Comparative Analysis of Serum Calcium and Phosphorus Levels: Cord Blood *vs.* Maternal Blood

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Abstract

Background: The fetal demand for calcium and phosphorus is nearly inexhaustible, with the placenta transporting these minerals from the mother to meet the growing needs of the fetus.
Objective: To compare the status of calcium and phosphorus in cord blood versus maternal blood and assess the impact on maternal metabolism in coping with increased demands.
Methodology: After obtaining verbal consent, blood samples (n=104) were collected from mothers and the umbilical cord at the time of delivery in the maternity ward of JPMC. Serum calcium was analyzed using the Boehringer kit method, and phosphorus was estimated via atomic absorption spectrophotometry (Hitachi Z-8000). Statistical analysis was performed using SPSS version 20.
Results: The mean age of pregnant mothers was 25.3 ± 6.182 years, while the mean age of controls (n=24) was 25 ± 2.1 years. Among neonates, 42.9% (n=21) were female, and 57.1% (n=28) were male, with a mean weight of 2.99 ± 0.63 kg. The mean cord serum calcium was 8.69 ± 0.28 mg/dl, while maternal serum calcium was significantly lower at 8.13 ± 0.40 mg/dl ($p<0.01$) compared to controls (10.52 ± 0.6 mg/dl). Cord serum phosphorus levels were significantly higher than maternal levels ($p<0.0001$). A statistically significant negative relationship was found between the weight of the baby and maternal calcium level ($r = -0.352$, $p = 0.024$), but not with cord calcium or maternal/cord phosphate levels.
Conclusion: Mothers with low serum calcium concentration had correspondingly lower cord blood calcium levels compared to controls, despite compensatory mechanisms. However, the mean concentration of phosphorus in cord blood was significantly higher compared to maternal blood and controls.

Keywords: Calcium, phosphorus, maternal, newborn, cord.

1. INTRODUCTION

Calcium and phosphorus are crucial for numerous physiological processes, including neuromuscular function and the formation and mineralization of bone [1]. More than 99% of the total body calcium is present in the form of calcium hydroxyapatite ($Ca_{10}[PO_4]_6[OH]_2$), along with phosphorus, which is responsible for the mineralization of hard tissues such as bones and teeth. The total serum calcium concentration is typically between 8.5 and 10.5 mg/dl. Slight deviations in calcium levels are sensed by receptors in the parathyroid gland, which stimulate the release of parathyroid hormone (PTH) to maintain strict regulation within this range [2].

Calcium plays essential roles in blood clotting, neuronal stimulation, and hormone secretion, whereas phosphorus is necessary for energy metabolism, cell communication, and the stability of cell membrane phospholipid content [3]. Approximately 2% of an adult human body is composed of calcium, which is about 1200 grams. The requirement for cal-cium varies throughout life, increasing during childhood, adolescence, pregnancy, and lactation due to different phases of growth [4].

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Serum phosphorus, another essential mineral, exists in the body with 50% in the free form as $H_2PO_4^-$ and HPO_4^{2-}, and the remaining 50% bound to protein (10%) or other compounds (40%). Free phosphorus ions perform functions such as: (1) regulating the acidic or basic state and maintaining normal pH levels, (2) facilitating energy transfer and storage resulting from fuel metabolism, and (3) phosphorylating catalytic proteins to activate them. Approximately 85% of the 550-770 grams of phosphorus in the human body is present in hydroxyapatite crystals and phosphoproteins [5]. Blood phosphate levels range from 2.5 to 4.5 mg/100 ml. While phosphorus deficiency is rare, severe deficiencies can lead to problems with the nervous system, muscles, blood, and renal function [6].

During fetal development, the placenta is the primary source of minerals, rather than the fetal bones, intestine, or kidneys. Calcium and phosphorus are actively transported from the mother's circulation to the developing fetus, meeting the fetus's extensive mineral needs. Higher concentrations of these vital minerals are typically found in maternal blood compared to fetal circulation [7].

Therefore, this study aimed to assess the concentrations of serum calcium and inorganic phosphorus in cord blood and maternal blood to understand the maternal-fetal mineral transfer.

2. METHODOLOGY

A case-control study was conducted at the maternity ward of Jinnah Post Graduate Medical Centre, Karachi. Out of 110 mothers and newborns recruited for the study, 104 completed the study. The mean age of the mothers was 25.3 years, with a range of 15-42 years. For comparison, 24 non-pregnant women of the same age group were selected as controls.

Prior the collection of samples, approval from the Ethics Review Committee of JPMC was sought. Before sample collection, written informed consent was obtained from the mothers.

Serum samples were obtained from the whole blood of the mothers and the umbilical cord at the time of delivery. Cord blood was collected immediately after birth directly from the cord into acid-washed tubes while the placenta was still attached to the mother. Serum was extracted, and calcium and inorganic phosphorus were analyzed using kits from Boehringer and Sigma, respectively. These specific kits were chosen due to their high reliability and validity in measuring calcium and phosphorus levels in biological samples, which are critical for ensuring accurate and reproducible results.

