Serum Biochemical and Hematological Parameters of Sinclair(S-1) Miniature Sows During Gestation and Lactation

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SUMMARY

Venous blood samples were collected from 29 Sinclair(S-1) miniature sows at 14, ten, six and two weeks prior to parturition and two, four and six weeks postpartum to determine the effect of pregnancy and lactation upon 19 serum biochemical and 12 hematological parameters. During gestation, the levels of serum cholesterol, blood urea nitrogen and alpha$_1$-globulin, as well as packed cell volume and hemoglobin concentration, decreased; whereas, the level of serum beta-globulin increased. During lactation, the concentrations of serum glucose, total protein, albumin, beta-globulin, calcium, sodium and hemoglobin, as well as packed cell volume, decreased; whereas, the concentration of serum cholesterol and the activity of serum alkaline phosphatase increased.

RÉSUMÉ

On récolta des échantillons de sang veineux de 29 truies miniatures Sinclair(S-1) à quatorze, dix, six et deux semaines avant la parturition et à deux, quatre et six semaines après la mise-bas; ceci afin de déterminer le rôle joué par la gestation et la lactation sur 19 paramètres biochimiques et sur 12 paramètres hématologiques du sérum. Au cours de la gestation, les taux de cholestérol sérique, d'azote urique sanguin et d'alpha-globuline, ainsi que le volume érythrocytaire et la concentration en hémoglobine diminuèrent. Cependant, le taux de beta-globuline sérique augmenta. Pendant la lactation, les concentrations en glucose sérique, en protéines totales, en albumine, en beta-globuline, en calcium, en sodium, en hémoglobine et le volume érythrocytaire diminuèrent. La concentration du cholestérol sérique et l'activité des phosphatases alcalines sériques augmentèrent.

INTRODUCTION

Studies have been conducted to determine changes in serum, blood and urine of various species of animals and man; however, few longitudinal studies have been done to determine the changes associated with both pregnancy and lactation in swine. Several investigators (5, 6, 12, 21, 37, 38, 42) have demonstrated the usefulness of swine in biomedical research as a result of the similarities of anatomical and physiological parameters in man and pigs. This study was designed, utilizing serial blood collections, to identify changes in serum biochemical and hematological parameters during both gestation and lactation.

MATERIALS AND METHODS

The 29 Sinclair(S-1)[1] miniature sows used in this study were one to two years of age. Each sow was individually bred and housed in floorless wooden buildings on pasture. Each sow farrowed in a 3 x 4 meter pen in a building with radiant heat in concrete floors; the sow and her piglets were maintained in the farrowing pens until weaning at six weeks postpartum. The mean number of live piglets per litter at birth, 24 hours, 21 days and 42 days was 8.7, 7.8, 5.9 and 5.6, respectively. The duration of the experiment was from July, 1968, through June, 1969. Plastic syringes were used to collect each blood sample from the cephalic vein as previously reported (36). Blood samples were collected from each sow, between 8 and 10 am., at 14, ten, six and two weeks prepartum and two, four and six weeks postpartum.

For hematological determinations, 2 ml of blood were collected using EDTA-K as the anticoagulant. The remainder of the blood was allowed to clot in Corex tubes at

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[1] Sinclair(S-1) miniature swine stock is a random bred population derived from Hormel miniature swine purchased from the Hormel Foundation.

room temperature for three to four hours and the serum was separated by centrifuging at 12,500 X g and 2°C for ten minutes. The serum was recentrifuged at 20,000 X g and 0°C for five minutes. Each serum sample was frozen and stored at $-10°C$ until analyzed.

Serum total protein (TP), glutamic-oxaloacetic transaminase (G-OT), alkaline phosphatase (AP), lactic dehydrogenase (LDH), calcium (Ca), inorganic phosphorus (IP), blood urea nitrogen (BUN), creatinine (Crt), chloride (Cl), cholesterol (Chol), glucose (Glu) and total bilirubin (TB) were determined with a modified survey model Sequential Multiple AutoAnalyzer[2] (SMA-12/30) (35). The serum protein fractions — albumin (Alb), *alpha*$_1$-globulin (α_1-Glob), *alpha*$_2$-globulin (α_2-Glob), *beta*-globulin (β-Glob) and *gamma*-globulin (γ-Glob) — were separated electrophoretically, using the microzone technique, on cellulose polyacetate strips, stained with Ponceau S and quantitated with a densitometer[3]. From these values the albumin/globulin (A/G) ratios were calculated. Sodium (Na) and potassium (K) were determined by flame photometry[4].

