Electrolyte supplementation on workers under heat stress: a preliminary study on workers' hydration and performance

by Daru Lestantyo

Submission date: 30-Mar-2020 10:49AM (UTC+0700)
Submission ID: 1284984824
File name: Daru_Lestantyo_-_Electrolyte.docx (202K)
Word count: 3406
Character count: 19022

Electrolyte supplementation on workers under heat stress: a preliminary study on workers' hydration and performance

Daru Lestantyo [1*], Suroto [2]

[1] Occupational Health Department, Faculty of Public Health, Diponegoro University, Indonesia, 50275
[2] Master Of Health Promotion, Postgraduate Program, Faculty of Public Health, Diponegoro University, Indonesia, 50275

*Corresponding author : Daru Lestantyo, Occupational Health Department Public Health Faculty, Diponegoro University, Jl. Prof. Sudarto, SH,Tembalang, Semarang, 50275. Email: daru@undip.ac.id, daru71@gmail.com

Abstract. *Background*. Heat exposure could harmed employees on many aspects. Prolonged activity under extreme heat often results in fatigue, poor concentration and dehydration. Lack of water consumption would make impact either in electrolyte balance or urinary tract system. This study examined electrolyte water supplementation and its impactin urine osmolality and employee's performance under extreme heat condition .
Methods. Indoor temperature, workers' performance and indoor air humidity were measured. Seventy people were participated and divided evently into group A (isotonic) and group B (hypotonic). In a single blind experimental study, 3000 ml of isotonic and hypotonic solution were administered into group A and B, respectively, within 8 hours. Urine sample were taken at 10 am and 15 pm and reaction time test was done to measure performance at the end of working time.
Result. Low consuming water (400 –1100 ml) in the first 4 hours was found in both group. Most of participants were stated as moderately hypohydrated state (average of urine specific gravity 1.026) in the beginning of working hours. There was no differences of urine specific gravity between two groups (U= 608.00, p=0.954). Workers' performance was found elongated (moderately fatigue) and there was no differences in both groups (U=706.05 and p= 0. 657).
Conclusions. Electrolyte supplementation in this study is not appropriately enough to maintain electrolyte balance among workers under heat stress environment. Heat stress and lack of water replacement will caused moderate fatigue

Keywords: heat stress ; electrolyte supplementation ; hydration status ; work performance

Introduction

According to the Indonesian Minister of Labour Regulation No. 5/2018 on Occupational safety and Health Standards , it has been assigned that Indoor Temperature Threshold Limit Value (TLV) was at arnge between . TLV is determined with a view to giving limits in occupational safety and health through physical and chemical hazards[1] .vv Heat exposures can triggered fatigue and work performances. Research conducted in Central Java on steel billet factory workers find a correlation of ambient temperature and body core temperature rise [2].

Although the liquid adequacy rate has been set in the RDA (Required Daily Allowance/Nutrition Adequacy Score) for Indonesian people, but specifically not obtained figures for the adequacy of minerals (Na, K, Cl) in drinking water either for people working under high temperature . Adequacy of water and electrolytes were also needed by employees who worked with exposure of high temperature [3]. Regulations determine the safe working limits in order to avoid illness and accidents. The objectives of the study were to measure hydration status of employees and examine the role of urine specific gravity test in fluid replacement decision of workers under heat stress condition. The present investigation was designed to assess the effect of high temperature for employees'health, and hydration status.
Heat stress is common for workers in a laundry processing with dry cleaning method. Work processes and tools / machines used have great potential of heat injuries/illnesses. These extreme conditions were sourced from workplace lay out with less functioning of air conditioned. This will increase the temperature of the room . Approximately 10 persons work under hot temperature in 10-12 workhours everyday. Workplace measurements at baseline condition was conducted in February 2018. From baseline survey, we have workplace temperature in production area was 30°C-33°C (WBGT).

Further issue for this study was to observed fatigue level which tecnically correlated with hydration status. People who are involved in hot conditions job, without access to shade or sufficient fluid replacement, are at especially elevated risk in heat related injuries. Heat related injuries can cause discomfort, fatigue, exhaustion, heat cramps, and heat stroke in employees[4,5]. During four hours of work, we observed that employees drank as much as 2-3 cups (400-600 ml) of water and taken outside during lunchtime . Based on observation,

employees must cope with, high temperature, humid and less fresh air ventilation. They also have less frequent of water and electrolyte replacement. The employer had never done urine specific gravity test before.

