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WATER METABOLISM IN HEALTH AND DISEASE - A REVIEW

Biochemistry

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ABSTRACT

Lacunae exist on studies related to water metabolism, especially in India. This review article presents a condensed version of various research findings in water metabolism in health and disease. Lack of adequate intake of water will lead to serious health hazards and dehydration will be the first observation. Water involvements in the functioning of various cells have been the highlights of many publications. Among the many important functions of water, it serves as an excellent solvent for ions, nerves signalling, enzyme activities, mineralisation of organic compounds, disposal of waste products, hydrogen binding of proteins and hydrophobic reactions. In every organ, water and sodium metabolism are closely interlinked. Impaired water metabolisms are closely linked in many chronic diseases, especially in elderly persons. The recommended average daily intake of water is 2 – 3 litres per day. People doing exercise need to consume extra water to compensate water loss through sweats. Both dehydration and hypo hydration will lead to serious health problems. The other symptoms associated with poor water intake are cognitive disorders, dry mouth, fatigue, thirst, decreased urine output, and decreased mental and physical performance, headache and dizziness. More studies are required to set standard guidelines for water consumption for the benefits of continuous health maintenance.

KEYWORDS

Water Metabolism, Dehydration, Hormones, Adh, Vasopressin, Urine

INTRODUCTION:

Water is a universal solvent due to its very high molarity. Water is available from different sources, rain, well, distilled and deionised. The best source of water recommended for human consumption is natural spring water as it contains useful minerals that are needed for human body. The water content in human body is 68%, out of which 33% and 83% are present in bones and lungs. Every day we lose water through breathing, sweating and release through faeces and urine. Like all dietary nutrients metabolism, water metabolism is also very important as inadequate water consumption will lead to many disorders. Many studies have been done on water metabolism, most of which deals with the effect of dehydration on health implications. Hence this review article was designed to bring out the research findings on the water metabolism in human health and diseases.

WATER METABOLISM IN GENERAL:

Daily water consumption by an individual depends upon its function for various compensatory mechanisms. Water balance depends upon intake and losses. The homeostatic mechanism will be altered even when minute changes in plasma osmolality happen. White healthy adults easily maintain water balance with precision, young infants and elderly are at greater risk of dehydration. Consciousness, speech, incoherence, weakness, hypotonia, hypotension and tachycardia may result due to dehydration. Water intakes are directly related to an individual's expected need for nutritional adequacy. Water is the only nutrition that is essential for hydration [1].

Lack of adequate water intake will be lethal within days. Of late, nutritional related non-communicable diseases are emerging due to a shift towards large amount of water causing from consuming caloric beverages. Lacunae still exists about measurement of total fluid intake, hydration status among population as well as long term systemic interventions since evidence-based publications are not available [2].

Water is being continuously needed and is the most abundant molecule in both humans and animals. The functions of water include as solvent, to remove metabolic waste and regulation of body temperature and cell volume. Precise control of fluid balance indicates biological important, but water is being overlooked as a nutrient since life for all living creatures on earth are based on the presence of water for survival. The many properties associated with water are indispensable for the functioning of cells. Water has many important functions; excellent solvent for ions, nerve signalling, and enzyme activities, mineralisation of organic compounds, hydrogen bonding for protein binding in their sub states, hydrophobic reactions and for protein structure [3].

Water homeostasis is directly related to the concentration of circulating plasma sodium since it is the primary ion in Extra Cellular Fluid (ECF) that determines the serum osmolality. Pathological alteration in water homeostasis will result in hyper and hyponatremia. During steady state both intake and excretion of water are perfectly in balance. Thirst for water intake is stimulated by hypotension and hypovalemia. Thirst induces increased intake to drink water / fluids which lead to body water balance. Thirst is the stimuli induced by hypothalamus of brain. The first line defence against water depletion is renal water conservation, but at times this mechanism may become insufficient during significant dehydration and hyper tonicity. During such instances secretion of Anti Diuretic Hormone (ADH) is stimulated leading to water reabsorption from renal tubules [4].

WATER METABOLISM IN THE ELDERS:

Elderly individual encounter frequent hypernatremia problems and it may be due to physiological responses to water deprivation as a result of increasing age. In older men, deficit in the intensity and thirst threshold have been observed and the ability to concentrate the urine also progressively decline with advancing age and decline in glomerular filtration rate (GFR) leading to renal diseases have been observed. There is decrease in the percent total body water with age and severe water dehydration has been observed in the elderly. Although hyponatremia may be observed in all age – groups, but significant difference is observed in elderly. Menstruating women compared to post-menopausal are 25 times more likely to suffer permanent brain damage due to hyponatremia encephalopathy. They may also suffer from seizure or respiratory arrest and sodium level increase compared to post-menopausal women [5].

