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THIRST PERCEPTION AND DRINKING IN EUHYDRATE AND DEHYDRATE HUMAN SUBJECTS

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Summary: Studies on how the body senses the need to correct extracellular and intracellular volumes and ionic concentration changes is relatively scanty. The present studies were designed to determine the effect of oral distilled water (DW) and saline loads, gargling with DW and DW preload on thirst perception (TP) and drinking in euhydrate and dehydrated subjects. The subjects were healthy male volunteers between the ages of 17 and 35 years. Group A subjects were given DW or various concentrations of sodium chloride (NaCl) orally. Subjects in groups B, C and D were dehydrated for 18 hours before the experiment. Group B gargled 500ml of DW in divided volume of 50ml at five minutes interval over a period of 50 minutes. Group C gargled with DW and different concentrations of NaCl. Group D were preloaded with four volumes of DW before *ad libitum* DW intake. TP was rated using the Visual Analogue Scale. Results showed that in Group A, drinking DW reduced TP, suggesting that baseline TP in normal euhydrate subjects is slightly elevated. Drinking DW reduced TP more than drinking NaCl solutions. Gargling resulted in a gradual fall in TP. The decrease in TP was statistically significant after 30 minutes of gargling. Gargling with different concentrations of NaCl solutions resulted in significant reductions in TP in all the groups. There was a significant decrease in TP in the group preloaded with 1000ml of distilled water at 5 minutes of rehydration. At 20 minutes TP was abolished suggesting that approximately 1000ml of water was needed for the rehydration. These results show that baseline TP in euhydrates is elevated and that TP increases in dehydrated subjects. Gargling reduces TP, but did not abolish thirst. It is suggested that a fall in plasma osmolality due to drinking may be responsible for abolishing thirst.

Key Words: Dehydration, Thirst perception, Fluid intake, Gargling, Drinking.

Introduction

Thirst is a conscious sensation of a need for water (Robertson, 1991). Associated with the sensation of thirst is the desire to drink water and usually thirsty subjects report a dry feeling in the mouth and find that water intake feels pleasant.

Thirst and drinking normally arise from a lack of water, which acts through changes in the body fluid compartments to initiate drinking. Thus, drinking in response to lack of water, or to alteration in the body fluid compartments is described as homeostatic in that it reduces the disturbances in the body fluid compartments.

Normal human cellular function depends on constant tonicity of the extracellular fluid. As water is constantly being lost from the kidneys, lungs, skin, and alimentary tract even in conditions of antidiuresis, there is a need to replace fluid deficits by the maintenance of adequate water intake (Thompson and Mckenna, 1998). Restoration of total body water after dehydration depends in part on osmoregulatory center, on arginine vasopressin (AVP) secretion, and on behavioral reflexes that control thirst and fluid intake (Figora and Mack, 1997). In humans, thirst and AVP are controlled by similar sensitive osmoregulatory mechanisms such that above a certain osmotic threshold of 280 – 288 mOsm/kg H2O, there is a linear relationship between the increase in plasma osmolality (pOsm) and the increase in AVP and thirst (Bayliss and Robertson, 1980). Robertson (1991) determined the osmotic threshold for the onset of thirst to be about 294 mOsm/kg H2O while that of vasopressin release threshold to be about 284 mOsm/kg H_2O in healthy humans.

In addition, different signals originating from the oropharyngeal region contribute to the sensation of thirst and the control of vasopressin secretion (Applegren *et. al.*, 1991; Holmes, 1964).

The homeostasis of body fluid is traditionally viewed as involving the regulation of its osmolality and of blood volume. However, the control of thirst is more complex than can be described in a two-factor model. There are four signals that have been reported by (Sticker and Sved, 2000) to be excitatory for thirst and appear to influence water intake in rats. These signals include increased plasma osmolality detected by cerebral osmoreceptors, decreased blood volume presumably detected by cardiac stretch receptors, increased circulatory levels of angiotension II (Ang. II) detected by Ang. II receptors in the subfornical organ and increased gastric sodium load apparently detected by putative sodium receptors in the abdominal viscera.