Erythrocyte counts (RBC) and leukocyte counts (WBC) were enumerated using an electronic cell counter[5]. Differential leukocyte counts were made on thin blood smears stained with Wright's stain. Hemoglobin concentrations (Hgb) were determined with an hemoglobinometer[6] and packed cell volumes (PCV) were determined by the microhematocrit method. Mean corpuscular volumes (MCV), mean corpuscular hemoglobins (MCH) and mean corpuscular hemoglobin concentrations (MCHC) were calculated.

RESULTS

Means and standard errors of the measured parameters during gestation and lactation are presented in graphic form in Figs. 1-10. The significant linear changes in parameters, during gestation and during lactation, are shown in Table I.

There was a significant ($P<0.01$) linear decrease in serum Chol concentration from 115 ± 3 mg/100 ml at 14 weeks prepartum to 100 ± 3 mg/100 ml at two weeks prepartum (Fig. 1; Table I). The increase in serum Chol concentration, from 87 ± 3 mg/100 ml at two weeks postpartum to 104 ± 4 mg/100 ml at six weeks postpartum, was significant ($P<0.05$). Also, there was a significant ($P<0.05$) linear decrease in serum Glu concentration from 94 ± 6 mg/100 ml two weeks postpartum to 85 ± 7 mg/100 ml six weeks postpartum.

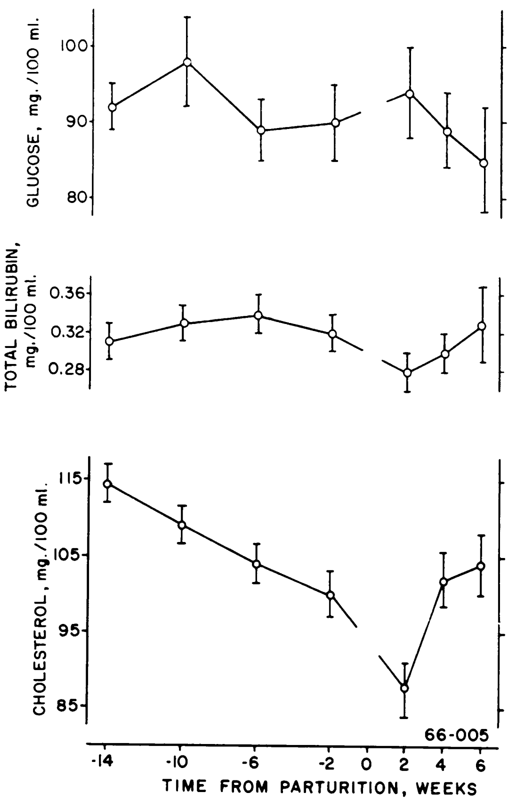

Fig. 1. Means (± SEM) of serum cholesterol, total bilirubin and glucose concentrations during gestation and lactation of 29 Sinclair(S-1) miniature sows.

The level of serum BUN decreased significantly ($P<0.01$) from 14.6 ± 0.6 mg/100 ml at 14 weeks prepartum to 11.1 ± 0.4 mg/100 ml at two weeks prepartum (Fig. 2; Table I). The concentration of serum TP decreased significantly ($P<0.05$) from 8.6 ± 0.1 Gm/100 ml two weeks postpartum to 8.0 ± 0.2 Gm/100 ml six weeks postpartum. This decrease was a reflection of the significant ($P < 0.01$) decrease in concentration of serum A/b and β-Glob from 2.44 ± 0.04 and 1.79 ± 0.07 Gm/100 ml two weeks postpartum to 2.10 ± 0.06 and 1.52 ± 0.07 Gm/100 ml six weeks post-

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[2] Technicon Corporation, Tarrytown, New York.
[3] Gelscan; Gelman Instrument Co., Ann Arbor, Michigan.
[4] Model 105; Beckman Instruments, Fullerton, California.
[5] Model B; Coulter Electronics, Hialeah, Florida.
[6] Model 231; Instrumentation Laboratory, Watertown, Massachusetts.

