J Occup Health 2010; 52: 209–215

Journal of Occupational Health

Effect of Oral Rehydration Solution on Fatigue during Outdoor Work in a Hot Environment: A Randomized Crossover Study

Tomohisa ISHIKAWA[1–3], Hideru TAMURA[2, 3], Haruya ISHIGURO[1], Keiko YAMAGUCHI[3] and Kazufumi MINAMI[3, 4]

[1]Division of Gastroenterology and Hepatology, Department of Internal Medicine, The Jikei University School of Medicine, [2]JAL Ground Service Haneda, Co., Ltd., [3]Health Consulting Section, JAL Ground Service, Co., Ltd. and [4]Department of Orthopaedic Surgery, Nippon Medical School Chiba Hokusoh Hospital, Japan

Abstract: Effect of Oral Rehydration Solution on Fatigue during Outdoor Work in a Hot Environment: A Randomized Crossover Study: Tomohisa ISHIKAWA, *et al*. Division of Gastroenterology and Hepatology, Department of Internal Medicine, The Jikei University School of Medicine—Objectives: The effects of an oral rehydration solution (ORS) on fatigue were studied in workers engaged in manual work during the summer. **Methods:** One hundred and fifty-three workers engaged in loading cargo onto aircraft at Tokyo International Airport who consented to participate in the study were the subjects. The study was carried out on two summer days with fine weather during the daytime shift. The subjects were randomly divided into two groups: with one group restricted to ORS intake and the other group having free-choice of their favorite drink (FAD) in a randomized crossover study. The subjects were asked about the amount of beverage that they consumed and the type of FAD that they chose on the days of the survey. The effects of the ORS and the FAD were compared using a visual analogue scale (VAS) to determine the degree of fatigue experienced immediately after completing work. **Results:** The average wet bulb globe temperature (WBGT) on the survey days was 30°C. The beverage intake during work was 1,000 m*l* for most participants and the most commonly chosen types of FAD were tea and coffee. The fatigue VAS was significantly lower on the ORS intake days than on the FAD intake days (50.0 ± 18.3 vs. 53.9 ± 16.3). **Conclusions:** The results of this study suggest that the intake of ORS during outdoor work in a hot environment would be effective for preventing industrial accidents and heat stroke. It is important to select an appropriate drink to ensure adequate intake of water and electrolytes.
(J Occup Health 2010; 52: 209–215)

Key words: Fatigue, Hot environment, Oral rehydration solution, Visual analogue scale

Working on aircraft ground handling includes many outdoor tasks, such as directing aircraft schedule at the time of takeoff and landing, loading cargo, cleaning, inspection, and maintenance. As the amount of heat radiated from the ground and generated by the planes can be high in the summer, in addition to the effects of direct sunlight, the work is often carried out in a very hot environment, not only during the daytime, but also during the nighttime. Working outdoors in summer can lead to heat stroke, thus, employers are responsible for ensuring that measures are implemented to combat this situation from the point of view of health and safety. It is also advisable for individual workers to be aware of such difficulties associated with their working environment. Heat stroke during work in a hot environment is very dangerous, and some fatalities have been reported[1, 2]. In order to prevent heat stroke, water and salt supplementation are important, in addition to body temperature control[3].

In clinical practice in recent years, oral rehydration therapy (ORT) for dehydration has proven to be effective, and has been established as one of the methods outlined in treatment guidelines[4]. Compared with commercially available sports drinks, oral rehydration solutions (ORS) are high in sodium, low in sugar, and have an osmotic pressure that is lower than that of plasma. One characteristic of their composition is that they contain glucose at an optimal concentration to promote sodium absorption. As a result, effective water absorption by the

Received Dec 9, 2009; Accepted May 11, 2010
Published online in J-STAGE Jun 14, 2010
Correspondence to: T. Ishikawa, Department of Internal Medicine, Gastroenterology and Hepatology Unit, The University Hospital, The Jikei University School of Medicine, 3–25–8, Nishi-Shinbashi, Minato-ku, Tokyo 105-8461, Japan (e-mail: ishito@jikei.ac.jp)

