide turnover and subsequent UA generation. Increased insulin level following fructose intake has also been shown to raise of urate reuptake and reduce the excretion of UA in kidney [1].

Due to hepatic metabolism of fructose, fat accumulation occurs in the liver. Perhaps, this disrupts the beta oxidation of hepatic fatty acids and rises of de novo lipogenesis. Some studies have shown that an increased expression of keto-hexokinase (fructo-kinase C) plays a major role in hepatic fat accumulation through a reduction of ATP, UA generation and nucleotide modification [7,50,51].

We restricted our analysis to reports of animal. As a result, because of the incompatibility between human's parameters with animal, it may have led to decrease the number of studies that were available for inclusion.

In the present study, the amount of fructose consumption by animals has been neglected. Therefore, the increase of uric acid level may be related to the amount of consumed fructose (fructose entering the body/day), not the concentration and duration of consumption.

CONCLUSION

Results of the current meta-analysis study showed that there is a significant relationship between fructose feeding and HP regardless of the time duration of treatment, animal race, concentration and method of fructose consumption. Further researches are needed to assess the relationship between dietary fructose intake and risk of HP according to the amount of fructose consumption.

https://doi.org/10.7762/cnr.2020.9.2.122

REFERENCES

1. Rho YH, Zhu Y, Choi HK. The epidemiology of uric acid and fructose. Semin Nephrol 2011;31:410-9.
PUBMED | CROSSREF
2. Zhu Y, Peng X, Ling G. An update on the animal models in hyperuricaemia research. Clin Exp Rheumatol 2017;35:860-4.
PUBMED
3. Jamnik J, Rehman S, Blanco Mejia S, de Souza RJ, Khan TA, Leiter LA, Wolever TM, Kendall CW, Jenkins DJ, Sievenpiper JL. Fructose intake and risk of gout and hyperuricemia: a systematic review and meta-analysis of prospective cohort studies. BMJ Open 2016;6:e013191.
PUBMED | CROSSREF
4. Jiao H, Hua Y, Yedan L, Sijia M, Weibo C, Xiaomeng L, Chen J, Zhang L. Establishment of rat models for screening slow-acting drugs of hyperuricemia. Int J Clin Exp Med 2018;11:830-9.
5. Lima WG, Martins-Santos ME, Chaves VE. Uric acid as a modulator of glucose and lipid metabolism. Biochimie 2015;116:17-23.
PUBMED | CROSSREF
6. Ferder L, Ferder MD, Inserra F. The role of high-fructose corn syrup in metabolic syndrome and hypertension. Curr Hypertens Rep 2010;12:105-12.
PUBMED | CROSSREF
7. Dornas WC, de Lima WG, Pedrosa ML, Silva ME. Health implications of high-fructose intake and current research. Adv Nutr 2015;6:729-37.
PUBMED | CROSSREF
8. Rafati A, Anvari E, Noorafshan A. High fructose solution induces neuronal loss in the nucleus of the solitary tract of rats. Folia europathol 2013;51:214-21.
PUBMED | CROSSREF
9. Wang DD, Sievenpiper JL, de Souza RJ, Chiavaroli L, Ha V, Cozma AI, Mirrahimi A, Yu ME, Carleton AJ, Di Buono M, Jenkins AL, Leiter LA, Wolever TM, Beyene J, Kendall CW, Jenkins DJ. The effects of fructose intake on serum uric acid vary among controlled dietary trials. J Nutr 2012;142:916-23.
PUBMED | CROSSREF
10. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med 2009;6:e1000097.
PUBMED | CROSSREF
11. Richardson WS, Wilson MC, Nishikawa J, Hayward RS. The well-built clinical question: a key to evidence-based decisions. ACP J Club 1995;123:A12-3.
PUBMED
12. Lachat C, Hawwash D, Ocké MC, Berg C, Forsum E, Hörnell A, Larsson CI, Sonestedt E, Wirfält E, Åkesson A, Kolsteren P, Byrnes G, De Keyzer W, Van Camp J, Cade JE, Slimani N, Cevallos M, Egger M, Huybrechts I. Strengthening the reporting of observational studies in epidemiology – nutritional epidemiology (STROBE-nut): an extension of the STROBE statement. Nutr Bull 2016;41:240-51.
CROSSREF
13. Higgins JPT, Green S. Cochrane handbook for systematic reviews of interventions version 5.0.2 [Internet]. London: Cochrane Collaboration; 2009 [cited 2020 Apr]. Available from https://training.cochrane.org/handbook/archive/v5.0.2/.
14. Ades A, Lu G, Higgins JP. The interpretation of random-effects meta-analysis in decision models. Med Decis Making 2005;25:646-54.
PUBMED | CROSSREF
15. Zhang J, Diao B, Lin X, Xu J, Tang F. TLR2 and TLR4 mediate an activation of adipose tissue renin-angiotensin system induced by uric acid. Biochimie 2019;162:125-33.
PUBMED | CROSSREF
16. Erukainure OL, Oyebode OA, Ijomone OM, Chukwuma CI, Koorbanally NA, Islam MS. Raffia palm (Raphia hookeri G. Mann & H. Wendl) wine modulates glucose homeostasis by enhancing insulin secretion and inhibiting redox imbalance in a rat model of diabetes induced by high fructose diet and streptozotocin. J Ethnopharmacol 2019;237:159-70.
PUBMED | CROSSREF
17. Ng HY, Lee YT, Kuo WH, Huang PC, Lee WC, Lee CT. Alterations of renal epithelial glucose and uric acid transporters in fructose induced metabolic syndrome. Kidney Blood Press Res 2018;43:1822-31.
PUBMED | CROSSREF

