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EFFECT OF PHYSICAL ACTIVITY ON SEVERAL LIPIDS, AMINO ACIDS, AND PEPTIDE-DERIVED HORMONES IN HEALTHY INDIVIDUALS

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Abstract:
Physical activity induces many changes in the human body by increasing energy metabolism and resting energy expenditure and hormones play a major role in these changes. Hormones are chemical messengers that stimulate biochemical reactions that trigger cell activity and functions. Hormones are secreted from the glands of the endocrine system and communication between the endocrine system and nervous system regulates both internal and external changes and maintains homeostasis. Hormones are classified into lipid, amino acid, and peptide-derived hormones and they play major roles in the human body. Lipid-derived hormones perform many important functions i.e., muscle growth, neuromuscular adaptation, protein metabolism, carbohydrate metabolism, gluconeogenesis, fat oxidation, salt and water homeostasis, etc. Amino acid-derived hormones also perform many important functions like vasoconstriction, thermoregulation, tissue differentiation, fight or flight response, maintaining circadian rhythm and sleep-wake cycle, etc. Peptide-derived hormones play a major role in body fluid homeostasis, regulating appetite, gluconeogenesis, glucose production, and lipid metabolism, maintaining circadian rhythm, maintaining energy balance, reducing weight gain, delaying gastric emptying, etc. Physical activity regulates hormone levels in the body to provide major benefits and enhance the health status of healthy individuals. This review will provide a brief description of all lipid, amino acid, and peptide-derived hormones that perform many important functions and how their functions are influenced by physical activity.

Keywords: physical activity, lipid hormones, amino acid hormones, peptide hormones

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1. Introduction

Physical activity refers to any voluntary body movement that is produced by the contraction of skeletal muscles and requires energy. It includes walking, cycling, wheeling, sports, active recreation, and play, and their level can vary. Physical activity induces many changes in healthy individuals by increasing energy metabolism and resting metabolic rate for several hours after exercise but if people keep doing physical activity for a long time, then these changes become long-lasting. One big reason behind all these changes is the regulation of the secretion of hormones.

Hormones are the chemical messengers that are secreted by our body's endocrine glands i.e. hypothalamus, pituitary glands, adrenal gland, thyroid gland, testes, ovary, placenta, pineal gland, pancreas, and kidney (Figure 1). The term "endocrine" means that in response to specific stimuli, the chemicals of these glands will be released into the bloodstream. These hormones will reach their specific target cell via the bloodstream. These hormones will attach to their receptors which are present on their target cell only and the receptor may be present on the surface of the cell or inside the cell. The interlinkage between a hormone and its receptor will stimulate several biochemical reactions that trigger the cell's activity and functions. Only some hormones have their target cell, whereas others affect numerous cell types in the whole body.

