

The Forgotten Longevity Benefits of Taurine

The Japanese have a life expectancy that is among the highest in the world. In fact, Okinawa, Japan's famous "Island of Longevity," likely has the world's highest percentage of people over 100 years old.¹

Undoubtedly, there are many factors that play into the life spans of the longest-living populations, but evidence shows that they all have one thing in common: high dietary intake of an amino acid called **taurine**.²

The connection between taurine and a long life is so strong that researchers have dubbed taurine, "*The nutritional factor for the longevity of the Japanese.*"³

Taurine promotes cardiovascular health, insulin sensitivity, electrolyte balance, hearing function, and immune modulation. In animal research, taurine protected against heart failure, *reducing mortality by nearly 80%*.⁴

Its benefits are so broad and extensive that scientists have described taurine as "**a wonder molecule.**"⁵

Taurine is found abundantly in healthy bodies.⁶ However, certain diets, particularly vegetarian or vegan diets, lack adequate amounts of taurine.^{7,8} Disease states—including liver, kidney, or heart failure, diabetes, and cancer—can all cause a deficiency in taurine.⁹⁻¹¹ And *aging* bodies often cannot internally produce an optimal amount of taurine, making supplementation vital.¹²

That's why those interested in longevity should consider this vital and super low-cost nutrient. In this article, you'll learn how boosting **taurine** levels can contribute to better cardiovascular, metabolic, and neurologic health.

Why We Need Supplemental Taurine

In the enthusiasm to investigate new longevity compounds, sometimes the importance of venerable ones that have been around for decades is forgotten. Such is the case of **taurine**. Foundation members used to get taurine as part of multi-nutrient formula, but this product is not as popular as it once was.

A study released in November 2012 made the bold statement that taurine is one of the most essential substances in the body. The authors wrote:⁸ "*Considering its broad distribution, its many cytoprotective attributes, and its functional significance in cell development, nutrition, and survival, **taurine is undoubtedly one of the most essential substances in the body.***"

Although it's possible for your body to produce taurine on its own, you still need to obtain taurine through diet and supplementation in order to achieve optimal amounts of this essential nutrient.^{8,11,13}

Because of taurine's essential role in the body, supplementing with taurine can provide numerous health benefits, including restoring insulin sensitivity, mitigating diabetic complications, reversing cardiovascular disease factors, preventing and treating fatty liver disease, alleviating seizures, reversing tinnitus, and more.

Taurine Prevents Obesity

One of the ways taurine can help improve overall health is by fighting obesity. Obesity impacts every area of the body, especially because of the inflammation-generating **abdominal fat stores**. Human studies show that **3 grams per day** of taurine for 7 weeks reduced body weight significantly in a group of overweight or obese (but not-yet-diabetic) adults.¹⁴ Subjects saw significant declines in their serum triglycerides and “atherogenic index,” a ratio of multiple cholesterol components that predicts atherosclerosis risk.

Various animal studies support the **anti-obesity** and **lipid-lowering** capabilities of taurine, both alone and combined with other natural products.^{15,16} These studies highlight taurine’s ability to improve glucose tolerance in obese animals, an important benefit given how many overweight people go on to develop diabetes.^{17,18}

Perhaps most alarming, animal research reveals that obesity itself causes a *decline* in plasma taurine levels, which, in a vicious cycle, further promotes obesity.¹⁹ The observed decline in taurine levels was seen in mouse models of both genetic obesity and diet-induced obesity. Fortunately, in the same study, taurine supplementation interrupted the cycle, helping to prevent obesity and its consequences.¹⁹

Taurine Promotes Glucose Control—and Treats Diabetes

It is a known fact that taurine concentrations are lower among diabetics than they are in healthy individuals.²⁰ Given the above information about low taurine levels promoting obesity, it is clear that the low levels of taurine only serve to promote the interdependence of diabetes and obesity.²⁰ Fortunately, human studies have shown that supplementing with just **1.5 grams** of taurine a day can restore taurine levels to those in healthy control subjects, and additional animal research has shown that taurine supplementation can help prevent the onset of *type II diabetes*.^{20,21}

Normal taurine concentrations are essential in controlling diabetes and the impact of its consequences. Animal studies have found that having adequate taurine concentrations helps control diabetes by reducing blood glucose and restoring insulin sensitivity.²² But it doesn’t stop there. Taurine helps prevent—and *even reverse*—many of the consequences associated with the disease.