Weisinger *et al* (1997) evaluated the contribution of brain Ang. II to thirst and sodium appetite of sheep. His findings are consistent with the proposition that brain Ang. II working via angiotensin I receptors is involved in the neural system controlling some aspects of physiological thirst and sodium appetite.

It has been established that body fluid deficits such as cellular dehydration or depletion of extracellular fluid volume lead to the initiation of drinking (Figora and Mack, 1997). But what stops drinking? One possibility is that drinking continues until the body fluid deficits that initiated the drinking are repleted. But, because absorption of ingested water must take time, this mechanism is unlikely to be sufficiently rapid to account for the rapid termination of drinking, except perhaps in species in which the drinking pattern is slow and intermittent. This suggests that a pre-absorptive mechanism using signals from the mouth, the oesophagus, the stomach, and the duodenum could be important in satiation.

Given that systemic factors do not change rapidly enough to account for the termination of drinking in many species, some other, rapid, perhaps pre-absorptive factor or factors must be important. One of such possible mechanism could arise from the oropharyngeal stimulation which occurs while water is being ingested. Simply tasting the water and swallowing it could be sufficient to induce satiety and therefore terminate drinking. Experiments with sham drinking show that fluid intake is guided and maintained by oropharyngeal sensation (Epstein, 1973).

The simple act of filling of the oral cavity with fluid and swallowing alleviates thirst in the absence of any change in plasma sodium concentration (Bruner, 1993). Many researchers (Applegren *et. al.*, 1991; Bruner, 1993; Figora and Mack, 1997) have documented a steep and sudden inhibition of AVP after drinking and/or oropharyngeal stimulation, concomitant with a similar inhibition of thirst in humans. This inhibition cannot be attributed to the dilution of plasma or the inhibition of osmoreceptor activity because it occurs before any significant changes in plasma osmolality occurs. Instead, the rapid inhibition of thirst and AVP secretion appears to be a response to oropharyngeal stimulation since the dehydrated subject ingested water by mouth.

Sham-drinking experiments show that oropharyngeal factors acting alone are not sufficient to account for the normal termination of drinking in most species, but oropharyngeal metering may be able to make a rapidly acting contribution to the termination of drinking (Ajayi and Obika, 2000).

The purpose of this study therefore was to determine the effect of oral saline intake on thirst perception and drinking in euhydrate subjects; the effect of gargling and of repeated gargling on thirst perception and drinking in dehydrated subjects. Finally, we studied the effect of water preload on thirst perception and drinking in dehydrated subjects.

Methodology

The studies were carried out using four different groups of subjects - A, B, C and D.

GROUP A: Effect of distilled water and NaCl loads on thirst perception and drinking in euhydrate subjects.

This involved 48 subjects of age range 19 - 30 years and mean weight of 59.5 ± 8.8Kg. They were subdivided into 4 groups of 10 subjects each and another group of 8 subjects who were given a preload of distilled water (DW) before a saline load. The different subgroups were given the oral fluid loads as shown in Table 1.

Table 1: Oral water and NaCl loads in Group A

Group	*N*	*Oral Load, (8.4 ml/kg), 500 ml*
A_1	10	Distilled Water (DW)
A_2	10	0.9% NaCl
A_3	10	1.8% NaCl
A_4	10	2.7% NaCl
A_5	8	Preload of DW, followed by 2.7% NaCl

The subjects were told to void their bladder and thereafter their weights were taken. A control interval of 30 minutes was allowed during which physiological variables like thirst perception and blood pressure were taken. At the end of this interval, the oral load was administered and the thirst perception ratings (TP) were recorded at 30 minutes interval for 120 minutes.

Thirst perception ratings (TP) were recorded in subjects using a marked but uncalibrated 10 cm long line called Visual Analogue Scale (VAS) as modified by Thompson et. al., (1991). The readings obtained from 0 cm to the point marked by the subject is a subjective record of the thirst rating measured in centimetres at that point in time. At the end of the 120 minutes, subjects were asked to drink ad. libitum till satiety from vessels containing distilled water whose volume was unknown to the subjects. The amount of water intake was calculated as the difference between the initial volume of water in the container and the final volume after drinking.

