BODY WATER COMPARTMENTS OF GROWING DAIRY CALVES

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Introduction

It is evident that water is one of the most essential components of the animal body and that it plays numerous physiological and biophysical roles. Reliable procedures for indirect *in vivo* determination of the body fluids have been investigated and developed over many years. SOBERMAN *et al.* (22) suggested that antipyrine is a satisfactory substance for use in the estimation of total body water. It was later pointed out that it was not an ideal reagent for the determination of body water *in vivo* because of its nature of binding in plasma proteins and of diffusing into the alimental canal (4, 12, 17, 18, 20, 23). Further, BRODIE *et al.* (4) suggested the use of N-acetyl-4-aminoantipyrine (NAAP) in measurements of total body water.

At present antipyrine (AP), NAAP, deuterium oxide (D_2O) and tritiated water (TOH) are in common use for the estimation of this fluid phase.

Generally total body water is distributed between two phases—the intracellular and extracellular compartments. The estimations of extracellular water are generally made by studying the distribution of various substances. Thiocyanate is widely used to determine the extracellular water compartment because of its rapid distribution throughout the body, its slow excretion and ease of determination (2, 9, 10, 13, 24).

On the other hand dilution techniques for determinig the plasma and blood volumes were investigated for many years and DAWSON *et al.* (6) conducted studies with various dyes and showed that blue azo dye T-1824 (Evans Blue) was a reliable indicator for determining the plasma and blood volumes. Thereafter, the dye has been widely used to estimate plasma and blood volumes (7, 16).

As described above the body fluid contents of animals have been studied extensively by many workers, however hitherto little attention has been paid to the effects of age, sex and growth on body water compartments. In line with this a review of the literature (19) shows that the total body water decreases with age. WRENN *et al.* (24) studied the extracellular body water of growing calves and reported a decrease with age and the different relationships of thiocyanate space between male and female. Further MEDWAY and KARE (14) investigated the relationship between thiocyanate space and age in growing domestic fowl and showed the thiocyanate space reduced from 61% for one week of age to 26% for 32 weeks of age.

Thus in the present study alterations in the body water compartments, such as total body water, intracellular water, extracellular water, interstitial and plasma water were studied in young calves to determine the effects of the physiological factors of age, sex and growth.

Materials and Methods

56 estimates of antipyrine space, SCN space and plasma water were made in 6 Holstein male calves and 33 trials were carried out in 5 Holstein female calves.

The calves were fed with colostrum until 3 to 5 days after birth, then they were placed on experiment and given a commercial milk replacer for males and milk for females. On the 11th to 14th day after birth they were given a commercial calf-starter with mixed hay.

The calves were weighed prior to the initiation of injections, and were deprived of feed and water during the sampling periods.

All estimations for body water compartments were carried out at approximately the same time of day in order to obtain estimations under approximately equal conditions.

Antipyrine and sodium thiocyanate solutions at a rate of 50 mg per kg body weight and a 0.5% solution of T-1824 at a level of 30 ml per head were injected into the jugular vein and blood samples for analyses were removed from the opposite jugular vein at intervals of 30 minutes, 1 hour, 2 hours and 4 hours after administration.

Each space was calculated by the following equations:

$$\begin{array}{l}\text{Antipyrine space} \\ \text{(Total body water)}\end{array} = \frac{\text{amount of antipyrine injected}}{\text{concentration of antipyrine in plasma}}$$

$$\begin{array}{l}\text{SCN space} \\ \text{(Extracellular water)}\end{array} = \frac{\text{amount of SCN injected}}{\text{concentration of SCN in plasma}}$$

$$\text{Plasma water} = \frac{\text{amount of T-1824 injected}}{\text{concentration of T-1824 in plasma}}$$

Concentrations of antipyrine, SCN and T–1824 in plasma were calculated by extrapolation back to instant $t=0$ and corrected for the amounts of solids in plasma for each estimation. Intracellular water was calculated by deducting SCN space from the total body water while interstitial water was obained by deducting plasma water from SCN space. The body water compartments were then expressed as percentage of body weight.

Antipyrine was determined by the method described by BRODIE *et al.* (3) and the analysis of SCN was made by the method of BOWLER (2) on trichloroacetic acid filtrates of plasma. The concentration of T–1824 was determined by the method described by HIX *et al.* (10).

