ENZYMES IN SEMINAL FLUID AND THEIR DIAGNOSTIC SIGNIFICANCE

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Abstract: *Seminal fluid is a complex biological medium composed of secretions from the testes, epididymis, seminal vesicles, prostate gland, and bulbourethral glands. Beyond providing a transport medium for spermatozoa, seminal plasma contains a wide range of biochemical substances, including enzymes, hormones, proteins, antioxidants, and trace elements. Among these components, enzymes play a crucial role in sperm maturation, motility, capacitation, and fertilization. Moreover, alterations in enzymatic activity are closely associated with various pathological conditions of the male reproductive system. This review article aims to explore the major enzymes present in seminal fluid, their biological functions, and their diagnostic significance in the evaluation of male fertility. Understanding the enzymatic profile of seminal plasma can significantly enhance laboratory diagnostics and contribute to more accurate identification of male infertility causes.*

Keywords: *Seminal fluid, enzymes, spermogram, male infertility, biochemical diagnostics*

INTRODUCTION

Male infertility accounts for approximately 40–50% of infertility cases worldwide and remains a significant public health concern. Laboratory evaluation of male reproductive potential relies primarily on semen analysis, commonly known as spermogram, which assesses parameters such as sperm concentration, motility, morphology, volume, and pH. While conventional spermogram provides valuable information, it often fails to reveal the underlying biochemical and molecular mechanisms responsible for impaired fertility.

Seminal plasma, the liquid component of semen, constitutes about 95% of ejaculate volume and serves as a vital environment for spermatozoa. It contains numerous enzymes that originate from accessory sex glands and sperm cells themselves. These enzymes are involved in semen liquefaction, energy metabolism, protection against oxidative stress, and facilitation of sperm movement through the female reproductive tract.

Biochemical analysis of seminal enzymes offers additional diagnostic insight, particularly in cases of unexplained infertility, obstructive azoospermia, prostatitis, seminal vesicle dysfunction, and oxidative stress-related sperm damage. Therefore,

enzymatic evaluation of seminal fluid has gained increasing attention in laboratory medicine and andrology.

MATERIAL AND METHODS

Composition of Seminal Fluid

Seminal fluid is a heterogeneous mixture of secretions produced by different male reproductive organs:

- Testes and epididymis: contribute spermatozoa and enzymes related to sperm maturation
- Seminal vesicles: provide fructose, prostaglandins, and coagulating proteins
- Prostate gland: secretes proteolytic enzymes, citric acid, zinc, and acid phosphatase
- Bulbourethral glands: produce mucus and lubricating substances

Enzymes constitute a significant fraction of seminal plasma proteins and reflect the functional state of these organs. Measuring their activity can help localize pathological processes within the male reproductive tract.

Major Enzymes in Seminal Fluid

1.A prostate-specific antigen (PSA) test is a blood test that measures the level of PSA in a sample of our blood. PSA is a protein made by your prostate. The prostate is a gland in the male reproductive system. It lies just below the bladder. It makes the fluid part of semen.It's normal to have a low level of PSA in our blood. A high PSA level may be caused by:

-Prostate cancer

-An enlarged prostate (also called benign prostatic hyperplasia or BPH)

-Prostatitis, inflammation (swelling and pain) in the prostate gland

-Other common prostate problems

-Urinary tract infections (UTIs)

-Taking certain medicines

A PSA test can't tell the difference between abnormal PSA levels from prostate cancer and noncancerous conditions. If the PSA level is high, a prostate biopsy is the only way to find out if the cause is cancer. And prostate biopsies have possible harms, such as bleeding at the biopsy site, blood in the semen or urine, infection, or difficulty urinating.A PSA test may lead to finding and treating prostate cancer that would never have affected to health. If prostate cancer is found:It can be difficult to tell the difference between slow-growing cancers and those that are likely to grow faster and spread in our body.We could have prostate cancer treatment that you never really needed. And cancer treatment may cause serious harms, such as:

-Erectile dysfunction, when a man has trouble getting or keeping an erection

-Urinary incontinence, uncontrolled urination causing you to leak pee

-Bowel incontinence, problems controlling your bowels (poop)

High PSA levels can mean you have prostate cancer or a prostate condition that's not cancer, such as an infection (causing prostatitis) or an enlarged prostate. If your

