

## Life threatening water intoxication

Shahad W. Ahmed<sup>1</sup>

<sup>1</sup> Department of Clinical Laboratory Sciences-College of Pharmacy-University of Baghdad-Baghdad, Iraq.

### Article Review

#### ABSTRACT

Water intoxication is a fatal disorder associated with disturbance in brain function, known as hypo-osmolar syndrome which resulting from an excessive water intake, with dilutional hyponatremia leads to a potentially fatal outcome. A change in the electrolyte equilibrium such as this sudden drop in serum sodium level and then subsequent mortality. With hyponatremia, the plasma osmolality decreased leading to water movement into the brain according to the osmotic gradient, resulting in hyponatremic encephalopathy and cerebral oedema. Increased water intake such as in Psychogenic polydipsia is followed by urination of high amount of diluted urine (polyuria) which are the main initial symptoms of water intoxication with headache, blurred vision, nausea, tremor, and deterioration in psychosis. Other serious symptoms involve muscle spasms, Early detection of seizures and coma are more serious outcomes, Untreated cases may lead to death, Risk factor for water intoxication are Marathon runners, military population and athletes and due to this endurance events, these behaviors encouraging heavy sweating that result in heat exhaustion and consume large volumes of fluid, then hyponatremia developed as a result of excessive fluid substitution. Child abuse is other pediatric clinical cases reported with water intoxication. Psychogenic polydipsia which is psychiatric disorder with obsessive water drinking leading to a serious self-induced water intoxication (SIWI), water is normally metabolized and excreted by different means and it is mainly by kidneys in urine, evaporation through the skin, by respiratory system through the respired water vapor and little quantity of water was lost from the gastrointestinal tract (GI). The LD<sub>50</sub> of water is > 90 ml/kg orally in rats. The current review illustrates the Life threatening effects of water when it is aggressively consumed.

**Keywords:** water intoxication, psychogenic polydipsia, hyponatremia, child abuse, Marathon runners, heat exhaustion, LD<sub>50</sub> of water.

### Introduction

#### General Considerations

Human body consist of 75% Water during childhood, in adulthood this percentage decreased to 45%, and it is still a significant part of the body mass (1), when the body's water balance are affected by excessive water intake and various physiological symptoms occurred, this imbalance

within a short period of time without adequate intake of electrolytes (3), and this cause a lethal disorder with disturbance in brain function, known as hypo-osmolar syndrome, with dilutional hyponatremia that caused mainly by water retention exceeding kidney-free water excretion or impaired kidney-free water excretion (4), this condition also described as hyperhydration, water toxemia, overhydration or water poisoning, and that will happened when imbalance of electrolytes in the body is occurred by excessive water intake, in normal conditions too much water consuming is rare (5), acute hyponatremia can cause cerebral oedema, cerebral hernia, and may lead to death (6). Due to numerous etiologies, water toxicity may occur, but it is difficult to diagnose because it presents with symptoms of altered mental status, disorientation, confusion, nausea, and vomiting that may resemble with psychosis, This variability of symptoms it may be

\*Correspondence: [Shahad\\_wisam2020@yshoo.com](mailto:Shahad_wisam2020@yshoo.com),  
Department of Clinical Laboratory Sciences-College of Pharmacy-University of Baghdad-Baghdad, Iraq. Received: 1 September 2020, Accepted: 25 October 2020, Published: 28 December 2020.

This article is an open access article under the terms and conditions of the Creative Commons Attribution License (CC BY 04 <https://creativecommons.org/licenses/by/4.0>). is called water intoxication (2). Water can be considered as a poison when over consumed

misdiagnosed upon presentation, Early detection of seizures are more serious outcomes, untreated Cases may lead to death (7).

### Metabolism of water in human body

Water is the major component of humans body fluids which plays a vital role for many chemical and enzymatic reactions in the body, in the gastrointestinal (GI) tract specifically the proximal intestine, the mucosal surface plays a significant role in water metabolism, normally little quantity of water is lost from the gastrointestinal tract (8). The other important route of water excretion from the body is through the respired water vapor, significant isotopic fractions of the stable atoms of hydrogen and oxygen occur in the respiratory system between water vapor and condensed water (9). The body mainly loss water by excretion though the kidneys with urine ,the kidneys can excrete less than a pint or up to several gallons of urine a day, its depends on body needs. less than a liter of water are evaporates from the skin daily ,excessive sweating may cause by heavy exercise, hot weather, or elevated body temperature will significantly increase the amount of water lost by evaporation through the skin (10).