For example, in adult diabetics, supplementation with **1.5 grams** of taurine daily for just 14 days can *reverse* diabetes-induced abnormalities in arterial stiffness and in the ability of the vasculature to respond to changes in blood flow or pressure.²³ This can be critical to the longevity of diabetics, since these types of abnormalities are to blame for diabetics’ increased risk of dying from cardiovascular disease. In addition, studies in diabetic rats show that taurine helps protect heart function and helps prevent heart muscle damage, due in part to the ability of taurine to increase glucose transport from blood into energy-hungry heart muscle cells.^{24,25} In the process of increasing glucose transport into energy producing cells, blood glucose levels are lowered.

Additional animal and cell culture studies have revealed that taurine supplementation is effective against **diabetic complications** as well. Taurine supports nerve fiber integrity, potentially slowing or reversing painful diabetic **neuropathy**.²⁶⁻²⁹ And in the retina, another target of destructive elevated blood glucose, taurine fights glucose-induced oxidant stress and preserves the health of light-sensing cells in diabetic **retinopathy**.³⁰⁻³² **Kidney damage**, another consequence of diabetes, can be minimized with taurine supplementation in diabetic animals.³³

Taurine: Bountiful Benefits

- Taurine is the most abundant amino acid you've never heard of; it is found throughout the body, but especially in tissues containing excitable cells, like nerves and heart muscle.
- Strong epidemiological evidence suggests that certain groups with the longest life spans consume higher amounts of taurine than those of us in the rest of the world.
- Taurine supplementation can prevent diabetes and obesity in animal models, and can mitigate the effects of both conditions in humans.
- Taurine supplementation strengthens heart muscle cells, extends their life spans, and protects them from damage, while reducing many of the factors that produce atherosclerosis and its deadly consequences.
- Taurine protects retinal and inner ear cells from damage, normalizing the flow of calcium ions they require for proper function.
- Evidence is growing for taurine's role in preventing epileptic seizures and liver disease, two conditions that can be attributed to toxic effects on delicate tissue.
- If you are interested in a longer, healthier, and more active life, consider supplementing with taurine.

Taurine Reverses Cardiovascular Disease Factors

Taurine has powerful effects on the heart and blood vessels. People with higher levels of taurine have significantly lower rates of dying from coronary heart disease.^{1,34} Additionally, they have lower body mass index, lower blood pressure, and lower levels of dangerous lipids. Many different mechanisms account for these powerful effects on the heart and blood vessels.

In animal models of hypertension, taurine supplementation lowers blood pressure by reducing the resistance to blood flow in the blood vessel walls and by minimizing nerve impulses in the brain that drive blood pressure up.^{35,36} Oral taurine supplementation has been found to reduce the arterial thickening and stiffness characteristic of atherosclerosis, to restore arteries' responses to beneficial endothelial nitric oxide, and to reduce inflammation (a direct contributor to cardiovascular disease).^{34,35}

A study of patients needing coronary bypass surgery showed that consuming a liquid drink containing **3 grams** of taurine, combined with **3 grams** carnitine, **150 mg** CoQ10, and basic multivitamin nutrients, reduced left-sided ventricular volume during the heart's resting phase (diastole).³⁷ This is important since an increased left-ventricular diastolic volume is the single greatest predictor of death in patients requiring bypass or stent placements. This makes taurine a vital component of such patients' diets.

Enhance Your Exercise Performance

Want a better workout? Try taking taurine supplements! Trained athletes who supplement with taurine experience better exercise performance, and cyclists ride longer distances with less fatigue.^{38,39}

There's good reason for these positive effects: Taurine helps muscles work harder, longer, and safer.

Harder. Taurine increases muscle contractility (the force with which muscle cells pull together) in both skeletal and cardiac muscle.^{40,41} That means more powerful workouts as muscle works harder.