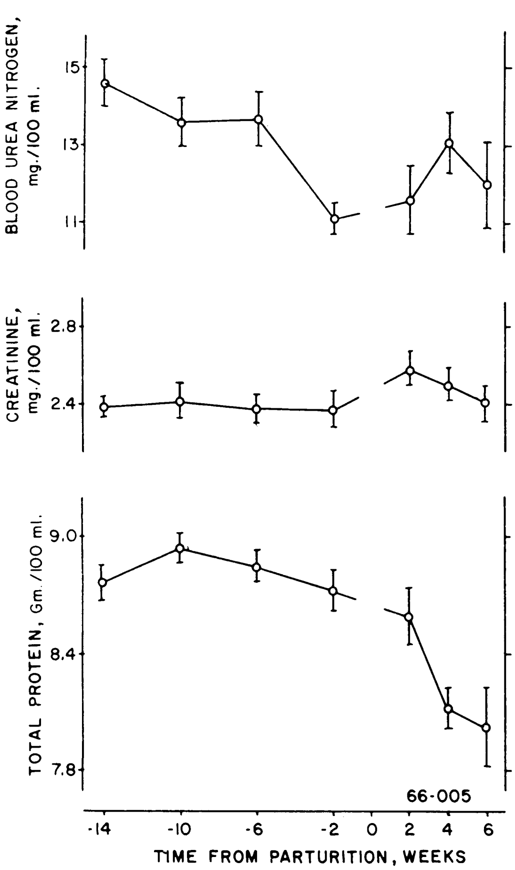


Fig. 2. Means (± SEM) of serum total protein, creatinine and blood urea nitrogen concentrations during gestation and lactation of 29 Sinclair(S-1) miniature sows.

partum, respectively (Figs. 3 & 4; Table I). There was a significant ($P<0.01$) linear increase in serum β-Glob concentration from 1.75 ± 0.04 Gm/100 ml at 14 weeks prepartum to 1.94 ± 0.04 Gm/100 ml at two weeks prepartum. The concentration of serum α_1-Glob decreased significantly ($P<0.01$) from 0.46 ± 0.02 Gm/100 ml at 14 weeks prepartum to 0.38 ± 0.02 Gm/100 ml at two weeks prepartum. There was a significant ($P<0.01$) linear decrease in serum A/G ratio from 0.40 ± 0.01 at two weeks postpartum to 0.35 ± 0.01 at six weeks postpartum (Fig. 4; Table I). There was a significant ($P<0.01$) linear increase in serum AP activity from 6.9 ± 0.2 K-AU two weeks postpartum to 9.0 ± 0.6 K-AU six weeks postpartum (Fig. 5; Table I).

The significant ($P<0.01$) linear decrease in serum Ca concentration from 11.5 ± 0.1 mg/100 ml two weeks postpartum to 10.8 ± 0.1 mg/100 ml six weeks postpartum, resulted in a significant ($P<0.01$) linear decrease in Ca/P ratio from 1.75 ± 0.05 at two weeks postpartum to 1.61 ± 0.06 at six weeks postpartum (Fig. 6; Table I). The linear decrease in serum Na concentration, (Fig. 7; Table I), from 156.8 ± 1.5 mEq/L two weeks postpartum to 153.1 ± 1.7 mEq/L six weeks postpartum, was significant ($P<0.05$).