Results

Figures 1 and 2 illustrate the changes occurring in body water compartments with growth and age in male calves. The total body water was large in newborn calves, comprising approximately 80% of body weight. This dropped rapidly to 60% or so during the first four or five months of life. Thereafter, changes were very small or negligible. Extracellular water comprised approximately 55% of body weight for the newborns and decreased gradually for the first three months. During the subsequent one or two months, this was followed by a more rapid decline, while showing a slight

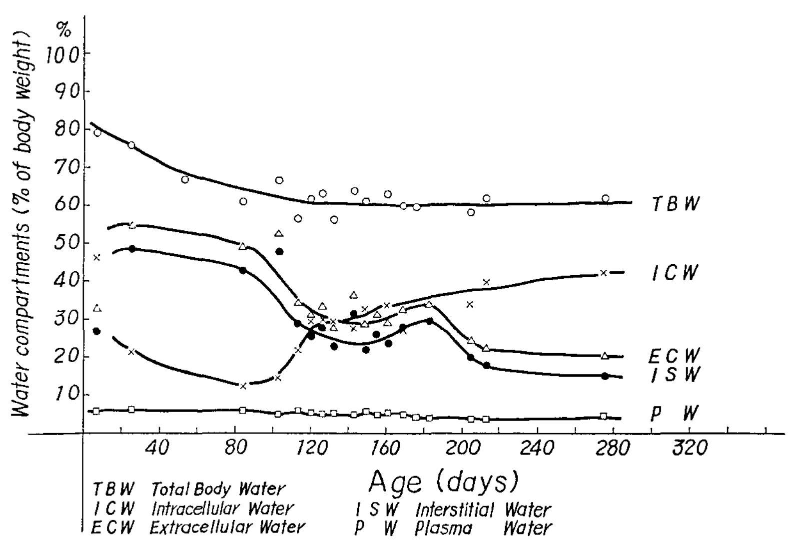

Figure 1. Relation of body water compartments to age in bull calves
(All dotts were the average values of estimates and lines were drawn by inspection.)

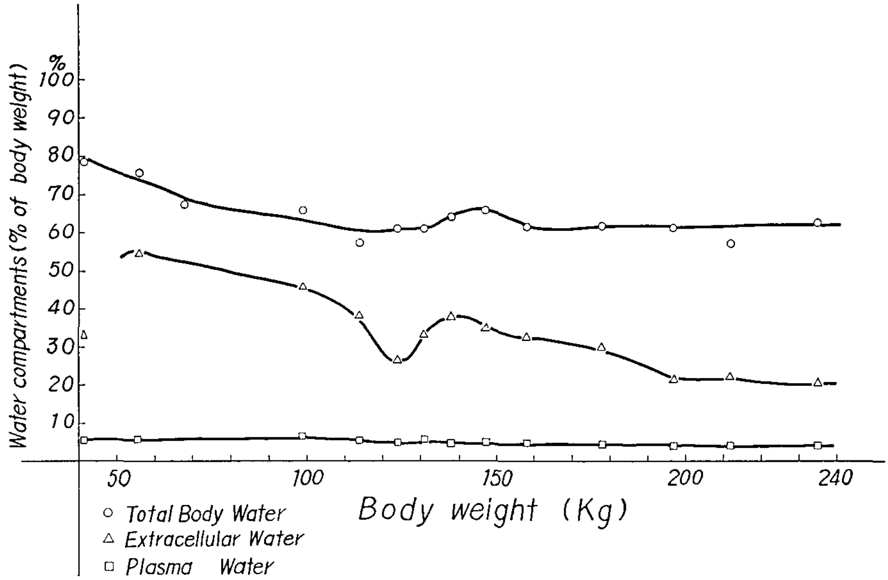

Figure 2. Relation of body water compartments to body weight in bull calves

(All dotts were the average values of estimates and lines were drawn by inspection.)

increase at 150 to 180 days of age. After the slight increase in extracellular water, there was a further decline to a level of 20% of body weight. Plasma water was found to be relatively constant, being about 5 to 6% of body weight, but a slight decline was noted at 180 days of age, producing a similar pattern of decline in interstitial water as seen in extracellular water. Intracellular water showed a very low level in early life and increased rapidly to 30% of body weight during a 3 to 5 month period after birth. Thereafter, changes were small, although a gradual increase in size of this water compartment was noted.