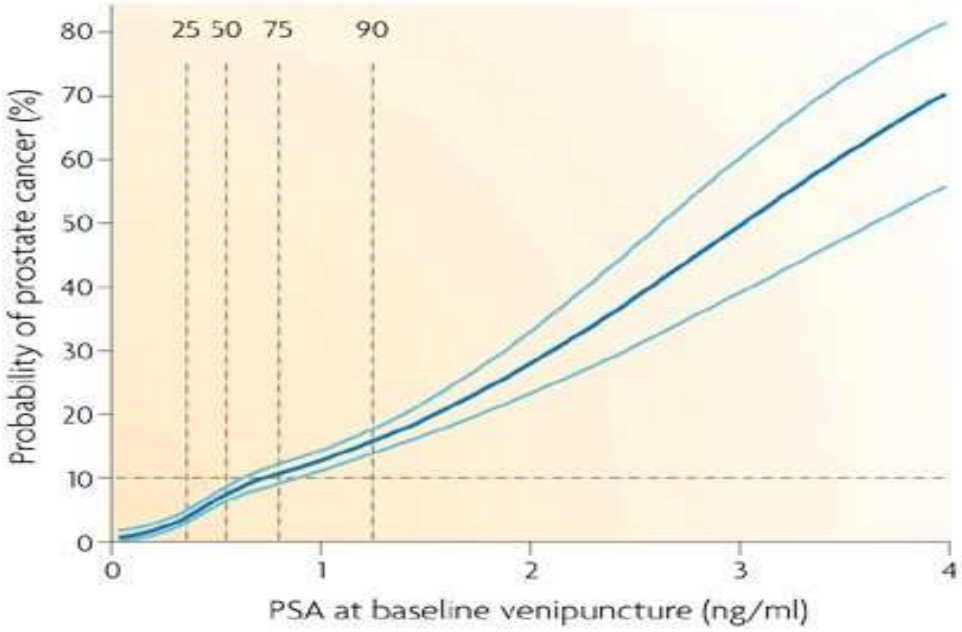
PSA levels are higher than normal, your provider may talk with you about having more tests to diagnose the cause. These tests may include:

-Another PSA test, more commonly if you don't have any symptoms. PSA levels can go up and down, so it's helpful to see if your PSA levels change over time.

-A digital rectal exam (DRE). For this test, your provider inserts a gloved, lubricated finger into your rectum to feel your prostate for lumps or anything unusual.

-A urine test. A sample of your urine is tested for infection.

-A prostate biopsy. A biopsy is minor surgery. A provider removes samples of tissue from your prostate so it can be studied under a microscope to look for cancer cells. A biopsy is the only way to diagnose cancer. It may be recommended if your provider thinks you may have prostate cancer.



2. Acid phosphatase (ACP) is an enzyme which catalyzes the hydrolysis of organic phosphate monoesters at acidic pH. It is present in the lysosomes of cells. There are different types of ACP isoenzymes depending on their tissue origin or the cells where they are expressed. Some types are lysosomal acid phosphatase, present in most cells, erythrocytic, liver, spleen and lung macrophages, osteoclastic and prostate, the latter being its main source. In addition to differing in origin and other molecular characteristics, certain isoenzymes are resistant to some inhibitors such as L (+) tartrate and fluoride, while others do not have this resistance, such as prostate ACP.Determination of ACP concentration in serum is mostly used in the assessment of the prostatic enzyme and its association with pathologies as prostatic hypertrophy, prostate infarction and prostatitis.

Normal values in serum:

-Total ACP, up to 10 U/L = 167 nkat/L

-Prostatic ACP, up to 3.5 U/L = 58 nkat/L

This range is given for orientation only; each laboratory should establish its own reference range. Decreased levels: total lysosomal ACP deficiency

Increased levels:

Total ACP:

-Hematological diseases: idiopathic thrombocytopenia and myelocytic leukemia

-Bone diseases: Paget's disease and bone carcinoma

- Liver diseases: hepatitis and obstructive jaundice

-Niemann-Pick disease and Gaucher's disease

Primary or secondary hyperparathyroidism

Prostatic ACP:

-Prostate carcinoma

-Hypertrophy

-Prostatitis

Enzymes Involved in Oxidative Stress Regulation

1.Superoxide Dismutase (SOD)

Superoxide dismutase (EC 1.15.1.1) is an essential antioxidant enzyme that catalyzes the dismutation of the superoxide radical (O_2^-) into molecular oxygen (O_2) and hydrogen peroxide (H_2O_2). This reaction protects cells from oxidative damage caused by reactive oxygen species (ROS). Superoxide radicals are generated as by-products of normal cellular metabolism, especially during mitochondrial electron transport. Excess superoxide can damage lipids, proteins, and nucleic acids. SOD acts as the first line of defense against oxidative stress by rapidly converting superoxide radicals into less reactive molecules.