Methods

This is an experimental studies with Randomized Controlled Trial (RCT) in a double-blind design. In this study subjects were treated with electrolyte solution for eight hours work. The research observed differences in urine osmolality and specific gravity between treatment group and the comparison through fluid-electrolyte supplementation for 8 hours of work. Affordable population is laundry workers in Semarang District, Indonesia as many as 90 people. Eligible participants were examined before the data was collected. The enumerators reached the workplaces 1/2 hour before work began, after which baseline assessment was carried out. Samples selected by purposive sampling using the inclusion criteria, as follows:

a. Age 20-40 years
b. Working in a place with heat exposure WBGT> 30° C
c. Willing to become respondents (informed consent)
d. NaCl consumption of 2400-2500 mg / day
e. No history of urinary tract disease (infections, *calculi*)
f. No history of hypertension or cardiovasculair disease

Workplace temperature was measured by using a digital Questtemp Heat Area Monitor. NaCl intake measured using a questionnaire of 3 x 24 hour recall and analyzed with open source software for nutritional analysis. The nutritional status was measured by using the Body Mass Index (BMI) refers to the classification from Indonesia Ministry of Health. Urine Specific Gravity was measured by using Urinometer. Electrolyte supplementation given were:

1. isotonic electrolyte solution , containing 0.9 g of sodium chloride and potassium chloride 0.6 g per 1 L
2. hipotonic electrolyte solution as a placebo containing 0.52 g of sodium chloride and potassium chloride 0.30 g per 1 L

The solution was preserved and validated by Department Of Pharmacy Faculty of Medicine, Diponegoro University. Statistical analysis conducted in non-parametric test (Mann-Whitney) for urine specific gravity and osmolality of the treatment group and control. Workplace temperature was measured in a 3-point measurement of Questtemp. It measured twice daily : at 10:00 and 15:00.

Hydration status based on USG samples in this study are cathegorized in :

1. ≤ 1.015 – optimal level of hydration (euhydrated).
2. 1.016–1.020 – marginally adequate hydration.
3. 1.021–1.025 – hypohydrated.
4. 1.026–1.030 – severely hypohydrated, at increased risk of heat illness and impaired performance. Should not work in hot conditions.
5. > 1.030 – a clinically dehydrated state, based on the criterion used by the Australian Pathology Association (APA)[6]. Flicker fusion test was conducted to identify general fatigue. The test done 15 minutes before lunch break. Subjects were not allowed to drink, eat or going out before the test.

Results and discussions

Ambient Temperature

The ambient parameters required for calculating the TLV indicator were measured twice a day at the middle, and end of the working hours in the working place of both group (1000 am and 1500 pm).

Table 1. Ambient Indoor Temperature

No	Location	WBGT		Rate Humidity (%)	
		1000	1500	1000	1500
	1	30,3	31,1	74,4	74, 8
	2	30,5	33,3	73,8	74,3
	3	30,1	32,2	74,5	74,6

According to Indonesia Ministry Of Labour Regulation No. 5/2018 , the observed workplace indoor temperature has exceeded the Threshold Limit Value (TLV) in the amount of 26,7 ^{0}C. The result was still lower when compared with mining workers with the working environment temperature was higher from 30,7 ^{0}C to 35,2^{0}C . Studies in Australia on mining workers showed results 29,5° C dry temperature (dry bulb) . Both studies demonstrate the need to control the temperature in the workplace so as not to exceed the Threshold Limit Value (TLV). Heat induced injuries are related by a combination of ambient temperature , employees' health status, dehydration , drugs and/or alkohol abuse [7] Many studies reported that working activities in an extreme hot environment (>40°C) could improve peripheral nerve mechanisms and could result in the sweating response [8,1,9]

Participants' age

Respondents who participated in this study were between the ages of 20-40 years. Selection of this age range based on the hypothesis that people under 40 still have good adaptability for extremely high temperature [1].

