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## Review Article

# Role of Mango in Immune System

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Prince Sasu<sup>1</sup>

1. Department of Animal Science, Faculty of Agriculture, College of Agriculture and Natural Resources, Kwame Nkrumah University of Science and Technology, Ghana

The mango, known throughout the world for its gastronomic and cultural value, occupies an exceptional place in the world of fruits. In addition to its pleasing taste, mango has a nutrient-rich profile, containing essential vitamins, minerals, and bioactive substances. In this chapter, "Role of Mango in Immune System," the fascinating relationship between mango consumption and its potential effects on immune health is explored, paying particular attention to improving immunological function. The detailed nutritional facts about mangoes will help readers better understand how this tropical fruit may support a healthy immune system. The potential for mangoes to greatly boost immune cell activity, as well as their proliferation and functionality, is emphasized through a thorough examination of the scientific literature. The chapter also highlights how eating mangoes increases cytokine synthesis, which is important for immunological control and pathogen defence. Mangoes also contain high levels of vitamins A, C, and E, which improve immune system function by enhancing antioxidant enzymes and reducing oxidative stress. Readers will be motivated to eat more mangoes to reap the benefits of a stronger immune system and live a life full of health and vigour.

Corresponding author: Prince Sasu,  
[psasu.research@gmail.com](mailto:psasu.research@gmail.com)

## 1. Introduction

A robust immune system acts as our body's fortification against a constant barrage of infectious germs, shields the body against disease, and preserves general health. This intricate defence system is made up of a network of cells, tissues, and substances that continuously seek out, thwart, and destroy potentially harmful invaders [1]. Understanding how specific foods, like mangoes, might bolster our body's natural defences requires understanding the complex processes involved in the immune response.

The mango (*Mangifera indica* Linn), also referred to as the "king of fruits," is a tropical stone fruit admired for its attractive colours, tender flesh, and robust flavour [2] [3]. Mangoes are tropical fruits native to Southern Asia that are widely produced throughout the world, with

India alone producing 55% of the global crop [4]. Mango is significant in many cultures for reasons other than its gastronomic merits. It is a symbol of fertility, abundance, and even divine attributes in some cultures [5]. Mangoes have also been used in traditional medicine because they are thought to have therapeutic characteristics [6][7][8][9]. The mango is a symbol of the motherland and conjures up sentiments of nostalgia and authenticity in South Asian literature and culture [10]. Mangoes can be eaten raw, frozen, dried, or added to beverages and desserts [11]. Mangoes come in many different types, each with its unique flavour, texture, and aroma.

Many authors agree that the majority of the carbohydrates in mangoes come from naturally occurring sugars, including glucose, fructose, and sucrose, which also give them their sweet flavour. A study on the fragrance characterization of mangoes found many aroma-active substances that are

responsible for the fruit's distinctive flavour [12]. According to [13][14], the quantity of sugars like fructose and glucose in a mango fruit affects how sweet it is. The mango flavour is attributed to certain compounds like car-3-ene and cis-ocimene [15]. The conversion of starch to sugar is an important index of the ripening process in mangoes [16]. Therefore, the sweetness and flavour of mangoes are indeed influenced by the sugars present in them. In addition to their culinary pleasures and cultural significance, mangoes contain a variety of bioactive compounds, vitamins, and minerals that may have significant health benefits. The specific nutrients that make mangoes a potential ally in boosting the immune system and supporting general well-being will be revealed as we examine their nutritional profile in this chapter. The dietary composition of mangoes and their potential effects on immune system function will be thoroughly examined in the pages that follow. Mangoes have special properties that we can take advantage of to improve our health and vigour.

## 2. Nutritional Profile of Mango

The dietary composition of ripe and unripe mangoes is shown in Table 1. Mango is a delicious fruit that is also packed with nutrients. It contains a wealth of minerals like potassium and magnesium, as well as vitamins (vitamin C, vitamin A), and folate [17][18].

### 2.1. Vitamin C

Ascorbic acid, also known as vitamin C, is an essential water-soluble antioxidant that supports various bodily processes [19]. It acts as an antioxidant, promotes the immune system, and prevents oxidative stress on cells. Additionally, vitamin C is crucial for collagen production, iron absorption, and maintaining good skin [20]. The vitamin C content in mangoes can vary depending on the age or ripeness of the fruit. Ripe mangoes generally contain higher levels of vitamin C compared to unripe mangoes, with ripe mangoes containing approximately 16 milligrams of vitamin C per 100 grams, while unripe mangoes contain about 3 milligrams [17][18][21]. The enzymatic activity and respiration processes during ripening lead to an increase in the breakdown of vitamin C [21]. It is important to note that the specific vitamin C levels in mangoes can be influenced by various factors, such as variety, growing conditions, and post-harvest handling [19]. Therefore, selecting ripe mangoes can provide a higher intake of vitamin C, contributing to

overall dietary needs and potential health benefits associated with this essential nutrient [21].