### How much water needs to be toxic

The Food standards Agency (FSA) makes a guideline for the amount of fluid that should be drink daily to be in a safe side which is about 1.2 Liters that equivalent to 6-8 glasses, while the World Health Organization (WHO) suggest that the men should drink about 2.5 Liters and 2.2 Liters for women per day, However this quantities of water must increase in hot weather, during heavy work and illness (11).

There is no fixed amount of water that someone drinks causing life-threatening water intoxication because it is related to person's age, gender and the overall health which play an important role in addition to the quantities of water that someone drinks hourly, in a healthy human, the kidneys can flush out about 20-28 Liter of water daily, it is difficult for the kidneys to filter when person drinks more than Liter per hour, the kidneys function tend to be less efficient in children and elderly people, so the amount of water that safely consume hourly is lower, for this reason water intoxication occurs rapidly in children and elderly

people (12). The median lethal dose (LD<sub>50</sub> ;abbreviation for "lethal dose, 50%") of water is > 90 ml/kg orally in rats, toxicologically, the LD<sub>50</sub> is a term used measure the lethal dose of pathogen, toxin or any substance required to kill half of the population in a specific test duration, and the smaller LD<sub>50</sub> value the most toxic substance is (13).

### Etiology

#### Endurance exercises (i.e. marathon runners, army)

Marathon runners are susceptible to water poisoning, if they drink too much while running, This is occurred when a decrease in sodium levels is below 135 mmol/ L due to athletes consuming large volumes of fluid, which has been noted as the result of excessive fluid substitution (14), In athletic endurance events and in the military population ,exercise-associated hyponatremia (EAH) has been identified (15), military field activities such as load marching and equipment (backpack, camelback and canteens) are often practiced in hot and humid climate (16). EAH Symptoms vary from mild for example, lightheadness, dizziness and nausea to sever; e.g. Vomiting, headache, mental status alteration, seizure, and coma, also defined as exercise associated hyponatremic encephalopathy (EAHE) (17). These behaviors encouraging heavy sweating can result in heat exhaustion or exertional heat disease, which is a mild to moderate sickness with moderate(> 38.5 ° C, 101 ° F) to high (< 40 ° C, 104 ° F) rectal temperatures and often it comes with hot skin and dehydration (18).

### Psychiatric illness

Excessive drinking of water can occur in nearly any psychological illness, For example; in patients with mental illnesses and hysterical characteristics (19), excessive drinking of water by psychiatric disorders may lead to water intoxication and hyponatremia involved with headache, convulsions, delirium, coma, and even death (20). Psychogenic polydipsia (PPD) or self-induced water intoxication (SIWI) both used to identify obsessive water drinking, In PPD there is a thirst control abnormality not caused by dysfunction in the producing or releasing of Anti Diuretic Hormone (ADH), beginning with polydipsia and

polyuria, followed by hyponatremia (water is sustained as the kidneys fail to excrete extra fluid, resulting in low levels of serum sodium), finally water intoxication developed with nausea, vomiting, delirium, ataxia, seizures, and coma, and may be death (21). This caused disturbances in the electrolyte balance which resulted in a rapid reduction of serum sodium concentration and early death (22). Water intoxication are considerably common in patients with schizophrenia, sometimes called patients with PHS (polydipsic-hyponatremic-schizophrenia), which notably in hospital settings and this may potentially cause serious health problems and death (23).

### **Child abuse**

For children, water intoxication is a rare phenomenon that happened as a result of excessive water consumption, and when the amount of water intake exceeds that of kidneys water excretion, the result is the dilution of the sodium concentration in the blood, and hyponatremia evolves. Water intoxication is noticed in child abuse (24) and the probability of water toxicity is high in children due to their immature kidney functions (25). Symptoms of hyponatremia can occur rapidly in children. Since hyponatremic encephalopathy for children can happen at a higher sodium level than for older people, this is linked to the smaller space in which the brain can enlarge in children due to its greater brain to skull size ratio (26).