Statistical analysis was performed using SPSS version 20. The Student's t-test was used to assess the differences between means of two groups (mothers and controls) because it is suitable for comparing the means of two independent groups. The Pearson correlation coefficient (r) was employed to determine the strength and direction of the relationship between the weight of the newborns and maternal serum calcium and inorganic phosphorus, as well as umbilical cord calcium and inorganic phosphorus levels. Pearson's correlation is appropriate for assessing linear relationships between continuous variables. One-way ANOVA was used to compare mean serum calcium and inorganic phosphate levels among different groups because it allows for the comparison of means across multiple groups to determine if there are any statistically significant differences. This method is particularly useful when dealing with more than two groups to avoid the increased risk of Type I error associated with multiple t-tests.

3. RESULTS

The mean age of pregnant mothers was 25.3 ± 6.182 years, while controls had a mean age of 25 ± 2.1 years. Among the target population, 44.9% (n=22) were primigravida, 36.7% (n=18) had a parity of 4 and below, and 18.4% (n=9) had a parity of 5 and above. The mean weight of the newborns was 2.99 ± 0.63 kg. In our sample of neonates, 42.9% (n=21) were female, and 57.1% (n=28) were male (Table **1**).

Table 1: Characteristics of the target population.

Characteristic	Value
Age (years)	25.49 ± 6.182
Parity	
- Primigravida	44.9% (n=22)
- Parity 4 and below	36.7% (n=18)
- Parity 5 and above	18.4% (n=9)
Gender of newborn	
- Male	57.1% (n=28)
- Female	42.9% (n=21)
Weight of newborn (kg)	2.99 ± 0.638

The mean cord serum calcium was 8.69 ± 0.28 mg/dl, while the maternal serum calcium was 8.13 ± 0.40 mg/dl. There was a significant increase in serum phosphorus levels in the cord blood compared to mothers among primipara, multipara with 4 children, and multipara with 10 children, but no significant changes were observed in serum calcium levels (Table **2**).

Table 2: Calcium and phosphate levels of cases and controls.

Variable	Controls (n=24)	Primigravida (n=22)	Parity 4 and below (n=18)	Parity 5 and above (n=9)
	Mother	Cord	Mother	Cord
Calcium (mg/dl)	10.52 ± 0.6	8.22 ± 3.37	8.07 ± 2.13	8.34 ± 2.31
Phosphate (mg/dl)	3.57 ± 0.20	3.63 ± 1.38	5.67 ± 0.809	3.60 ± 0.82

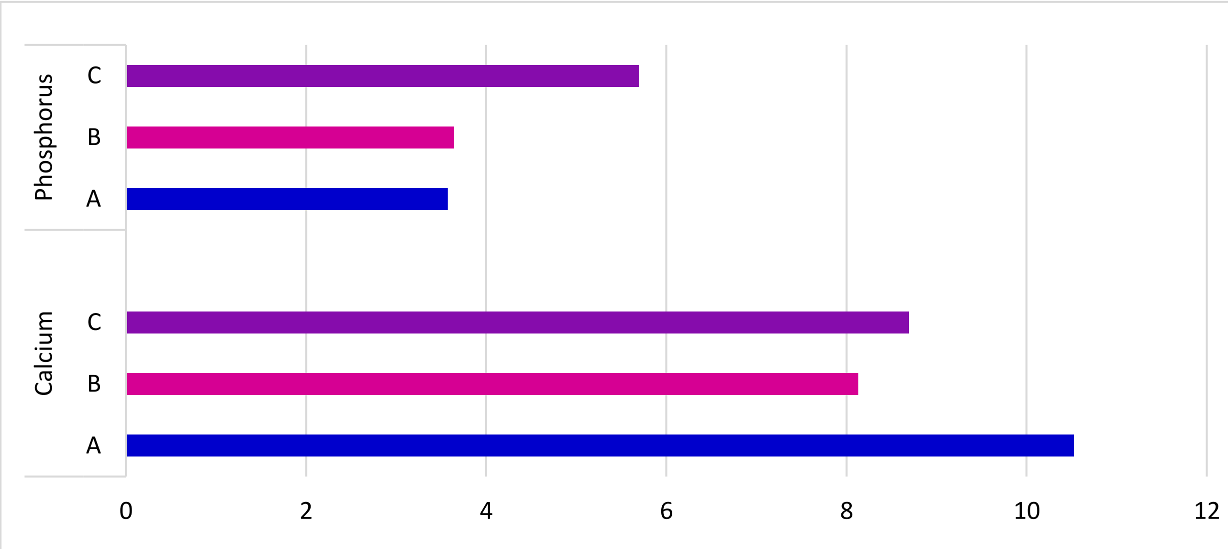

Figure 1: Comparison of Serum Calcium and Phosphorus among controls, mothers and cord blood**.** (*A: Control subjects, B: Mothers and C: Newborn's cord*).

There was an increase in the birth weight of the newborns when compared with parity, from primipara (2.83 kg) to mothers with 2-4 children and mothers with more than 5 children (3.30kg), but this increase was not significant.

