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Research Article

The Effect of Calcium Intake on Faecal Calcium and its Relation to Spasticity in The Spastic Rats Model

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ABSTRACT

The most important element in food in the formation of teeth, bones and soft tissues and plays a role in various metabolic processes in the body is calcium. Hypocalcemia causes hyperexcitability of the nervous system which can induce spasticity due to deficiency of calcium intake or impaired absorption of calcium due to hypoparathyroidism or due to excessive loss of calcium through the kidneys. High phosphate intake can also increase calcium in the intestine. If the absorption of calcium in the intestine decreases, there will be an increase in calcium excretion through the faecal. The theory about the role of calcium in muscle contraction and its excretion through faecal needs to be investigated to determine the effect of calcium intake on faecal calcium in relation to spasticity in spastic rat models. The main materials used in this study were calcium lactate powder and aquadest. A total of 42 experimental animals were male Sprague Dawley rats aged 10-12 weeks weighing 200-250 g. Rats were obtained from Biofarmaka IPB and received a laboratory animal health certificate. Stool samples were taken as much as 2 g before and after the intervention. Calcium mineral solution was measured by the intervention AAS method carried out for 15 days. in groups K5 and K6 who received calcium intake of 400 mg and 500 mg experienced a decrease in faecal calcium levels. Increased calcium intake causes increased absorption of calcium in the intestine and reduced excretion of calcium with faecal, associated with increased levels of calcium in the blood.

Keywords: Calcium Intake, Faecal Calcium, Spasticity, Spastic Rats.

INTRODUCTION

Calcium is a chemical element belonging to group 2 (IIA) elements or alkaline earth metals. Calcium has an ionization energy of 589.5 kJ/mol. Calcium is also a wet oxide and is easily soluble in water at room temperature. Calcium is an important element in food because it is a building block for bones, teeth and soft tissues and plays a role in various metabolic processes in the body (Dominguez et al., 2024).

The total calcium in the body is about 1-2% of the adult body weight, of which 99% is stored in the teeth and bones. Total plasma calcium levels range from 8.8-10.4 mg/dl, consisting of 40-50% calcium ions, 46% calcium bound to proteins, especially albumin and the remaining 8% calcium in organic complexes bound to anions, namely bicarbonate, citrate, phosphate, lactate and sulfate. Calcium enters the plasma through absorption from the small intestine, bones and reabsorption from the kidneys. Conversely, calcium exits the plasma via the gastrointestinal tract (100-200 mg/day), urine (50-300 mg/day), and sweat (100 mg/day) (Czigle et al., 2022).

Increase the efficiency of absorption of calcium from the intestine by increasing the synthesis of 1,25(OH)2-D3. The most rapid changes occur through action on the kidneys (W. Li et al., 2022). In calcium deficiency originating from food that lasts a long time, parathyroid hormone will prevent hypocalcemia by taking calcium deposits in the bones. Parathyroid hormone will also reduce calcium excretion by increasing reabsorption in the kidneys so that the concentration of calcium in the extracellular fluid will increase (Ng et al., 2024).

Research has shown that excitation of frog striated muscles by motor nerve stimulation will stop if the concentration of calcium in the medium is too high or too low. In subsequent studies, it was explained that calcium plays a role in bone mineralization, blood clotting, complement activation and neuromuscular transmission (Butnariu et al., 2022; Rehman et al., 2022). Control of contraction and relaxation by Ca2+ through three mechanisms, including troponin-tropomyosin associated with actin filaments, occurs in skeletal muscle and cardiac muscle. The second mechanism occurs in vertebral smooth muscle, namely Ca2+ together with calmodulin activates myosin light-chain kinase

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through myosin light-chain phosphorylation. The third mechanism is through the direct binding of Ca2+ to myosin which makes the muscles contract (Wu et al., 2023).

Spasticity is characterized by muscle hypertonus, increased deep tendon reflexes, clonus and very painful muscle spasms. Spasticity of 80% is experienced by people with spinal cord injuries or sufferers of stroke and other central nervous disorders. Changes in intracellular Ca2+ concentration play an important role in the excitation-contraction-relaxation cycle of skeletal muscle. Abnormal changes in intracellular Ca2+ concentration cause abnormal muscle contractions including spasticity. An increase in intracellular Ca2+ concentration results in excessive muscle contraction, causing spasticity. Sarcoplasmic reticulum Ca2+- ATPase (SERCA) actively pumps Ca2+ ions back into the lumen of the sarcoplasmic reticulum (SR) to induce muscle relaxation. Reducing the activity of this pump can cause a prolonged increase in Ca2+ which can cause spasticity (Niu et al., 2021; Sugino et al., 2022).