### **Pathophysiology**

Water intoxication causes changes in the electrolyte equilibrium, leading to a sudden drop in serum sodium level and subsequent mortality. The occurrence of acute dilutional hyponatraemia triggers neurological illness as a response to the decline of extracellular osmolality due to the influx of water through the brain cells, when the serum sodium level falls below 120 mmol/l the Symptoms appeared, but are generally linked with levels below 110 mmol/l, with level of 90–105 mmol/l Severe symptoms developed. As the sodium level decreased, the symptoms advanced from confusion to coma (3). The secretion of antidiuretic hormone (ADH) is inhibited when the sodium level is decreased, and therefore, the amount of water excreted through the kidney

increased, when the water uptake amount is above the water excretion capacity of the kidney, Hyponatremia will occurs (25). The brain osmolality is in balance with extracellular fluid osmolality in normal biological system, but with hyponatremia, the plasma osmolality decreased leading to water movement into the brain according to the osmotic gradient, resulting in Hyponatremic encephalopathy and cerebral oedema, the Hyponatremic encephalopathy is a complication of acute hyponatremia which is a brain swelling and is associated with a mortality rate of 34% (27), hyponatremia causing an abnormalities of the central nervous system and these clinical symptoms become more intense with the significant decline of sodium serum level (28). This disturbance in brain osmolality leading to brain swelling and this swelling increases intracranial pressure (ICP), cerebral edema happened when the brain cells swell to the point where blood flow is interrupted, central nervous system dysfunction occur due to the Swollen brain cells that apply pressure on the brain stem, this cerebral edema leading to central nervous system abnormalities such as seizures, brain damage, coma or even death (29). Blood osmotic pressure alterations occurred due to increased loss, increased consumption or retention of water, preceded by sodium imbalance and hyponatremia appeared (30).

### **Symptoms of water toxicity**

First symptoms of water intoxication are headache, blurred vision, frequent urination, nausea, tremor, and deterioration in psychosis. Other serious symptoms involve muscle spasms, ataxia, restlessness, coma, and seizures. Major seizures are frequent in psychiatric patients with about 80% of cases reported (31).

### **Treatment**

Water intoxication may cause serious cerebral edema, the brain swelling could be reduced and death avoiding by the giving of hypertonic saline (32). True hyponatremic emergency cases such as self-induced water intoxication and symptomatic hospital-acquired hyponatremia requiring serious intervention with intravenous hypertonic saline. Under these situations, the aggressive treatment should be avoided to eliminate the risk of osmotic demyelination due to electrolyte disturbance (33),

the aggressive treatment of chronic hyponatremia, which exceeds the capacity of the brain to restore the lost osmolytes, the osmotic pressure reversed and then resulting with dehydration of brain tissue with subsequent white matter demyelination. This consequence is described as osmotic demyelination syndrome (ODS) (34). It is typically happens when sodium levels increase above 18 mEq/L in 48 hours or more than 10 mEq/L in 24 hours (35). Hyponatremia Consensus Development Conference advised that any athlete with hyponatremia and encephalopathy must giving them rapidly a bolus infusion of 100 mL of 3% NaCl to decrease brain oedema, and if there is no therapeutic effects, a 2 additional 100-mL of 3% NaCl bolus infusions to be administered at 10-minute periods (36).

### Cases of water intoxication

#### Child abuse case

A 9-years old girl was admitted to hospital with drowsiness, nausea, vomiting, that begun four hours before her admission, she drinks two 1.8 Liter bottles of water within 1–2 hours, forced by her stepfather a 8 months before, She have an appendicitis operation, the physician told her to drink high amount of water after the surgery due to her constipation. Since she had been discharged after the surgery, her stepfather make her to drink two bottles of 1.8 L- water a day, when the doctors take her history with the symptoms appeared, they recognized it is water intoxication child abuse case (24).

#### Psychiatric illness case

A 40-year-old man diagnosed with schizophrenia for 14 years reported with polydipsia, nausea and vomiting for the first time one year before his death, he was consuming massive quantities of water, his health status gradually worsened, with weight loss and continuous consumption of large quantities of water which was followed by unable to speak and frequent vomiting. The following year, he admitted to emergency room with consciousness disruption, and then he died (30).

