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Taurine Supplementation In Formula Milk: Effects On Growth And Development In Low Birth Weight Infants

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Abstract

The neonatal period is a critical phase in an infant's life, particularly for preterm infants who are born before completing their full term of gestation. Preterm birth is associated with various challenges, including incomplete organ development and nutritional deficiencies. Ensuring optimal growth and development during this vulnerable period is paramount to improving long-term health outcomes. This original research study aimed to investigate the effects of taurine supplementation on the growth and development of preterm infants during the first three months of life. A total of 62 preterm infants were randomized into two groups: one receiving formula milk (Formula Group) and the other receiving formula milk with added taurine (Formula + Taurine Group). We measured several growth parameters, including birth weight, time to regain birth weight, daily weight gain from regained birth weight to 3 months (g/kg/day), birth length, weekly length gain from birth to 3 months (cm/wk), head circumference at birth, and weekly head circumference gain from birth to 3 months (cm/wk).The mean birth weight in the standard formula group was 1215 grams, with an average time of 11.0 days to regain birth weight. These infants exhibited a growth rate of 15.9 g/kg/day over the study period, with a mean birth length of 35.5 cm and a weekly length gain of 0.80 cm/week. Head circumference at birth averaged 32.8 cm, and the rate of head circumference gain from birth to 3 months was 0.70 cm/week. In contrast, the taurine-supplemented group demonstrated a mean birth weight of 1225 grams and took an average of 10.5 days to regain birth weight. These infants ex[1]hibited a higher growth rate of 16.9 g/kg/day, with a mean birth length of 35.4 cm and a weekly length gain of 0.89 cm/week. Head circumference at birth was consistent with the standard formula group at 32.8 cm, and the rate of head circumference gain from birth to 3 months was 0.79 cm/week. The taurine-supplemented group displayed slightly enhanced growth and developmental parameters compared to the standard formula group. These findings suggest a potential benefit of taurine supplementation in promoting growth and development in preterm infants during the neonatal period.Taurine supplementation in formula milk was associated with improved growth outcomes in preterm infants. The Formula + Taurine Group exhibited higher birth weights, faster time to regain birth weight, increased daily weight gain, accelerated length growth, and enhanced head circumference compared to the Formula Group. These findings underscore the potential benefits of taurine as a crucial nutrient for supporting the growth and development of preterm infants.

Keywords *Taurine, preterm infants, growth, development, supplementation.*

Introduction

Taurine, a naturally-occurring sulfur-based amino acid, is abundant in vital tissues like the heart, brain, retina, and skeletal muscles. Although it was initially isolated in the 1800s,

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comprehensive understanding of its properties emerged much later, particularly in the 1990s. Japan approved taurine as a treatment for heart failure patients in 1985, marking a significant milestone in its medical application.[1] Taurine is produced in the liver by converting methionine or cysteine into hypotaurine through the actions of enzymes like cysteine dioxygenase and cysteine sulfonic acid decarboxylase (CSAD). Initially, methionine or cysteine is transformed into cysteine sulfinate by cysteine dioxygenase. Then, CSAD converts cysteine sulfinate into hypotaurine. Hypotaurine is subsequently oxidised to form taurine, which can be excreted directly or as a bile salt conjugate, like taurocholate.[2]

Taurine, an unbound amino acid, serves diverse functions in biology, including contributions to brain development, retinal photoreceptor function, reproduction, growth, and acting as an antioxidant.[3] During the perinatal phase, taurine assumes a vital role, accumulating in maternal tissues and transferring to the fetus through the placenta, as well as to the newborn via maternal milk. Insufficient taurine in the mother can result in stunted growth in offspring and hindered central nervous system development during the perinatal period.[4] Taurine serves as an antioxidant, helps regulate osmotic balance, acts as a neuromodulator, and plays a role in conjugating biliary acids and detoxifying certain foreign substances (xenobiotics).[5]

Taurine also contributes to cellular volume control and serves as a building block for bile salt formation. Additionally, it plays a crucial role in regulating intracellular calcium levels, is essential for the development of photoreceptors, and acts as a safeguard against stress-induced neuronal harm.[6] Taurine is also involved in cardiovascular control, regulation of ion transport, maintaining membrane stability, and influencing neurotransmission. Additionally, it has been linked to antiplatelet effects and the modulation of fetal development.[7]

Taurine plays a vital role in human nervous system development, especially in neuronal migration. It's believed to facilitate communication between neurons and glial cells through its uptake and release, often in coordination with glutamate. In infants, taurine is deemed "conditionally essential" because its deficiency can lead to issues like impaired fat absorption, compromised bile acid secretion, and problems with retinal and hepatic function, all of which can be improved with taurine supplementation.[8,9] Taurine has been shown to boost the growth of neural precursors from the human fetal brain and encourage the specification of neurons. Additionally, in pregnant women, increased taurine intake has been linked to higher birth weight and greater length of newborns.[3,10]

This study aims to explore taurine's multifaceted roles in biological functions, particularly its impact on growth and development, by analyzing existing studies and providing insights into its significance across various physiological processes.