During gestation, there was a significant ($P<0.05$) linear decrease in Hgb and PCV from 14.8 ± 0.2 Gm/100 ml and 44.6 ±

TABLE I. Values for Predicting Serum Biochemical and Hematological Parameters for Gestation from Time of Breeding and for Lactation from Time of Farrowing

Parameter	Gestation or Lactation	Constant	Regression Coefficient	Standard Error of Estimate
Cholesterol, mg/100 ml	G	116.70	−1.2689[b]	15.14
	L	90.38	3.4865[a]	19.36
Glucose, mg/100 ml	L	94.19	−4.2253[a]	25.35
Total Protein, Gm/100 ml	L	8.73	−0.1277[a]	0.73
Blood urea nitrogen, mg/100 ml	G	15.25	−0.2760[b]	3.48
Albumin, Gm/100 ml	L	2.68	−0.0852[b]	0.26
α_1-Globulin, Gm/100 ml	G	0.47	−0.0068[b]	0.11
β-Globulin, Gm/100 ml	G	1.75	0.0129[b]	0.24
	L	1.86	−0.0679[b]	0.31
Albumin/globulin ratio	L	0.42	−0.0101[b]	0.04
Alkaline phosphates, K−AU	L	5.96	0.5386[b]	1.97
Calcium, mg/100 ml	L	11.95	−0.1942[b]	0.54
Calcium/phosphorus ratio	L	1.78	−0.0376[b]	0.25
Sodium, mEq/L	L	159.10	−1.0956[a]	7.40
Packed cell volume, %	G	45.81	−0.3099[b]	3.65
	L	43.42	−1.0029[b]	3.04
Hemoglobin, Gm/100 ml	G	15.33	−0.1056[a]	1.44
	L	13.69	−0.3941[b]	1.19

[a]$P < 0.05$.
[b]$P_L < 0.01$.

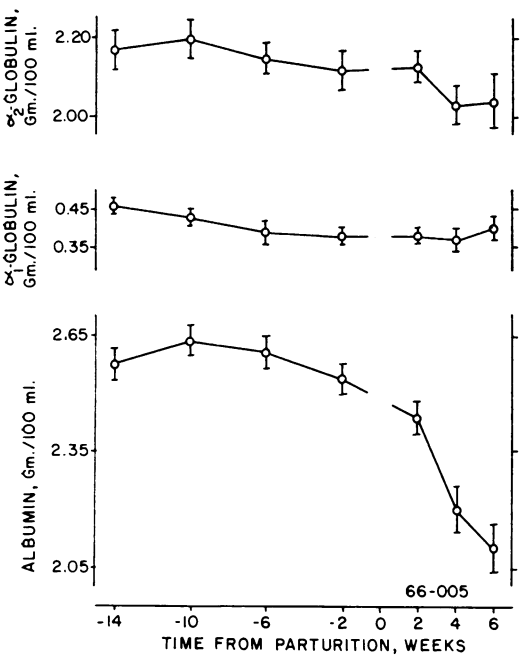


Fig. 3. Means (± SEM) of serum albumin, α_1-globulin and α_2-globulin concentrations during gestation and lactation of 29 Sinclair(S-1) miniature sows.

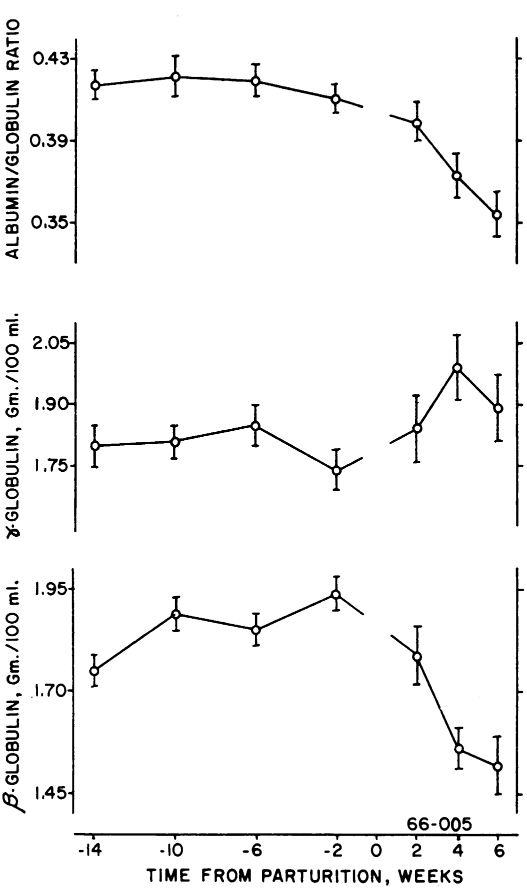


Fig. 4. Means (±SEM of serum β-globulin ratios γglobulin concentrations and albumin/globulin ratios during gestation and lactation of 29 Sinclair(S-1) miniature sows.