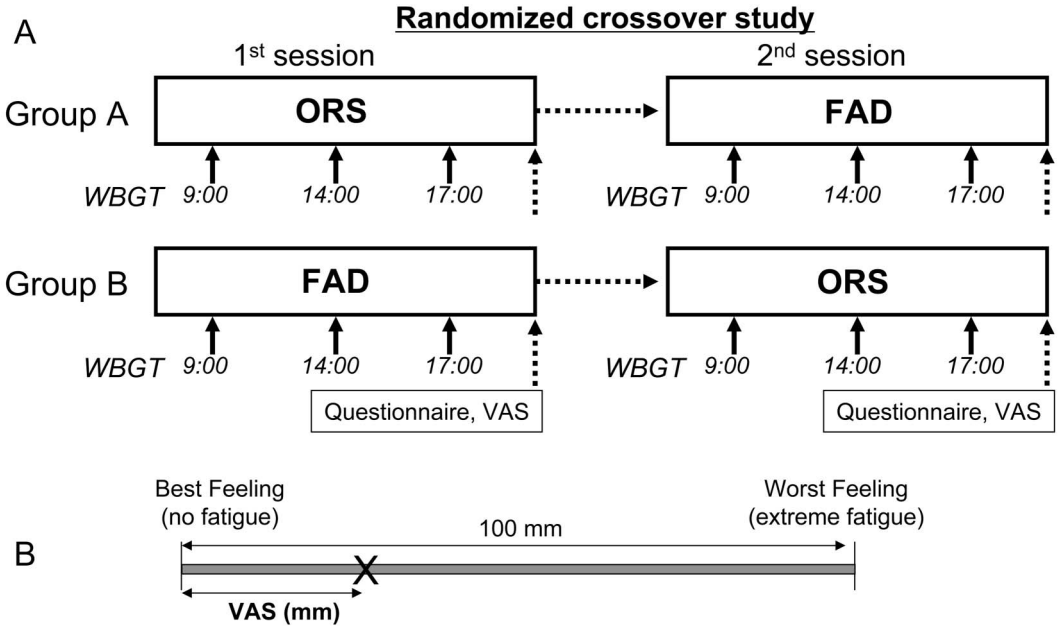

Fig. 1. Design of the study. One-hundred and fifty-three subjects were randomly divided into two groups (OS-1 and FAD) and a randomized crossover study was conducted. An interval of at least five days was set up according to the work shift between the two survey days (A). Immediately after work, questionnaires about the amount of drink consumed and the types of FAD chosen were completed, and the degree of fatigue was evaluated using the visual analog scale (VAS). Horizontal simple VAS was used in this study (B). FAD: free-choice favorite drink.

body is possible[5]. In this study, the effect of ORS intake on fatigue during work was evaluated in workers engaged in outdoor manual work of aircraft ground handling in summer.

Subjects and Methods

One hundred and fifty-three workers (142 men, 11 women, and average age of 25.6 ± 6.4 years old) engaged in loading cargo onto aircraft at Tokyo International Airport who agreed to participate were the subjects of the study. Prior to obtaining their consent all participants in this study were provided with information concerning the study, including the composition and safety of the ORS, and the fact that it had already been used in clinical practice. Their work clothes were coveralls made of cotton and nylon (70%:30%) with a good sweat absorption property. In the 12 days of the survey period from July to August in 2008, 2 days were set as the study session, with investigations being carried out during the daytime shift (Fig. 2). The subjects were randomly divided into two groups, with one group restricted to intake of ORS and the other group having of a drinks of their own choice (FAD: free-choice favorite drink) in a randomized crossover study. An interval of at least five days and one day off was set up according to the work shift between the two survey days.

The participants worked for 8 hr on both days and the type of work involved was the same (Fig. 1A). The participants consumed the drink at the time of work breaks except the lunch break. The ORS and FAD were kept at 4°C in a refrigerator.