Longer. Taurine helps exercising muscle rid itself of lactic acid.^{42,43} Lactic acid is what causes the feelings of pain and soreness and is what limits how much a muscle can continue to work. By cleaning up lactic acid, taurine helps muscles work longer.^{38,43}

Safer. Working muscles generate oxidant stress and damage DNA, leading to the potential for muscle damage and poorer performance. Taurine protects muscles from such damage, so muscle works more safely.^{38,44}

Taurine Provides Potent Retina Protection

Taurine is especially vital when it comes to eye health. Adequate levels can help prevent age-related vision loss; conversely, a deficiency can lead to troubling vision problems. Age-related vision loss has many different causes, but near the top is the impact of oxidative stress on light-sensing cells in the retina. Such damage leads to age-related macular degeneration and other forms of retinal disease.⁴⁵

While taurine is found in very high concentrations in the retina, it declines significantly with age.⁴⁶⁻⁴⁸ Additionally, the taurine found in the retina fights oxidative stress, especially in diabetes, and helps restore deficient levels of nerve growth factor, required for maintaining retinal health.^{46,30,31}

When taurine levels are deficient, a variety of vision problems can occur including retinal ganglion cell degeneration,⁴⁹ and in children, retinal dysfunction;⁷ taurine supplementation has been shown to ameliorate diabetic retinopathy.³⁰ Evidence is strong that taurine is vital in maintaining optimal retinal function.⁵⁰

Certain drugs deplete the body of taurine, which can induce retinal damage.^{48,49,51} These include frequently used chemotherapy drugs such as cyclophosphamide (Cytosan[®]) and busulfan (Bulsufex[®]) as well as the anti-epileptic drug vigabatrin (Sabril[®]). Radiation therapy has also been shown to deplete the body of taurine.⁵¹ Fortunately, supplementation can restore taurine levels to normal and protect the retina in such cases.^{32,46,47,52}

Taurine Helps Reverse Tinnitus

Taurine plays a vital role in hearing. In fact, studies have found that in some cases, taurine can *reverse* the biochemical processes behind **hearing loss**.^{53,54} Other studies have demonstrated that taurine can almost completely eliminate the ringing in the ears associated with tinnitus.⁵⁵

Much of the damage to hearing occurs not in the mechanical parts of the ear, but rather in the nerve cells that convert sound waves into the electrical energy that is perceived in our brains. Like other nerve cells, these so-called “hair cells” depend on the flow of calcium ions into and out of the cell. Taurine helps restore and control normal calcium ion flow in auditory cells.^{53,56}

Taurine improves the hearing ability in animals exposed to drugs like the antibiotic gentamicin, which is notoriously toxic to hearing.⁵⁴ And in a boon for the **17%** of us troubled by chronic tinnitus (ringing in the ears), taurine may be helpful in quieting the noise.⁵⁷ Animal studies using human equivalent doses of **700 mg to 3.2 grams** per day of taurine over the course of several weeks demonstrate near-complete resolution of tinnitus with taurine supplementation (the animals had been trained in tasks that are sensitive to distraction by tinnitus).⁵⁵ And a human pilot study has shown encouraging results, with **12%** of people responding to taurine supplementation.⁵⁸

Solution for Seizures

While there are many types and many causes of epilepsy (seizures), a disruption in the function of excitable brain tissue underlies all of them. One of taurine's major roles in mammalian biology is the regulation of such excitable tissues, making taurine of natural interest to scientists and clinicians who study epilepsy.⁵⁹

Animal studies reveal that taurine *depletion* makes seizures more likely, while *supplementation* with taurine is capable of preventing seizures induced by a number of drugs and chemical toxins.⁵⁹⁻⁶¹ Taurine appears to work by increasing the levels of glutamic acid decarboxylase (GAD), the enzyme responsible for the production of the neurotransmitter GABA, as well as by binding to so-called GABA receptors in brain cells, calming them and reducing their likelihood of participating in the random, uncoordinated electrical firing that produces an epileptic seizure.^{59,61}

Taurine and Energy Drinks

Energy drinks such as Red Bull, Monster, and others have been getting a lot of press recently, most of it unfavorable. There's concern that the drink's biggest consumers, adolescents and young adults, are at risk for sudden death and seizures following high consumption.

Because taurine is a major ingredient in these drinks, some readers may be concerned that taurine might be contributing to these ill effects.

The good news (for taurine) is that there's no evidence at all for taurine's involvement in any adverse outcome of consuming energy drinks. It has been well-established that the high caffeine content in energy drinks (ranging from **80 milligrams**, the amount in a strong cup of coffee, to **300 milligrams** per serving) is to blame for the health problems associated with the drink. Side effects of energy drinks are the same as those of caffeine intoxication, and include nervousness, jitteriness, seizures, cardiac arrhythmias, and (rarely) death.⁶⁶

It's probably best to avoid energy drinks entirely and instead focus on getting your energy from safe, natural sources. Taurine alone offers many of the advantages attributed to energy drinks, such as improved exercise performance.