Hypocalcemia causes hyperexcitability of the nervous system which can induce spasticity due to deficiency of calcium intake or impaired absorption of calcium due to hypoparathyroidism or due to excessive loss of calcium through the kidneys. High phosphate intake can also increase calcium in the intestine. If calcium absorption in the intestine is reduced, there will be an increase in calcium excretion through the faecal (Rodríguez-Hernández et al., 2022).

Based on the theory about the role of calcium in muscle contraction and excretion through faecal, it is necessary to conduct research to determine the effect of calcium intake on faecal calcium in relation to spasticity in spastic rat models.

METHODS

Design, Place and Time

This experimental research was carried out after obtaining ethical approval from the Institute for Research and Community Service (LPPM) IPB number 92-2018 IPB at the Laboratory of the Animal Hospital, Faculty of Veterinary Medicine, IPB from August to November 2018. Maintenance of rats and intervention treatments were carried out at the Faculty of Veterinary Medicine IPB. Faecal calcium examination was carried out in the integrated laboratory of FMIPA IPB.

Materials and Tools

The main materials used in this study were calcium lactate powder and aquadest. A total of 42 experimental animals were male Sprague Dawley rats aged 10-12 weeks weighing 200-250 g. Rats were obtained from Biofarmaka IPB and received a laboratory animal health certificate. Trial animal feed is made at PT Indofeed Bogor. The material for spastic induction used a solution of erythrosine B (ErB) obtained at PT Cipta Bangun Nauli Bogor. Preparation of mineral analysis in faecal with dry ashing method using HCl.

RESEARCH STAGES

Materials Preparation

Feed is prepared in 2 types, namely standard feed and intervention feed. Standard feed contains 200 mg of calcium in 20 g of feed (P3). The intervention feed contains 50 mg (P1) and 100 mg (P2) of calcium in 20 g of feed. Calcium solution preparations were made in 3 preparations, namely calcium 100 mg, 200 mg and 300 mg dissolved in distilled water up to 3 ml.

Maintenance of Experimental Rats and ErB Induction

Rats aged 10-12 weeks were acclimatized for 14 days. Rats were weighed before and after adaptation. During adaptation, they were given standard feed containing calcium of 200 mg in 20 g of feed and drink ad libitum. Day 15, rats were induced with ErB at a dose of 80 mg/KgBW.

Spasticity Assessment

Induction was carried out by inserting 1 mL of ErB which had been dissolved in distilled water through the lateral tail vein. Shortly after induction, there were physical changes in the rats, namely changes in the skin and mucosa and

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body fluids to a pink color. Spasticity was evident with an Asworth scale of 4 and passive flexion resistance of the limbs of 100%. Spasticity was assessed before and after the intervention started the next day.

Intervention

A total of 42 rats were divided into 6 groups, namely K1 with P1, K2 with P2, K3 with P3, K4 with P3 and 100 mg calcium supplementation, K5 with P3 and 200 mg calcium supplementation and K6 with P3 and supplementation calcium 300 mg. Calcium supplementation is given through a sonde. The intervention was carried out for 15 days.

Measurement of Calcium Levels in The Faecal

Stool samples were taken as much as 2 g before and after the intervention. Calcium mineral solution was measured using the AAS (Atomic Absorption Spectrophotometer) method (AOAC 2005).

Processing and Data Analysis

The initial stages of analysis of faecal calcium data in experimental rats before and after the intervention were carried out by the Sapiro-Wilk normality test because the sample was < 50. Data distribution was declared normal if $p > 0.05$. Analysis of the effect of calcium intake between groups used the Anova test if the data distribution was normal. The Kruskal-Wallis test is used if the data distribution is not normal. Correlation analysis between variables using the Spearman test if one of the data is not normally distributed. The Pearson correlation test is used when both variables are normally distributed.

RESULTS

Faecal Calcium

Sources of calcium can be obtained from intakes containing calcium salts. Calcium is absorbed in the digestive tract and excretion of calcium occurs through the digestive tract, kidneys and bones. Calcium absorption occurs in the small intestine and can be increased by parathyroid hormone which is synergistic with the active metabolite of vitamin D. From 25 mmol of calcium intake per day, only about 5 mmol is absorbed into the body per day (Shirzadi et al., 2025; Zhang et al., 2021).