Table 2. Participant's Age

* Corresponding author: daru71@gmail.com

No	Age group (yrs)	Freq	%
1.	20-25	18	25,7
2.	26-30	2	31,4
3.	31-35	20	28,5
4.	36-40	10	14,2
	Total	70	100

Age plays a role in an individual's health status, especially under continuous hazardous heat exposure. Although not specific, studies have shown a correlation of age with episodes of heat exhaustion in miners. Workers with over 40 years of age were relatively more vulnerable to be attacked by heat exhaustion [10] Physiologically, the age factor relates to the ability of the kidneys to excrete the rest of biochemical metabolites to maintain the acid-base balance of the blood. Increasing age of a person or a disturbance in the kidney will reduce glomerular and tubular function in the formation of urine. A number of studies have examined age-related differences in thermoregulatory function under extreme hot conditions[11,12]. Unhealthy lifestyle such as lack of physical activity, consumption of drugs in the long term as well as the lack of drinking habits can also be a trigger factor [8]

Body Mass Index (BMI)

Body Mass Index measurements conducted to determine the anthropometric nutritional status. It could identify possible malnutrition from food intake and/or workplace exposure.

Table 3. Body Mass Index

No	BMI	Freq	Percentage
1	Normal	65	92,84%
2	Overweight	5	7,16 %
	Total	70	100 %

BMI measurements were applied to estimate the individual adaptability to high temperature. Body weight monitoring is beneficial to determine the participant's weight loss due to dehydration. Studies in 51 workers in California in mid-summer earned weight loss of 2.3 kg per day [13]. Excess weight loss , followed by the build up of fatty tissue caused body to produce more heat . Dehydration predisposes the participants to healt exhaustion, heat stroke and heat cramps. This is disadvantageous for employees who worked in a high/extreme temperature . Adaptability of extreme heat will be low so workers will quickly feel tired compared to individuals with normal BMI [9,3]

Work period

Table 4 .Work Period

No	Work Period (yrs)	Freq	Percentage
1	1-3	30	42,85 %
2	4-6	30	42,85 %
3	7-9	10	14,2 %
	Total	70	100 %

Respondent has been working for - 6 years of average.

3.5. Urine specific gravity (USG) and osmolality

Table 5. Frequency Distribution of Urine Density and Osmolality (Average per group for each sample)

USG I		Osmol I		USG II		Osmol II	
A	B	A	B	A	B	A	B
1,021	1,026	1050	1050	1,0264	1,0264	1050	1050

USG = Urine Specific Gravity
Osmol = Osmolality

Mean of urine sampling in two group were 1.0258 (SD 0.0057) . Osmolality mean 893.50 (SD 212.48). Mann-Whitney test for urine specific gravity of the two groups of workers showed U 608.00, and the p value 0.954 which means that Ho is accepted ($\rho > 0.05$) ie no urine specific gravity differences between two groups . Median value of urine osmolality test results showed UD = 611.00, and the p value was 0.984 which mean that Ho is accepted ($\rho > 0.05$). There was no difference in mean urinary osmolality of two groups.

Research showed differences in the ability of sweating sensitivity based on tenure . Workers with tenure of more than five years tend to have lower sweating rate compared to the group with a newer ones. This condition is caused by adaptation functions that have been run better. Although there have been adaptations, but does not mean the system is not impaired renal excretion [1].

Urinary density and osmolality was depend on fluid and amount of solute produced by the kidney tubules . Urine osmolality was defined as number of moles of solute per kg of solvent (water)[6]. Examination of urine specific gravity is a method to assess renal function or hydration status, especially in conditions of high ambient temperature [1] . For practical purposes, urine specific gravity were able to assess hydration status either euhydrated (UD = 1.015) as well as voluntary hypohydrated (UD> 1.025) based on the

* Corresponding author: daru71@gmail.com

classification of Australian Pathology Association (APA) [9]. Fluid loss due to physical workload or environmental temperature as much as 1.5% of body weight can have an effect on the physical performance of individuals [3].

From laboratory examination result of urine specific gravity,70 respondents earned an average of 1.0258, while the osmolality was 893.5 mOsm / Kg. USG value was related with the "voluntary hypohydrated"cathegory according to APA classification. This condition can be caused by lack of water replacement during work hours . Many studies examined influence of hydration level on body fluids and exercise performance in the heat environment. They addressed the issues of hypohydration and the effects on performance/fatigue [7,1]. From the preliminary data obtained 16 workers (47%) had urinary SG 1,030 which should be monitored physical condition andalso need a rapid fluid and electrolyter replacement. Compared to the USG indicators , urine osmolality levels more believed to evaluate renal concentrating ability because relatively few factors that influence [1]. Results of the examination with the conversion of urine specific gravity showed the average value of osmolality remained at physiological range (normal value 50-1400 mOsm / Kg) This physiological range indicates that the body is capable of adapting to the formation of urine in a state of high temperature[14]. Majority of the respondents (80%) drank less water during work hours and experienced excessive sweating.