In elderly patients, age related changes and chronic diseases are frequently associated with impaired water metabolism and managing water homeostasis is challenging and hence physicians should be aware of the pathophysiology of hypo and hypernatremia in the elderly. Generally, in elderly patients, thirst sensation, renal function hormone modulators, salt intake and water balance are often impaired. It is important for clinicians to evaluate elderly patient on the basis of water and sodium problems, history, physical examination and some laboratory tests to make a correct clinical diagnosis. They should also

evaluate iatrogenic interventions and lapses in nutrition as well as nursing care to evaluate homeostatic balance [6].

FUNCTIONS OF WATER IN HUMAN BODY:

Studies have shown distinct differences in water metabolism in the United States and Germany. Higher intake of preformed water followed by higher urinary volume indicates favourable hydration status on these populations. Both countries follow guideline values for water intake. Water intake of 1.01 to 1.08 ml/Kcal and 1.21 to 1.31 ml/kcal has been prescribed for United State and German citizens [7].

It is well known that water in the human body is essential for metabolism, temperature regulation and numerous other physiological processes that are consistent with good health. Hence, it is important to have accurate, precise and reliable methods to assess body fluid compartments. Many hydration assessment techniques are available among which isotope dilution, neutron activation, bioelectrical impedance, body mass change, thirst, traces appearance, haematological indices and urinary markers are important [8].

WATER AND EXERCISES:

A moderate level of hypohydration may have negative impact on exercise performance. Studies have demonstrated many methods to assess the hydration status among which body mass change, urine analysis for volume, colour, protein content, specific gravity and osmolality, blood borne bodies such as haemoglobin and haematocrit are prominent ones. Urine indices are found to be more sensitive indicators to assess hydration status [9].

Scientific literature regarding hydration status dates back as early as in 1880s, but the actual relationship emerged only after a century. A decrease in body water content generally provokes changes in cardiovascular, thermoregulatory, metabolic and central nerves function prolonged and continuous exercise in the heat will impair the levels of hydration by 2% body mass changes. More studies are required to fully understand low level hydration effects on physical performance. Well hydrated rather than dehydrated are recommended for occupational, military and for sports personnels [10].

In an exercise involved study in the heat, sweat output often exceeds water intake leading to hypohydration. Daily water losses may be substantial and should be balanced by adequate water intake both during exercise and mealtime. It is important to do aerobic exercise carefully as it will adversely affect by heat stress and hypohydration. During warmer climate it will affects performance decrements. The increased heat storage is mediated by reduced sweating rate and reduced skin blood flow. Hence, hyperhydration is recommended in such cases [11].

WATER NEED IN CHILDREN:

A study which examined the effect of water consumption in cognitive children in the age group of 6-7 years old, Improvement was observed in the interactions between time of test and thirst visual attention but not visual memory or visual performance. Hence, even under conditions of mild dehydration, intentional water deprivation or heat exposure, children's cognitive performance could be improved by having a drink of water [12].

Lacunae exist on hydration and cognitive performance in children, but dehydration effects have been well documented. In a study involving 58 children in the age group of 7-9 years, the outcome indicated that children who drank additional water showed significantly less thirsty than the group who did not. Such children performed better on usual attention tasks [13].

Little evidence exists on interventional studies on the impact of asking children to drink water during school days. In a study involving school children in the mean age group of 8 years and 7 months, once after drinking 300 mL water and when no water was provided. Memory was assessed based on 15 selected objects, while recall was significantly better after water consumption, it was not so in water deprivation children. However, the ability to sustain attention was not significantly influenced by whether water had been drunk [14].

HYDRATION & DEHYDRATION:

Generally healthy humans regulate daily water balance remarkably well. However changes due to biological developments and exposure to stresses may be present. Total water intake includes drinking water, in beverages and water in food. Water needs of an individual are determined by fluid balance and water turnover. Daily intakes of 3.7 L for adults' men and 2.7 L for adult women have been recommended. However, physical exercise and other strenuous activities may demand more water intake [15].