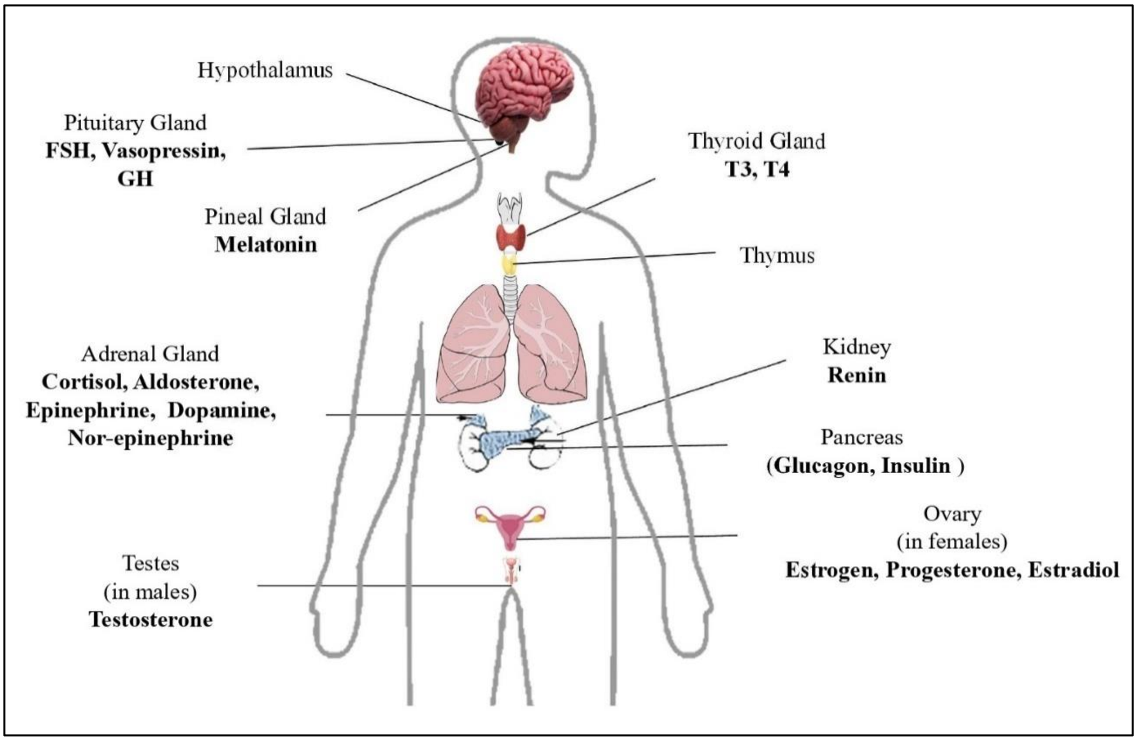

Figure 1: Schematic representation of the major hormones producing endocrine glands

The hormonal system cannot secrete hormones alone; it needs to communicate with other organs or systems to perform properly or maintain homeostasis. For Example, neither the blood glucose nor the level of glucagon and insulin must go beyond the preset limits. Communication between different parts of the body is essential to better regulate any changes in the internal and external environment. Communication between the nervous system and the hormonal (i.e., neuro-endocrine) system is responsible for the proper regulation of homeostasis. The nervous system regulates the transmission (i.e., within fractions of seconds) of information from one part of the body to different parts of the body. The hormonal system produces and releases hormones via glands into the bloodstream. Both systems interact: the nervous system's stimulus can influence the secretion of hormones and vice versa [1]. Any change in the homeostasis state of the nervous system via external or internal factors will affect the level of hormones so it's necessary to measure hormone levels to identify the change which can be beneficial or harmful for our body. The level of hormones can be measured by immunoassay techniques. The immunoassay technique has become a commonly used method to measure the quantitative, semi-quantitative, or qualitative levels of the hormones in the blood [2]. It has various types: enzyme-linked immunosorbent assay (ELISA), radioimmunoassay (RIA), fluoroimmunoassay, chemiluminescent immunoassay (CLIA), and counting immunoassay. ELISA, RIA, and CLIA are the most common assays used to measure the levels of different hormones [3]. RIA and ELISA are both competitive binding assays in which an antigen (hormone/biomarker) competes with a labeled (radioactive element/enzyme) reagent antigen for a limited number of binding sites on an antibody [4]. The displaced amount of labeled antigen is equal to the quantity of antigen (hormones/biomarker) bound to the antibody or present in the serum [5]. RIA test required two vital pieces of equipment namely centrifuge and radioactive counters. The usual equipment used by ELISA are pipettes, a device for plate washing, an ELISA reader (photometer), and a computer with evaluation software [6, 7]. CLIA uses an enzyme that converts a substrate into a reaction product which develops a photon of light when the product returns to a ground state from an excited state [8] and a chemiluminescence immunoassay analyzer is being used [9]. CLIA and ELISA are the most vital sensitive, safe, and specific techniques for blood screening. These are the latest methods used by many laboratories to measure the level of hormones [10].

Hormones are basically divided into 3 major categories:

- lipid-derived,
- amino-acid derived, and
- peptide-derived hormones.

On the basis of their chemical structure, and each category of hormones regulated by physical activity is discussed in detail in subsequent sections of this review.

2. Physical Activity Effect on Lipid-derived Hormones

Lipid-derived hormones are the steroid hormones, obtained from cholesterol and they are usually ketones or alcohol in chemical nature. They are insoluble in water so they travel with the help of transport proteins from one part of the body to another part of the body and perform many important functions to provide beneficial inputs to the human body such as enhance muscle mass, regulate salt and water homeostasis etc. There are lot of examples of lipid-derived hormones which are explained in this section with their different functions, benefits, effect of physical activity on its level and how it helps athletes.