As an ORS, OS-1® (Otsuka Pharmaceutical Factory, Inc., Tokushima, Japan) was used (Table 2B). The work environment on each survey day was evaluated by measuring the WBGT at 1.5 m above ground at 9:00 am, 2:00 pm, and 5:00 pm using a heat stroke index meter (WBGT-113, Kyoto Electronics Manufacturing, Kyoto, Japan). Questionnaires about the amounts of ORS and FAD consumed (selected from the following options: 500 m*l*, 1,000 m*l*, 1,500 m*l*, 2,000 m*l*, and more than 2,000 m*l*) and the type of FAD chosen on the survey days were completed. Immediately after the work, the degree of fatigue experienced by the subjects was evaluated using a visual analog scale (VAS). An horizontal simple VAS was used in this study (Fig. 1B, a straight horizontal line of 100 mm in length with the left end for no fatigue and the right end for extreme fatigue). Subjects were instructed to make a mark on the scale according to the intensity of their fatigue. The results are expressed in millimeters from zero (no fatigue) to 100 (severe fatigue).

The difference in fatigue as assessed by VAS was evaluated between ORS and FAD with the paired *t*-test

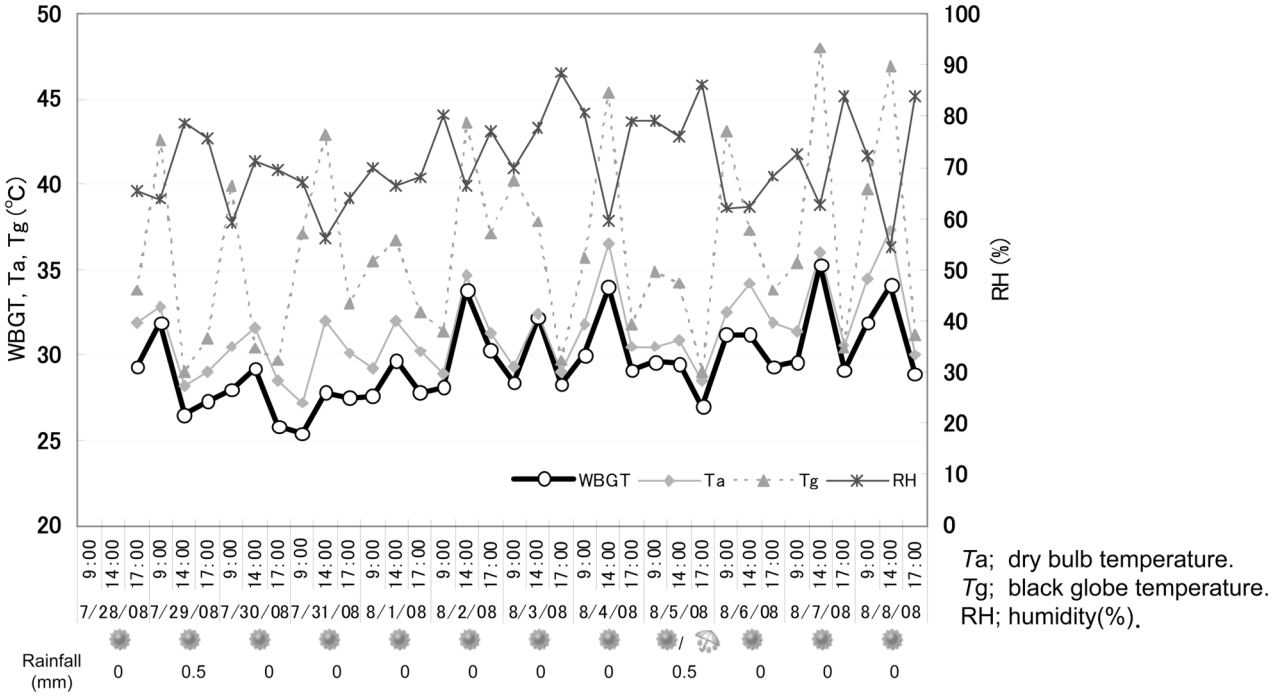

Fig. 2. WBGT in the working environment. The working environment on each survey day was evaluated by measuring WBGT at 1.5 m above the ground at 9 am, 2 pm, and 5 pm using a heat stroke index meter. The average WBGT during the 12-day study period was 30.0 ± 2.4°C.