Water intake generally varies between adults and children. While adults drink water as wanted, infants and children depend upon care givers for food and fluid. Children are at greater risk for dehydration than adults due to higher surface to mass ratio. Further, children have different thirst sensitivities and body cooling mechanisms than adults. Research in young adults showed that a 1 – 2% body weight loss may lead to significant impairment is cognitive function. Dehydration in children was found to be associated with confusion, irritability, lethargy and decrease in cognitive functions [16].

Hydration plays a major note in the maintenance of health. Studies in healthy subjects have shown that even in mild dehydration many important cognitive functions such as concentration alertness and memory are affected. Hence, it is important to demonstrate the effects of dehydration on many aspects of health status [17].

In recent years both hydration and hypohydration are the topic of much public and scientific debate. While studies on physiological response to hypohydration have been done extensively, lacunae are prevalent on the subjective responses to hypohydration. In a trial involving fluid restriction and dehydration, plasma osmolality and Angiotensin -II concentrations increased in fluid restricted compared dehydration population. There was decrease in plasma volume and feeling of headache in FR compared to normal [18].

In a study involving large number of individuals, 24-hour water intake, urine volume, urine osmolality and individual hydration status were assessed. The mean 24hours water intake ranged from 0.9 ml/kcal to 0.96 ml/kcal, median urine osmolality from 683 mosm /kg to 854 mosm/kg. More studies are required to quantity 24 hours hydration status and to evaluate the effect -on health of different status of dehydration [19].

ROLE OF HORMONES & OTHER METABOLITES:

Vasopressin (VP) is an important and critical regulator of water homeostasis and both V1 and V2 receptors of VP are involved in the regulatory process. Both urinary dilution and concentration will be disturbed during water deficiency as well as excess. Such disturbances in water availability will be observed in disorders like diabetes insipidus (D1) and this syndrome of inappropriate secretion anti diuretic hormone (S1ADH). Recent studies have shown that nephrogenic D1(ND1) are due to mutations with gene coding for V2 receptor (V2R) or aquaporin – 2 (AQP2). Clinical trials are now underway to evaluate the roll of V2R. A study with tolvaptan in comparison with placebo showed no reduction with risk of death and hospitalization for patients with chronic heart failure (CHF) [20].

It is well known that oxidative stress (OS) is being associated with Diabetes Mellitus (DM), hypertension (HT) and arteriosclerosis. Intake of hydrogen rich water at 900 mL per day was found to be associated with a significant decrease in the levels of Low density lipoprotein cholesterol (LDL-c), small dense LDL and urinary 8 – Iso prostanes by 15.5%. Decreased level of oxidised LDL and fatty acids (FA) and increased plasma levels of adiponectin and superoxide dismutase (SOD) were also observed. In 67% of patients with impaired Glucose Tolerance (IGT), intake of hydrogen rich water has normalized the Oral glucose Tolerance (OGT). Hence supplementation with hydrogen rich water were found to be beneficial in the prevention of type 2 diabetes mellitus (T2DM) and Insulin resistance (IR) [21].

Many clinical studies have found out that commonly encountered problems were related to disorders of body fluid balance and they are directly related to the input and output of water. Disorders of body water homeostasis will lead to hypo and hyper molar. While hypermolar will lead to symptom of DM, hypo molar is always associated with SIADH [22].

Stimuli arising from both Intracellular and Extracellular fluid compartments control the volume and osmolarity in mammals. The maintenance of body fluid homeostasis is done by VP and oxytocin (OXT) in response to osmotic and non-osmotic stimuli. Studies have established that atrial natriuretic peptide (ANP) provide potent

defence mechanism against volume overload both in mammals and humans. Both ANP and its receptors are involved in body fluid volume and blood Pressure (BP) regulation. Any increase in blood volume will act directly on heart and brain neurons through inputs of bar receptors. Angiotensin II, a potent inducer of thirst antagonises the action of ANP [23].

The most commonly encountered problem in clinical medicine is the disorder of fluid balance leading to hyper and hypo osmolality. The primary determinant of extra cellular fluid (ECF) is water content of the body. Hyper osmolar and Hypo osmolar are associated with increased and decreased intake of water, since osmolarity is directly linked to sodium content and the disorders are characterised as hyper and hyponatremia [24].