Taurine Prevents and Treats Liver Disease

Increasing evidence suggests that taurine may help treat the most common cause of liver disease in the US, **non-alcoholic fatty liver disease** (or **NAFLD**). Non-alcoholic fatty liver disease occurs when too much fat accumulates in the liver, and it can be caused by insulin resistance and metabolic syndrome. Over time, the end result is the loss of liver function, leading to *liver cirrhosis*.

The human liver is our master detoxifying organ, screening our blood flow many times over each day for substances that can damage our bodies. Taurine is an integral part of the liver's self-protective mechanisms.

Studies show that taurine defends liver cells against free radicals and toxins, helping to reduce the severity of oxidative stress-induced liver injury.⁶² This is vitally important in alcoholic and *non-alcoholic fatty liver diseases*, both of which can progress to cirrhosis and liver failure.^{63,64}

Human studies reveal the impact of taurine on liver disease. When 24 patients with chronic hepatitis took **2 grams** of taurine 3 times daily for 3 months, serum markers of liver damage, as well as markers of oxidative stress, decreased significantly, as did their elevated levels of cholesterol and triglycerides.⁶⁵

Dietary Sources of Taurine

Taurine occurs naturally in food, especially in seafood and meat.⁷⁶ The amount consumed in most societies, however, is quite low. The mean daily intake from omnivore diets was determined to be around **58 mg** (range of **9** to **372 mg**).⁷⁷ In another study, taurine intake was estimated to be generally less than **200 mg** a day, even in individuals eating a high-meat diet.⁷⁸ According to another study, taurine consumption was estimated to vary between **40** and **400 mg** a day.⁷⁷

Successful clinical studies with taurine have used daily doses of **1,500** to **3,000 mg**.^{14,20,23,37,65} It is challenging to obtain this amount of taurine from traditional dietary sources.

Taurine is made by the body from the metabolism of the amino acid cysteine.^{9,10} Aging can reduce the amount of taurine made from cysteine, thus making taurine supplementation desirable in maturing individuals.^{12,51,79}

Taurine is not abundant in most plant foods.⁷ On average, non-vegetarians typically eat around **43-76 mg** of taurine per day.⁷⁷ Vegans have been shown to have lower blood levels of taurine.⁸⁰

Summary

Taurine is the most abundant amino acid you've never heard of. Strong evidence suggests that groups with the longest life spans consume higher amounts of taurine than those of us in the rest of the world. High intakes of taurine could be the underlying factor in the world's longest-living populations—and for good reason.

Taurine supplementation can mitigate the damaging effects of fat, glucose, and excess insulin. Taurine strengthens and protects heart muscle cells and the system of blood vessels that supplies blood throughout the body, helping to protect against atherosclerosis, heart attacks, and strokes.

And taurine protects vision and hearing. It can prevent and alleviate seizures, and it has been shown to treat the most common cause of liver disease in the United States.

With epidemiological evidence that it contributes to the longevity of famously long-lived groups, taurine belongs on the short-list of supplements necessary for maintaining optimal health in the face of aging.

If you have any questions on the scientific content of this article, please call a Life Extension® Health Advisor at 1-866-864-3027.

Taurine: One of the Most Essential Substances in the Body!

- It increases the action of insulin, improving glucose tolerance, and acting as an antioxidant.⁶⁷
- It is vital for the proper function of the minerals potassium, calcium, magnesium, and sodium.⁶⁸
- Taurine regulates heart rhythm, cardiac contraction, blood pressure, and platelet aggregation,^{69,70} and regulates the excitability of neurons.⁶⁹
- It detoxifies liver cells of various toxins.⁷¹⁻⁷⁴
- It helps form bile acids and maintains cell membrane stability.⁹
- It reduces the synthesis of lipids and cholesterol that are associated with atherosclerosis.⁷⁵