#### Endurance exercise cases

- A 27 years old male soldier admitted to emergency room with weakness and drowsiness.

The day of admission, he performed an outdoor training exercise in 84°F, and 32% humidity, in the field, an oral temperature is 98.7°F and he was eventually ice sheeted. He was unable to handle any fluids due to his nausea and vomiting. On arrival, he reported vomiting six times, he admitted because he drinks 6 quarts of water in 2 hrs when he was training, then a 1 Liter of 0.9% NS was started with him (16).

- A 19-year-old Marine man at Camp Pendleton, after a 26-mile march with his unit in California he died from hyponatremia due to brain oedema, He admitted with altered mental status, confusion, acidosis, and lethargy after completing the 8-hour march carrying a pack and gear of more than 90pounds, He did well on the beginning of the march, but at end he starting with vomiting and showed signs of excessive tiredness. After completion of the march, he had mental status alteration and was admitted to the hospital. Initial serum sodium level was 128mmol/L, later it was 126mmol/L 8 hours. he progressed to coma, with reported brain edema until he dead the next day (37).

### Conclusions

Water toxicity can occur due to numerous etiologies, the diagnosis can be confusing because of the diverse presentation and high morbidity, Drinking water more than the ability of kidneys to flush out, it will dilute the serum sodium, leading to dilutional hyponatremia. There is on specific amount of drinking water that considered as a life threatening quantity because it depends on someone health, age and gender, the amount of water should increase according to person conditions. Almost all cases of water intoxication are considered as acute water toxicity because water is inert important liquid that required for life and the human body consist of high percentage of water also there is different ways to excrete it from human body and the body can handle well the high amount of water consumed unless someone consume large quantity that exceeded the ability of kidneys to flush out. Life-threatening water intoxication present in some cases, which is reported in endurance activities, such as military training or running a marathon, others have resulted from excessive water consumption due to mental health condition or forced consumption as a form of abuse such as in

child abuse, It is important to prevent more serious outcomes including early identification of seizures and coma. Cases which are not treated will lead to death.

### Acknowledgment

I would like to express my special thanks to my Assist. Prof. Inaam A. Amen, who support me and gave me this opportunity to do this article review ,also she doesn't hesitate to help at any time I need to, so I am really thankful to her.