https://doi.org/10.7762/cnr.2020.9.2.122

18. Olaniyi KS, Olatunji LA. Oral ethinylestradiol-levonorgestrel attenuates cardiac glycogen and triglyceride accumulation in high fructose female rats by suppressing pyruvate dehydrogenase kinase-4. Naunyn Schmiedebergs Arch Pharmacol 2019;392:89-101.
PUBMED | CROSSREF

19. Soutelo J, Samaniego YA, Fornari MC, Reyes Toso C, Ponzo OJ. Cardiometabolic changes in different gonadal female states caused by mild hyperuricemia and exposure to a high-fructose diet. Int J Endocrinol 2018;2018:6021259.
PUBMED | CROSSREF

20. Jayakumar V, Ahmed SS, Ebenezar KK. Multivariate analysis and molecular interaction of curcumin with PPARγ in high fructose diet induced insulin resistance in rats. Springerplus 2016;5:1732.
PUBMED | CROSSREF

21. Chen G, Jia P. Allopurinol decreases serum uric acid level and intestinal glucose transporter-5 expression in rats with fructose-induced hyperuricemia. Pharmacol Rep 2016;68:782-6.
PUBMED | CROSSREF

22. Shahataa MG, Mostafa-Hedeab G, Ali EF, Mahdi EA, Mahmoud FA. Effects of telmisartan and pioglitazone on high fructose induced metabolic syndrome in rats. Can J Physiol Pharmacol 2016;94:907-17.
PUBMED | CROSSREF

23. Ma CH, Kang LL, Ren HM, Zhang DM, Kong LD. Simiao pill ameliorates renal glomerular injury via increasing Sirt1 expression and suppressing NF-κB/NLRP3 inflammasome activation in high fructose-fed rats. J Ethnopharmacol 2015;172:108-17.
PUBMED | CROSSREF

24. Wilson RD, Islam MS. Effects of white mulberry (Morus alba) leaf tea investigated in a type 2 diabetes model of rats. Acta Pol Pharm 2015;72:153-60.
PUBMED

25. Aygen B, Kucuksu M, Aydin S, Ozercan IH. Effect of enalapril maleate on ghrelin levels in metabolic syndrome in rats. Peptides 2015;67:39-44.
PUBMED | CROSSREF