References

1. Available at: <http://www.okicent.org>. Accessed February 28, 2013
2. Yamori Y. Food factors for atherosclerosis prevention: Asian perspective derived from analyses of worldwide dietary biomarkers. *Exp Clin Cardiol.* 2006 Summer;11(2):94-8.
3. Yamori Y, Liu L, Mori M, et al. Taurine as the nutritional factor for the longevity of the Japanese revealed by a world-wide epidemiological survey. *Adv Exp Med Biol.* 2009;643:13-25.
4. Azuma J, Takihara K, Awata N, et al. Beneficial effect of taurine on congestive heart failure induced by chronic aortic regurgitation in rabbits. *Res Commun Chem Pathol Pharmacol.* 45(2):261-70.
5. Yamori Y, Taguchi T, Hamada A, Kunimasa K, Mori H, Mori M. Taurine in health and diseases: consistent evidence from experimental and epidemiological studies. *J Biomed Sci.* 2010;17 Suppl 1:S6.
6. Wu JY, Prentice H. Role of taurine in the central nervous system. *J Biomed Sci.* 2010 Aug 24;17 Suppl 1:S1.
7. Kendler BS. Taurine: an overview of its role in preventive medicine. *Prev Med.* 1989 Jan;18(1):79-100.
8. Ripps H, Shen W. Review: Taurine: A “very essential” amino acid. *Mol Vis.* 2012;18:2673-86. Epub Nov 12, 2012.
9. Birdsall TC. Therapeutic applications of taurine. *Altern Med Rev.* 1998 Apr;3(2):128-36.
10. Stapleton PP, O’Flaherty L, Redmond HP, Bouchier-Hayes DJ. Host defense—a role for the amino acid taurine? *J Parenter Enteral Nutr.* 1998 Jan-Feb;22(1):42-8.
11. Lourenço R, Camilo ME. Taurine: a conditionally essential amino acid in humans? An overview in health and disease. *Nutr Hosp.* 2002 Nov-Dec;17(6):262-70.
12. Cañas PE, Valenzuela A. Biological and nutritional role of taurine and its derivatives on cellular and organic physiology. *Arch Latinoam Nutr.* 1991 Jun;41(2):139-51.
13. Szymański K, Winiarska K. Taurine and its potential therapeutic application. *Postepy Hig Med Dosw (Online).* 2008 Feb 25;62:75-86.
14. Zhang M, Bi LF, Fang JH, et al. Beneficial effects of taurine on serum lipids in overweight or obese non-diabetic subjects. *Amino Acids.* 2004 Jun;26(3):267-71.
15. Du H, You JS, Zhao X, Park JY, Kim SH, Chang KJ. Antiobesity and hypolipidemic effects of lotus leaf hot water extract with taurine supplementation in rats fed a high fat diet. *J Biomed Sci.* 2010;17 Suppl 1:S42.
16. Nardelli TR, Ribeiro RA, Balbo SL, et al. Taurine prevents fat deposition and ameliorates plasma lipid profile in monosodium glutamate-obese rats. *Amino Acids.* 2011 Oct;41(4):901-8.
17. Batista TM, Ribeiro RA, da Silva PM, et al. Taurine supplementation improves liver glucose control in normal protein and malnourished mice fed a high-fat diet. *Mol Nutr Food Res.* 2012 Dec 26.