Table 1. The amount of fluid consumed on the survey day

	500 m*l*	1,000 m*l*	1,500 m*l*	2,000 m*l*	2,000 m*l*<	NA
ORS	48	88	7	6	0	4
	(31.4%)	(57.5%)	(4.6%)	(3.9%)	(0%	(2.6%)
FAD	37	85	16	5	1	9
	(24.2%)	(55.6%)	(10.5%)	(3.3%)	(0.7%)	(5.9%)

The numbers and percentages of subjects who consumed various amounts of drink during the work were determined for ORS and FAD. N=153 pairs.

and a test of the relative proportions. Relations between these two parameters were assessed using Pearson's correlation analysis. Differences were considered statistically significant at $p<0.05$.

Results

During the survey period, the weather was fine except for an evening shower on one day. The average WBGT during the 12-day study period was 30.0 ± 2.4°C, which constitutes a hot environment, with the WBGT being over 25°C each day and with the highest WBGT being 35.3°C (Fig. 2). The diurnal WBGT reached the maximum at 2:00 pm on 9 days out of 12 survey days (75%). The average humidity was 71.1 ± 8.7% in the study period. There were no adverse events during the study period and the study was conducted safely as scheduled. As for the amount of beverage consumed, the numbers of subjects who ingested 1,000 m*l* during 8 hr of work were 88 (57.5%) for ORS and 85 (55.6%) for FAD out of 153 participants (Table 1). The numbers of subjects who ingested 500 m*l* of liquid during work were 48 (31.4%) for ORS and 37 (24.2%) for FAD. Those who consumed 2,000 m*l* or more were a minority, and accounted for about 4% of the subjects for both ORS and FAD. The types of FAD chose were tea (106 answers, 25.3%), coffee (86 answers, 20.5%), sports drinks (85 answers, 20.3%), and water (64 answers, 15.3%) (Multiple responses per participant, Table 2A). The drinks chosen by 77% of

Table 2A. Type of free-choice favorite drink

Tea	Coffee	Sports drink	Juice	Water	Others
106 (25.3%)	86 (20.5%)	85 (20.3%)	68 (16.2%)	64 (15.3%)	10 (2.4%)

Questionnaire results concerning the type of FAD chosen (multiple responses per participant). The number of answers was 419 in total.

Table 2B. Composition of OS-1 and typical composition of tea, coffee, sports drink and juice

	OS-1	Tea*1	Coffee*1	Sports drink*2	Juice*1
Na^+ (mEq/*l*)	50	0–1	0	9–23	3
K^+ (mEq/*l*)	20	2–87	17	3–5	15
Carbohydrate (%)	2.5 (glucose 1.8)	0.2	0.7	6–10	10

*1: typical composition of green tea infusion, coffee infusion, and 30% orange juice (Ref. 6),
*2: package data from commercially available products.