### Conflict of interest

The author has no conflict of interest to report and no funding to declare

### References

- Hall, J.E, Guyton, A.C. Guyton and Hall textbook of medical physiology. (12<sup>ed</sup>). Philadelphia: Saunders Elsevier; 2011.
- Lingampalli. N. Water Intoxication. Berkeley Scientific Journal.2013; 17(2).
- Farrell DJ, Bower L. Fatal water intoxication. J Clin Pathol. 2003 Oct; 56(10): 803-4.
- Yamashiro, M, Hasegawa, H, Matsuda, A, Kinoshita, M. and Matsumura, O. et al, A Case of Water Intoxication with Prolonged Hyponatremia Caused by Excessive Water Drinking and Secondary SIADH, Case Rep Nephrol Urol 2013;3:147–152.
- Noakes TD, Speedy DB, Case proven: exercise associated hyponatraemia is due to overdrinking. So why did it take 20 years before the original evidence was accepted? . Br J Sports Med, 2006; 40 (7): 567–72.
- Fraser CL, Arief AL. Fatal central diabetes mellitus and insipidus resulting from untreated hyponatremia: a new syndrome. Ann Intern Med 1990; 112:113-9.
- Siegel AJ. Fatal water intoxication and cardiac arrest in runners during marathons: prevention and treatment based on validated clinical paradigms. Am. J. Med. 2015; 128 (10):1070-5.
- 8-Leiper J B. Intestinal Water Absorption - Implications for the Formulation of Rehydration Solutions. Int J Sports Med. 1998; 19:129–132.
- Epstein S, Zeiri L. Oxygen and carbon isotopic compositions of gases respired by humans. Proc Natl Acad Sci U S A. 1988;85 (6):1727-31.
- Lewis, J. MSD manual. [Online]. Available from: <https://www.msmanuals.com/home/hormonal-and-metabolic-disorders/water-balance/about-body-water> [Accessed 6 June 2020].
- Kellow, J. Weightloss resources co uk. Drinking Too Much Water Can Kill You. Weblog. [Online] Available from: [https://www.weightlossresources.co.uk/diet/healthy\\_eating/drinking-too-much-water-can-kill-you.htm](https://www.weightlossresources.co.uk/diet/healthy_eating/drinking-too-much-water-can-kill-you.htm) [Accessed 9 June 2020].
- Raypole, C. Healthline. Can Drinking Too Much Water Be Fatal? Know the Facts. Weblog. [Online] Available from: <https://www.healthline.com/health/how-much-water-can-kill-you> [Accessed 9 June 2020].
- Material Safety Data Sheet Water MSDS". Section 11:toxicological Information for the LD<sub>50</sub> verification.Archived from the original on 2012-09-02.Retrieved 2012-05-09.
- Almond CS, Shin AY, Fortescue EB, et al .Hyponatremia among runners in the Boston Marathon. N Engl J Med .2005; 352 (15): 1550–6.
- Danz M, Pöttgen K, Tönjes PM, Hinkelbein J, Braunecker S: Hyponatremia among triathletes in the Ironman European Championship. N Engl J Med .2016; 374(10): 997–8.
- Robert C Oh, MC, Bryan Malave, MC, Justin D Chaltry, MC, Collapse in the Heat – From Overhydration to the Emergency Room – Three Cases of Exercise-Associated Hyponatremia Associated with Exertional Heat Illness, Military Medicine, 2018; 183 (3): e225–e228.
- Hew-butler T, Rosner MH, Fowkes-godek S, et al. Statement of the Third International Exercise-Associated Hyponatremia Consensus Development Conference, Carlsbad, California. Clin J Sport Med .2015; 25(4): 303–20.
- APA Carter, Robert III Exertional Heat Illness and Hyponatremia: An Epidemiological Prospective, Curr Sports Med Rep : 2008; 7(4):S20-S27.

19. Kuluarnia J, McLachlan R, Copolov D. The medical and psychological investigation of psychogenic polydipsia: a case study. *Br J Psychiatry*. 1985;146:545-7.
20. Chinn TA. Compulsive water drinking. *J. Nerv. Ment. Dis*. 1974;58:78-80.
21. Bhatia MS, Goyal A, Saha R, Doval N. Psychogenic Polydipsia - Management Challenges. *Shanghai Arch Psychiatry* . 2017 Jun 25;29(3):180-183.
22. Umansky L, Sella A. Psychogenic polydipsia leading to water intoxication. *Harefuah*. 2000;138(1):9-12, 87.
23. Poirier S, Legris G, Tremblay P, Michea R, Viau-Guay L, Mérette C, Bouchard RH, Maziade M, Roy MA. Schizophrenia patients with polydipsia and water intoxication are characterized by greater severity of psychotic illness and a more frequent history of alcohol abuse. *Schizophr Res*. 2010;118(1-3):285-91.
24. Joo MA, Kim EY. Hyponatremia caused by excessive intake of water as a form of child abuse. *Ann Pediatr Endocrinol Metab*. 2013;18(2):95-8.
25. Bruce RC, Kliegman RM. Hyponatremic seizures secondary to oral water intoxication in infancy: association with commercial bottled drinking water. *Pediatrics* 1997;100:E4.
26. Moritz ML, Ayus JC. Disorders of water metabolism in children: hyponatremia and hypernatremia. *Pediatr Rev*. 2002;23:371-80.
27. Ayus JC, Achinger SG, Arieff A. Brain cell volume regulation in hyponatremia: role of sex, age, vasopressin, and hypoxia. *Am J Physiol Renal Physiol*. 2008;295(3):F619-24.
28. Adrogué H.J, Madias N.E, Hyponatremia. *N. Engl. J. Med*. 2000;342,1581–1589.
29. Moreau, D. *Fluids & Electrolytes Made Incredibly Easy*. (4th ed.). Philadelphia: Lippincott Williams & Wilkins; 2008.
30. Radojevic N, Bjelogrić B, Aleksic V, Rancic N, Samardzic M, Petkovic S, Savic S. Forensic aspects of water intoxication: four case reports and review of relevant literature. *Forensic Sci Int*. 2012;220(1-3):1-5.
31. Jose CJ, Barton JL, Perez-Cruet J. Hyponatremic seizures in psychiatric patients. *Biol Psychiatry* .1979;14: 839-43.
32. Helwig FC, Schutz CB, Kuhn HP. Water intoxication. Moribund patient cured by administration of hypertonic salt solution. *JAMA*. 1938;110:644-5.
33. Cherney DZ, Davids MR, Halperin ML. Acute hyponatraemia and ‘ecstasy’: insights from a quantitative and integrative analysis. *QJM*. 2002;95:475-83.
34. Berl T. Treating hyponatremia: damned if we do and damned if we don't. *Kidney Int*. 1990;37(3):1006-18.
35. Sterns RH. Severe symptomatic hyponatremia: treatment and outcome. A study of 64 cases. *Ann. Intern. Med*. 1987;107(5):656-64.
36. Hew-Butler T, Ayus JC, Kipps C, Maughan RJ, Mettler S, Meeuwisse WH, Page AJ, et al. Statement of the Second International Exercise-Associated Hyponatremia Consensus Development Conference, New Zealand, 2007. *Clin J Sport Med*. 2008; 18(2):111-21.
37. Gardner JW. Death by water intoxication. *Military medicine*. 2002; 167(5):432-4

