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## Thirst Perception and Dryness of Mouth in Healthy Young Adults Nigerians

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### ABSTRACT

This study examined the threshold for thirst perception (TP) using the visual analogue scale (VAS). Thirst perception (TP) and dryness of mouth (DM) were studied in normal subjects, (n = 137; 78 males of height,  $1.72 \pm 0.01$ , age,  $23 \pm 0.26$ , body mass index,  $21.11 \pm 0.29$ , and 59 females of height,  $1.65 \pm 0.01$ , age,  $21 \pm 0.23$ , body mass index,  $21.0 \pm 0.27$ ). The results showed that (i) TP and DM in males, ( $1.21 \pm 0.15$  cm and  $1.14 \pm 0.16$ cm respectively) and in females, ( $1.10 \pm 0.16$ cm and  $1.04 \pm 0.17$ cm respectively) were similar. (ii) The relationship, Thirst (cm) =  $0.75$  (plasma arginine vasopressin  $\pm 1.2$ ) exists and has a mean of not thirsty of 1.2cm at the lower end of the scale. (iii) The plasma osmolality of 281mOsm/kg cannot be the threshold for TP and the plasma osmolality of 285mOsm/kg or 284.3mOsm/kg cannot be the threshold for plasma arginine vasopressin secretion but rather the mean of the lower set point of the scales for TP and plasma arginine vasopressin [ $P_{AVP}$ ] secretion. (iv) The threshold for TP using the VAS is between 1.50 - 1.575cm markings, and plasma osmolality of 286.0 - 286.25 mOsm/kg.  $P_{AVP}$  of 0.4 – 0.5 pmol/l being the sensitivity of the osmoregulatory unit.

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**Key Words;** Thirst perception, Dryness of mouth, plasma osmolality, osmotic threshold, Visual Analogue Scale

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## INTRODUCTION

Definition of thirst has been the subject of much debate, with major disagreement focusing on whether it is a local (for example, pharyngeal) or general sensation (Fitzsimons, 1972). Dryness of the mouth (DM) and throat region is a striking feature in thirst, and some have gone so far as to say that this feeling of dryness of mouth is an essential component of thirst, but very few claim that we drink when we are thirsty solely to abolish the disagreeable sensations that arise in the mouth when salivation is insufficient to keep the mouth and pharynx moist. The evidence being that the sensation of thirst and the sensation of dryness of the mouth could be dissociated from each other (Fitzsimons, 1972). Robertson (1984), defined thirst as 'a generalized deep-seated feeling of a desire for water'. As thus defined, thirst is not synonymous with drinking, because drinking can be affected positively or negatively by a variety of factors such as personal and cultural factors. Also, this terminology is only appropriate for human studies as animals cannot report the sensation of thirst.

Studies of thirst mechanism and dryness of mouth have been hampered by the lack of objective methods of quantification. Estimates of thirst and DM rely solely on the subject's ability to perceive and to report the sensation. Sometimes one can check such information by observing the amount of water drunk spontaneously.

A geometric rating scale was devised by Thompson and Campbell (1977), to quantify acute changes in thirst in controlled experimental settings. Using this method (Robertson, 1984), assessed the effects of osmotic stimuli on thirst mechanism and vasopressin secretion at various times during the infusion of hypertonic solution in healthy adults. The result showed the function;  $P_{AVP} = 1.48(P_{osm} - 284.7)$ ;  $r = 0.977$  and  $Thirst = 9.06(P_{osm} - 293.5)$ ;  $r = 0.966$ . According to their analysis the osmotic threshold for the onset of thirst was 293.5 mOsm/Kg, which is approximately 10 mOsm/Kg above the osmotic threshold for vasopressin release.

Thompson *et al* (1986) employing a visual analogue scale (VAS), where subjects defined their own thirst ratings before the experiment rather than be assigned to zero thirst ratings (Rolls *et al*, 1980), explored the characteristics of osmotically induced thirst throughout a wider range of plasma osmolalities than previously examined. From linear regression analysis of their results, they defined the functions:

$Thirst (cm) = 0.3 (P_{osm} - 281)$ ;  $r = + 0.92$ ,  $P < 0.001$  and  $P_{AVP} (pmol/l) = 0.4 (P_{osm} - 285)$ ;  $r = + 0.96$ ,  $P < 0.001$ . They concluded that (1) the osmolar threshold for thirst onset thus defined (281 mOsm/Kg) is at the lower end of the physiological range of plasma osmolality and was much lower than that quoted in previous studies (Robertson *et al*, 1976; Baylis & Robertson, 1980; Robertson, 1984). 2) Thirst perception (TP) rises in a progressive fashion throughout a wide range of plasma osmolalities and that the osmolar threshold for thirst onset (281 mOsm/kg) was similar to the theoretical osmolar threshold for vasopressin release (285 mOsm/kg).