Mothers were divided into three groups based on age: Group A (20 years and below), Group B (21-25 years), and Group C (26 years and above). Serum phosphorus levels were significantly higher ($p < 0.05$) in cord blood compared to maternal blood across all age groups, with no significant differences in serum calcium levels. However, Group B showed significant differences in phosphorus levels between maternal and cord blood. The mean calcium level in cord serum for Group B (9.19 mg/dl) was significantly higher than the maternal group level cord (8.63 mg/dl).

Using ANOVA, serum calcium concentrations were found to be significantly lower in maternal and cord blood compared to controls ($p < 0.01$), while mean concentrations phosphorus in cord blood were significantly higher than in maternal blood and controls ($p < 0.0001$) (Fig. **1).**

The Pearson correlation coefficient indicated a statistically significant, negative relationship between the weight of the newborn and maternal calcium levels ($r = -0.352$, $p = 0.024$). There was a statistically non-significant positive relationship between the weight of the newborn and maternal inorganic phosphate ($r = 0.087$, $p = 0.590$) and umbilical cord inorganic phosphate levels ($r = 0.304$, $p = 0.057$). The umbilical cord calcium level showed a statistically non-significant correlation with the weight of the newborn ($r = -0.308$, $p = 0.815$).

4. DISCUSSION

The mean cord serum calcium level in our population was lower (8.69 ± 0.28 mg/dl) than the normal range (9-11 mg/dl). In contrast, a study by Zhang *et al*., reported higher cord serum calcium levels (10.64 ± 0.40 mg/dl) [8]. However, the mean cord serum phosphorus level in our study was higher (5.69 ± 0.28 mg/dl), which is consistent with findings from a study by Kassai *et al*. showing mean cord phosphorus levels of 5.17 ± 0.38 mg/dl [9]. The maternal serum calcium level in our study was lower than the normal range (8.13 ± 0.40 mg/dl), similar to findings from studies involving preterm births. However, maternal serum phosphorus levels were comparable to our findings [10].

The birth weight of the newborns showed a significant negative correlation with maternal calcium levels ($r = -0.352$, $p = 0.024$), but no significant correlation with cord calcium or maternal/cord phosphate levels. Colak *et al.* reported positive correlations between cord blood serum levels and birth weight, birth length, and head circumference ($r = 0.308$, $p = 0.009$; $r = 0.324$, $p = 0.006$; $r = 0.296$, $p = 0.013$, respectively), as well as a positive correlation between cord serum phosphorus levels and birth length ($r = 0.358$, $p = 0.002$). These findings suggest that cord blood phosphorus and calcium levels are associated with birth size parameters, possibly due to interactions between these minerals influencing fetal growth [11].

Other studies have demonstrated correlations between cord and maternal calcium levels, suggesting that increased maternal calcium could enhance cord calcium levels and subsequently improve fetal growth. Calcium supplementation in mothers with low dietary calcium intake has been shown to increase fetal bone mineralization [12, 13]. However, there is ongoing debate about calcium supplementation during pregnancy, with recent recommendations suggesting the dietary allowance for calcium should be the same for pregnant and non-pregnant females [14].
Phosphorus, despite its abundance, has been less studied in relation to pregnancy. Our study found significantly higher

mean concentrations of inorganic phosphorus in cord blood compared to maternal blood and controls, with significant differences ($p < 0.0001$) between maternal (3.64 ± 0.1 mg/dl) and cord (5.69 ± 0.28 mg/dl) serum phosphorus concentrations. Previous research has linked cord phosphorus levels with birth length and found lower phosphorus levels in babies small for gestational age [15]. The Recommended Dietary Allowance (RDA) for phosphorus is 700 mg/day for both pregnant and non-pregnant women, indicating no extra requirement during pregnancy [16].

Although there was an observed increase in the birth weight of newborns with increasing parity—from primipara (2.83 kg) to mothers with 2-4 children, and mothers with more than 5 children (3.30 kg)—this increase was not statistically significant.

Calcium and phosphorus, previously considered passive minerals, are now recognized for their active roles in cell growth and proliferation. Calcium is crucial for signal transduction, regulating cell growth, and numerous cellular activities, including cell proliferation and its regulation [17]. Phosphorus is vital for energy provision and plays an essential role in various metabolic and physiological processes, including phospholipid biosynthesis, DNA synthesis, cell division, and energy metabolism, primarily as phosphate (Pi) or Pi esters [18].

5. CONCLUSION

Mothers with low serum calcium concentrations provide lower calcium to the fetus despite compensatory mechanisms from maternal sources such as vitamins, parathyroid hormone (PTH), and bone. However, we observed that older mothers tended to deliver heavier infants, even though they themselves were hypocalcemic. Given the active role of calcium and phosphorus in cell growth and proliferation, dietary calcium supplementation should be encouraged during pregnancy to support fetal development and maternal health.

LIMITATION

Serum Vitamin D levels of the mother and cord blood should also be studied to ascertain the differences in calcium and phosphorus concentrations between mother and cord blood.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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This study has received no financial support.

CONSENT TO PARTICIPATE

Informed consent was taken from the patients.

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AUTHOR'S CONTRIBUTION

All authors contributed equally to the study.

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