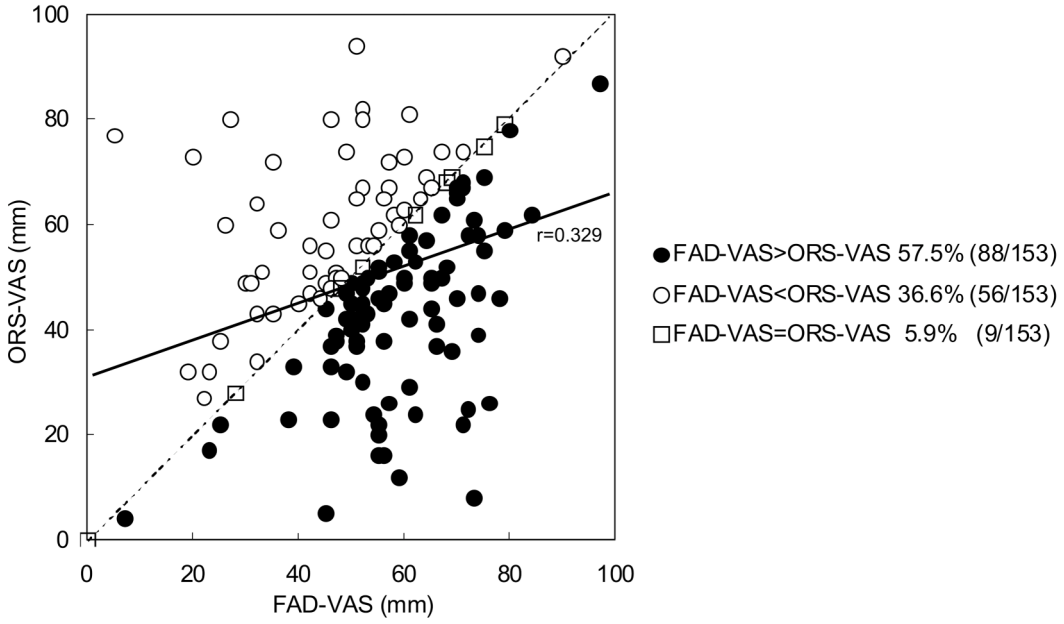

Fig. 3. Comparison of fatigue VAS between ORS and FAD. A scatter plot was produced with FAD-VAS represented by the X-axis and ORS-VAS by the Y-axis. Data with FAD-VAS>ORS-VAS are plotted as closed circles (●), FAD-VAS<ORS-VAS as open circles (○), and FAD-VAS=ORS-VAS as open squares (□). The percentage of the data that was FAD-VAS>ORS-VAS (57.5%) was larger than that of the data that was FAD-VAS<ORS-VAS (36.6%).

participants (tea, coffee, water, and juice) contained a very small amount of sodium (Table 2B)[6].

The analysis of fatigue VAS at the end of work showed that there were 88 subjects (57.5%) who recorded a lower fatigue VAS score on the ORS intake day than on the FAD intake day and 9 subjects (5.9%) who showed no difference (Fig. 3). On the other hand, the number of subjects who recorded a lower fatigue VAS score on the FAD intake day than on the ORS intake day was 56 (36.8%). Among the subjects, excluding the 9 participants

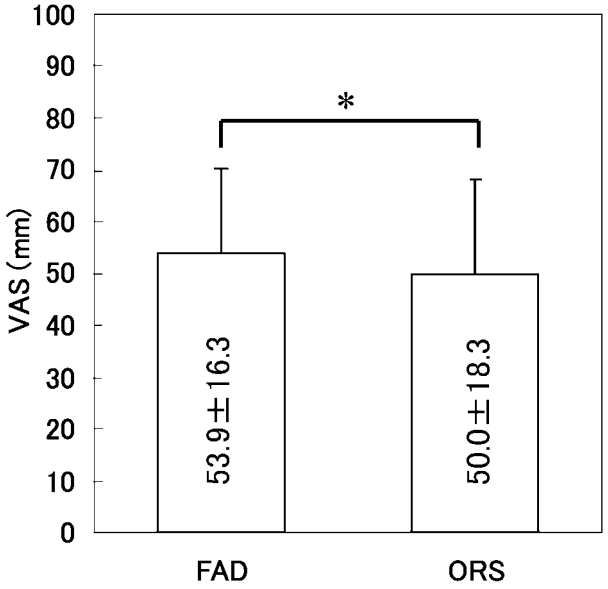

Fig. 4. The average fatigue VAS score. The average and standard deviation of the fatigue score. A significant difference was seen between FAD-VAS and ORS-VAS (* $p<0.05$ by paired *t*-test).

who showed no difference between ORS and FAD, the percentages of subjects who recorded a lower ORS-VAS score (n=88) was significantly higher than that of the subjects who recorded a lower FAD-VAS score (n=56) ($p<0.05$). There was a significant discrimination between ORS and FAD on the fatigue VAS (r=0.329, $p<0.05$). The average fatigue VAS score for the FAD intake day (53.9 ± 16.3 mm) was significantly higher than the score for the ORS intake day (50.0 ± 18.3 mm) ($p<0.05$) (Fig. 4).