In the works of Robertson (1984) and Thompson *et al* (1986) it was not clear whether a linear relationship also exists between thirst (cm) and  $P_{AVP}$ . Also not clear is, what exactly is the range for normal not thirsty markings on the VAS as currently used for the estimation of TP? This study therefore is to, (1) determine normal TP and DM in young healthy male and female adults using the VAS (2) investigate whether a linear relationship also exists between TP and  $P_{AVP}$  using the equations of Thompson *et al* (1986). (3) Determine whether there are differences between the sexes in the responses above and (4) determine the range for normal not thirsty markings on the VAS.

## MATERIALS AND METHODS

### Subjects

Healthy young volunteer males ( $n = 78$ , age 17-30years) and females ( $n = 59$ , age 18-29years) were used in this study following approval by the local Research Ethics committee of the University of Benin, College of Medicine. All the subjects were active but none was athletically trained as

defined by the absence of a regular physical exercise programme during the last six months before the experiment (Kokkinos *et al*, 1995).

Exclusion criteria for this study were any history of diabetes and cardio - respiratory disease.

### Procedure

Each subject came to the laboratory on the day of the experiment. Participants completed a general health questionnaire to determine physical fitness, personal and family history of diabetes, heart disease, hypertension and current use of medication. The subject's anthropometric data then were obtained. Body surface area was calculated from height [H (cm)] and weight [W (kg)] with the formular of Dubois and Dubois (Peyreigne *et al* 1998), and the body mass index (BMI), calculated from

$$BMI = \frac{Wt(kg)}{H^2 (cm)}$$

Base-line (resting) blood pressure (BP) and heart rate (HR) were measured with the subject in the seated position and after fifteen minutes of rest in the laboratory at a room temperature of 29°C. The right arm supported at the heart level (Frohlich *et al* 1988), was used for blood pressure and heart rate measurements. Measurements were made by digital blood pressure and HR monitor (Walgreen's, Model 93). Three basal readings were obtained on each subject at 3-minutes interval and the mean of these readings recorded as the normal blood pressure and heart rate. Mean arterial blood pressure (MABP) was calculated from the formular  $MABP = \frac{1}{3}$  systolic blood pressure +  $\frac{2}{3}$  Diastolic blood pressure (Zappe *et al*, 1996).

### Thirst and Dryness of Mouth Rating

Thirst perception and dryness of the mouth were obtained using the visual analogue scale (VAS) (Thompson *et al*, 1991, Takamata *et al*, 1994). Thirst perception and dryness of mouth ratings were defined for statistical purposes as the distance in centimeters of the mark from the "Not thirsty" or 'Not dry' extreme. The visual analogue scale is an indirect approximation of the plasma

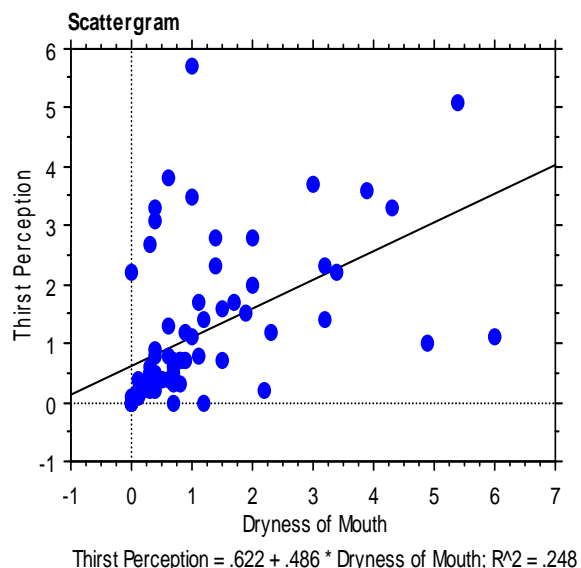
osmolality (Robertson *et al*, 1982) which we have not measured in this work.

### Statistical Analysis

Data are presented as means  $\pm$  SEM. Differences in TP, DM, WT, HT, BMI, Age, HR, and BP between the groups were analysed using the unpaired students't-test. The sensations of thirst and dryness of mouth within the groups were also analysed for possible difference using the paired t-test. Changes were considered statistically significant when  $p \leq 0.05$ . Regression plot was also done for possible correlation between thirst perception and dryness of mouth.