It was no difference in mean results of these two groups, could be sourced from the amount of fluid which had drunk and did not meet body metabolic needs and fluid balance. The addition of electrolytes (Na, K) in the fluid being offset by a sufficient volume will not be able to fix the value of urine SG and osmolality, due to a smaller volume than the concentration of solute to produce concentrated urine . Provision of electrolytic more expected shortly on improving the body's electrolyte balance. Giving proper electrolyte is expected to prevent heat cramps or heat exhaustion [15]. Urine density improvement can be achieved when consumption reaches 1.4 to 1.8 liters of fluid per hour in extreme conditions such as underground miners and the military personnel in desert [13]. Consuming water without any electrolytes may be problematic for physical activity under hot environment exceeding several hours that produce high sweat rates[16, 17]

Work Performance (Fatigue Level)

Table 6 Level Of Fatigue

Fatigue Level	n	%
Mild	10	14,28
Moderate	50	71,43
Severe	10	14,28
Total	70	100

Concerning employee's fatigue, table 6 showed that most of participants were in moderate fatigue state. The participants reported that they felt more tired in the hotter weather and experienced sweating and headaches that slowed their job. Participants from both groups reported that it required a longer time to finish their tasks in extreme high ambient temperature. On average, respondents worked 10 hours a day in their routine job. Most of participants reported that they took breaks to rest every 20 minutes or less. This finding was in the same line with prior research which stated that the highest percent of chronic fatigue was shown in moderate level [18]. There was no differences in both groups (U=706.05 and p= 0. 657) in level of fatigue .

Conclusions

The result showed that urine specific gravity (USG) was high and cathegorized in moderately/voluntary hypohydrated. This condition was caused due to the volume of electrolyte replacement drink had has not reached the required needs . Osmolality value was stated in "normal" cathegory. There was proved that anyn acclimatization and adapttation to high temperatures amongst participants. Due to USG result, it also proved that kidney still be able to compensate urine concentration. Even though,"voluntary dehydration" is the primary issue for this study[1,19] . The company can educate workers to increase consumption of drinking water with electrolytes until it reaches 1.5-2 liters for 4 hours. Urine Specific Gravity could also be examined to check the osmolality every 3 months periodically. Drinking water was expected to be placed closer to the workspace.

Employees should do little exercise on the workplace. It benefits is reducing stress and fatigue at work. They should done every 2 hours. The research showed that heat management based on ambient monitoring but without addressing the hydration status cannot protect workers from the effects of heat stress injuries [7,20]

Conflict of Interest

The author hereby disclose all of our conflict of interest and other potentially conflicting interests ,including specific financial interests and relationships and affiliations relevant to International Journal Of Public Health Research and Development . This applies to the past 5 years and the foreseeable future.

Acknowledgements

This research was supported partially by Indonesian Association Of Occupational Health Physician . We thank for undergraduate students from Faculty Of Public Health, Diponegoro University who provided insight and expertise that greatly assisted the research although they may not agree with all of the interpretations of this research.

* Corresponding author: daru71@gmail.com

Ethical Clearence

Ethical clearance were obtained from the ethical committee of the university. Participation was voluntary and informed consent was given by all the participants.

References

1. Brake DJ, Bates GP. Fluid losses and hydration status of industrial workers under thermal stress working extended shifts. Occup Environ Med. 2003;60(2):90–6.

2. Sawka MN, Leon LR, Montain SJ, Sonna L a. Integrated physiological mechanisms of exercise performance, adaptation, and maladaptation to heat stress. Compr Physiol [Internet]. 2011;1(4):1883–928. Available from: http://www.ncbi.nlm.nih.gov/pubmed/23733692

3. Byrne C, Lim CL, Chew SAN, Ming ETY. Water versus carbohydrate-electrolyte fluid replacement during loaded marching under heat stress. Mil Med. 2005;170(8):715–21.

4. Kjellstrom T, Lemke B, Otto M. Mapping Occupational Heat Exposure and Effects in South-East Asia: Ongoing Time Trends 1980-2011 and Future Estimates to 2050. Ind Health [Internet]. 2013;51(1):56–67. Available from: http://apps.webofknowledge.com/full_record.do?product=UA&search_mode=GeneralSearch&qid=10&SID=V2EZkWL7jYiSpbhjNEX&page=1&doc=10

5. Rahman J, Fakhruddin SHM, Rahman AKMF, Halim MA. Environmental Heat Stress Among Young Working Women: A Pilot Study. Ann Glob Heal [Internet]. 2016;82(5):760–7. Available from: http://dx.doi.org/10.1016/j.aogh.2016.07.007

6. Montazer S, Farshad AA, Monazzam MR, Eyvazlou M, Yaraghi AAS, Mirkazemi R. Assessment of construction workers' hydration status using urine specific gravity. Int J Occup Med Environ Health. 2013;26(5):762–9.