2.1 Testosterone

Testosterone is a well-known anabolic hormone with multiple physiological functions in the human body secreted from the Leydig cells of testes for the stimulation of secondary male-sex characteristics, muscle growth, and neuromuscular adaptation [11]. It produces anabolic effects on the body via two paths a) enhancing amino acid uptake and protein synthesis and b) restricted protein degradation [12]. However, existing literature confirmed the enhancement of testosterone levels after doing a physical activity [13, 14] enhances the lean mass, muscle area, and strength [15]. When exercise is done for long duration with specific intensity produces significant elevation in testosterone level in human body which enhances muscle mass and enhances sports performance of all athletes specially in bodybuilding, athletics, wrestling and cycling.

2.2 Cortisol

Cortisol is the main glucocorticoid in humans and plays a crucial role in metabolic reactions and the immune system [16]. It performs catabolic activities like protein and carbohydrate metabolism [17]. It stimulates gluconeogenesis to spare blood glucose and reduces protein stores [18]. The response induced by physical activity confirmed the significantly increment of cortisol level [19, 20] which prevents the depletion of carbohydrate stores and ultimately stimulates use of fat stores for energy, it also improve sleep quality and enhances mental health and sports performance. Several findings suggest that moderate to high intensity exercises enhance the level of circulating cortisol in human body and a study by Hansen *et al* concluded that cortisol is positively correlated with performance of weight lifters and rugby players and negatively correlated with tennis and golf players [21].

2.3 Progesterone

It is a steroid hormone that is commonly produced by the corpus luteum, placenta, and adrenal glands. It is a precursor of male and female sex hormones [22]. It plays a major role in females regulating the condition of the inner lining of the uterus. It enhances fat oxidation in energy deficit conditions. According to a study by Deon *et al.*, physical activity increases the concentration of the level of progesterone [23] and helps in utilization of more fat than carbohydrate for energy production in females [24]. It plays major role in endurance related activities and helps in performance enhancement of athletes who are actively involved in endurance related sports.

2.4 Estradiol

It is a steroid form of female sex hormone released by the adrenal gland, ovaries, and placenta during pregnancy. It acts like a growth hormone for the reproductive system. It can produce various physiological actions on a variety of tissues [25]. It enhances the utilization of lipid and availability of lipid by decreasing gluconeogenesis and glycogenolysis [26]. It develops glucose intolerance via altering the key enzyme activity. There are significant increments in estradiol levels after doing the physical activity which enhances the energy production by lipid and prevent muscle and liver glycogen.

The efficacy of anaerobic exercise was found to be more vigorous on the estradiol level so we can suggest estradiol is positively correlated with anaerobic sports such as weightlifting and sprinting etc. [27].

2.5 Follicle-stimulating Hormone

It is a gonadotropin, a glycoprotein polypeptide hormone. It is an important hormone of the female reproductive system and it is secreted by the pituitary gland of the hypothalamus [28]. It plays a major role in the growth of ovarian follicles which produces estrogen and progesterone in ovaries and regulates the menstrual cycle [29, 30]. In a study by Maryam *et al.,* no significant changes in its level was observed after doing physical activity in humans and normal functions were maintained [31].

2.6 Aldosterone

It is a major mineralocorticoid steroid hormone secreted by zona glomerulosa of the adrenal cortex part of the adrenal gland [32]. It plays a major role in the regulation of salt and water homeostasis in the human body by enhancing the reserve of sodium and water, and excretion of potassium via kidneys, skin, and intestines [33]. In a study by Goessler *et al.,* aldosterone levels displayed a significant increase after doing a physical activity which improves the cardiovascular stability and prevents heat injury [34, 35] Differential aerobic exercises, acute exercises are positively correlated with the level of aldosterone hormone in the human body so it will be more helpful for athletes who are actively engaged in aerobic sports such as swimming, running etc.

These are some examples of lipid-derived hormones that show major change in the level of hormones due to different types of physical activity and ultimately help in the enhancement of sports performance via different beneficial functions. Table 1 shows the full summary of lipid-derived hormones with their characteristics, effects and benefits of physical activity on human body. After that, amino-acid derived hormones are explained in detail with their examples.