Changes in relative composition of body water are shown in figure 3. Extracellular water shows a very high level (70 to 80% of total body water) during first three months. Thereafter, this decreased to a 30% level. Thus, intracellular water showed a reverse pattern of extracellular water. Interstitial water showed approximately the same pattern as extracellular water. Plasma water showed a relatively low level (5 to 7% of total body water) for the first three months and then rose to 8 to 10% in the next three months. This was followed by a slight decline at 6 months of age.

Figures 4 and 5 illustrate changes occurring in the body water compartments with growth and age in female calves. The total body water was very

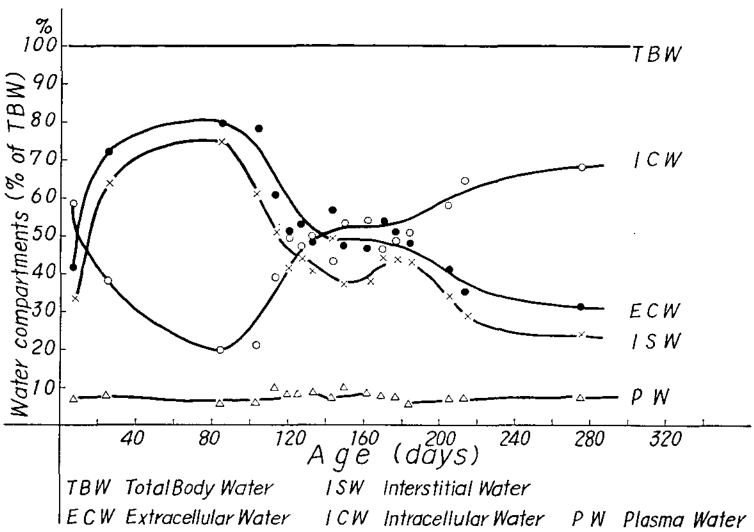

Figure 3. Changes of relative composition related to age in bull calves
(All dotts were the average values of estimates and lines were drawn by inspection.)

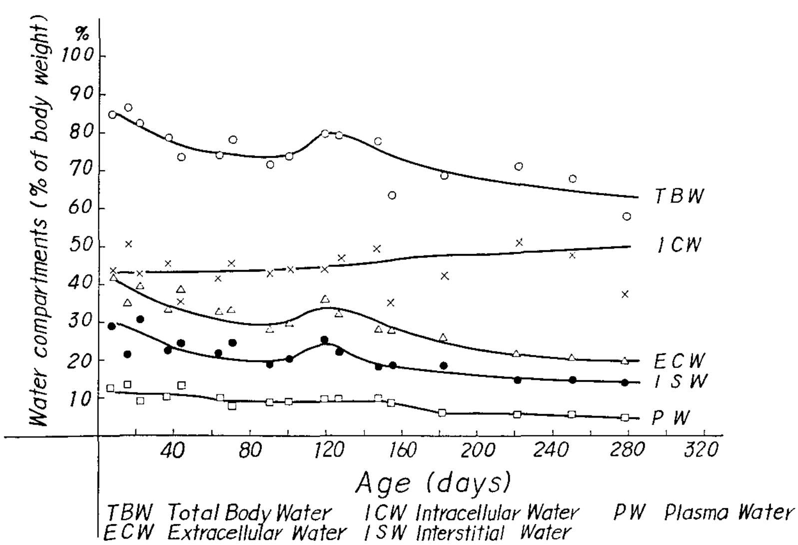

Figure 4. Relation of body water compartments to age in heifer calves
(All dotts were the average values of estimates and lines were drawn by inspection.)