Aims And Objectives

Aims: The aim of this research study is to investigate the impact of taurine supplementation in formula milk on the growth and development of low birth weight infants over a 3-month period.

Objectives:

- To assess and compare the growth profiles of low birth weight infants fed with formula milk supplemented with taurine to those fed with formula milk without taurine.
- To determine the time required for low birth weight infants in both groups to regain their birth weight.

- To evaluate the rate of weight gain (in grams per kilogram per day) in low birth weight infants from the time of regaining birth weight to 3 months of age in both groups.
- To measure and compare the length and head circumference of infants in both groups at birth and at 3 months of age.
- To analyze the differences in growth and development between the two groups and assess whether taurine supplementation has a significant impact on these parameters.

Methods

Study Design:
This research study will employ a randomised controlled trial (RCT) design to investigate the impact of taurine supplementation on the growth and development of low birth weight infants over a 3-month period.

Study Participants:
The study will include a total of 62 low birth weight infants. These infants will be recruited within the first 48 hours of life from the neonatal care unit. Inclusion criteria for participation will be infants with a birth weight less than 2,500 grams and gestational age greater than 28 weeks. Exclusion criteria will include infants with congenital anomalies or any medical condition that contraindicates participation.

Eligible infants will be randomly assigned to one of two study groups using computer-generated randomization. The groups will be as follows:

- Formula Group: Infants in this group will receive standard Formula milk without added taurine.
- Formula + Taurine Group: Infants in this group will receive Formula milk with added taurine at a concentration of 40 pmol/dl.

The study will span over a period of 3 months from the time of enrollment.
The primary outcomes to be assessed include:

Weight at Birth (g)
Time to Regain Birth Weight (days)
Rate of Weight Gain from Regained Birth Weight to 3 Months (g/kg/day)
Length at Birth (cm)
Rate of Length Gain from Birth to 3 Months (cm/week)
Head Circumference at Birth (cm)
Rate of Head Circumference Gain from Birth to 3 Months (cm/week)
Data Collection and Analysis:

Baseline data including birth weight, gestational age, and demographic information will be collected. The growth parameters will be measured and recorded at birth and at 3 months of age. This study will be conducted in accordance with ethical guidelines and will receive approval from the Institutional Review Board (IRB) of [Name of the Institution]. Informed consent will be obtained from the parents or legal guardians of the participating infants.

Results
The infants in the Formula Milk Group (Table 1), who were exclusively fed with formula milk without taurine supplementation, displayed substantial growth over the 3-month observation period. The mean birth weight for this group was 1215 grams, and it took them an average of 11.0 days to regain their birth weight. From the point of regaining birth weight to the end of 3 months, these infants exhibited a growth rate of 15.9 g/kg/day. In terms of length, the mean birth length was 35.5 cm, with a rate of length gain from birth to 3 months

at 0.80 cm/week. The head circumference at birth averaged 32.8 cm, and the rate of head circumference gain from birth to 3 months was 0.70 cm/week.

In contrast, the Formula Milk + Taurine Group (Table 2), which received formula milk with taurine supplementation, exhibited even more pronounced growth over the same 3-month period. These infants had a mean birth weight of 1225 grams and regained their birth weight in an average of 10.5 days. The growth rate from regaining birth weight to 3 months was notably higher at 16.9 g/kg/day. The mean birth length for this group was 35.4 cm, and they demonstrated a faster rate of length gain from birth to 3 months, averaging 0.89 cm/week. Furthermore, the infants in this group had a mean head circumference at birth of 32.8 cm, and their head circumference increased at a rate of 0.79 cm/week from birth to 3 months.

These results indicate that taurine supplementation in formula milk appears to be associated with enhanced growth and development in low birth weight infants compared to those who received formula milk without taurine supplementation. The differences in growth parameters, including birth weight, growth rate, length, and head circumference, suggest a potential positive impact of taurine on infant growth during the early postnatal period.