Table 1: Characteristics, effect and benefits of physical activity on lipid-derived hormones

S.N.	Hormones	Characteristics	Effect of Physical Activity on hormone levels	Benefits	References
1.	Testosterone	• Secondary male-sex characteristics • Muscle growth • Neuromuscular adaptation	Increase	• Enhances lean mass, muscle area, strength	[12-15]
2.	Cortisol	• Protein metabolism • Carbohydrate metabolism • Gluconeogenesis	Increase	• Prevents carbohydrate stores • Improve sleep quality	[17-21]
3.	Progesterone	• Regulate the inner lining of the uterus • Fat oxidation	Increase	• Enhances fat utilization • Prevents carbohydrate stores	[23-24]
4.	Estradiol	• Lipid utilization and availability • Glucose intolerance	Increase	• Enhances fat oxidation • Prevents muscle and liver glycogen stores	[26-27]
5.	Follicle-stimulating hormone	• Support reproductive system • Ovarian follicles growth	No change	• Levels remain same and normal functions maintained	[29-31]
6.	Aldosterone	• Salt and water homeostasis	Increase	• Enhances cardiovascular stability • Prevents heat injury	[33-35]

3. Physical Activity Effect on Amino Acid-derived Hormones

Amino acid-derived hormones are the small molecules that are formed by the amino acids tyrosine and tryptophan. Their chemical name ends in "ene". They are water-soluble hormones and insoluble in lipids. They cannot pass through the plasma membranes of the cells. Receptors of these hormones will be found on their target cell surface. There are lot of examples of amino-acid derived hormones which are described in this review with their different functions, benefits, effect of physical activity on its level and how they help athletes in the enhancement of sports performance.

3.1 Epinephrine

Epinephrine is also known as adrenaline which acts as both hormone and neurotransmitter [36]. It is an amino acid derivative of tyrosine and secreted from the adrenal medulla and a small number of neurons in the brain [37]. It triggers the fight-or-flight response in the human body. It also plays small roles in metabolism, attention, focus, panic, and excitement [38]. Epinephrine concentration enhances rapidly after doing physical activity [39] and it helps in the enhancement of mental concentration. Several studies conclude that physical aerobic activity is positively correlated with the level of epinephrine concentration in the human body so it will be helpful for the athletes who are engaging with that type of sport and it is also associated with extreme sports such as skydiving etc. to enhance focus, mood and outlook during play [40].

3.2 Nor-epinephrine

Nor-epinephrine is also called nor-adrenaline. It also acts as both a hormone and neurotransmitter. It is classified as catecholamine because it contains a catechol group and binds with an amine group [41]. It also plays a vital role in fight or flight response and prepares the body for acute threats [42]. It triggers the vasoconstriction in blood vessels which will increase blood pressure for more flow of blood from the heart [43]. It also enhances blood glucose levels and blood circulating free fatty acids levels. Physical activity enhances the concentration of the nor-epinephrine hormone which in turn increases alertness, arousal and attention [44]. Several researchers based on their studies concluded that aerobic activity shows change in the level of nor-epinephrine hormone in the human body and helps in the enhancement of sports performance of the athletes who participate in aerobic sports such as running, swimming etc. [45, 46].

3.3 Thyroid Hormones

Triiodothyronine (T3) and tetraiodothyronine (T4), these two hormones are thyroid hormones. These hormones are secreted from the thyroid gland which is located in the front of the neck and wrapped around the windpipe (trachea) [47]. It plays a major role in the regulation of general metabolism, growth, and tissue differentiation as well as gene expression [48]. It also acts in fatty acid oxidation and thermoregulation [49]. Hackney et al. studied the thyroid hormonal responses to intensive endurance exercise sessions and found that physical activity enhances the turnover of thyroid hormones which in turn enhance the body’s metabolism to stay healthy [50] . Studies by Hawamdeh et al. and Ciloglu et al. suggested that acute aerobic exercise with moderate intensity is highly correlated with the level of thyroid hormones in the human body which plays major role in the enhancement of sports performance such as athletes of endurance sports [51-53].