Group B: effect of gargling with distilled water and NaCl solutions on thirst perception and drinking in *dehydrated subjects (role of oropharyngeal receptors)*

This group comprised of 10 apparently healthy male subjects between the ages of 20 and 30 years. They were required to undergo dehydration (abstain from drinking water and fluid) for 18 hours prior to the time of the experiment and their 12 hour urine volumes were recorded. Subjects were not included in the study if the 12 hour urine volume after dehydration was greater than 400 ml. The subjects gargled 600 ml of fluid at divided volume of 50 ml at ten minutes interval over a period of 60 minutes. Gargling was done at five minutes within the ten minutes interval, and the TP recorded five minutes later, i.e. at ten minutes intervals. This was used to activate the oropharyngeal receptors and it was repeated for varying concentrations of sodium chloride at 0.9%, 1.8%, 2.7%, and distilled water after an interval of two weeks on each subject. The VAS was used to rate their thirst perception at intervals of 10 minutes. At the end of 60 minutes and after recording the TP, the subjects were requested to drink water *ad libitum* and the volume taken was calculated as in Group A.

Group C: Effect of repeated gargling with distilled water on thirst perception and drinking in dehydrated subjects

Sixty (60) apparently healthy male volunteers between the ages of 20 and 30 years were studied. They were required to undergo dehydration as in Group B above, and were subdivided into 4 groups of 15 each as shown in Table 2. Their thirst perception was recorded at intervals of 10 min. for a period of 110 min using the VAS.

TABLE 2: Description of procedure in Group C

Group	*N*	*Description of procedure*
C_1	15	Dehydrated, did not gargle, did not drink at 60 min, drank *ad libitum* at 110 min
C_2	15	Dehydrated, did not gargle, drank *ad libitum* at 60 min, drank ad libitum at 110 min.
C_3	15	Dehydrated, gargled 500 ml of water at divided dose of 50 ml at 5 min interval, stopped gargling at 60 min did not drink at 60 min, drank *ad libitum* at 110 min.
C_4	15	Dehydrated, gargled 500 ml of water at divided dose of 50 ml at 5 min interval, stopped gargling at 60 min, drank *ad libitum* at 60 min and at 110 min

GROUP D: Effect of water preload on thirst perception and drinking in dehydrated subjects

Group D is comprised of 32 subjects who were divided into 4 groups of 8 subjects each. Dehydration was carried out as in Group B above. Immediately after dehydration and recording of control data, each subject in the group was preloaded orally with varied amounts of distilled water as follows: D1 = 250ml (4.3ml/Kg), D2 = 500ml (8.6ml/Kg), D3 = 750ml (12.9ml/Kg) and D4 = 1000ml (17.2ml/Kg) body weight respectively. Thereafter, TP was assessed using the visual analogue scale (VAS) at every 5 minutes for 20 minutes after the preload.

Control measures

Urine samples produced during the 12 hours of dehydration were collected and measured. Subjects who produced more than 400 ml of urine were excluded from the study as this indicated their non-compliance with the dehydration protocols.

Statistical analyses

All values are expressed as Means ± standard error. Intra-group and inter-group comparisons were made using the one way analysis of variance (ANOVA). The Student t-test was used for comparison between the experimental and control values. A P value equal to or less than 0.05 was considered significant.

Results

Effect of oral distilled water and nacl solution loads on thirst perception and drinking in euhydrate subjects

There was a significant reduction ($p<0.05$) in TP only in the first 60 minutes after the fluid load in Groups A1 and A2. Changes at 90 and 60 minutes after the fluid load were not statistically significant. Groups A3 and A4 showed a slight decrease in TP only at 30 minutes, then a slight increase at 60 minutes, although these were not significant. At 90 and 120 minutes, there were significant increases in TP ($p<0.001$) in Groups A3 and A4. These are summarised in Table 3.