Discussion

WBGT is now the most widely used index for measuring heat stress to the body and is used as a standard tool in work and sport environments[7]. Heat stress standard ISO 7243 is based upon WBGT and is used worldwide[8]. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends threshold limit values (TLV) in hot environments based on WBGT[9]. The Japan Society for Occupational Health (JSOH) recommends the standard limits of hot environments for workers based on WBGT[10]. At the WBGT of 30.0 ± 2.4°C in the working environment reported on in this study, the onset of severe heat stroke is a concern and its an prevention is extremely important issue for the employer.

In addition to the direct effects of sunlight, workers engaged in outdoor manual work on aircraft handling are strongly exposed to radiation heat, because their working environment is on a concrete surface and in the vicinity of aircraft jet engines, and the work involves the use of various vehicles. It is estimated that the relative metabolic rate (RMR) of workers engaged in cargo loading at the ramp is 5.5–6.0. The standard of JSOH states that the limit for heat stress is WBGT 26.5°C for manual work activity and RMR below 5.0. Even if workers are acclimated to hot environments, TLV of ACGIH is a recommended WBGT 27.5°C under 75% work/25% rest conditions. Although the workers wear coverall clothing that has slashes in sleeves and back, the working conditions in the cargo loading area near the aircrafts were very severe because of the very hot environment with an average WBGT of 30°C and high humidity of 71.1 ± 8.7%. Irrespective of these severe working conditions, manual work on aircraft ground handling is essential for the operation of aircraft and directly affects the safety of passengers. Therefore, careful attention must be paid to the health and physical condition of the workers, and fluid and electrolyte management by taking appropriate drinks such as clear fluids is important particularly in summer.

The frequent intake of a small amount of fluids, for example, about 250 m*l* in 20 min intervals, has been recommended for work in hot environments[11]. In addition, according to the guidance on hydration in hot environments used by the military, an intake of 700 m*l* of fluid per hour is advised at a WBGT of 30°C, even with only a mild workload[12]. However, in this study, the amount of fluid consumed in the cases of both beverages during 8 hr of work was only 1,000 m*l* in half of the subjects, with maximums of 2,500 m*l* for FAD and 2,000 m*l* for ORS. Although aircraft ground handling may not to be as severe as military operations the fluid intake of the ground handling workers was probably insufficient in the hot environment recorded in this study. Tea and coffee, which were most frequently chosen by the workers, contain caffeine, but a recent literature review does not support caffeine as it may cause diuretic effect and harmful dehydration[13].

Insufficient fluid intake may lead to dehydration, and electrolytes are also lost by perspiration during work. As tea, coffee, water, and juice contain only a very small amount of sodium (Table 2), the sodium balance would be negative if these beverages were preferentially consumed.

In order to study the effect of ORS on fatigue in a hot environment, a visual analog scale (VAS) was used to evaluate fatigue. Various types of VAS are now widely used in epidemiological studies and clinical research as well as being directly applied to the analysis of disease variables such as cancer pain[14]. The single-item VAS has been shown to have excellent reproducibility in evaluating quality of life compared with multi-item questionnaires[15]. The scores from VAS are considered

to be suitable for experimental designs employing repeated measures and within-subject comparisons since they provide values for examining the significance of differences in distributions[16] In the present study, as VAS scores were not measured before work from the viewpoint of the safety of the aircraft ground handling and the timetable of the flights, we could not compare the relative fatigue VAS scores based on the scores before work. However, VAS can show the absolute subjective fatigue states of the subjects. The present survey was carried out using a randomized crossover design including 153 subjects, making it possible to compare the results within the same subjects without influence from different environmental conditions on the survey days. As two survey days were scheduled at intervals of more than five days, it seems unlikely that the fatigue degree of the first survey would have affected the subsequent survey result.