Table 1. Average faecal calcium levels (mg/kg)

Groups (K)	Before Intervention (mg/kg)	After Intervention (mg/kg)	Transformation (mg/kg)
K1 (Ca 50)	0.3465±0.7147	0.4183±0.0764	0.0718±0.1255
K2 (Ca 100)	0.2978±0.1414	0.3776±0.0936	0.0798±0.1747
K3 (Ca 200)	0.3626±0.0753	0.3823±0.0858	0.0197±0.1237
K4 (Ca 300)	0.2996±0.0874	0.3084±0.0799	0.0088±0.0820
K5 (Ca 400)	0.3842±0.1110	0.3749±0.1185	-0.0093±0.1696
K6 (Ca 500)	0.3433±0.1419	0.2068±0.1093	-0.1205±0.1354

Table 1 shows that the K5 and K6 groups who received 400 mg and 500 mg of calcium experienced a decrease in faecal calcium levels. Increased calcium intake causes increased absorption of calcium in the intestine and reduced excretion of calcium with faecal, associated with increased levels of calcium in the blood. The results obtained are in line with the study of (Barbagallo et al., 2021).

Statistical tests between groups before and after the intervention and their changes used the Anova test because the data distribution was normal ($p > 0.05$). Before the intervention between groups, $p = 0.625$ was obtained which indicated that there was no significant difference. Between groups after the intervention there was a significant difference with a value of $p = 0.003$. Changes in stool content between groups showed no significant difference with

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p = 0.117. The results of the study are in line with research by Gasser et al. 1972 who concluded that calcium retention can increase calcium absorption in the intestine and decrease calcium excretion with faecal in 2 groups of rats given different calcium intakes with the addition of injections of disodium ethane-1-hydroxy-1,1-diphosphonate (EHDP).

Calcium is absorbed by the body through intestinal epithelial cells and bound to calbindin, a calcium-binding protein that is dependent on vitamin D (Baj et al., 2020). Calbindin carries calcium into the endoplasmic reticulum of epithelial cells. Calcium is transferred to the basement membrane on the opposite side of the cell, without entering the cytosol. TRPV6 and the calcium pump (PMCA1) actively transport calcium into the body. Active transport of calcium occurs mainly in the duodenum when calcium intake is low and passive transport in the jejunum and ileum when calcium intake is high (Taheri et al., 2021).

The active absorption of calcium in the intestine is regulated by the concentration of calcitriol (1,25 dihydroxycholecalciferol or 1,25 dihydroxyvitamin D3) in the blood. Calcitriol is a cholesterol derivative. Under the influence of ultraviolet light on the skin, cholesterol is converted to previtamin D3 which spontaneously isomerizes to vitamin D3 or cholecalciferol. Under the influence of parathyroid hormone, the kidneys convert cholecalciferol into the active hormone 1,25 dihydroxycholecalciferol which acts on the enterocyte epithelial cells lining the small intestine to increase the rate of calcium absorption in the intestine. Low parathyroid hormone levels in the blood when high plasma ionized calcium levels inhibit the conversion of cholecalciferol to calcitriol thereby inhibiting the absorption of calcium in the intestine. When plasma ionized calcium levels are low, parathyroid hormone is secreted into the blood and kidneys and converts more cholecalciferol into active calcitriol thereby increasing calcium absorption in the gut (Oh et al., 2020; Zhou et al., 2024)

Not all calcium in food is easily absorbed from the intestines. The most easily absorbed calcium is found in dairy products and eggs, as well as in canned fish products. About 15 mmol of calcium is excreted into the intestine via the bile per day and the total amount of calcium that reaches the duodenum and jejunum each day is approximately 40 mmol (25 mmol from food plus 15 mmol from bile) so that an average of 20 mmol is reabsorbed into the blood. The net result is that about 5 mmol more calcium is absorbed from the gut than excreted in the bile. Much of the excretion of excess calcium is via the bile and faecal, because plasma calcitriol levels regulate how much bile calcium is reabsorbed in the gut (Jamila et al., 2020).

The Correlation Between Faecal Calcium and Calcium Balance

Calcium balance in the body is regulated by the concerted action of calcium absorption by the intestine, reabsorption by the kidneys and exchange from bone. This regulation is regulated by calciotropic hormones. Most of the excretion of excess calcium can be via bile and faecal. Plasma calcitriol levels regulate how much bile calcium is reabsorbed from the intestinal contents. Excretion of calcium excreted through the faecal is about 15 mmol per day (Fell et al., 2024; Wang et al., 2025).

After Spearman's correlation test, the results showed a significant negative correlation between faecal calcium levels before the intervention (p= 0.008; r = -0.402) and changes in faecal calcium levels (p = 0.019; r = -0.360). These results concluded that before the intervention, calcium in the faecal was metabolized by absorption and excretion were interrelated. (Mu, Nikpoor, et al., 2022) reported that increasing calcium absorption through the intestine by active transport would increase calcium reabsorption through the kidney tubules (Visco et al., 2023).