When the subjects were preloaded with distilled water (Group A5) there were significant increases in TP at 30, 60, 90 and 120 minutes from the preload value of 1.6 + 0.4 as shown in Table 3. The preload with DW in Gp. A5 significantly ($p<0.05$) reduced the baseline TP when compared with baseline values in Groups A1 - A4.

Effect of gargling with distilled water and NaCl solutions on thirst perception and drinking in dehydrated subjects.

These subjects gargled distilled water and various concentrations of NaCl solution every 10min. for sixty minutes. Thereafter, they were given distilled water to drink *ad libitum* at the end of the 60 minutes. TP was recorded every 10 minutes for 70 minutes. The results are shown in Table 4.

TP declined gradually and significantly ($p<0.05$) up to the 60th minute in Groups B1 and B2. Immediately after the *ad libitum* water intake at the end of the 60th minute, TP was further reduced significantly ($p<0.001$) in these groups. In Gp. B3 there was a significant decrease ($p<0.05$) in TP up to the 30th minute, and it started rising thereafter. The changes in TP at 50th and 60th minutes were however not statistically significant from the baseline values. There was a significant decrease ($P < 0.05$) at 70 minutes after *ad libitum* drinking.

In contrast to the other groups, Group. B4 showed a steady rise in TP although it was not statistically significant till at the 50th and 60th minutes when it increased significantly ($p<0.05$). There was a significant decrease ($P<0.001$) at 70th minute after *ad libitum* drinking.

Effect of repeated gargling with distilled water on thirst perception and drinking in dehydrated subjects

These subjects were dehydrated like those in Group B. Groups C1 and C2 did not gargle water for 60 minutes. Thereafter, Group C2 subjects were given water *ad libitum*, and TP was recorded for another 50 minutes with water gargling. Additional *ad libitum* water was allowed at the end of the 50 minutes. TP was recorded at 10 minutes interval for the 110 minutes duration of the experiment. On the other hand, Gp. C1 was not allowed to drink at 60 minutes, but only at 110 minutes. TP was recorded at 10 minutes interval till the end of the experiment
(Fig. 1a and Fig. 1b).

Groups C3 and C4 gargled water for 60 minutes. Thereafter, Gp. C3 was not allowed *ad libitum* water at 60 minutes, but only at 110 minutes, while Gp. C4 was given water *ad libitum* at 60 and at 110 minutes. TP was recorded every 10 minutes till termination of the experiment. Results are shown in Fig. 1. Dehydration increased TP in all the Groups. While gargling with DW reduced the TP (Gp. C3 and C4) in 60 minutes, none gargling with water further increased TP (Gp. C1 and C2). *Ad libitum* drinking of water at 60 minutes significantly reduced and indeed abolished TP (Gps. C2 and C4). There was a further reduction in TP in all 4 groups when ad. libitum water was offered at 110 minutes (Fig. 1b). Gargling for 60 minutes reduced TP in Gps. C3 and C4, but remained significantly high till water was offered at 60 min. (Gp. C4) and at 110 minutes (Gp. C3), when TP was abolished. On the other hand, when there was no gargling as in Gps. C1 and C2, the TP continued to rise until at 60 min. (Gp. C2) and at 110 minutes (Gp. C1) when it was abolished by ad. libitum water intake (Fig. 1a and Fig. 1b).

Table 3: the effect of oral load of distilled water and NaCl solution on thirst perception