0.6% at 14 weeks prepartum to 14.0 ± 0.3 Gm/100 ml and 41.6 ± 0.5% at two weeks prepartum, respectively (Fig. 8; Table I). During lactation, there was a significant ($P<0.01$) decrease in PCV and Hgb from 41.5 ± 0.6% and 13.9 ± 0.3 Gm/100 ml two weeks postpartum to 38.1 ± 0.8% and 12.3 ± 0.3 Gm/100 ml, respectively. No significant changes in MCV, MCH or MCHC, during either gestation or lactation, were observed (Fig. 9). There was a significant ($P<0.01$) linear increase in neutrophil count from 2492 cells/mm^3 at six weeks prepartum to 8498 cells/mm^3 four weeks postpartum (Fig. 10).

A multiple regression equation:

Weeks postconception =

—0.10 Chol(mg/100 ml) —0.31 BUN(mg/100 ml) + 0.61 AP(K-AU) —2.63 Ca/P + 23.79

was calculated, from the serum biochemical parameters, for the best estimation of time after conception. The multiple r was 0.50 and the standard error of estimate was 3.92 weeks. Other parameters considered for the equation included: Ca, Cl, TB, Crt, TP, IP, Glu, LDH and G-OT. The addition or substitution of any of these to the equation did not increase the efficiency of the estimating equation.

DISCUSSION

Increased blood volume has been reported (7, 10, 24, 32, 40) for the pregnant human female. During lactation, increased blood volume has been reported for the rat (3), burro (18) and cattle (31, 39); however, Donovan *et al* (11) did not find an increased blood volume in the lactating human female. As blood volume was not measured in the present study, the results will be discussed assuming no change in blood, plasma or erythrocyte volume.

The serum Chol concentration, which decreased linearly from 14 to two weeks prepartum, did not follow the same pattern reported for pregnant women (4, 9, 17, 28, 29), subhuman primates (1, 41, 44), beagles (34) or rats (15, 22). In most species, there is a rise in serum or plasma Chol levels during the latter stages of pregnancy. The increase, observed in this study during lactation, has been reported, to a lesser degree, in subhuman primates (41, 44). Oliver and Boyd (29) and de Alvarez *et al* (9) reported a decrease in plasma Chol concentration, from a relatively high prepartum level, during lactation to a level only slightly above that observed in early pregnancy. They also reported a relative increase in Chol associated with *beta* lipoproteins as compared with *alpha* lipoproteins.

Hormonal influence has been implicated as a cause for the changes observed. However, definitive information, to resolve the complex interactions, has not been published. The lack of consistency of change in the various species studied indicated that different mechanisms may have been operational. Wolf and Bowman (43) reported that the level of unconjugated 17-hydroxycorticosteroids in plasma of pregnant rhesus monkeys was not different from those observed in nonpregnant females. However, they reported an increased cortisol half-life during the late stage of pregnancy in rhesus monkeys. Fillios *et al* (15), using rats as experimental subjects, found the highest concentration of serum Chol to be during the follicular phase of the estrous cycle. Because the maximum increase in serum Chol level was during the time of maximum estrogen production, they suggested that an increase in estrogen "may be primarily associated with an increased endogenous biosynthesis of cholesteral." Fabian *et al* (13) have also implicated the increased production of estrogen