Types of Superoxide Dismutase

SOD enzymes are classified based on their metal cofactors and cellular localization:

1.Cu/Zn-SOD (SOD1)

-Located mainly in the cytosol

-Found in eukaryotes

-Uses copper and zinc as cofactors

2.Mn-SOD (SOD2)

-Located in the mitochondrial matrix

-Plays a crucial role in protecting mitochondria

3.Fe-SOD

-Found primarily in prokaryotes and chloroplasts

4.Ni-SOD

-Present in some bacteria

-Physiological Importance

-Protects cells from oxidative damage

-Maintains redox balance

-Prevents lipid peroxidation

-Plays a role in aging, inflammation, and immune defense

Deficiency or dysfunction of SOD has been linked to diseases such as:

-Amyotrophic lateral sclerosis (ALS)

-Cancer

-Cardiovascular diseases

-Neurodegenerative disorders

Hydrogen peroxide produced by SOD is subsequently detoxified by catalase or glutathione peroxidase.

2.Catalase

Catalase is a very important enzyme that supports the protective control and activity of sperm.

Main effects:

Oxidative stress resistance

– During the process of metabolism of sperm, hydrogen peroxide (H_2O_2) is formed.

– Catalase breaks it down into water and oxygen.

– This protects the DNA, membrane and tail of sperm from damage.

Sperm motility is also

– If there is a lot of H_2O_2, the activity of the tail of sperm is weakened.

– If there is enough catalase, sperm can move faster and farther.

Maintains viability (vitality)

– Oxidative stress leads to rapid death of sperm.

– Catalase maintains the courtship period.

Improves sperm healing

– Healthy membrane and D → high penetration into the egg.

Conclusion:

If catalase is low → sperm are immobile, weak, DNA may be damaged.

If there is enough catalase → sperm are active, healthy and capable of fertilization

3.Glutathione Peroxidase (GPx)

GPx is a powerful antioxidant enzyme that protects cells, especially sperm cells, from oxidative stress.

Effect on sperm activity

-Protects the membrane

-Sperm membrane is rich in unsaturated fatty acids

-GPx inhibits lipid peroxidation

Maintains motility

-When ROS increases, sperm tail is damaged

-If GPx is sufficient, sperm are active and motile

Protects DNA

-Oxidative stress increases sperm DNA fragmentation

- GPx prevents DNA damage

Increases fertilization ability

- Membrane + DNA is healthy → high probability of fusion with the egg

Important point

-GPx contains selenium (Se)

-Selenium deficiency → GPx activity decreases → increased risk of male infertility

Conclusion

-Low GPx → lipid peroxidation, low motility, DNA damage

-Sufficient GPx → healthy, active, fertilizing sperm

Enzymes and Sperm Function

Enzymes in seminal plasma directly influence critical sperm functions:

Motility: LDH, CK, ATPases

Capacitation: protein kinases, phosphatases

Acrosome reaction: acrosin, hyaluronidase

Membrane integrity: phospholipases

Disruption of enzymatic balance leads to impaired fertilizing capacity even when standard spermogram parameters appear normal.

Diagnostic Applications in Male Infertility

1.Obstructive Azoospermia

Low ALP

Reduced fructose

Normal testicular volume

2.Prostatic Disorders

Altered PSA and ACP levels

Changes in seminal pH

3.Oxidative Stress-Related Infertility

Decreased antioxidant enzyme activity

Increased reactive oxygen species

4.Unexplained Infertility

Subtle enzymatic abnormalities despite normal spermogram

Laboratory Methods for Enzyme Analysis

Spectrophotometric assays

Enzyme-linked immunosorbent assay (ELISA)

Automated biochemical analyzers

Proper sample handling, liquefaction time, and temperature control are essential for accurate results.

Limitations and Future Perspectives

While enzymatic analysis offers valuable diagnostic information, several limitations exist:

Lack of standardized reference ranges

Inter-laboratory variability

Influence of abstinence period and lifestyle factors

Future research should focus on:

Establishing international standards

Integrating enzymatic markers with molecular diagnostics

Developing point-of-care testing methods

Conclusion

Enzymes in seminal fluid play a fundamental role in maintaining sperm viability, motility, and fertilizing potential. Their diagnostic evaluation provides essential insight into the functional status of the male reproductive system beyond conventional semen analysis. Incorporating enzymatic assays into routine laboratory diagnostics can significantly improve the accuracy of male infertility assessment and contribute to personalized treatment strategies.

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