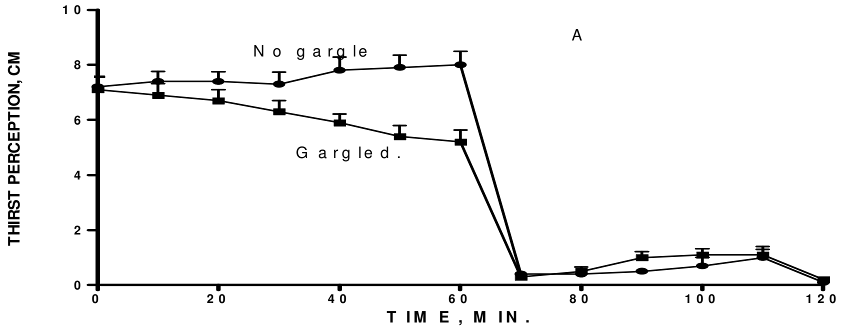
GROUP	*N*	*THIRST PERCEPTION, CM.*				
		Before fluid load (0 min)	*Time after fluid load*			
			30min	*60min*	*90min*	*120min*
A_1 *DW Load*	10	3.0 ± 0.5	1.7 ± 0.5*	1.6 ± 0.6*	2.7 ± 0.7	3.4 ± 0.7
A_2 *0.9% NaCl load*	10	4.5 ± 0.8	2.7 ± 0.7*	3.0 ± 0.6*	4.8 ± 0.6	5.5 ± 0.6
A_3 *1.8% NaCl load*	10	3.8 ± 0.8	3.0 ± 0.7	4.1 ± 0.8	5.9 ± 0.8	8.2 ± 0.7**
A_4 *2.7% NaCl load*	10	3.4 ± 0.6	3.1 ± 0.9	4.5 ± 1.0	6.0 ± 1.1	6.6 ± 1.1**
A_5 *Preload of DW + 0.9% NaCl load*	8	1.6 ± 0.4	2.8 ± 0.5*	3.7 ± 0.5*	4.7 ± 0.6**	5.8 ± 0.7**

Values are means ± SEM. *$p<0.05$; **$p<0.01$

Table 4: *The effect of gargling with distilled water and NaCl solutions on thirst perception in dehydrated subjects*

Group; and fluid for gargling	*N*	*Thirst perception, cm*							
		Before gargling (0 min)	*Time after fluid was gargled.*						
			10 min	*20 min*	*30 min*	*40 min*	*50 min*	*60 min*	*70 min (after DW ad libitum)*
B_1 *Distilled Water*	10	5.29 ± 0.50	5.0 ± 0.53*	4.63 ± 0.40*	4.45 ± 0.39*	4.03 ± 0.45*	3.49 ± 0.54*	3.54 ± 0.62*	1.17 ± 0.21**
B_2 *0.9% NaCl*	10	5.62 ± 0.60	5.09 ± 0.45*	5.33 ± 0.44*	4.98 ± 0.37*	4.84 ± 0.43*	5.18 ± 0.59*	5.18 ± 0.65*	1.82 ± 0.22***
B_3 *1.8% NaCl*	10	5.62 ± 0.59	5.01 ± 0.53*	5.07 ± 0.41*	4.85 ± 0.47*	5.20 ± 0.44*	5.29 ± 0.66	5.65 ± 0.72	2.13 ± 0.69*
B_4 *2.7% NaCl*	10	5.07 ± 0.64	5.42 ± 0.54	5.30 ± 0.62	5.72 ± 0.61	6.12 ± 0.66	6.28 ± 0.79*	6.26 ± 0.88*	1.62 ±.0.33***

Values are means ± SEM. $p<0.05$; **$p<0.01$; ***$p<0.001$.



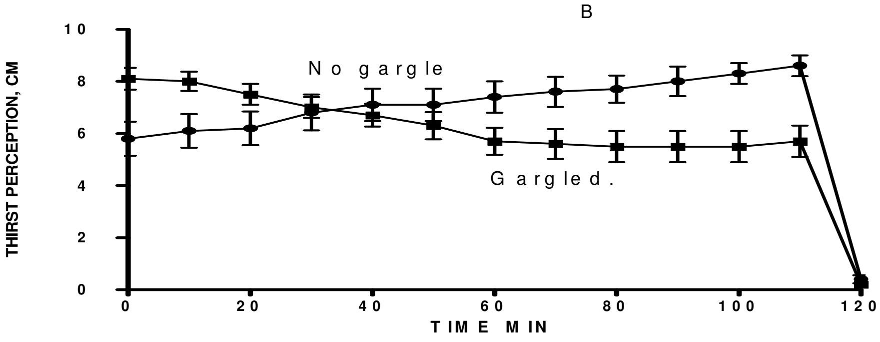


Fig. 1A shows the mean thirst perception (cm), in dehydrated subjects who garled DW or did not, but drank dw at 60 min while Fig. 1B shows mean thirst perception (cm), in dehydrated subjects who gargled DW or did not, but drank DW at 110 min.