The Correlation Between Faecal Calcium and Blood Calcium

Table 2 shows the results of the Pearson correlation test between calcium levels in the faecal and the subjects' blood calcium levels.

Table 2. The results of faecal calcium correlation test with blood calcium

Correlation with blood calcium	Faecal calcium
Before intervention	p = 0.618
After intervention	p = 0.027
Transformation	p = 0.274

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The results obtained concluded that there was a significant positive correlation between faecal calcium levels after the intervention and the subject's blood calcium levels ($p = 0.027$, $r = 0.342$). The active absorption of calcium by the gut is regulated by the concentration of calcitriol (1,25 dihydroxycholecalciferol or vitamin D3) in the blood. Calcitriol is a cholesterol derivative. Under the influence of ultraviolet light on the skin, cholesterol is converted to previtamin D3 which spontaneously isomerizes to vitamin D3 or cholecalciferol which is then converted from cholecalciferol to calciferol in the liver. The kidneys convert calciferol into the active hormone calcitriol by the influence of parathyroid hormone which acts on the enterocyte epithelial cells lining the small intestine to increase the rate of absorption of calcium in the intestine (Mu, Choudhary, et al., 2022; Wahid et al., 2023)

The kidneys are stimulated to produce the hormone calcitriol, which increases the ability of the cells lining the intestines to absorb calcium from the intestines into the blood. The kidneys influence ionized plasma calcium concentrations by processing vitamin D3 into calcitriol which is most effective in intestinal calcium absorption. This conversion of vitamin D3 to calcitriol, is also promoted by high plasma levels of parathyroid hormone (Tao et al., 2021).

The Correlation Between Faecal Calcium and Spasticity

The kidney plays a central role in calcium ion homeostasis. Renal regulation of calcium ions occurs via glomerular filtration and tubular reabsorption and secretion. This is an important determinant of the concentration of calcium ions in plasma. Changes in intracellular Ca2+ concentration play an important role in the excitation-contraction-relaxation cycle of skeletal muscle. Calcium is absorbed through the intestinal epithelial cell membrane, bound to calbindin (a vitamin D-dependent calcium binding protein), calbindin transfers calcium directly to the endoplasmic reticulum of epithelial cells (N. Li et al., 2024).

Table 3. Correlation test results of faecal calcium on spasticity

Correlation with spasticity	Faecal Calcium
Before intervention	$p = 0.542$
After intervention	$p = 0.363$
Transformation	$p = 0.04$

Table 3 shows the results of the correlation test between calcium levels in the stool and spasticity before and after the intervention and the changes. The results of the Spearman correlation test showed that there was a significant negative correlation between changes in faecal calcium levels and spasticity ($p = 0.04$, $r = -0.319$). The results of this study are in line with research by Rafique et al. 2016 who found a shift in the concentration of calcium in muscle cells after being given Elaeagnus umbellata in cases of diarrhea causing sphincter muscle contractions thereby reducing the occurrence of diarrhea.

The voltage maintained the sodium ion channels in the cell membranes of nerves and muscles are very sensitive to the concentration of calcium ions in the plasma. Decreased levels of ionized calcium in plasma (hypocalcemia) cause these channels to release sodium into nerve cells or axons causing hyper-excitation so that muscles become excessively contracted and paresthesias (needle sensation) can occur in the limbs and around the sphincter including the mouth (Anjum et al., 2023).

CONCLUSION

This study demonstrated that increased calcium intake significantly influences faecal calcium levels and its relationship with spasticity in spastic rat models. Specifically, supplementation with 400 mg and 500 mg of calcium resulted in a decrease in faecal calcium excretion, indicating enhanced intestinal absorption and elevated blood calcium levels. These findings highlight the pivotal role of calcium metabolism in regulating neuromuscular function, where improved calcium homeostasis may alleviate spasticity symptoms by modulating intracellular calcium concentrations in muscle tissues.

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The significant positive correlation between faecal calcium levels post-intervention and blood calcium levels confirms that higher dietary calcium intake enhances systemic calcium availability. Furthermore, the observed negative correlation between changes in faecal calcium and spasticity suggests that reduced calcium excretion through faeces is associated with a decrease in muscle spasticity severity.

Overall, the results support the hypothesis that calcium intake affects calcium absorption and excretion dynamics, which in turn influence neuromuscular excitability and spasticity outcomes. This study provides a foundation for further research on calcium supplementation as a potential therapeutic approach for managing spasticity in clinical settings.

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