18. Ribeiro RA, Santos-Silva JC, Vettorazzi JF, et al. Taurine supplementation prevents morpho-physiological alterations in high-fat diet mice pancreatic beta-cells. *Amino Acids*.2012 Oct;43(4):1791-801.
19. Tsuboyama-Kasaoka N, Shozawa C, Sano K, et al. Taurine (2-aminoethanesulfonic acid) deficiency creates a vicious circle promoting obesity. *Endocrinology*.2006 Jul;147(7):3276-84.
20. Franconi F, Bennardini F, Mattana A, et al. Plasma and platelet taurine are reduced in subjects with insulin-dependent diabetes mellitus: effects of taurine supplementation. *Am J Clin Nutr*.1995 May;61(5):1115-9.
21. Franconi F, Loizzo A, Ghirlanda G, Seghieri G. Taurine supplementation and diabetes mellitus. *Curr Opin Clin Nutr Metab Care*.2006 Jan;9(1):32-6.
22. Kim KS, Oh da H, Kim JY, et al. Taurine ameliorates hyperglycemia and dyslipidemia by reducing insulin resistance and leptin level in Otsuka Long-Evans Tokushima fatty (OLETF) rats with long-term diabetes. *Exp Mol Med*. 2012 Nov 30;44(11):665-73.
23. Moloney MA, Casey RG, O'Donnell DH, Fitzgerald P, Thompson C, Bouchier-Hayes DJ. Two weeks taurine supplementation reverses endothelial dysfunction in young male type 1 diabetics. *Diab Vasc Dis Res*. 2010 Oct;7(4):300-10.
24. Tappia PS, Thliveris J, Xu YJ, Aroutiounova N, Dhalla NS. Effects of amino acid supplementation on myocardial cell damage and cardiac function in diabetes. *Exp Clin Cardiol*.2011 Fall;16(3):e17-22.
25. Das J, Vasan V, Sil PC. Taurine exerts hypoglycemic effect in alloxan-induced diabetic rats, improves insulin-mediated glucose transport signaling pathway in heart and ameliorates cardiac oxidative stress and apoptosis. *Toxicol Appl Pharmacol*. 2012 Jan 15;258(2):296-308.
26. Li F, Abatan OI, Kim H, et al. Taurine reverses neurological and neurovascular deficits in Zucker diabetic fatty rats. *Neurobiol Dis*. 2006 Jun;22(3):669-76.
27. Askwith T, Zeng W, Eggo MC, Stevens MJ. Oxidative stress and dysregulation of the taurine transporter in high-glucose-exposed human Schwann cells: implications for pathogenesis of diabetic neuropathy. *Am J Physiol Endocrinol Metab*.2009 Sep;297(3):E620-8.
28. Askwith T, Zeng W, Eggo MC, Stevens MJ. Taurine reduces nitrosative stress and nitric oxide synthase expression in high glucose-exposed human Schwann cells. *Exp Neurol*. 2012 Jan;233(1):154-62.
29. Obrosova IG, Fathallah L, Stevens MJ. Taurine counteracts oxidative stress and nerve growth factor deficit in early experimental diabetic neuropathy. *Exp Neurol*. 2001 Nov;172(1):211-9.
30. Yu X, Xu Z, Mi M, et al. Dietary taurine supplementation ameliorates diabetic retinopathy via anti-excitotoxicity of glutamate in streptozotocin-induced Sprague-Dawley rats. *Neurochem Res*. 2008 Mar;33(3):500-7.
31. Zeng K, Xu H, Mi M, et al. Dietary taurine supplementation prevents glial alterations in retina of diabetic rats. *Neurochem Res*. 2009 Feb;34(2):244-54.
32. Zeng K, Xu H, Mi M, et al. Effects of taurine on glial cells apoptosis and taurine transporter expression in retina under diabetic conditions. *Neurochem Res*. 2010 Oct;35(10):1566-74.
33. Das J, Sil PC. Taurine ameliorates alloxan-induced diabetic renal injury, oxidative stress-related signaling pathways and apoptosis in rats. *Amino Acids*.2012 Oct;43(4):1509-23.
34. Murakami S. Taurine and atherosclerosis. *Amino Acids*.2012 Dec 8.
35. Abebe W, Mozaffari MS. Role of taurine in the vasculature: an overview of experimental and human studies. *Am J Cardiovasc Dis*. 2011;1(3):293-311.
36. Rahman MM, Park HM, Kim SJ, et al. Taurine prevents hypertension and increases exercise capacity in rats with fructose-induced hypertension. *Am J Hypertens*.2011 May;24(5):574-81.
37. Jeejeebhoy F, Keith M, Freeman M, et al. Nutritional supplementation with MyoVive repletes essential cardiac myocyte nutrients and reduces left ventricular size in patients with left ventricular dysfunction. *Am Heart J*. 2002 Jun;143(6):1092-100.

