

PANCREAS: FUNCTIONS, DISORDERS, AND ITS PHYSIOLOGICAL ROLE IN MAMMALIAN ORGANISMS

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Abstract: This review examines scientific literature on pancreatic diseases, with a focus on exocrine pancreatic insufficiency (EPI), and explores the relationship between pancreatic health and obesity. It highlights the impact of pancreatic exocrine function on the physiological development of adults and adolescents. Studies conducted on piglets, frequently used as a model to optimize treatments for human pancreatic diseases, are also discussed. The pancreas, performing both exocrine and endocrine functions, is a vital organ in both humans and animals. Pancreatic diseases are often severe and challenging to manage. A well-balanced diet and appropriate dietary supplements can significantly enhance patient well-being and improve disease progression. Adopting a healthy diet and lifestyle plays a crucial role in maintaining optimal pancreatic function and overall physiological efficiency.

Keywords: pancreas, pancreatic diseases, exocrine pancreatic insufficiency (EPI), obesity, diabetes, dietary intervention.

Introduction

The pancreas is a vital glandular organ that significantly influences the functioning of the entire body. Pancreatic insufficiency arises when the pancreas is unable to produce or secrete digestive enzymes in sufficient quantities to enable proper digestion and absorption of nutrients in the intestines. This condition typically results from pancreatic damage, which can be caused by various clinical conditions, including recurrent acute pancreatitis, chronic pancreatitis, diabetes, autoimmune disorders, or surgical procedures like pancreatectomy. In some cases, insufficiency is linked to pancreatic or gastrointestinal cancer. In children, pancreatic insufficiency is most commonly associated with cystic fibrosis (affecting approximately 90% of patients) or rare genetic disorders such as Shwachman-Diamond syndrome.

The condition is characterized by symptoms such as malabsorption, malnutrition, avitaminosis, and weight loss or, in children, a failure to gain weight. Treatment focuses on addressing the underlying cause, preventing further pancreatic damage, and alleviating symptoms.

This paper explores the impact of pancreatic dysfunction on higher mammals. Through a comprehensive review of the literature, the role of pancreatic exocrine function in the physiological development of adults and adolescents is examined. Key diseases affecting pancreatic health are identified and briefly discussed. Additionally, the correlation between pancreatic disorders and factors such as diet, lifestyle, and obesity is analyzed.

Structure of the Pancreas

The pancreas is anatomically divided into three distinct parts: the head, body, and tail (Figure 1). The organ has a lobular parenchymal structure, comprising numerous secretory vesicles that account for 80–85% of its mass. The pancreas's functionality is heavily reliant on its ductal system. Each lobule contains a small duct that connects with others, ultimately

forming the main pancreatic duct. This primary duct originates in the pancreatic tail, extends through the length of the organ, and empties into the duodenum via the major duodenal papilla (Vater's papilla).

Additionally, an accessory pancreatic duct exists in approximately 70% of individuals. This duct typically connects with the main pancreatic duct, facilitating the transport of pancreatic secretions to the major duodenal papilla.

The pancreas consists of two principal histological components. The pancreatic islets (islets of Langerhans), numbering up to 2 million, produce essential pancreatic hormones. The remaining portion of the pancreas is composed of secretory cells, which are responsible for producing pancreatic juice and enzymes, critical for digestion and nutrient absorption. This dual functionality underscores the pancreas's importance in both endocrine and exocrine processes.

Physiological Functions of the Pancreas

The pancreas performs two vital functions within the body: endocrine and exocrine. The endocrine function, carried out by the islets of Langerhans, involves the production of hormones such as insulin, proinsulin, amylin, C-peptide, somatostatin, pancreatic polypeptide (PP), and glucagon. Insulin plays a crucial role in lowering blood sugar levels, while glucagon raises blood sugar levels, maintaining glucose homeostasis.

The exocrine function of the pancreas serves as a digestive gland, producing enzymes that form part of the iso-osmotic, alkaline pancreatic juice, which facilitates food digestion in the intestines. The enzymatic components of pancreatic juice are synthesized by acinar cells and delivered to the duodenum via the pancreatic ducts. Additionally, goblet cells in the pancreatic ducts secrete mucus, contributing to the juice composition. Pancreatic juice contains enzymes for digesting proteins, fats, carbohydrates, and nucleic acids, along with electrolytes and a small amount of mucus.

Proteolytic enzymes, such as trypsin, chymotrypsin, carboxypeptidase, and elastase, are responsible for protein digestion. Trypsin and chymotrypsin are secreted as inactive proenzymes, trypsinogen and chymotrypsinogen, which are activated in the intestine. Lipolytic enzymes, including lipase, phospholipase, and esterase, digest fats, while glycolytic enzymes, such as lactase and amylase, break down carbohydrates like starch into maltose, maltotriose, and dextrans. Nucleolytic enzymes, including ribonuclease and deoxyribonuclease, digest nucleic acids into mono- and oligonucleotides.

The secretion of digestive enzymes is regulated by food consumption and neurohormonal mechanisms, with the pancreas producing 1–4 liters of pancreatic juice daily, depending on dietary intake. This coordinated endocrine and exocrine activity underscores the pancreas's essential role in metabolism and digestion.