## RESULTS

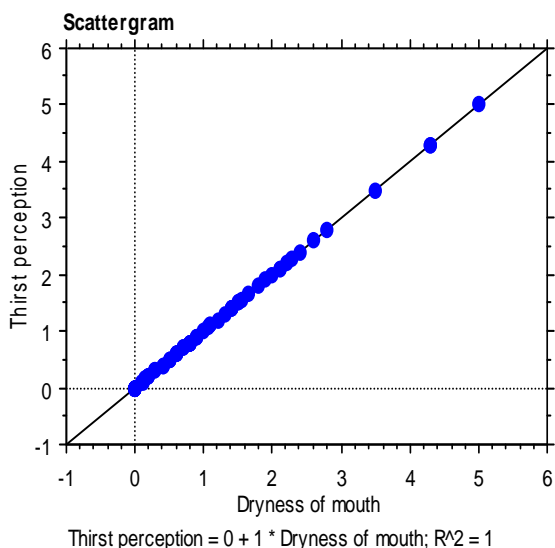
The male and female groups studied showed thirst perceptions of  $1.21 \pm 0.15$  and  $1.10 \pm 0.16$  respectively, while the dryness of mouth was  $1.14 \pm 0.16$  and  $1.04 \pm 0.17$  respectively.



**Figure 1.**

Scatter gram showing the relationship between Thirst Perception (TP) and Dryness of Mouth (DM) in the male group. The regression equation given by the straight line and defining the relationship between Thirst perception and Dryness of Mouth is:

$$TP = 0.622 + 0.486 DM (r = 0.498; p < 0.0001).$$



**Figure 2.** Scatter gram showing the relationship between Thirst Perception (TP) and Dryness of Mouth (DM) in the female group. The regression equation given by the straight line and defining the relationship between Thirst perception and Dryness of Mouth is: TP = 0 + 1 DM (r = 1; p = 0).

There was no significant difference in thirst perception and dryness of mouth between the male and female groups. They were also of comparable body mass index (male = 21.11± 0.29, female = 20.70± 0.27). Table 1 gives a summary of their

anthropometric data, with their data for thirst perception and dryness of mouth.

## DISCUSSION

This work examined thirst perception and dryness of mouth using the (VAS) visual analogue scale in young male and female adults. The subjects were comparable in body mass index. The VAS, though, might be, susceptible to distortion by a variety of personal, and cultural influences, this method however provides the best available description of the function of the thirst mechanism so far, (Robertson, 1984). It has been shown that thirst ratings using the VAS are highly reproducible within individuals on repeated testing (Thompson *et al*, 1991).

This work shows a thirst perception (TP) and dryness of mouth (DM) of 1.21 ± 0.15cm and 1.14 ± 0.16cm in males, and 1.10 ± 0.16cm and 1.04 ± 0.17cm in females as ‘not thirsty ‘ and ‘not dry’ respectively. The TP and DM observed in the male group did not show any significant difference from that of the female group. They were found to be similar to each other. Burrell *et al*, (1991) reported a value of thirst perception (TP) of 1.3 ± 0.4cm and 1.5 ± 0.4cm in experimental and control male subjects respectively as ‘not thirsty’.

**Table 1.** Thirst Perception and Dryness of Mouth, expressed as mean ± SEM, in the male and female subjects.

	Thirst Perception (Tp)Cm	Dryness Of Mouth (Dm) Cm	Weight (Kg)	Height (M)	Body Mass Index (Bmi)	Body Surface (M <sup>2</sup> )	Age (Yrs)	Heart Rate (Bpm)	Blood Pressure (Mmhg)
Male n = 78	1.21 ± 0.15	1.14 ± 0.16	62.8 ± 1.01	1.72 ± 0.01	21.11 ± 0.29	1.74 ± 0.02	22.69 ± 0.26	69.5 ± 1.04	112 ± 1.60 <u>66 ± 1.57</u>
Female n = 66	1.10 ± 0.16	1.04 ± 0.17	56.2 ± 0.8	1.65 ± 0.01	20.70 ± 0.27	1.61 ± 0.01	20.52 ± 0.23	77.3 ± 1.66	103 ± 1.42 <u>62 ± 1.00</u>
	p > 0.05	p > 0.05	p < 0.01	p < 0.01	p > 0.05	p < 0.01	p < 0.01	p < 0.05	<u>p &lt; 0.05</u> p > 0.05

Obika *et al*, (1996) in their work on kolanut activity in young dehydrated subjects reported thirst rating of  $2.5 \pm 0.5$  in control young subjects as 'not thirsty.' Figaro and Mack (1997) also in their work in dehydrated humans showed ratings of perceived thirst and mouth dryness of  $1.5 \pm 0.6$  and  $0.9 \pm 0.2$  as 'not thirsty' and 'not dry' respectively in control subjects. This work therefore is found to correlate very well with the findings of Burrell *et al*, (1991) and Figaro and Mack (1997).