26. Bernasconi PA, Cardoso NP, Reynoso R, Scacchi P, Cardinali DP. Melatonin and diet-induced metabolic syndrome in rats: impact on the hypophysial-testicular axis. Horm Mol Biol Clin Investig 2013;16:101-12.
PUBMED | CROSSREF

27. Essawy SS, Abdel-Sater KA, Elbaz AA. Comparing the effects of inorganic nitrate and allopurinol in renovascular complications of metabolic syndrome in rats: role of nitric oxide and uric acid. Arch Med Sci 2014;10:537-45.
PUBMED | CROSSREF

28. Citil C, Konar V, Aydin S, Yilmaz M, Albayrak S, Ozercan IH, Ozkan Y. Brain, liver, and serum salusin-alpha and -beta alterations in Sprague-Dawley rats with or without metabolic syndrome. Med Sci Monit 2014;20:1326-33.
PUBMED | CROSSREF

29. Ibraheem ZO, Basir R, Aljobory AK, Ibrahim OE, Alsumaidaee A, Yam MF. Impact of gentamicin coadministration along with high fructose feeding on progression of renal failure and metabolic syndrome in Sprague-Dawley rats. BioMed Res Int 2014;2014:823879.
PUBMED | CROSSREF

30. Tran LT, MacLeod KM, McNeill JH. Selective alpha(1)-adrenoceptor blockade prevents fructose-induced hypertension. Mol Cell Biochem 2014;392:205-11.
PUBMED | CROSSREF

31. Jung MH, Seong PN, Kim MH, Myong NH, Chang MJ. Effect of green tea extract microencapsulation on hypertriglyceridemia and cardiovascular tissues in high fructose-fed rats. Nutr Res Pract 2013;7:366-72.
PUBMED | CROSSREF

32. Cardinali DP, Bernasconi PA, Reynoso R, Toso CF, Scacchi P. Melatonin may curtail the metabolic syndrome: studies on initial and fully established fructose-induced metabolic syndrome in rats. Int J Mol Sci 2013;14:2502-14.
PUBMED | CROSSREF

33. Erion DM, Popov V, Hsiao JJ, Vatner D, Mitchell K, Yonemitsu S, Nagai Y, Kahn M, Gillum MP, Dong J, Murray SF, Manchem VP, Bhanot S, Cline GW, Shulman GI, Samuel VT. The role of the carbohydrate response element-binding protein in male fructose-fed rats. Endocrinology 2013;154:36-44.
PUBMED | CROSSREF

34. Kitagawa A, Ohta Y, Ohashi K. Melatonin improves metabolic syndrome induced by high fructose intake in rats. J Pineal Res 2012;52:403-13.
PUBMED | CROSSREF