3.4 Melatonin

It is a hormone found in the body and secreted by the pineal gland, a pea size gland, which is located just above the middle of the brain [54]. This hormone is secreted in response to darkness [55]. It maintains the circadian rhythm (24-hour internal clock) and a sleep-wake cycle of our body [56]. Many studies observed the significant increment of circulating melatonin hormones in the body [57]. In a systematic review,Lopez Flores *et al* discussed the effect of melatonin on sports performance and suggested that the increase in melatonin also depends on the circadian phase at which exercise was taken and it helps in the proper sleep cycle, eye health, and reduces depression [58]. In a recent study by O Donnell et al., sleep responses and melatonin were studied in female athletes following exercise and it was found that the training environment such as nocturnal exercise suppresses melatonin levels and impairs sleep indices which can have potential health implications [59]. Based on the research in last decade, it can be concluded that moderate and high-intensity aerobic exercise enhances the production of melatonin hormones in the human body so athletes who are engaging in that type of exercises will get more benefit of this hormone [60, 61].

3.5 Dopamine

It is an amino acid-derived hormone and is classified as catecholamines. It is also called a happy hormone, which results in the feeling of well-being [62]. It is a major signal of the brain award system, its level enhances when we feel something pleasurable [63]. It also acts as a neurotransmitter used by the nervous system to send signals between nerve cells [64]. It plays a major role in the unique ability of the human body to think and plan [65]. In a study by Shimojo et al., exercise was found to induce dopamine secretion and attenuate systemic inflammation. [66]. It assists in striving, focusing and finding things interesting. Physical activity enhances the level of dopamine levels in the human body which enhance mood regulation and improve ability to store and recall memories [67, 68]. Several findings conclude that aerobic exercise has been shown to enhance the level of dopamine hormones in the human body and helps in the enhancement of sports performance of athletes related to aerobic sports [69-71].

The above-mentioned hormones are some examples of lipid-derived hormones whose levels and secretionare majorly affected due to different types of exercises and eventually helps in the enhancement of sports performance via individual beneficial functions. Table 2 shows the full summary of amino-acid derived hormones with their characteristics, effects and benefits of physical activity on human body. After that, protein derived hormones will be explained in detail with their examples.

Table 2: Characteristics, effect and benefits of physical activity on amino acid - derived hormone

S.N.	Hormones	Characteristics	Effect of Physical Activity on hormone levels	Benefits	References
1.	Epinephrine	• Fight or flight response	Increase	• Enhances mental concentration	[38-40]
2.	Nor-epinephrine	• Vasoconstriction • Blood glucose availability • Free fatty acid availability	Increase	• Enhances alertness, arousal and attention.	[42-44]
3.	Thyroid hormones	• Fatty acid oxidation • Thermoregulation • Tissue differentiation • Gene expression	Increase	• Enhances body's metabolism	[46-49]
4.	Melatonin	• Maintain circadian rhythm • Sleep-wake cycle	Increase	• Improves eye health • Reduce depression	[52-55]
5.	Dopamine	• A feeling of well-being • The ability to think and plan	Increase	• Enhances mood regulation • Improves ability to store and recall memories	[59-61]

4. Physical Activity Effect on Peptide-derived Hormones

Peptide-derived hormones are the hormones whose molecules are made up of peptides, it consists of a short polypeptide chain. These hormones are soluble in water and insoluble in lipids so they cannot cross the plasma membranes. Their specific receptors are found on target cells. They play a major role in energy homeostasis and metabolism. They also control the function of the gastrointestinal system, cardiovascular system, energy expenditure, reproduction, etc. [72]. There are plenty of examples of peptide-derived hormones which will be explained in this review with their different functions, benefits, effect of physical activity on its level and how they help athletes in the enhancement of sports performance.

4.1 Vasopressin

It is also called the Antidiuretic hormone (ADH). It is made in the brain and released into the posterior pituitary gland. It plays a major role in whole body fluid homeostasis [73]. It activates gluconeogenesis and glycogenolysis via stimulation of ADH receptors and

ADH infusion enhances the blood glucose levels in the human body [74]. It also helps to enhance blood pressure by acting on kidneys and blood pressure [75]. It regulates kidneys to excrete less water, decreasing the amount of urine produced [76]. Research confirmed the enhancement of ADH levels after doing a physical activity which helps in maintaining of body's internal temperature, its blood volume, and proper flow of urine from the kidneys [77-79] . Many research findings suggest that intense aerobic exercises are positively correlated with the level of vasopressin hormones of athletes hence it will be beneficial for the athletes who are participating in the sports in which intense aerobic activity performed [80].

