Abstract
Klotho is a protein that has been found to play a role in regulating parathyroid hormone (PTH) levels. The literature suggests an intricate relationship between Klotho and PTH. Klotho acts as a co-receptor for fibroblast growth factor 23 (FGF23), a hormone that helps regulate phosphate and vitamin D metabolism. Klotho deficiency has been associated with increased PTH levels and secondary hyperparathyroidism. Several studies have investigated the relationship between Klotho and PTH levels. Some studies have shown that Klotho levels are inversely correlated with PTH levels, suggesting that higher Klotho levels may lead to lower PTH levels. Other studies have found that Klotho deficiency can contribute to PTH resistance, leading to persistent hyperparathyroidism. Additionally, the Klotho-PTH axis holds promise as a potential target for therapeutic interventions in calcium and phosphate disorders.

Keywords: Klotho, Parathyroid hormone, Fibroblast growth factor 23, Vitamin D, Secondary hyperparathyroidism, Parathyroid gland, Phosphate, Kidney, Bone

Introduction
Klotho is a protein that has been found to play a role in regulating parathyroid hormone (PTH) levels. The literature suggests an intricate relationship between Klotho and PTH. Klotho acts as a co-receptor for fibroblast growth factor 23 (FGF23), a hormone that helps regulate phosphate and vitamin D metabolism. Klotho deficiency has been associated with increased PTH levels and secondary hyperparathyroidism. Several studies have investigated the relationship between Klotho and PTH levels. Some studies have shown that Klotho levels are inversely correlated with PTH levels, suggesting that higher Klotho levels may lead to lower PTH levels. Other studies have found that Klotho deficiency can contribute to PTH resistance, leading to persistent hyperparathyroidism. Additionally, the Klotho-PTH axis holds promise as a potential target for therapeutic interventions in calcium and phosphate disorders.

Mechanistic action of Klotho
Klotho is a protein that has been primarily studied for its anti-aging properties. It was first discovered in mice, where its deficiency resulted in accelerated aging and multiple age-related disorders. Klotho is mainly expressed in organs such as the kidneys, brain, and parathyroid glands, and it exists in two forms: membrane-bound and soluble. sKL can directly inhibit PTH secretion from parathyroid cells. The exact mechanisms underlying the interaction between Klotho and PTH are not fully understood. However, it has been proposed that FGF23 signaling through mKL may inhibit PTH secretion indirectly by reducing vitamin D synthesis or directly by acting on parathyroid cells. In addition to their roles in calcium and phosphate homeostasis, both Klotho and PTH have been implicated in various other physiological processes. In this literature review, we will explore the connection between Klotho and PTH, highlighting their individual roles and potential interactions.

Search strategy
For this review, we searched PubMed, Web of Science, EBSCO, Scopus, Google Scholar, Directory of Open Access Journals (DOAJ) and Embase, using different keywords including Klotho, parathyroid hormone, fibroblast growth factor 23, vitamin D, secondary hyperparathyroidism, parathyroid gland, phosphate, kidney, and bone.
Klotho is a protein that plays a key role in various physiological processes, including calcium and phosphate homeostasis. Parathyroid hormone (PTH), on the other hand, is a hormone that regulates calcium and phosphate metabolism primarily by acting on the kidneys, bones, and intestines. Several studies have investigated the relationship between Klotho and PTH, with growing evidence suggesting an interplay between the two. Studies have shown that serum Klotho levels are inversely correlated with PTH levels. Higher PTH levels have been associated with lower Klotho levels and vice versa. It has been suggested that Klotho may suppress PTH secretion by inhibiting the expression and release of PTH from the parathyroid glands.

The membrane-bound form functions as a co-receptor for fibroblast growth factor (FGF) 23, while the soluble form acts as a circulating hormone (4,10). One of the crucial roles of Klotho is its regulation of mineral homeostasis. Klotho deficiency in mice leads to dysregulation of calcium and phosphate metabolism, resulting in hyperphosphatemia, hypercalcemia, and increased PTH levels. These findings suggest that Klotho plays a role in the negative regulation of PTH secretion (11,12). On the other hand, PTH is a hormone produced by the parathyroid glands, which are four small glands located near the thyroid gland. PTH is essential for maintaining calcium and phosphorus balance in the body. It acts on target organs such as the kidneys, bones, and intestines to increase calcium levels when they are too low (11,13,14). Several studies have examined the relationship between Klotho and PTH levels. Some have shown that Klotho deficiency leads to increased PTH secretion, while others have reported a decrease in PTH levels with Klotho supplementation or overexpression (9,15). These findings indicate a potential modulatory role of Klotho in PTH secretion and activity (16). Additionally, emerging evidence suggests a direct interaction between Klotho and PTH signaling pathways. Klotho has been found to inhibit PTH-induced calcium release from bone cells and decrease PTH-stimulated gene expression in renal cells (9,17). These findings further support the idea that Klotho may act as a negative regulator of PTH activity. Although the exact mechanisms underlaying the interaction between Klotho and PTH require further investigation (3,9). It is evident that these two factors play significant roles in maintaining mineral homeostasis and overall physiological balance. Understanding their relationship may have implications for the treatment and management of conditions associated with dysregulated calcium and phosphorus metabolism, such as chronic kidney disease and osteoporosis (18,19).

Klotho and parathyroid hormone
Klotho and PTH are two essential factors involved in the regulation of various physiological processes in the body. Studies have shown that serum Klotho levels are inversely correlated with PTH levels. Higher PTH levels have been associated with lower Klotho levels and vice versa (3,9).

Klotho and parathyroid gland function
Klotho has been found to play a role in the regulation of parathyroid gland function. It has been suggested that Klotho may suppress PTH secretion by inhibiting the expression and release of PTH from the parathyroid glands (3,9).

Vitamin D and Klotho
Vitamin D, which is involved in calcium and phosphate metabolism, has been shown to upregulate the expression of Klotho. In turn, Klotho may modulate the effects of vitamin D on PTH secretion (9,20).

Genetic variations
Certain genetic variations in the Klotho gene (KL) have been associated with altered PTH levels. One study found that individuals with a KL variant had higher PTH levels compared to those without the variant (21,22).

Clinical implications
Dysfunction of the Klotho-PTH system has been implicated in various clinical conditions. For example, low Klotho levels and high PTH levels have been observed in patients with chronic kidney disease, which may contribute to the development and progression of secondary hyperparathyroidism (9,23).

Conclusion
The literature suggests a complex interplay between Klotho and PTH, with Klotho potentially acting as a negative regulator of PTH secretion and activity. Further research is needed to elucidate the precise mechanisms involved and explore the therapeutic potential of targeting this interaction for various disorders.

Conflicts of interest
The author declare that she has no competing interests.

Ethical issues
Ethical issues (including plagiarism, data fabrication, double publication) have been completely observed by the author.

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References