Effect of water preload on thirst perception and drinking in dehydrated subjects

These subjects were also dehydrated and thereafter preloaded with various volumes of distilled water. TP was recorded before the preload and thereafter at every five minutes for 20 minutes. The control TPs after dehydration and before water preload (0 minutes) were not significantly different within the groups (Fig. 2). Five minutes after water load, all groups had significant decrease in TP. This decrease continued till the end of the experiment in Gps. D3 and D4. On the other hand, in Gps. D1 and D2, TP increased after the initial decrease at 5 minutes after the water load. However, these increases were not statistically significant and did not get to the control values of TP.

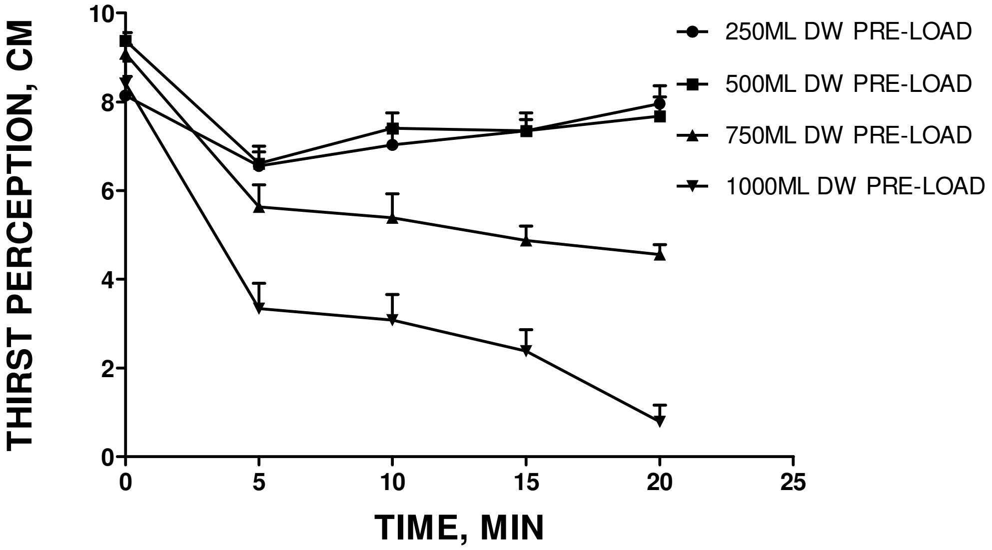


Fig. 2: Thirst perception (cm) in dehydrated subjects that were preloaded with distilled water orally.

Discussion

The reliability and validity of measurements of the subjective ratings of thirst have been previously reported as follows: thirst positively correlates with plasma osmolality (Baylis and Robertson, 1980); subjective ratings of thirst using VAS were also found to correlate positively with plasma osmolality (Obika and Mowoe, 1997; Seckl *et al*, 1986).

In all subjects in group A, there was a transient decline in thirst perception at 30 minutes over control values (see Table 1). This was not significant for distilled water, 1.8% and 2.7% NaCl, but significant for 0.9% NaCl. In a similar work by Geelen, *et al,* (1984), the authors reported a decrease in thirst after drinking hypertonic saline. Obika and Mowoe (1977), and Rolls, *et al*, (1980) had reported an earlier observation of a fall in TP in normal euhydrate subjects when hypertonic and/or hypotonic fluid load was administered. However, in the subgroup that took a preload of distilled water and then 2.7% NaCl, there was a highly significant increase in thirst perception. This subgroup also showed an initial thirst perception that was lower than all other subgroups. The difference between the thirst perception in this group and other groups was statistically significant. This shows that there is a moderately high thirst perception amongst individuals without their necessarily reporting a feeling of thirst.