38. Zhang M, Izumi I, Kagamimori S, et al. Role of taurine supplementation to prevent exercise-induced oxidative stress in healthy young men. *Amino Acids*.2004 Mar;26(2):203-7.
39. Balshaw TG, Bampouras TM, Barry TJ, Sparks SA. The effect of acute taurine ingestion on 3-km running performance in trained middle-distance runners. *Amino Acids*.2013 Feb;44(2):555-61.
40. Goodman CA, Horvath D, Stathis C, et al. Taurine supplementation increases skeletal muscle force production and protects muscle function during and after high-frequency in vitro stimulation. *J Appl Physiol*. 2009 Jul;107(1):144-54.
41. Molaparast-Saless F, Nellis SH, Liedkte AJ. The effects of propionylcarnitine taurine on cardiac performance in aerobic and ischemic myocardium. *J Mol Cell Cardiol*. 1988 Jan;20(1):63-74.
42. Manabe S, Kurroda I, Okada K, et al. Decreased blood levels of lactic acid and urinary excretion of 3-methylhistidine after exercise by chronic taurine treatment in rats. *J Nutr Sci Vitaminol (Tokyo)*. 2003 Dec;49(6):375-80.
43. Imagawa TF, Hirano I, Utsuki K, et al. Caffeine and taurine enhance endurance performance. *Int J Sports Med*. 2009 Jul;30(7):485-8.
44. Dawson R, Jr., Biasetti M, Messina S, Dominy J. The cytoprotective role of taurine in exercise-induced muscle injury. *Amino Acids*.2002 Jun;22(4):309-24.
45. Drobek-Słowik M, Karczewicz D, Safranow K. The potential role of oxidative stress in the pathogenesis of the age-related macular degeneration (AMD). *Postepy Hig Med Dosw (Online)*. 2007;61:28-37.
46. Militante JD, Lombardini JB. Taurine: evidence of physiological function in the retina. *Nutr Neurosci*. 2002 Apr;5(2):75-90.
47. Militante J, Lombardini JB. Age-related retinal degeneration in animal models of aging: possible involvement of taurine deficiency and oxidative stress. *Neurochem Res*. 2004 Jan;29(1):151-60.
48. Jammoul F, Degardin J, Pain D, et al. Taurine deficiency damages photoreceptors and retinal ganglion cells in vigabatrin-treated neonatal rats. *Mol Cell Neurosci*.2010 Apr;43(4):414-21.
49. Froger N, Cadetti L, Lorach H, et al. Taurine provides neuroprotection against retinal ganglion cell degeneration. *PLoS One*.2012;7(10):e42017.
50. Chesney RW. Taurine: its biological role and clinical implications. *Adv Pediatr*. 1985;32:1-42.
51. Desai TK, Maliakkal J, Kinzie JL, Ehrinpreis MN, Luk GD, Cejka J. Taurine deficiency after intensive chemotherapy and/or radiation. *Am J Clin Nutr*. 1992 Mar;55(3):708-11.
52. Yu X, Chen K, Wei N, Zhang Q, Liu J, Mi M. Dietary taurine reduces retinal damage produced by photochemical stress via antioxidant and anti-apoptotic mechanisms in Sprague-Dawley rats. *Br J Nutr*.2007 Oct;98(4):711-9.
53. Liu HY, Gao WY, Wen W, Zhang YM. Taurine modulates calcium influx through L-type voltage-gated calcium channels in isolated cochlear outer hair cells in guinea pigs. *Neurosci Lett*. 2006 May 15;399(1-2):23-6.
54. Liu HY, Chi FL, Gao WY. Taurine attenuates aminoglycoside ototoxicity by inhibiting inducible nitric oxide synthase expression in the cochlea. *Neuroreport*.2008 Jan 8;19(1):117-20.
55. Brozoski TJ, Caspary DM, Bauer CA, Richardson BD. The effect of supplemental dietary taurine on tinnitus and auditory discrimination in an animal model. *Hear Res*. 2010 Dec 1;270(1-2):71-80.
56. Liu HY, Chi FL, Gao WY. Taurine modulates calcium influx under normal and ototoxic conditions in isolated cochlear spiral ganglion neurons. *Pharmacol Rep*. 2008 Jul-Aug;60(4):508-13.
57. Galazyuk AV, Wenstrup JJ, Hamid MA. Tinnitus and underlying brain mechanisms. *Curr Opin Otolaryngol Head Neck Surg*. 2012 Oct;20(5):409-15.
58. Davies E, Donaldson I. Tinnitus, membrane stabilizers and taurine. *Practitioner*.1988 Oct 22;232(1456 (Pt 2)):1139.