Influence of the Exocrine Function of the Pancreas on the Development of the Adult and Adolescent Organism

The exocrine function of the pancreas is regulated by both the central nervous system and hormones, with secretin and cholecystokinin (CCK) being the primary intestinal hormones influencing pancreatic enzyme secretion (Morisset, 2020). Secretin is released by enteroendocrine cells in the small intestine, while CCK is secreted by the duodenum and jejunum in response to lipids and proteins in ingested food. Kapica et al. (2018) demonstrated

the role of obestatin, a hormone produced in specialized gastric and intestinal cells, in modulating pancreatic juice secretion through dual mechanisms in rats.

Understanding the physiological impact of pancreatic functions on the human body has been a longstanding area of research. The pig model is widely regarded as the most accurate analog for human studies. Despite the absence of CCK receptors in pigs, CCK has been identified as the main regulator of pancreatic exocrine function (Schweiger et al., 2000; Morisset et al., 2003). Research also indicates that pancreatic development in pigs is more influenced by dietary changes during weaning than by age (Pierzynowski et al., 1993). For example, milk consumption in piglets triggers a postprandial glucose increase without a corresponding rise in insulin, suggesting milk's role in regulating pancreatic enzyme production for digestion (Pierzynowski et al., 1995).

Studies highlight a positive correlation between pancreatic exocrine function and weight gain in suckling and young piglets (van den Borne et al., 2007; Botermans and Pierzynowski, 1999; Pierzynowski et al., 2005). Pierzynowski et al. observed an increase in exocrine pancreatic secretion with body weight and noted higher secretion levels postprandially compared to preprandial levels in seven out of ten tested piglets (Flegal et al., 2010). However, pigs with exocrine pancreatic insufficiency (EPI) exhibit impaired digestion and feed absorption, leading to slowed growth. This impact diminishes with age, as seen in studies where EPI caused stunting in 30 kg pigs (Gregory et al., 1999) but resulted in only a 25% growth reduction in 40 kg pigs (Corring and Bourdon, 1977).

Research by Pierzynowski et al. (1990) on the development of pancreatic exocrine function in piglets revealed that basal pancreatic secretion and the response to feeding remained low during the first 4–5 weeks of life. Significant increases in pancreatic juice secretion and trypsin activity were observed only after weaning. The composition of pancreatic juice also underwent qualitative changes during this period. Furthermore, intravenous administration of CCK and secretin showed no stimulation of exocrine function during the first two weeks of life, but their effects became pronounced from weeks 3 to 4. These findings indicate that the exocrine pancreatic function and the enzymatic profile of pancreatic juice evolve during development, with an increased hormonal response emerging during the feeding period.

Pancreatic Exocrine Insufficiency

Exocrine pancreatic insufficiency (EPI) impairs the digestion of food by preventing the pancreas from producing sufficient enzymes required for breaking down and absorbing nutrients. This deficiency hinders the body's ability to efficiently process fats, proteins, carbohydrates, vitamins, and minerals. The damage to the pancreas leading to EPI can result from several factors, including chronic pancreatitis, pancreatic, gastric, or intestinal surgeries, cystic fibrosis, and Shwachman-Diamond syndrome. Additionally, conditions such as Crohn's disease and celiac disease can contribute to EPI in some individuals. Excessive alcohol consumption is another significant cause, with chronic alcohol use (exceeding 80 g of ethanol daily for 6–12 years) being a primary contributor to alcohol-induced chronic pancreatitis (Dufour and Adamson, 2003). Clinical studies also indicate that diabetic patients are particularly prone to developing EPI (Hardt et al., 2000, 2003).

EPI may initially be asymptomatic, but as pancreatic damage progresses and the ability to absorb fats diminishes, symptoms such as abdominal pain, tenderness, diarrhea, gas, and a

sensation of fullness may appear. Other complications include weight loss, bone pain due to vitamin D deficiency, and bleeding disorders caused by insufficient vitamin K absorption.

Diagnosis typically involves blood tests to evaluate vitamin levels and pancreatic enzyme production. Additionally, patients may be screened for underlying conditions like celiac disease. A "3-day stool test" can measure fat content in bowel movements, while imaging techniques such as CT scans, MRIs, and endoscopic ultrasounds are used to detect pancreatic inflammation.

Conclusion

The pancreas plays a critical role in processing essential nutrients to provide energy for cellular function. Any disruption in its performance can significantly impact overall health. Even healthy and relatively young individuals should prioritize a balanced diet and a healthy lifestyle to maintain optimal pancreatic function over the long term.

Dysfunction of the pancreas adversely affects the body, contributing to the development of pancreatic diseases and conditions like obesity. Similarly, unhealthy dietary habits and poor lifestyle choices can impair pancreatic function. Chronic conditions such as obesity not only compromise overall health but also increase the risk of developing pancreatic disorders.

Obesity, often underdiagnosed and underestimated, poses serious health risks. Effective treatment involves a multifaceted approach, including a proper diet, physical activity, and psychological support. The primary goals in managing obesity are improving metabolic function and preventing associated complications. As a chronic condition, obesity requires long-term, consistent management.

For those with exocrine pancreatic insufficiency (EPI), symptoms can be effectively managed through the use of enzyme replacement therapies and a carefully tailored nutritional plan. It is essential to adopt a diet rich in nutrient-dense foods while supplementing pancreatic enzymes with every meal and snack.

A well-structured diet, customized to an individual's specific condition, can greatly enhance well-being and positively influence disease progression. Conversely, poorly managed diets can exacerbate related conditions, such as diabetes, and may even pose life-threatening risks. A pancreas-friendly diet emphasizes lean protein sources, minimizes animal fats and simple sugars, and incorporates health-promoting ingredients to support overall health and functionality.

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