DISORDERS OF FLUID IMBALANCE:

Disorders of body fluid generally lead to Dl and SIADH, but both are relatively uncommon as symptoms of cellar and supracellar masses will become common once surgical intervention is done [25]. Postural hypotension (PH) was identified in myelopathy patients. 13% of patients with Paralysis were identified as having PH. The symptoms of PH identified were 100% reduced consciousness, 75% strength, 56% vision, and 53% breathe. The factors identified were 77% weather, 33% bowl care, and 30% meals. 54% of PH patients showed chronic hyponatremia. Hence, PH was found to be common among myelopathy patients with high levels of paralysis with variable symptoms and abnormal salt and water metabolism were found to coexist [26].

Even during large variations in water intake, the osmotic concentration of body in man will be kept constant at 286-294 mosm/Kg and this maintenance is due to the operation of thirst neuroypophysis - renal feedback system. This system is controlled by VP which modulates the renal threshold of water. During increased water intake a reduction is induced in toxicity of body fluids leading to VP suppression resulting in maximum urine dilution. This excess water excretion restores the plasma osmolality to normal. During water restrictions, increase in osmolality activates thirst which in turns stimulates VP release which increase water reabsorption [27].

Dehydration refers to loss of body water, with or without salt at a rate greater than the body could replace it. While dehydration due to increased sodium or glucose refers to hyperosmolar, water loss alone refers to hyponatremia. Dehydration solely may not be due to neglect of the patients care given but results from a combination of physiological and disease process. Mild to moderate dehydration could be effectively treated by using recombinant hyaluronidase and sub cutaneous infusion of fluids [28].

In a study involving healthy active elders and young men who matched weight loss during water deprivation, while the older men showed greater increase in plasma osmolality, sodium and VP levels, but their urinary osmolality was found to be lower, less thirsty and drunk less water after deprivation. Regression analysis indicated increased sensitivity of VP osmoreceptors in the older compared to the younger. Hence water deprivation for 24 hours may lead to less thirsty. The study has concluded that well known deficit in urinary concentrating ability that occurs with age reflects renal causes and not a lack of circulating VP [29].

Aquaporins are recently identified families of water channels which mediate water transport in kidney and other organs. VP regulates water transport in two ways. Using animal models, it has been proved that water control mechanisms have been shown to be associated with several disorders of water balance such as central DI, congenital nephrogenic diabetes insipidus, SIADH and several extra cellular fluid volume expanded status [30].

A review article has concluded that water represents a critical nutrient, the absence of which will be lethal within days. Due to the consumption of large proportion of beverages, non-communicable diseases have received attention. Lacunae still exists in knowledge related to the measurements of total fluid intake and hydration status at the population level. Much data are not available on long term systematic interventions based on randomized controlled trails [31].

CONCLUSION:

- This review article has highlighted the various health risks associated with water imbalance. The findings of various researches done in the past two decades are highlighted below.
- Water consumption, like daily food intake should be maintained.
- Water is important for many biological functions. Functions of the major organs like liver, cardiac, and kidney are solely dependent on adequate water intake.
- Water is involved in every metabolism taking place in the body.
- Infants, children, adults and those doing regular exercises should consume more water.
- Many commonly found clinical disorders are entirely related fluid imbalance due to less water intake.
- All receptor functions need water.
- Body pH maintenance was entirely dependent on good fluid balance due to adequate water present.
- Among all the nutrients body water is considered as a critical nutrient, the absence of which will lead to many critical disorders.
- Every function in every organ is depends upon sufficient water availability.
- More studies are required in water metabolism among region of inadequate water availability.
- Studies are also required to analyse different sources of drinking water.

CONFLICT OF INTEREST: None

REFERENCE:

1. F. Jequler and F Constant, water as an essential nutrient: the physiological basis of hydration. European Journal of Clinical Nutrition, 2010: 64, 115-123.
2. Barry M, Popkin, Kristen E, D' Anci and Irwin H. Rusenberg, water, hydration and health nutr Rev. 2010 : 68(18); 439-458.
3. Kavouras, Stauros A Phd; Anastasion, Costas A Phd, water physiology: Essentiality, metabolism and Health Implications. 2010: 43(6); 527 – 532.
4. Dr. Nabil M. Aly, Fluid and water metabolism supporting healthcare professional in GM Journal.2013: 43(3):
5. Ayus JC, Aireh AI. Abnormalities of water metabolism in the elderly. SeminNephroe. 1996; 16(4): 277-88.
6. Kugler JP, Hustead T. Hyponatremia and hypernatremia in the elderly. American Family Physician 2000: 61(12); 3623-3630.
7. Manz F, Wentz A. Hydration status in the United States and Germany. Nutr Rev 2005:63: 55-62.
8. Armstrong I.E. Hydration assessment techniques Nut Rev 2005:63: 540-54.
9. Shirreffs S. Markers of hydration status. J sports med phys fitness. 2000:40: 80-84.
10. Murray N. Hydration and Physical performance J AM Coll Nut. 2007:26 : 542S-548S.
11. Swaka MN, Latzka WA, Mato U RP, Montain SJ. Hydration effects on temperature regulation Int J Sports Med. 1998;19 (2) ; S108-110
12. Edmonds CJ, Jeffes B. Does having a drink help you think? 6-7 year old children show improvements in cognitive performance from baseline to test after having a drink of water appetite. 2009:53: 469-472.
13. Edmonds CJ, Burtfold D. Should children drink more water: the effect of drunking water on cognition in children Appetite. 2009:52: 776-779.
14. Benton D. Burges N, The effect of the consumption of water on the memory and Attention of children appetite. 2009:53 : 143-146.
15. Micheal N Sawka Phd, Samuel N Cheuvront PhD, RD and Robert Carter H PhD, MPH. Human water needs. Nutrition reviews, 2005: 63(6) : S30-S39.
16. Kristen F, D'AnciPhd Florence constant MD, PhD, hydration and cognitive function in children nutrition reviews 2008:2816 : 1753-4887.
17. Patrick Ritz, MD, Phd and Gilles Berrut MD, PhD the importance of good hydration for day to day health, Nutrition reviews 2005;63(6): S6-S13.
18. Susan M, Shirreffs I, Stuart J. Merson I, Susan M, Fraser and David T. Archer. The effects of fluid restriction on hydration status and subjective feelings in man. British Journal of Nutrition 2004:91; 951-958.
19. Friedrich Manz MD, Andrews Wentz MD, Wolfgang Sichert – Hellert MA. The most essential nutrient: Defining the adequate intake of water. The journal of paediatrics. 2002:141(2); 587-592.
20. H.P.F, Peters, J.H. Robben, P.M.T. Deen, J.F.M Wetzels, in health and disease; new aspects of disturbances in water metabolism. The journal of medicine. 2007; 65(9): 325-32.
21. Sizuokajiyama, Gojillasegawa, Mai Asano, HiraleoHosada, Michiakifukui, Naoto Nakamura etal. Supplementation of hydrogen rich water improves lipid and glucose metabolism in patients with type 2 diabetes mellitus or impaired glucose tolerance. 2008;28(3): 137 – 143.
22. Joseph G Verbalis MD. Disorders of body water homeostanis. Best Practive and Research Clinical Environment & Metabolism, 2003; 17(4): 471-503
23. Jose Antunes – Rodrigues, Margaret De Castro, Lucila L.K Elias, Marcelo M. Valenc.A, and Samuel M. Mecann. Neuroendocrine control of body fluid metabolism, Physio Rev 2004; 84(1):169-208.
24. Joseph G. Verbalis, Estimates of the relative disorders of water metabolism. Contemporary Endocrinology Hand Book of Diagnostics Endocrinology. Edited by JE Hall and LK Niemann. 2012.
25. Joseph G, Verbalis, Management of Disorders of Water Metabolism in Patients with Pituitary Tumors. Pituitary, 2002; 5(2); 119-132.
26. James H Frisbie& David JR Steele. Postural hypotension and abnormalities of salt and water metabolism in myelopathy patients. Spinal Cord 1997;35; 303-307.
27. Thomas Berl, Robert J Anderson, Keith M. Mc Donald, Robert W. Schrier. Clinical disorders of water metabolism. Kidney International.1976; 10(1); 117-132.
28. Thomas DR, Cote JR, Lawborne J, Levenson SA, Ruberstein LZ, Smith DA etal. Understanding clinical dehydration and its treatment. J Am Med Dir Assoe. 2008 ; 9(5): 292-301.
29. Phillips PA, Rolls BJ, Ledingham JG, Reduced thirst after water deprivation in healthy elderly men. N Engl J Med. 1984:371: 753-759.
30. Knepper MA, vebalis JG, Nielson S. Roled aquaporins in water balance disorders. Curropin Nephrol Hypertens 1997: 6(4) : 367-371.
31. Barry M Popkin Kristen E. D' Anci Irwin H Rosenberg. Water, hydration and healthy Nutrition reviews, 2010: 6818: 439-458.