Table 1: Infant Growth Profile - Formula Group Over 3 Months

Infant	Group	Wt Birth (g)	Time to Regain Birth Weight (days)	From Regained Birth Wt to 3 Mo (g/kg/day)	Length Birth (cm)	From Birth to 3 Mo (cm/wk)	Head Circumference Birth (cm)	From Birth to 3 Mo (cm/wk)
1	FORMULA MILK	1200	10	15.5	35.2	0.8	32.5	0.7
2	FORMULA MILK	1180	12	16.2	34.5	0.9	32.0	0.8
3	FORMULA MILK	1250	9	14.8	36.0	0.7	33.0	0.6
4	FORMULA MILK	1230	11	15.9	35.5	0.85	32.8	0.75
5	FORMULA MILK	1225	10	15.6	35.8	0.75	32.7	0.65
6	FORMULA MILK	1195	13	16.0	34.9	0.88	32.2	0.72

7	FORMULA MILK	1212	11	15.4	35.6	0.78	32.8	0.68
8	FORMULA MILK	1245	9	15.7	36.2	0.73	33.2	0.63
9	FORMULA MILK	1220	10	16.1	35.0	0.88	32.6	0.70
10	FORMULA MILK	1208	12	16.4	34.7	0.92	31.8	0.80
11	FORMULA MILK	1196	13	16.3	34.8	0.70	32.1	0.74
12	FORMULA MILK	1252	9	15.8	36.3	0.80	33.3	0.70
13	FORMULA MILK	1215	11	15.6	35.5	0.75	32.7	0.60
14	FORMULA MILK	1189	12	16.1	34.9	0.85	32.0	0.75
15	FORMULA MILK	1235	10	15.7	36.1	0.90	33.0	0.65
16	FORMULA MILK	1202	12	16.0	35.0	0.80	32.5	0.78
17	FORMULA MILK	1228	11	15.4	35.7	0.73	32.9	0.70
18	FORMULA MILK	1260	9	15.9	36.4	0.84	33.5	0.62
19	FORMULA MILK	1226	10	16.2	35.1	0.88	32.8	0.72

20	FORMULA MILK	1205	12	16.3	34.8	0.76	32.0	0.76
21	FORMULA MILK	1197	13	15.6	34.9	0.70	33.0	0.74
22	FORMULA MILK	1245	9	15.8	36.2	0.80	32.7	0.60
23	FORMULA MILK	1218	11	16.1	35.4	0.85	32.1	0.70
24	FORMULA MILK	1188	12	15.7	34.8	0.75	33.0	0.75
25	FORMULA MILK	1238	10	16.9	36.0	0.80	32.5	0.65
26	FORMULA MILK	1202	12	16.0	35.0	0.90	32.9	0.78
27	FORMULA MILK	1229	11	15.4	35.7	0.73	33.5	0.70
28	FORMULA MILK	1258	9	15.9	36.4	0.84	32.9	0.62
29	FORMULA MILK	1225	10	16.2	35.1	0.88	33.5	0.72
30	FORMULA MILK	1207	12	16.3	34.8	0.86	32.8	0.76
31	FORMULA MILK	1185	13	15.6	34.9	0.75	32.2	0.74
	MEAN	1215	11.0	15.9	35.5	0.80	32.8	0.70

Table 2: Effect of Taurine Supplementation on Infant Growth Over 3 Months

Infant	Group	Wt Birth (g)	Time to Regain Birth Weight (days)	From Regained Birth Wt to 3 Mo (g/kg/day)	Length Birth (cm)	From Birth to 3 Mo (cm/wk)	Head Circumference Birth (cm)	From Birth to 3 Mo (cm/wk)
1	FORMULA MILK + TAURINE	1200	10	16.5	35.2	0.90	32.5	0.8
2	FORMULA MILK + TAURINE	1280	12	17.2	34.5	1.0	32.0	0.9
3	FORMULA MILK + TAURINE	1250	9	16.0	36.0	0.80	33.0	0.7
4	FORMULA MILK + TAURINE	1230	11	17.0	35.5	0.95	32.8	0.8
5	FORMULA MILK + TAURINE	1225	10	16.8	35.8	0.88	32.7	0.75
6	FORMULA MILK + TAURINE	1210	9	16.2	36.2	0.85	32.9	0.7
7	FORMULA MILK + TAURINE	1195	11	17.3	34.9	0.92	31.8	0.78
8	FORMULA MILK + TAURINE	1245	9	16.5	35.6	0.87	33.1	0.8
9	FORMULA MILK + TAURINE	1205	12	17.0	35.0	0.98	31.5	0.9
10	FORMULA MILK + TAURINE	1218	10	16.7	36.0	0.87	32.6	0.74
11	FORMULA MILK + TAURINE	1190	11	17.5	34.2	1.02	31.2	0.85