## التسمم بالمياه المهدد للحياة

<sup>1</sup>شهد وسام احمد

<sup>1</sup> فرع العلوم المختبرية السريرية، كلية الصيدلة، جامعة بغداد

### الخلاصة

تسمم الماء هو اضطراب قاتل يرتبط باضطراب في وظائف المخ، يُعرف باسم متلازمة نقص الأسمولية الناتجة عن الإفراط في تناول الماء، مع نقص صوديوم الدم والذي يؤدي إلى نتيجة قاتلة. ان تغير في توازن الكهارل مثل هذا الانخفاض المفاجئ في مستوى الصوديوم في الدم قد يؤدي الى الوفاة. مع نقص صوديوم الدم، تنخفض الأسمولية في البلازما مما تؤدي إلى حركة الماء في الدماغ وفقاً للتدرج التناضحي، مما يؤدي إلى اعتلال دماغي ناقص صوديوم الدم ووذمة دماغية. ان زيادة تناول الماء كما في العطاش النفسي يتبعه التبول بكمية كبيرة من البول المخفف وهي من الأعراض الأولية الرئيسية لتسمم الماء مع الصداع وعدم وضوح الرؤية والغثيان والرغبة وتدهور الذهان. وتشمل الأعراض الخطيرة الأخرى التشنجات العضلية، والكشف المبكر عن اعراض اكثر خطورة مثل نوبات الصرع والغيبوبة، وقد تؤدي الحالات غير المعالجة إلى الوفاة، واكثر اشخاص عرضة لخطر تسمم المياه هم عدائي الماراثون والعسكريون والرياضيون، وبسبب أحداث التحمل هذه، هذه السلوكيات تزيد التعرق الشديد حيث ينتج عنها استنفاد حراري واستهلاك كميات كبيرة من السوائل، ثم يحدث نقص صوديوم الدم نتيجة لاستبدال السوائل المفرط. وايضاً إساءة معاملة الأطفال هي حالات سريرية أخرى للأطفال تم الإبلاغ عنها بتسمم الماء. العطاش النفسي هو اضطراب نفسي بسبب الوسواس في شرب الماء مما يؤدي إلى تسمم خطير ذاتي بالمياه، يتم التمثيل الغذائي للماء وطرحه بوسائل مختلفة ويتم بشكل رئيسي عن طريق الكلى في البول، والتبخر عبر الجلد، عن طريق الجهاز التنفسي من خلال بخار الماء المتنفس وكمية قليلة من الماء من الجهاز الهضمي. الجرعة المميتة هي 50 من الماء < 90 مل/كغم عن طريق الفم في الفئران. وهكذا فان المراجعة الحالية توضح الآثار المهددة للحياة للمياه عند استهلاكها بشراهة.

**الكلمات المفتاحية:** تسمم الماء، العطاش النفسي، نقص صوديوم الدم، إساءة معاملة الأطفال، عدائي الماراثون، استنفاد حراري، الجرعة المميتة 50 من الماء.