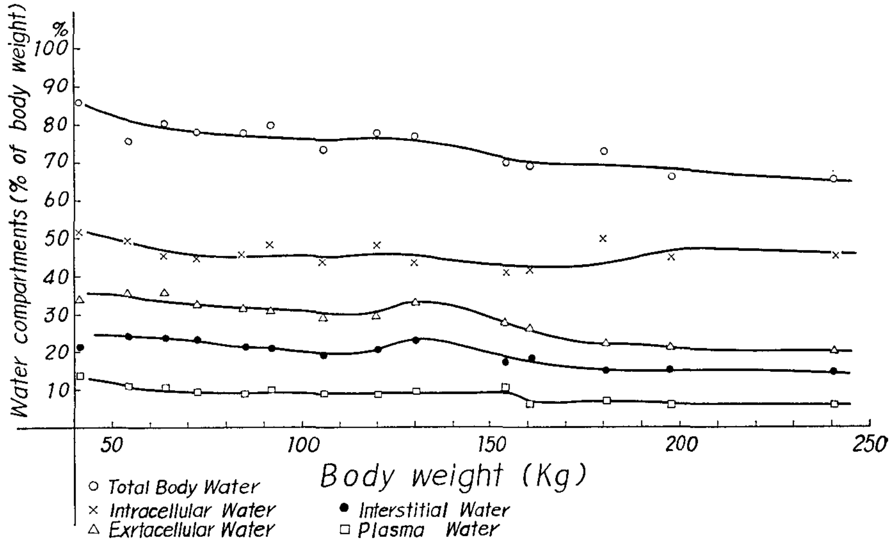

Figure 5. Relation of body water compartments to body weight in heifer calves

(All dotts were the average values of estimates and lines were drawn by inspection.)

large in newborns, coming to approximately 85% of body weight. This decreased to a 70% level during the first three months. A slight increase at four months of age was followed by a gradual decline and reached 60% at eight or nine months of age. Intracellular water tended to increase progressively with age. A decreasing change with age was seen in extracellular water, which showed a slight increasing trend at four months of age. The rate of decline in extracellular water appeared to be more rapid in the initial decline than the second. Plasma water was relatively constant, coming to 10% of body weight or thereabouts during the first six months and thereafter, this dropped to about half of this value at six months of age. Accordingly, it may be said that the interstitial water showed almost the same pattern of decline as seen in the extracellular water. Total body water in relation to body weight failed to show the same trend of a slight increase as seen in that related to age.

Changes in relative compositions of body water compartments are given in figure 6. Intracellular water increased with age from 50% of total body water to 60 to 70%, and extracellular water decreased from 50% to 30%. Plasma water showed a relatively constant level (13 to 15%) during the first six months. After this initial period of constancy, there was a decline to a value of 10% of total body water at 6 months of age and thereafter the

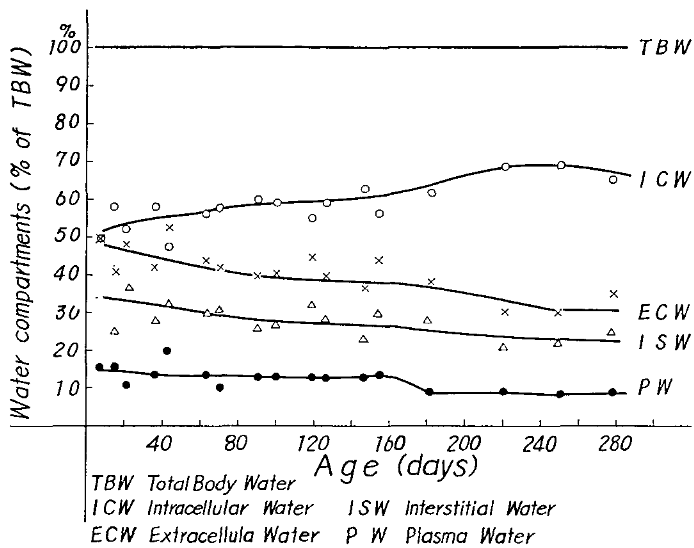

Figure 6. Changes of relative composition related to age in heifer calves

(All dotts were the average values of estimates and lines were drawn by inspection.)

level remained at the declined value. At corresponding ages heifers tended to show larger total body water and plasma water values than bulls. In extracellular water, this was the case during the first 3 or 4 months but after the elapse of these periods no differences were observed.