7. Storrie-lombardi M. Heat stress and electrolyte imbalance. 2015;(October).

8. Von Duvillard SP, Braun W a., Markofski M, Beneke R, Leithäuser R. Fluids and hydration in prolonged endurance performance. Nutrition. 2004;20(7–8):651–6.

9. Kenny GP, Jay O. Thermometry, calorimetry, and mean body temperature during heat stress. Compr Physiol. 2013;3(4):1689–719.

10. Yamazaki F. Effectiveness of exercise-heat acclimation for preventing heat illness in the workplace. J UOEH. 2013;35(3):183–92.

11. Nerbass FB, Pecoits-Filho R, Clark WF, Sontrop JM, McIntyre CW, Moist L. Occupational Heat Stress and Kidney Health: From Farms to Factories. Kidney Int Reports [Internet]. 2017;2(6):998–1008. Available from: https://doi.org/10.1016/j.ekir.2017.08.012

12. St EJ, Met C. The Effect of Heat Stress , Dehydration and Exercise on Global Left Ventricular Function and Mechanics in Healthy Humans The Effect of Heat Stress , Dehydration and Exercise on Global Left Ventricular Function and Mechanics in Healthy Humans A thesis subm. 2015;(March).

13. Coyle EF. Fluid and fuel intake during exercise. J Sports Sci [Internet]. 2004;22(1):39–55. Available from: http://www.tandfonline.com/doi/abs/10.1080/02640410310001405 45

14. Kenefick RW, Cheuvront SN. Hydration for recreational sport and physical activity. Nutr Rev. 2012;70(Suppl 2):s137–42.

15. Dehghan H, Habibi E, Khodarahmi B, Hosseinali Yousefi HA, Hasanzadeh A. The relationship between observational - perceptual heat strain evaluation method and environmental/physiological indices in warm workplace. Pakistan J Med Sci. 2013;29(1 SUPPL.):358–62.

16. Paik I-Y, Jeong M-H, Jin H-E, Kim Y-I, Suh A-R, Cho S-Y, et al. Fluid replacement following dehydration reduces oxidative stress during recovery. Biochem Biophys Res Commun [Internet]. 2009;383(1):103–7. Available from: http://dx.doi.org/10.1016/j.bbrc.2009.03.135

17. Clapp AJ, Bishop P a., Smith JF, Bauman TR. Palatability ratings of different beverages of heat exposed workers in a simulated hot industrial environment. Int J Ind Ergon. 2000;26(1):57–66.

* Corresponding author: daru71@gmail.com

18. Mate J. Global warming and heat stress among Western Australian mine , oil and gas workers . Edith Cowan; 2012.

19. Ganio MS, Armstrong LE, Casa DJ, McDermott BP, Lee EC, Yamamoto LM, et al. Mild dehydration impairs cognitive performance and mood of men. Br J Nutr. 2011;106(10):1535–43.

20. Rowlinson S, Yunyanjia A, Li B, Chuanjingju C. Management of climatic heat stress risk in construction: A review of practices, methodologies, and future research. Accid Anal Prev [Internet]. 2014;66:187–98. Available from: http://dx.doi.org/10.1016/j.aap.2013.08.011

* Corresponding author: daru71@gmail.com

Electrolyte supplementation on workers under heat stress: a preliminary study on workers' hydration and performance

ORIGINALITY REPORT

15%	13%	8%	13%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.i-scholar.in Internet Source	8%
2	Saideh Montazer, Ali Farshad, Mohammad Monazzam, Meysam Eyvazlou, Ali Yaraghi, Roksana Mirkazemi. "Assessment of construction workers' hydration status using urine specific gravity", International Journal of Occupational Medicine and Environmental Health, 2013 Publication	3%
3	eprints.ums.ac.id Internet Source	2%
4	digital.library.adelaide.edu.au Internet Source	2%

Exclude quotes	Off	Exclude matches	< 2%
Exclude bibliography	Off		