59. L'Amoreaux WJ, Marsillo A, El Idrissi A. Pharmacological characterization of GABAA receptors in taurine-fed mice. *J Biomed Sci.* 2010;17 Suppl 1:S14.
60. Jin HB, Li B, Gu J, Cheng JS, Yang R. Electro-acupuncture improves epileptic seizures induced by kainic acid in taurine-depletion rats. *Acupunct Electrother Res.* 2005;30(3-4):207-17.
61. El Idrissi A, L'Amoreaux WJ. Selective resistance of taurine-fed mice to isoniazide-potentiated seizures: in vivo functional test for the activity of glutamic acid decarboxylase. *Neuroscience.* 2008 Oct 15;156(3):693-9.
62. Miyazaki T, Bouscarel B, Ikegami T, Honda A, Matsuzaki Y. The protective effect of taurine against hepatic damage in a model of liver disease and hepatic stellate cells. *Adv Exp Med Biol.* 2009;643:293-303.
63. Gentile CL, Nivala AM, Gonzales JC, et al. Experimental evidence for therapeutic potential of taurine in the treatment of nonalcoholic fatty liver disease. *Am J Physiol Regul Integr Comp Physiol.* 2011 Dec;301(6):R1710-22.
64. Chen X, Sebastian BM, Tang H, et al. Taurine supplementation prevents ethanol-induced decrease in serum adiponectin and reduces hepatic steatosis in rats. *Hepatology.* 2009 May;49(5):1554-62.
65. Hu YH, Lin CL, Huang YW, Liu PE, Hwang DF. Dietary amino acid taurine ameliorates liver injury in chronic hepatitis patients. *Amino Acids.* 2008 Aug;35(2):469-73.
66. Wolk BJ, Ganetsky M, Babu KM. Toxicity of energy drinks. *Curr Opin Pediatr.* 2012 Apr;24(2):243-51.
67. Nandhini AT, Anuradha CV. Taurine modulates kallikrein activity and glucose metabolism in insulin resistant rats. *Amino Acids.* 2002;22(1):27-38.
68. Zhao L, Lou JS, Kang Y. Taurine-magnesium coordination compound attenuates hypoxia/reoxygenation induced Ion channel dysfunction in rat ventricular myocytes. *Drug Res (Stuttg).* 2013 Mar 13. [Epub ahead of print]
69. Schaffer S, Takahashi K, Azuma J. Role of osmoregulation in the actions of taurine. *Amino Acids.* 2000;19(3-4):527-46.
70. Fujita T, Ando K, Noda H, et al. Effects of increased adrenomedullary activity and taurine in young patients with borderline hypertension. *Circulation* 1987;75:525-32.
71. Timbrell JA, Seabra V, Waterfield CJ. The in vivo and in vitro protective properties of taurine. *Gen Pharmac* 1995;26:453-62.
72. Hwang DF, Wang LC. Effect of taurine on toxicity of cadmium in rats. *Toxicology.* Oct 2001;167(3):173-80.
73. Waters E, Wang JH, Redmond HP, et al. Role of taurine in preventing acetaminophen-induced hepatic injury in the rat. *Am J Physiol Gastrointest Liver Physiol.* Jun 2001;280(6):G1274-9.
74. Wu C, Kennedy DO, Yano Y, et al. Thiols and polyamines in the cytoprotective effect of taurine on carbon tetrachloride-induced hepatotoxicity. *J Biochem Mol Toxicol.* 1999;13(2):71-6.
75. Yanagita T, Han SY, Hu Y, Nagao K, Kitajima H, Murakami S. Taurine reduces the secretion of apolipoprotein B100 and lipids in HepG2 cells. *Lipids Health Dis.* 2008 Oct 17;7:38.
76. Wójcik OP, Koenig KL, Zeleniuch-Jacquotte A, Costa M, Chen Y. The potential protective effects of taurine on coronary heart disease. *Atherosclerosis.* 2010 Jan;208(1):19-25.
77. Rana SK and Sanders TA. Taurine concentrations in the diet, plasma, urine and breast milk of vegans compared with omnivores. *Br J Nutr.* 1986 Jul;56(1), 17-27.
78. Laidlaw SA, Grosvenor M, Kopple JD (1990). The taurine content of common foodstuffs. *JPEN J Parenter Enteral Nutr.* 1990 Mar-Apr;14(2):183-8.
79. Pierno S, De Luca A, Camerino C, Huxtable RJ, Camerino DC. Chronic administration of taurine to aged rats improves the electrical and contractile properties of skeletal muscle fibers. *J Pharmacol Exp Ther.* 1998 Sep;286(3):1183-90.
80. Laidlaw SA, Shultz TD, Cecchino JT, Kopple JD. Plasma and urine taurine levels in vegans. *Am J Clin Nutr.* 1988 Apr;47(4):660-3.