In this study, a significantly lower fatigue VAS score was recorded on the ORS intake day than on the FAD intake day (Fig. 4). In addition, a scatter plot comparison of ORS-VAS and FAD-VAS for the same participant showed significant discriminations (Fig. 3). Among the 144 subjects who exhibited a difference between ORS-VAS and FAD-VAS scores, the number of subjects who recorded a lower ORS-VAS score (n=88) was significantly higher than the number of those who recorded a lower FAD-VAS score (n=56) ($p<0.05$). Therefore, more people reported lower fatigue with ORS than with FAD.

Working in a hot environment causes loss of salts, primarily sodium, in addition to water loss due to intense sweating. This can have a serious impact on the body's ability to maintain homeostasis. Therefore, it is important to supply appropriate amounts of water and salts. If this is neglected, severe dehydration and progression to heat stroke may occur. ORS is ideal for the intestinal absorption of water and electrolytes because of its characteristic composition, and the sodium concentration of ORS is higher than those of commercially available sports drinks. The efficacy of ORS has been confirmed in infants with diarrhea, and a variety of compositions are recommended by WHO, the European Society of Pediatric Gastroenterology, Hepatology, and Nutrition (ESPGHAN), and the American Academy of Pediatrics (AAP)[4, 17]. The ORS used study contained 1.8% glucose, sodium at 50 mEq/*l* and potassium at 20 mEq/*l*, and had an osmotic pressure of 270 mOsm/*l*; the molar ratio of sodium to glucose was 1:2, which is the optimal concentration for water and electrolyte absorption[18, 19].

Dehydration studies in healthy subjects in hot environments have shown that the retention of ingested water in the body is affected by the sodium concentration of ingested drinks. A sodium concentration greater than 52 mmol/*l* keeps the water balance and sodium balance positive and significantly increases the plasma volume[20]. Tea, coffee, and some kinds of juice contain a very small amount of sodium, i.e., less than 5 mEq/*l*. In the sports drinks chosen by 20.3% of participants in this study, the sodium content ranged between 9 and 23 mEq/*l*.

The sodium concentration in sweat during exercise in a hot environment is reported to be 20–80 mEq/*l*, and ORS intake has been suggested to be effective for maintaining homeostasis[21]. It has also been found that the progression of fatigue due to dehydration during exercise can be avoided by proper hydration[22]. The reason why the degree of fatigue (VAS as an index) was reduced by ORS intake in this study was assumed to be that ORS contains the optimal concentration of glucose for facilitating sodium absorption resulting in sodium replacement in addition to water absorption.

A limitation of this survey is that the fatigue VAS just before and after work was not compared, and further study may be necessary to investigate this in the future. However, we feel that the comparison of the fatigue VAS between ORS and FAD, conducted in the present randomized crossover study with a relatively large number of participants, has given useful results and insight. Although it is difficult to carry out the study in actual working circumstances such as outdoor work, objective indexes such as blood and urine analysis are considered useful as the evaluation indexes in addition to subjective ones.

In conclusion, the results of this study suggest that ORS intake during outdoor work in a hot environment is effective for keeping the homeostasis of water and electrolytes in the body and may help prevent industrial accidents by reducing the degree of associated fatigue. ORS intake has been recommended in health guidelines issued by the Japanese Ministry of the Environment[23] and also in heat stroke prevention guidelines in the workplace issued by the Ministry of Health, Labor, and Welfare[24]. Employee education, including the provision of information concerning the types of beverage and the necessary amount of intake to prevent heat stroke in the summer, is advised in order to further improve safety in the workplace.