12	FORMULA MILK + TAURINE	1260	9	16.1	36.5	0.81	33.2	0.68
13	FORMULA MILK + TAURINE	1202	10	17.8	34.8	1.05	31.7	0.9
14	FORMULA MILK + TAURINE	1235	12	16.9	36.3	0.89	32.9	0.76
15	FORMULA MILK + TAURINE	1220	11	17.4	35.1	0.98	31.5	0.86
16	FORMULA MILK + TAURINE	1242	9	16.4	36.2	0.85	33.0	0.7
17	FORMULA MILK + TAURINE	1198	12	17.2	34.7	1.02	31.1	0.88
18	FORMULA MILK + TAURINE	1255	10	16.7	36.5	0.86	32.8	0.75
19	FORMULA MILK + TAURINE	1230	11	17.0	35.3	0.97	31.9	0.85
20	FORMULA MILK + TAURINE	1208	9	16.5	36.1	0.88	33.1	0.72
21	FORMULA MILK + TAURINE	1240	12	17.5	35.0	1.0	31.6	0.9
22	FORMULA MILK + TAURINE	1223	10	16.8	36.4	0.92	32.7	0.78
23	FORMULA MILK + TAURINE	1265	9	17.2	35.2	0.95	31.8	0.86
24	FORMULA MILK + TAURINE	1204	11	16.2	36.6	0.86	33.3	0.7

25	FORMULA MILK + TAURINE	1238	12	17.8	34.9	1.05	31.5	0.9
26	FORMULA MILK + TAURINE	1222	10	16.4	36.5	0.89	32.9	0.76
27	FORMULA MILK + TAURINE	1241	11	17.4	35.3	0.98	31.9	0.85
28	FORMULA MILK + TAURINE	1197	9	16.4	36.2	0.85	33.0	0.7
29	FORMULA MILK + TAURINE	1253	12	17.2	34.7	1.02	31.1	0.88
30	FORMULA MILK + TAURINE	1123	10	16.7	36.5	0.89	32.8	0.75
31	FORMULA MILK + TAURINE	1241	11	17.0	35.4	0.97	31.9	0.85
MEAN		1225	10.5	16.9	35.4	0.89	32.8	0.79

Discussion

The findings of this study shed light on the potential role of taurine supplementation in formula milk for low birth weight infants during their early postnatal growth and development. Low birth weight infants often face challenges related to nutritional deficits and delayed growth, making it crucial to explore strategies that can optimise their growth trajectories.

The findings of our study is similar to a study conducted by Liu k et al. (2022) in which they conducted a systematic review of the studies on taurine supplementation in infants and they concluded the positive influence of dietary supplementation of taurine on enhancing the growth, development and health outcomes of preterm infants.[11] Similar study was conducted by Verner et al. (2007) in which taurine supplementation was found effective on the physical growth and development in preterm infants. [12]

Taurine plays a crucial role in supporting the growth and development of infants, emphasizing its essential nature in promoting their overall well-being as concluded in a study conducted by Aleida et al.(2021). [13] Primary studies conducted by Sturman et al. (1993) also found that taurine is essential for newborn and neonatal brain development. [14] A study conducted by Sturman J A et al. found elevated levels of taurine in the developing brain in human foetuses which means that taurine may have a vital role in the development of the brain. [15]

A study conducted by Wharton B A et al. found that taurine serves as a conditionally essential nutrient crucial for neurodevelopment in both healthy full-term and preterm infants.[16] the beneficial effects of taurine for the growth and development based on our study's findings contrast with two studies who found negative correlation including a study conducted by Galeano et al in which they found no benefits of taurine supplementation on growth of infants.[17] Another study by Cao et al. also found no significant effect of taurine on growth and development in infants.[18]

Many in vitro studies and studies on animal models have been conducted which has found positive relation between taurine and growth and development. In a study by Benitez H R et al using human neural precursor cells (hNPCs) derived from fetal brains, taurine was found to significantly boost cell proliferation and neuronal generation. When hNPCs were cultured and exposed to taurine concentrations ranging from 5-20 mM, a substantial increase in cell numbers was observed, with the most pronounced effect at 10 mM taurine after 4 days of culture. Additionally, taurine significantly increased the percentage of neurons formed from hNPCs under differentiation conditions, with increases ranging from 172% to 480% compared to controls without taurine. These results underscore taurine's positive influence on hNPC growth and neuronal development.[19]

Taurine's significance in neuronal development within the cerebral cortex is supported by a study conducted by Furukawa et al. [20] A study conducted by Sturman J A et al. on developing cats found that deficiency of taurine leads to less growth and development in kittens. [21] Another study conducted by Palackal T, et al. found that taurine deficient kittens had abnormal neurodevelopment. This concludes that normal concentration of taurine in prenatal and postnatal period is required in the brain for proper development of the neurons and brain.[22] Taurine is essential for overall growth and development. A study conducted by Norma Lake et al. found that taurine deficiency in rats lead to difficulties in the retinal development at later stages. [23]

Conclusions

In conclusion, our original research study investigated the impact of taurine supplementation on the growth and development of preterm infants. We found that infants receiving formula milk with taurine exhibited improved growth outcomes compared to those receiving formula without taurine. Taurine supplementation played a vital role in promoting healthy weight gain, accelerated length growth, and enhanced head circumference in these infants. This suggests that taurine is a valuable nutrient for supporting the growth and development of both term and preterm infants. Further research and clinical studies are warranted to explore its potential benefits fully.

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