4.2 Glucagon

It is a peptide-derived hormone released from the alpha cells of the pancreatic islet of Langerhans. It plays a major role in glucose production in the liver and maintains blood glucose levels [81]. It also participates in hepatic lipid and amino acid metabolism and ultimately enhances energy expenditure. It also regulates the appetite. It is secreted in the condition of hypoglycemia, prolonged fasting, exercise, and protein-rich meals [82]. In two different studies by Hamasaki et al. and Ueda et al., it was found that physical activity enhances the significant level of glucagon hormone and combination of exercise and Glucagon-like peptide-1 helps in reducing cardio-metabolic disease incidence and treatment of type2 diabetes [83, 84]. Specially, acute aerobic exercise enhances the level of glucagon which supports the performance of the athletes who are participating in the aerobic sports [85].

4.3 Insulin

Insulin is a peptide hormone made up of beta cells of pancreatic islets. It regulates the amount of glucose in the bloodstream of the human body [86]. It plays a major role in the storage of in your liver, fat, and muscles [87]. It helps to control type 1diabetes or advanced type 2diabetes by regulating blood glucose levels [88]. Physical activity significantly decreased the insulin concentration in the bloodstream and maintains blood sugar level in human body [89]. Several researches conclude that aerobic exercises improve insulin sensitivity via decreasing the level of insulin hormone which will help in the enhancement of sports performance of the athletes who are related to aerobic sports [90-93].

4.4 Growth Hormone (GH)

It is also called somatotrophin. It is a peptide hormone secreted by the anterior pituitary. Human growth hormone is secreted throughout life [94]. It plays a major role in the building of bones and muscles and also influences height [95]. It also maintains circadian rhythm. It increases during childhood and reaches a peak in the puberty phase [96]. Physical activity enhances the level of growth hormone concentration in the bloodstream which increases the growth, turnover of muscle, bone and collagen and maintains healthier body composition in later stage of life [97]. Several studies conclude that athletes competing in power sports, wrestling, martial arts, weight lifting and several endurance sports are positively correlated with the level of growth hormone [98-100]. However, due to known performance enhancing effect of growth hormone, it has been misused in doping by athletes and was banned by World Anti-Doping Agency [101].

4.5 Leptin

Leptin is a protein-derived hormone, which is produced by white adipose tissue. It plays a major role in the regulation of the long-term energy balance between your food intake and energy expenditure [102]. It inhibits hunger and maintains energy balance [103] so that your body does not produce a hunger response when the body does not need energy [104]. The Level of leptin varies in the evening and early morning hours. Circulating leptin levels are directly proportional to the amount of stored fat in the body [105]. It also reflects the acute changes in calorie intake. Physical activity decreases the concentration of the leptin hormone and enhances the fat loss process [106]. Several studies shows that aerobic exercise decreases the level of leptin hormone in human body which will help in the performance of endurance athletes [107-110].

4.6 Ghrelin

It is also known as the hunger hormone. It is secreted from endocrine cells of the stomach but it is synthesized in many tissues, i.e. small intestine, pancreas, hypothalamus, placenta, etc [111]. It gives a signal to the brain that it's time to eat when the stomach is empty but it does more than control hunger [112]. It stimulates growth hormone secretion, plays role in insulin secretion, and prevents cardiovascular health. It maintains energy homeostasis and regulates somatotropic function [113]. Ghrelin levels enhance after doing physical activity and provide cardio-protective effects in myocardium, anti-atrophic effects in muscle [114]. Ghrelin hormone is positively correlated with the acute and chronic exercise which indicates it helps in the performance of the athletes who are engaged in acute and chronic exercise [115-117].

4.6 Obestatin

It is a 23 amino acid peptide hormone. It is secreted from the stomach. It is also found in many other organs including the spleen, mammary gland, breast milk, plasma, etc [118]. It works as a complex gut-brain network, whereby hormones and substances from the stomach and intestine send a signal to the brain about hunger [119]. It helps in reducing body weight gain by decreasing food intake [120]. It helps in improving memory, regulating sleep, enhancing the secretion of pancreatic juice enzymes [121], and inhibiting glucose-induced insulin secretion [122-124]. In a study by Issazadeh et al., it was found that aerobic and resistance combined exercise reduced body fat and weight and increased obestatin levels in plasma [125].