References

1) Heat related deaths among crop workers—United States, 1992–2006. MMWR Weekly 2008; 57: 649–53.
2) Industrial Health Division. Survey on deaths due to heat-related illness in 2007. Tokyo: Japanese Ministry of Health, Labor and Welfare, 2009 (in Japanese).
3) Sawka MN, Montain SJ. Fluid and electrolyte supplementation for exercise heat stress. Am J Clin Nutr 2000; 72(suppl): 564S–72S.
4) King CK, Glass R, Bresee JS, Duggan C. Centers for Disease Control and Prevention. Managing acute gastroenteritis among children; oral rehydration, maintenance, and nutritional therapy. MMWR Recomm

Rep 2003; 52(RR-16): 1–16.
5) Sladen GE, Dawson AM. Interrelationships between the absorptions of glucose, sodium and water by the normal human jejunum. Clin Sci 1969; 36: 119–32.
6) The Council for Science and Technology, Ministry of Education, Culture, Sports, Science, and Technology, Japan. Standard tables of food composition in Japan, 5th revised and enlarged edition.2005.
7) Grahame M. Budd. Wet-bulb globe temperature (WBGT)—its history and its limitations. J Sci Med Sport 2008; 11: 20–32.
8) International Organization for Standardization. Hot environments—estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature). ISO7243, 1989
9) ACGIH. 2010 TLVs and BEIs: Threshold Limit Values for chemical substances and physical agents; Biological Exposure Indices. American Conference of Governmental Industrial Hygienists.2010
10) The Japan Society for Occupational Health: Recommendation of occupational exposure limits (2009–2010). J Occup Health 2009; 51, 454–70.
11) Kenefick RW, Sawka MN. Hydration at the Work Site. J Am Coll Nutr 2007; 26: 597S–603S.
12) Department of the Army and Air Force. Heat stress control and heat casualty management. Washington, DC: Department of the Army and Air Force. [Online]. 2003 [cited 2009 Nov 11]; Available from: URL: http://chppm-www.apgea.army.mil/documents/tbmeds/tbmed507.pdf
13) Goldstein ER, Ziegenfuss T, Kalman D, et al. International society of sports nutrition position stand: caffeine and performance. J Int Soc Sports Nutr 2010; 7: 5–20.
14) Paul-Dauphin A, Guillemin F, Virion JM, Briançon S. Bias and precision in visual analogue scales: a randomized controlled trial. Am J Epidemiol 1999; 150: 1117–27.
15) de Boer AG, van Lanschot JJ, Stalmeier PF, van Sandick JW, Hulscher JB, de Haes JC, Sprangers MA. Is a single-item visual analogue scale as valid, reliable and responsive as multi-item scales in measuring quality of life? Qual Life Res 2004; 13: 311–20.
16) Aitken RC Measurement of feelings using visual analogue scales. Proc R Soc Med. 1969; 62: 89–93.
17) Mukai K. Oral rehydration solution OS-1 for treating dehydration. Journal of New Remedies & Clinics 2009; 58: 1025–31 (in Japanese).
18) Curran PF. Na, Cl, and water transport by rat ileum in vitro. J Gen Physiol 1960; 43: 1137–48.
19) Mauer AM, Dweck HS, Finberg L, *et al*. American academy of pediatrics committee on nutrition: use of oral fluid therapy and posttreatment feeding following enteritis in children in a developed country. Pediatrics 1985; 75: 358–61.
20) Maughan RJ, Leiper JB. Sodium intake and post-exercise rehydration in man. Eur J Appl Physiol Occup Physiol 1995; 71: 311–9.
21) Verde T, Shephard RJ, Corey P, Moore R. Sweat composition in exercise and in heat. J Appl Physiol 1982; 53: 1540–5.
22) von Duvillard SP, Arciero PJ, Tietjen-Smith T, Alford K. Sports drinks, exercise training, and competition. Curr Sports Med Rep 2008; 7: 202–8.
23) Environmental Health Department. Manual for prevention of heat-related illness. Japanese Ministry of the Environment, 2009 (in Japanese).
24) Labor Standards Bureau. Prevention of heat-related illness during work. Japanese Ministry of Health, Labor and Welfare, 2009 (in Japanese).