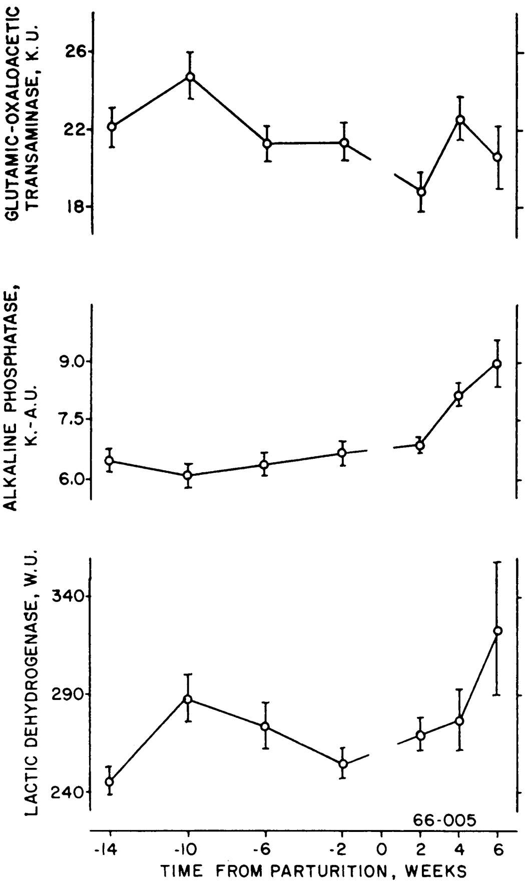


Fig. 5. Means (± SEM) of serum lactic dehydrogenase, alkaline phosphatase and glutamic-oxaloacetic transaminase activities during gestation and lactation of 29 Sinclair (S-1) miniature sows.

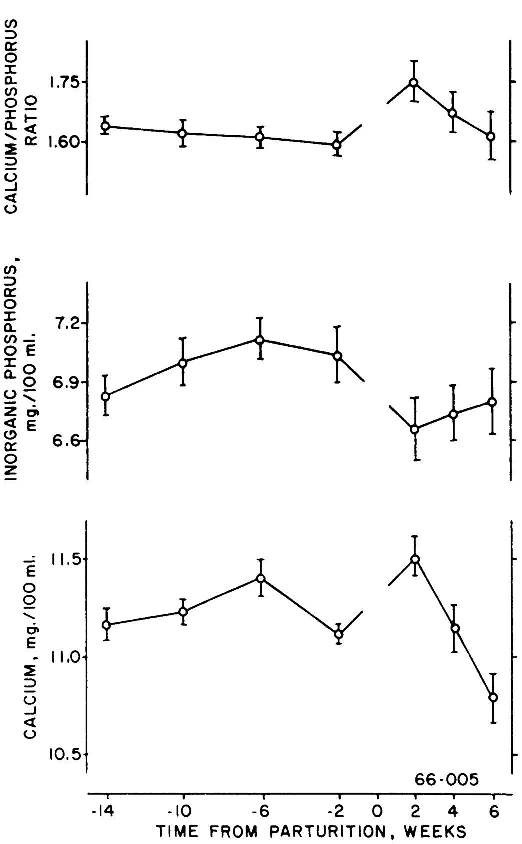
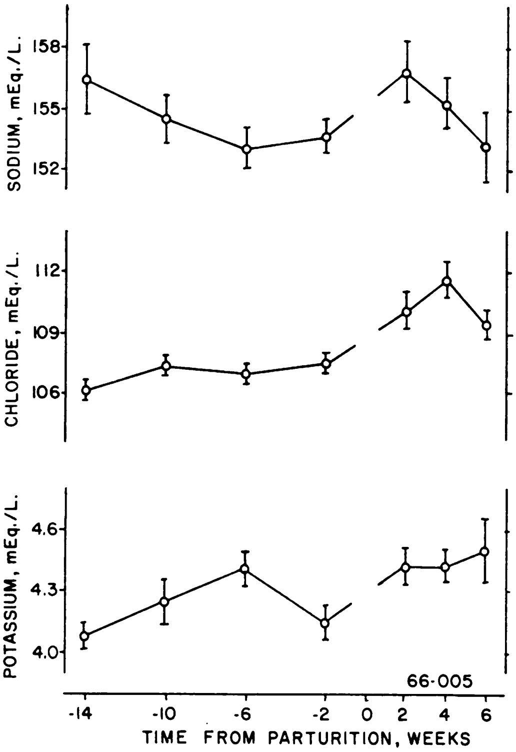


Fig. 6. Means (± SEM) of serum calcium and inorganic phosphorus concentrations and calcium/phosphorus ratios during gestation and lactation of 29 Sinclair(S-1) miniature sows.