### Correlation between DM and TP

In this study the sensations of thirst and dryness of mouth in the subjects were analysed for possible correlation using the t-test. The analysis did not show any significant difference between TP and DM either in the respective male and female group or between the groups. It is therefore concluded that using the visual analogue scale (VAS), the sensation of thirst is closely associated with dryness of the mouth. Rolls *et al*, (1980) on studies of thirst in humans showed that 'normally the subjective sensation of thirst has a very strong oral component described as a dry mouth'. Stachenfeld *et al* (1996) also showed that subjective ratings of mouth dryness were highly correlated with thirst ( $r = 0.96$ ). The observation of this study therefore conforms with the reports of the above two groups of workers.

The idea that thirst is related to the relative dryness of the mouth dates back to the Greeks (Grossman, 1967). Haller (1764), attributed this sensation to a deficiency of mucus and saliva. Canon (1919) stated that when the salivary glands fail to provide sufficient fluids to moisten the mouth, the local discomfort and unpleasantness which result constitute the feeling of thirst. Studies of the effect on thirst of altering oral sensations or blocking them have shown results consistent with a dry mouth theory (Adolph, 1947; Wolf, 1958; Epstein *et al*, 1964). However, against this local theory, are experiments demonstrating that there could be a dissociation between DM and TP (Montgomery, 1931; Steggerda, 1941).

Claude Bernard in (1856) prepared horses and dogs with an oesophageal or gastric fistula. When

the animals were tested with open fistula, they drank enormous quantities of water (sham-drinking), in spite of the mouth being bathed with large quantities of water. Bellows (1939) confirmed Bernard's early experiments in dogs and observed that during persistent sham-drinking water wets the mouth and therefore the dry mouth theory cannot be correct. Sham drinking had also been seen clinically in 1925 by Gairdner when in attempting suicide a man cut his oesophagus, but not his arteries or veins. After several days he became intensely thirsty, but all the water he drank ran straight out of the oesophagus and produced no relief of thirst. Thirst was, however, relieved by placing water into the lower half of the oesophagus. These evidence indicate that dry mouth and thirst can be dissociated and therefore there must be some other explanation for thirst.

The role of dryness of mouth in thirst, (although shown not to be an essential thirst stimulus), should not be completely disregarded. There is the need to look into, what exactly is the role of dryness of mouth in thirst, as seen in humans, if there is any. Figaro and Mack (1997), Rolls *et al*, (1980) have suggested that the oropharynx may have a role in the initiation, termination and maintenance of drinking.

### Relationship between thirst perception (TP) and Plasma arginine vasopressin (P<sub>AVP</sub>) Secretion.

Thompson *et al* (1986) reported that the osmolar threshold for thirst onset (281 mOsm/Kg) is at the lower end of the physiological range of plasma osmolality and it is similar to the theoretical osmolar threshold for vasopressin release (285 mOsm/Kg). While their work showed a clear linear relationship between plasma osmolality and thirst, and between plasma osmolality and arginine vasopressin, it however was silent on whether there was a linear relationship between plasma arginine vasopressin and thirst.

From Thompson's *et al* equations (1986), the relationship between thirst and plasma osmolality P(osm) can be expressed as

$$P_{(osm)} = \frac{T + 0.3(281)}{0.3} = \frac{10T}{3} + 281 \dots\dots\dots(1)$$

and the relationship between plasma osmolality and plasma arginine vasopressin ( $P_{AVP}$ ) can be expressed as:

$$P_{(osm)} = \frac{(P_{AVP}) + 0.4(285)}{0.4} = \frac{10(P_{AVP}) + 28}{4} \dots\dots(2)$$

since their work was within the same range of plasma osmolality, 280 - 320 mOsm/kg, (McKenna and Thompson, 1998; Thompson *et al*, 1986), equations (1) and (2) relating plasma osmolality can be solved. Solving these two equations yield the equation,

$$T_{(cm)} = 0.75 P_{AVP} + 1.2$$

The result of this work shows that the above equation relating thirst perception and plasma arginine vasopressin exists and has a mean lower set point of 'not thirsty' or 'not having a desire to drink' of 1.2cm. Table 1 shows a mean of  $1.21 \pm 0.15$ cm for males and  $1.10 \pm 0.16$ cm for females.