Discussion

Total body water, as measured by the space occupied by antipyrine and extracellular water as measured by SCN showed a definite decrease during growth of calves. Similar declining changes in the size of the total body water compartment were previously described in several reports. In line with this MOULTON (15) described in cattle that the water content decreased from 76% at birth to about 70% for 5 months of age and showed a practically constant percentage after 5 to 10 months. REID *et al.* (19) analysed the data of body water in cattle reported by several workers and found that there was a highly significant negative correlation between body water content and age.

In the present study, the total body water appeared to be larger in female calves than in male calves. It is not clear whether this difference is due to the sex or to the difference of rations which were milk replacer for males and milk for females. WHITING *et al.* (23) and WRENN *et al.* (24) suggested that diet and water ingestion influenced the body water estimations.

In terms of MOULTON's definition of chemical maturity, i. e., the time at which the concentrations of water, protein and mineral matter in the cell become constant, the data suggested that cattle are immature from birth to about 200 to 250 days of age. HIX *et al.* (10) reported that the total body water of 5 Short-horn calves, 8 to 9 months of age, were about 63% of body weight. This figure is in good agreement with data obtained in the present study.

Extracellular water alterations occurring with growth and age in calves were reported by WRENN *et al.* (24). These authors described that the SCN space was 50 to 60% in newborn calves and dropped rapidly during the first three months of life to about half of this value.

In the present study, the extracellular water generally appeared to be larger in male calves than in female, especially so during the first three or four months. A very similar trend was shown by WRENN *et al.* (24). These authors also reported that the declining curves in extracellular water with the advance in age differed markedly in the female and male calves, but such a difference between the curves in the female and male calves was not observed in this study (figures 1 and 4). Extracellular water in the male calves declined gradually during the first three months, and was followed by a more rapid decline, then showed a sharp declince during the 6 to 7 month period after the slight increasing trend. In female calves, the curve showed a rapid decline for 3 or 4 months followed by a slight increasing trend, which was followed by a relatively less rapid decline. The trend in male calves agrees considerably with the data of WRENN *et al.* (24) which shows a sharp decline of extracellular water in the female calves during the first 4 months of age and a very gradual decrease thereafter. In contrast a slight increasing trend at 4 months of age in female calves was noted in the present study. It is not known at present whether this trend is related to the effect of the onset of sexual function in heifers or to an increase of total body water which was reviewed by KEITH (11).

GUADINO and LEVITT (8) studied the body water distribution in normal dogs treated with desoxycorticosterone acetate for three weeks and found that the total body water remained nearly constant with a declining trend, while the extracellular water volume progressively expanded. The activity of adrenal cortex appeared to have effects on the body water distribution, but this was not the case for the present study which showed an increase of the total body water at the same time.

Plasma water was relatively constant regardless of growth and age during the first six months, then decreased in levels both in male and female, and the decline was smaller in the male than in the female.

RODBARD *et al.* (21), BASS and HENSCHEL (1) and DALE *et al.* (5) described that high environmental temperatures increased blood plasma volume and low temperatures exerted the opposite effect. As the estimations in the present work were carried out in winter time when the calves were six months to nine months of age, the decline of plasma volume in the present study appears to be affected by low ambient temperatures but the fact was not ascertained.

The large variable water compartment in the gut and rumen of cattle could be a factor resulting in greater variability in total body water determinations. Several attempts to estimate ruminal volume and size of this compartment have been made by differential determination with antipyrine which distributes throughout body water and NAAP which does not appear to enter the rumen (18, 20, 24), but this method does not seem to be reliable enough and further research may be anticipated.

Summary

Estimations of the body water compartments of growing calves were determined by antipyrine for total body water, sodium thiocyanate for extracellular water and T-1824 for plasma water. Eighty nine estimates were made on 11 calves. Data were collected in female and male calves up to 240 kg body weight (approximately 9 months of age). Total body water decreased from about 80% at 7 days of age to 60% at 9 months of age. This decrease occurred during the first 4 to 5 months in male calves and in the 8 to 9 months for female calves. Extracellular water declined rapidly from about 50% to 20%. This decrease occurred during the first 6 to 7 months for male calves and up to the 5th to 7th month in female calves. Plasma water was relatively constant but showed decreasing levels at 6 months of age in both sexes. Total body water of heifers tended to be higher than that of bull calves of the same age.

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