This study shows clearly that dehydrated subjects have higher TP than their euhydrate counterparts. In group B with various NaCl concentrations used for gargling, there was an initial slight decrease after gargling with 0.9% and 1.8% NaCl, but not with 2.7% NaCl solution. However, there was a gradual TP increase with time, particularly at the higher NaCl solutions. These findings suggest another osmoreceptive mechanism of the oropharyngeal receptors in that, with increasing concentrations of NaCl, there was concomitant increase in thirst ratings. Possibly, there is a reversal of the mechanism observed with distilled water where there is suppression of plasma arginine vasopressin during the act of swallowing water (Holmes and Greyerson, 1950). These findings show that oropharyngeal receptors play a role in the control of thirst and restoration of fluid intake since there is a concurrent decrease in thirst ratings after gargling.

Results from group C reveal a difference in thirst perception between dehydrated subjects who gargled and those who did not gargle. There was a gradual fall in the mean thirst ratings recorded in subjects who gargled with distilled water. These results suggest that the decrease in thirst perception was as a result of the oropharyngeal stimulation and not a direct reduction in plasma osmolality since the observation of this decrease was made from the 10th minute, a time not adequate for a significant reduction in plasma osmolality through the absorptive route and also since the study at this time was to stimulate the oropharyngeal receptors and not drinking. It is possible that oropharyngeal receptors may reduce TP unrelated to drinking. The fact that gargling without drinking results in a reduction in TP in dehydrated subjects as shown in this study supports the notion that neural mechanisms may play a part in this reduction of TP. This is further substantiated by the reports of Bruner (1993) who suggested that the simple act of filling the oral cavity with fluid and swallowing alleviates thirst in the absence of any change in plasma sodium concentration. Other researchers (Figora and Mack, 1997; Applegren *et al*, 1991) have also documented a rapid inhibition of thirst in humans after drinking/oropharyngeal stimulation. They also showed that this inhibition cannot be attributed to the dilution of plasma or the inhibition of osmorecepter activity because it occurred before any substantive changes in plasma osmolality occurred. Instead, the rapid inhibition was attributed to a response to oropharyngeal stimulation as the dehydrated subject ingested water by mouth. These findings also showed that the decrease in thirst perception with gargling was transient, since thirst perception as seen in group C3 remained almost constant after gargling up to the 100th minute with a slight increase at the 110th minute. However, there was a rapid drop in thirst perception in group C4 at the 70th minute as a result of ad libitum drinking. This clearly showed that oropharyngeal stimulation, though effective in reducing thirst was not enough on its own to abolish it. This is consistent with the results of the experiments carried out by Rolls *et al* (1980) that showed the satiating effects of oral stimulation by water on TP in man. They reported a relief of thirst, which was however only very temporary, outlasting the stimulation by only 30-50 sec. This shows that in the longer term, other post absorptive factors become more important.

Results from group D demonstrated that about 1000ml volume of distilled water ingested is sufficient to act rapidly to terminate drinking and abolish thirst. This is because the group preloaded with 1000ml of water showed a statistically significant decrease in the thirst perception rating recorded after 20 minutes of rehydration. Earlier studies by Obika and Mowoe (1997) showed that the basal thirst perception in euhydrate subjects varied between 2 and 4 cm on the VAS. Meanwhile, the group preloaded with 250 and 500 ml of distilled water showed no statistically significant difference before and after rehydration. Though the group preloaded with 750ml had their thirst perception significantly reduced, thirst was not completely abolished. Findings in this group suggest that dilution of plasma osmolality due to the volume of water ingested act to terminate thirst. Furthermore, the results of this study also suggest that between 500 ml and 750 ml of body fluid may have been lost during the period of dehydration, since rapid intake of distilled water of between 750 ml and 1000 ml abolished the increased TP after a period of dehydration.

It can be concluded from this study, that thirst perception is increased in normal dehydrated subjects and that gargling and stimulation of oropharyngeal receptors in dehydrated subjects reduce thirst perception but do not abolish thirst. The study also showed that the further reduction of thirst perception after ad libitum drinking or preload volume of between 750 and 1000 ml of distilled water suggest that dilution of plasma osmolality play an important role in abolishing thirst and drinking. Therefore, for thirst to be completely abolished, other factors such as dilution of plasma osmolality and expansion of plasma volume play important roles.

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