From Thompson's *et al* equations (1986), the values of some plasma osmolality ( $P_{osm}$ ) and their corresponding thirst (cm), and also corresponding plasma arginine vasopressin ( $P_{AVP}$ ) in pmol/l are shown below in their respective equations.

$$T(cm) = 0.3 (P_{osm} - 281); P_{AVP} = 0.4(P_{OSM} - 285)$$

$$T(0) = Posm (281); P_{AVP(0)} = Posm (285)$$

$$T(1) = Posm (284.33); P_{AVP(0.3)} = Posm (285.75)$$

$$T(1.2) = Posm (285); P_{AVP(0.4)} = Posm (286)$$

$$T(1.5) = Posm (286); P_{AVP(0.5)} = Posm (286.25)$$

$$T(1.575) = Posm (286.25); P_{AVP(1)} = Posm (287.5)$$

$$T(1.95) = Posm (287.5)$$

The osmotic threshold for thirst, which Thompson and his colleagues (1986) reported means that after 0cm mark on the VAS there should be a sensation of thirst or a desire to drink water. The observed data of this study shows a TP of  $1.21 \pm 0.15$  cm for males and  $1.10 \pm 0.16$ cm for females as 'not having a desire to drink water' or 'not thirsty' and our derived equation shows a

value of 1.2cm as 'not having a desire to drink water' or 'not thirsty'. Since 'threshold' means the adequate stimulus required to cause an impulse or sensation, in this case to actually want to drink water, the 0cm mark on the VAS cannot be said to be the threshold for thirst, but rather the lower set point of the scale for thirst perception. The threshold for TP on the VAS, from this study and from the derived equation, lies between a TP of 1.50 - 1.575cm marking on the VAS. Markings of 0.0 - 150cm on the visual analogue scale therefore are normal range for "not thirsty" or not having a desire to drink. Variations of individual markings on the lower end of the VAS could be due to differences in volume status of the subject.

It was also reported that plasma arginine vasopressin release is dependent on plasma osmolality and that the osmotic threshold of vasopressin secretion into the circulation is a plasma osmolality of 285mOsm/kg, (Thompson *et al*, 1986) or 284.3mOsm/kg in healthy man (Thompson & Mckenna, 1998). From the values shown in the equations above, at a plasma osmolality of 285mOsm/kg there is no appreciation of thirst and there is no marked arginine vasopressin secretion, which means that the plasma osmolality is not yet high enough to give a sensation of thirst and subsequent plasma arginine vasopressin secretion to conserve body fluid. Our analysis shows that given plasma osmolality, arginine vasopressin and thirst, the important factor in stimulating thirst is increase plasma osmolality, and it has a normal range of 'not thirsty' between 280.0 - 285mOsm/kg with a threshold of 286.0-286.25 mOsm/kg. It is therefore concluded that the plasma osmolality of 281 mOsm/kg cannot be the threshold for thirst perception and the plasma osmolality of 285 mOsm/kg or 284.3 mOsm/kg cannot be the threshold for plasma arginine vasopressin secretion but rather the mean of the lower set points on the scales for thirst perception and plasma arginine vasopressin secretion.

In summary, the sensation of thirst is closely associated with a dry mouth. The relationship: Thirst (cm) = 0.75 (plasma arginine vasopressin +1.2) exists, and the lower set point of "not thirsty" on the VAS has a mean value of

1.2cm thirst perception, and 285mOsm/kg of plasma osmolality. The work of Thompson *et al* (1986) shows the mean of the lower set point for plasma osmolality on the relation between thirst and plasma osmolality to be 281 mOsm/kg and the mean of the lower set point on the relationship between plasma osmolality and plasma arginine vasopressin to be 285 mOsm/kg. The threshold for thirst perception using the VAS lies between thirst perceptions of 1.50 - 1.575cm markings on the VAS, plasma osmolality of 286.0 - 286.25 mOsm/kg and plasma arginine vasopressin of 0.4 - 0.5 pmol/l being the sensitivity of the osmoregulatory unit. Markings of 0.0 - 1.4cm on the VAS, and plasma osmolality of 281 - 285 mOsm/kg are normal ranges of not thirsty.

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