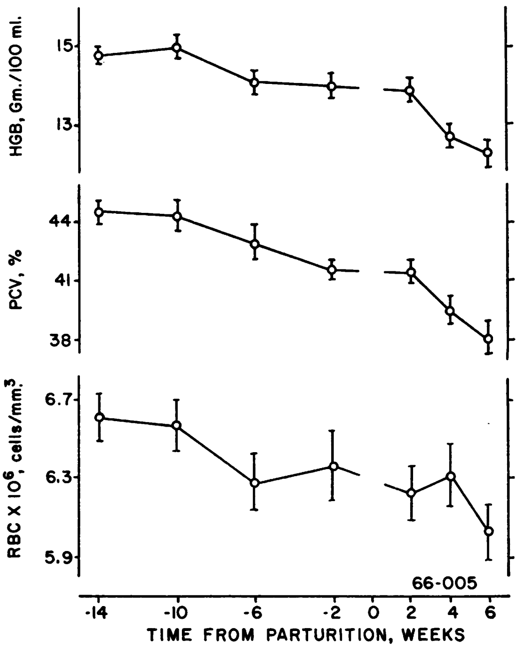


Fig. 8. Means (± SEM) of erythrocyte counts (RBC), packed cell volume (PCV) and hemoglobin concentrations (Hgb) during gestation and lactation of 29 Sinclair(S-1) miniature sows.

Fig. 7. Means (± SEM) of serum potassium, chloride and sodium concentrations during gestation and lactation of 29 Sinclair(S-1) miniature sows.

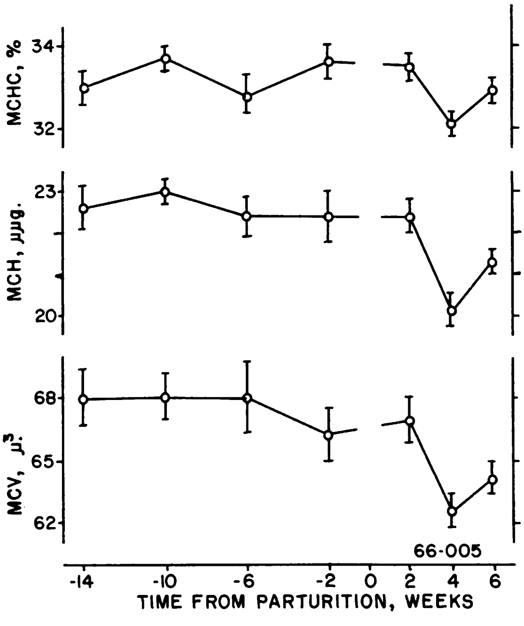


Fig. 9. Means (± SEM) of mean cell volumes (MCV), mean corpuscular hemoglobins (MCH) and mean corpuscular hemoglobin concentrations (MCHC) during gestation and lactation of 29 Sinclair(S-1) miniature sows.

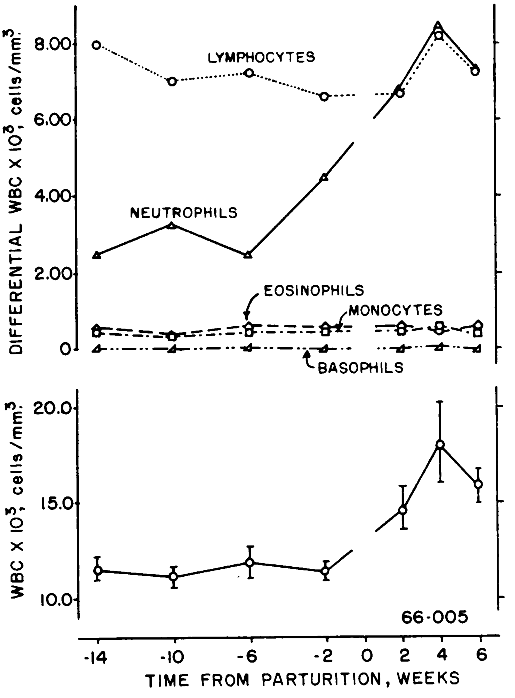


Fig. 10. Means (± SEM) of leukocyte counts (WBC) and differential leukocyte counts during gestation and lactation of 29 Sinclair(S-1) miniature sows.

during pregnancy in the alterations in fat metabolism. They reported a greater level of plasma free fatty acids and a lower activity of lipoprotein lipase and postheparin esterase during the third trimester of human pregnancy than in nonpregnant females. They suggested that the higher plasma free fatty acid levels were a result of an increased mobilization of fatty acids from peripheral tissues. Other investigators (19) have indicated that this mechanism may provide a readily available source of energy for the fetus since there is transplacental passage of free fatty acids.