4.7 Cholecystokinin

It is the main hormone of the gastrointestinal system and is secreted by I-cells of the small intestine after intake of food to the digestion of fat and protein [126]. It stimulates pancreatic enzyme secretion, delays gastric emptying, contracts gall bladder, and maintains satiety [127]. It controls gastrointestinal digestion and feeding behavior. It stimulates growth hormone and vasopressin secretion [128]. Physical activity enhances the secretion of cholecystokinin levels in the bloodstream [129] and improves digestion and stimulates bile production [130]. Several research conclude that endurance exercises are directly proportional to the cholecystokinin hormone which will directly help in the enhancement of athletic performance of endurance athletes [131].

4.8 Renin

Renin is a central hormone secreted from storage granules of juxtaglomerular kidney cells, a part of the kidney. It controls blood pressure and performs various other physiological functions [132]. It is released in the bloodstream when the body's blood pressure is too low or sodium concentration decline dramatically [133]. Baroreceptors sense the low blood pressure in arterial vessels, they send a signal to maintain blood pressure [134]. Physical activity stimulates the increment of renin concentration in the bloodstream [135] to maintain blood pressure and electrolyte homeostasis. Acute and chronic exercises are positively correlated with the concentration of renin in the human body which will directly related to the enhancement of sports performance of athletes who are engaging in that type of exercise during their sports. [136-138].

4.9 Angiotensin

It is a peptide hormone secreted by the liver and circulating in the bloodstream. Firstly it is found in angiotensin I form , converted by the angiotensin-converting enzyme into Angiotensin II form [139] which majorly performs all functions . It plays a major role in the regulation of blood pressure and fluid and electrolyte homeostasis [140]. It regulates homeostasis via constricting blood vessels and enhancing salt and water intake [141]. Angiotensin concentration increases after doing physical activity in plasma [142] and maintains fluid homeostasis in the human body. Several studies conclude that mild and moderate exercises are positively correlated with the angiotensin hormone which will support the athletic performance of the athletes who are actively participating in these exercises during their sports [143-145].

Above-named hormones are some examples of peptide-derived hormones that produces the positive effect on the concentration of hormones due to various types of physical activities which will finally help in the enhancement of athletic performance of athletes with the help of beneficial functions which will produced by these hormones on human body. Table 3 shows the full summary of peptide-derived hormones with their characteristics, effects and benefits of physical activity on the human body.

Table 3: Characteristics, effect and benefits of physical activity on peptide-derived hormones

S.N.	Hormones	Characteristics	Effect of Physical Activity on hormone levels	Benefits	References
1.	Vasopressin	• Body fluid homeostasis • Activate gluconeogenesis and glycogenolysis • Enhance blood pressure	Increase	• Maintains body's internal temperature • Maintain blood volume	[64-68]
2.	Glucagon	• Glucose production • Regulate appetite • Lipid and amino acid metabolism	Increase	• Reduces cardio-metabolic disease incidence	[69-72]
3.	Insulin	• Control glucose level	Decrease	• Maintains blood sugar level	[73-77]
4.	Growth hormone	• Building of bone and muscles • Maintain circadian rhythm • Influence height	Increase	• Increases turnover of muscle, bone and collagen • Maintains healthier body composition in later stage of life	[79-81]
5.	Leptin	• Inhibit hunger • Maintain energy balance	Decrease	• Enhances fat loss process	[83-87]
6.	Ghrelin	• Energy homeostasis • Somatotropic function • Growth hormone secretion	Increase	• Provides cardio-protective effects in myocardium, Provide anti-atrophic effects in muscle	[90-91]
7.	Obestatin	• Reduce weight gain • Improve memory • Maintain sleep cycle	No change	• Levels remain same and maintained its normal functions	[94-97]
8.	Cholecystokinin	• Pancreatic enzyme secretion • Delays gastric emptying • Gall bladder contraction • Maintain satiety	Increase	• Improves digestion • Stimulates bile production	[99-102]

		• Controls feeding behavior • Stimulates growth hormone and vasopressin secretion			
9.	Renin	• Maintain blood pressure	Increase	• Maintain electrolyte homeostasis	[105-107]
10.	Angiotensin	• Fluid and electrolyte homeostasis	Increase	• Enhance vasoconstriction and blood pressure	[109-112]

5. Summary

This review summarizes the functions of lipid, amino acid, and peptide-derived hormones and the effect of different type of physical activities on the level of these hormones and their beneficial functions for the enhancement of sports performance.