35. Padiya R, Khatua TN, Bagul PK, Kuncha M, Banerjee SK. Garlic improves insulin sensitivity and associated metabolic syndromes in fructose fed rats. Nutr Metab (Lond) 2011;8:53.
PUBMED | CROSSREF
36. Chen L, Lan Z, Zhou Y, Li F, Zhang X, Zhang C, Yang Z, Li P. Astilbin attenuates hyperuricemia and ameliorates nephropathy in fructose-induced hyperuricemic rats. Planta Med 2011;77:1769-73.
PUBMED | CROSSREF
37. Hu QH, Zhang X, Pan Y, Li YC, Kong LD. Allopurinol, quercetin and rutin ameliorate renal NLRP3 inflammasome activation and lipid accumulation in fructose-fed rats. Biochem Pharmacol 2012;84:113-25.
PUBMED | CROSSREF
38. Mohan M, Jaiswal BS, Kasture S. Effect of Solanum torvum on blood pressure and metabolic alterations in fructose hypertensive rats. J Ethnopharmacol 2009;126:86-9.
PUBMED | CROSSREF
39. Bagul PK, Middela H, Matapally S, Padiya R, Bastia T, Madhusudana K, Reddy BR, Chakravarty S, Banerjee SK. Attenuation of insulin resistance, metabolic syndrome and hepatic oxidative stress by resveratrol in fructose-fed rats. Pharmacol Res 2012;66:260-8.
PUBMED | CROSSREF
40. Kelany ME, Hakami TM, Omar AH. Curcumin improves the metabolic syndrome in high-fructose-diet-fed rats: role of TNF-α, NF-κB, and oxidative stress. Can J Physiol Pharmacol 2017;95:140-50.
PUBMED | CROSSREF
41. Zhou K, Kumar U, Yuen VG, McNeill JH. The effects of phentolamine on fructose-fed rats. Can J Physiol Pharmacol 2012;90:1075-85.
PUBMED | CROSSREF
42. Pereira CD, Severo M, Araújo JR, Guimarães JT, Pestana D, Santos A, Ferreira R, Ascensão A, Magalhães J, Azevedo I, Monteiro R, Martins MJ. Relevance of a hypersaline sodium-rich naturally sparkling mineral water to the protection against metabolic syndrome induction in fructose-fed Sprague-Dawley rats: a biochemical, metabolic, and redox approach. Int J Endocrinol 2014;2014:384583.
PUBMED | CROSSREF
43. Ibrahim MA, Amin EF, Ibrahim SA, Abdelzaher WY, Abdelrahman AM. Montelukast and irbesartan ameliorate metabolic and hepatic disorders in fructose-induced metabolic syndrome in rats. Eur J Pharmacol 2014;724:204-10.
PUBMED | CROSSREF
44. Wang W, Ding XQ, Gu TT, Song L, Li JM, Xue QC, Kong LD. Pterostilbene and allopurinol reduce fructose-induced podocyte oxidative stress and inflammation via microRNA-377. Free Radic Biol Med 2015;83:214-26.
PUBMED | CROSSREF
45. Zhang DM, Li YC, Xu D, Ding XQ, Kong LD. Protection of curcumin against fructose-induced hyperuricaemia and renal endothelial dysfunction involves NO-mediated JAK-STAT signalling in rats. Food Chem 2012;134:2184-93.
PUBMED | CROSSREF
46. Zhang QY, Pan Y, Wang R, Kang LL, Xue QC, Wang XN, Kong LD. Quercetin inhibits AMPK/TXNIP activation and reduces inflammatory lesions to improve insulin signaling defect in the hypothalamus of high fructose-fed rats. J Nutr Biochem 2014;25:420-8.
PUBMED | CROSSREF
47. Mahmoud AA, Elshazly SM. Ursodeoxycholic acid ameliorates fructose-induced metabolic syndrome in rats. PLoS One 2014;9:e106993.
PUBMED | CROSSREF
48. Ebrahimpour-Koujan S, Saneei P, Larijani B, Esmaillzadeh A. Consumption of sugar sweetened beverages and dietary fructose in relation to risk of gout and hyperuricemia: a systematic review and meta-analysis. Crit Rev Food Sci Nutr 2020;60:1-10.
PUBMED | CROSSREF
49. Bomback AS, Derebail VK, Shoham DA, Anderson CA, Steffen LM, Rosamond WD, Kshirsagar AV. Sugar-sweetened soda consumption, hyperuricemia, and kidney disease. Kidney Int 2010;77:609-16.
PUBMED | CROSSREF
50. Ter Horst KW, Serlie MJ. Fructose consumption, lipogenesis, and non-alcoholic fatty liver disease. Nutrients 2017;9:E981.
PUBMED | CROSSREF
51. Mai BH, Yan LJ. The negative and detrimental effects of high fructose on the liver, with special reference to metabolic disorders. Diabetes Metab Syndr Obes 2019;12:821-6.
PUBMED | CROSSREF

https://doi.org/10.7762/cnr.2020.9.2.122