The mean serum TB levels, during pregnancy and lactation, were within the normal range of values as has been reported (30) for pregnant humans. The concentration of serum Crt also did not change during pregnancy and lactation. This was in contrast to the findings of Kuhlback and Widholm (23) who reported a decrease in plasma Crt concentration during the course of normal pregnancy in humans.

There was no change in serum TP concentration when values were determined at 14, ten, six and two weeks prepartum. However, when only the observed values for ten, six and two weeks prepartum were evaluated, there was a linear decrease in serum TP concentration. This was in agreement with the studies of Friedell *et al* (16) and Miller *et al* (26) who reported a gradual decrease in serum TP concentration during the latter stages of gestation. In studies (1) done with the rhesus monkey, plasma TP concentration decreased throughout the gestation period; whereas, an increase in plasma TP concentration, during pregnancy, has been reported (34) in the beagle. The decrease in serum TP concentration, during lactation, was a reflection of the decrease in serum Alb and β-Glob levels. Friedell *et al* (16) also reported a decrease in serum TP during lactation. Increases in serum TP concentration, during lactation, have been reported for ewes (14) and rhesus monkeys (1).

The concentration of serum α_1-Glob decreased during gestation; whereas Friedell *et al* (16) reported no change in relative concentration of α-Glob and Allen and Ahlgren (1) found an increase in the relative concentration of both α_1-Glob and α_2-Glob during pregnancy of rhesus monkeys. The increase in serum β-Glob, during gestation, with a decrease during lactation was consistent with a previous report (2) for rhesus monkeys. However, other reports have shown no relative concentration changes in sows (16, 26) and rhesus monkeys (1). In this study, the level of serum γ-Glob was variable, and no definite patterns were noted. This is consistent with previous reports for rhesus monkeys (1, 2) and sows (16).

Serum Alb level did not change during gestation, but there was a decrease during lactation. This was in agreement with previous reports for sows (16) and ewes (14); however, a decrease, during gestation, has been reported for rhesus monkeys (1, 2). The level of serum Alb, as well as the concentration of serum or plasma free amino acids, reflects the availability of components for the synthesis of proteins. Kerr (20) reported a decrease in serum free amino acids during pregnancy in the rhesus monkey. Lucas *et al* (25) found plasma free amino acids to be lower during lactation than during gestation in sows. The decrease in the amino acid pool during gestation, with an even greater decrease during lactation, may reflect the depletion of body stores in the dam for the requirements of protein anabolism in the fetus and neonate.

The decreases in PCV and Hgb during gestation have been previously reported for humans (8, 30, 40) sows (27), monkeys (1, 2, 33) and beagles (34). The neutrophilia observed during late pregnancy and continuing into the puerperium has also been reported for humans (40), rhesus monkeys (1, 2) and sows (27).

If there was an hydremia associated with gestation, the decreases in PCV, Hgb, α_1-Glob, BUN and Chol of 7, 5, 16, 24 and 13%, respectively, may have been somewhat, or completely, negated. However, because these were affected to different degrees, there was probably an alteration in metabolism associated with pregnancy. Also, the increase in serum β-Glob concentration would have been more accentuated. To further evaluate the effect of pregnancy upon serum biochemical and hematological parameters, studies on blood, plasma and erythrocyte volumes will need to be conducted. If, at parturition, there was a decrease in hydremia, the decreases in Glu, TP, Alb, β-Glob, Ca, Na, PCV and Hgb would have been relatively more marked than was apparent in this study.

ACKNOWLEDGMENTS

This study was supported in part by USPHS Grants RR-00390 and RR-00285.

Acknowledgment is extended to Dr. P. D. Garrett and P. S. Evans for assistance in preparing the illustrations.

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