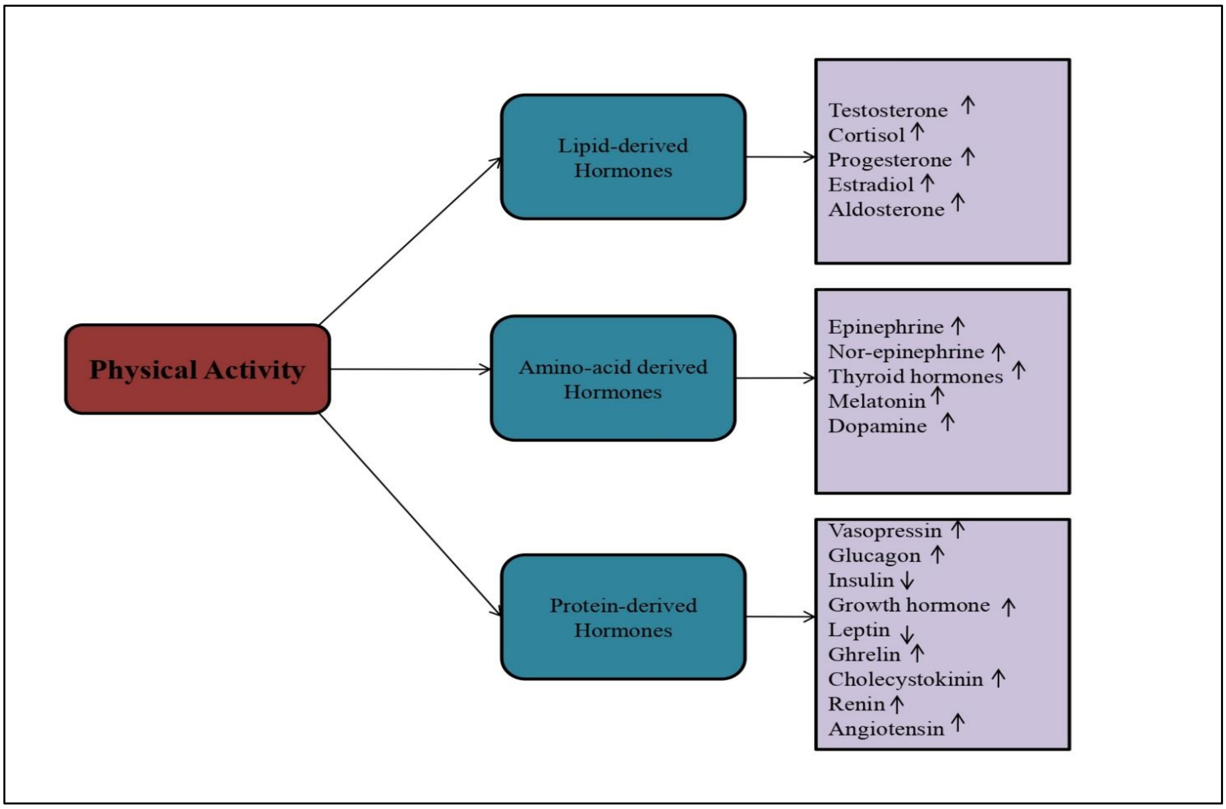

Figure 2: Overall summary of effect of the physical activity on the concentration of lipid, amino-acid, and peptide derived hormones

These hormones perform many important functions i.e. muscle growth, neuromuscular adaptation, protein metabolism, carbohydrate metabolism, lipid metabolism, body fluid homeostasis, vasoconstriction, thermoregulation, tissue differentiation, fight or flight response, maintaining circadian rhythm, sleep-wake cycle, energy balance, regulate appetite, glucose production, reduce weight gain, delays gastric emptying, etc. Most of the levels of hormones are regulated by doing physical activity in the human body and it promotes a healthy body along with improving sports performance in athletes (Figure 2). However, this manuscript is a review paper so IRB approval was not necessary.

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