### 2.2. Carotene, a precursor to Vitamin A

The total carotene in ripe mangoes amounts to 2,210 micrograms per 100 grams [17][18]. The sum of all the carotenoids found in mangoes is represented as total carotene. Plant pigments called carotenoids have antioxidant capabilities and help produce the bright colours of fruits and vegetables. One hundred grams of ripe mangos have 1,990 micrograms of beta-carotene [17][18]. As a precursor to vitamin A, beta-carotene functions as an antioxidant in the body, assisting in the removal of damaging free radicals and promoting several health-related functions. The notion that ripe mangoes contain beta-carotene is supported by several authors. [22] conducted a study on the carotenoid composition of mangoes and reported the levels of  $\beta$ -carotene and total carotene in different mango varieties. [23] also studied the effects of ripening and other factors on the carotenoid composition of mangoes. [24] identified  $\beta$ -carotene and other carotenoids in the mesocarp of *Pouteria lucuma*, a relative of mango. [25] assessed the accumulation of  $\beta$ -carotene during postharvest ripening of Thai mango cultivars and analyzed the stereoisomers of  $\beta$ -carotene. [26] examined the impact of mango ripeness on the in vitro bioaccessibility of  $\beta$ -carotene. Therefore, these studies provide evidence for the levels of total carotene and  $\beta$ -carotene in ripe mangoes. Vitamin A, primarily in the form of carotenoids like beta-carotene, is also present in significant amounts in mangoes. The findings of [17][18] show that immature mangoes have much less total carotene (90 micrograms) and beta-carotene (1,990 micrograms) than ripe mangoes (2,210 micrograms and 1,990 micrograms, respectively). Retinol, which is necessary for immune response, cellular differentiation, and eyesight, is produced by the body from the provitamin A molecule beta-carotene. Since ripe mangoes have more carotenes than unripe ones, how much of these pigments are produced by the fruit probably depends on its maturity stage. Numerous authors have backed up the idea that mangoes contain a sizable amount of vitamin A in the form of carotenoids like beta-carotene. Mangoes' carotenoid composition was examined by [23] concerning ripening, cultivar variations, and processing. Beta-carotene was one of the primary and secondary metabolites that [24] identified in the mesocarp of the *Pouteria lucuma* mango variety. The effect of mango beta-

carotene's bioaccessibility on the stage of ripening was investigated by [26]. In addition, [27] investigated the extraction of bioactive substances from mango peels and documented their nutritional characteristics. Therefore, these studies provide evidence for the presence of carotenoids, specifically beta-carotene, in mangoes, which serve as a precursor to vitamin A.

### 2.3. Fat

Mangoes are a healthy substitute for people wanting to follow a low-fat diet or cut back on their intake of dietary fat because of their low-fat level. Ripe mangoes contain 0.4 grams of fat per 100 grams, compared to 0.1 grams in unripe mangoes [17][18]. Mango pulp, according to studies [28][29][30], contains a negligible amount of fat—less than 1%. Similarly, the fat content varies depending on the mango variety [31]. Moreover, mango kernels, which are found within the seed of the mango fruit, contain fat ranging from 6% to 15.2% [32][33]. The fat content in mango kernels contributes to its overall composition, which includes carbohydrates, proteins, fibre, and ash [32][33]. It is worth noting that the fat content in mango pulp and kernels can vary depending on factors such as variety, ripeness, and processing methods [34]. Despite its low-fat content, mango pulp is a rich source of other nutrients, including vitamins, minerals, and dietary fibre [35]. Incorporating mango pulp into the diet provides nutritional benefits while maintaining a low fat intake [36]. Some studies even suggest that consuming mango fruit or its components may have protective effects against metabolic alterations induced by high-fat diets [37]. Therefore, consuming mango pulp can be a healthy addition to a balanced diet for those looking to limit their fat intake while enjoying the flavour and nutritional benefits of this tropical fruit.

### 2.4. Carbohydrates

Carbohydrates, the body's main source of energy, are present in mangoes. Unripe mangoes have 10.1 grams of carbs per 100 grams, but ripe mangoes have 16.9 grams [17][18]. Mangoes' naturally occurring sugars, such as glucose, fructose, and sucrose, make up the majority of their carbohydrate content and are what give them their sweet flavour.

### 2.5. Iron, Sodium, Calcium, Phosphorus, and Potassium

Mangoes also help with mineral intake, as seen by their high potassium, calcium, and phosphorus levels. The mango's high concentration of these minerals contributes to its possible health advantages. Maintaining fluid equilibrium, neuron function, and muscle contractions all depend on potassium, an essential mineral and electrolyte. Ripe mangoes have 205 milligrams of potassium per 100 grams, while immature mangoes have 83 milligrams [17][18]. Ripe mangoes have 14 milligrams of calcium and 16 milligrams of phosphorus, but unripe mangoes contain 10 milligrams of calcium and 19 milligrams of phosphorus, both of which are essential for bone health [17][18]. Mangoes may not be the main source of these minerals, but they nevertheless have a significant impact on dietary consumption overall, especially when included in a diverse diet. In comparison to immature mangoes, which have 43 milligrams of sodium per 100 grams, ripe mangoes have 26 milligrams. Sodium is a crucial mineral that is involved in neuron function, fluid homeostasis, and muscle contractions. Mangoes are a better option for people watching their salt intake since, despite having some sodium, they have comparatively low levels compared to processed meals [17][18]. Unripe mangoes only offer 0.33 milligrams of iron per 100 grams, compared to 1.3 milligrams in ripe mangoes. The immune system, the creation of energy, and the transportation of oxygen all depend on iron. For the maintenance of general health and the prevention of iron-deficiency anaemia, the intake of mango could help remedy the anaemic situation.

### 2.6. Fibre

Mango also contains a lot of dietary fibre, which promotes a healthy gut and helps with digestion. Mangoes provide a significant quantity of dietary fibre, with ripe mangoes containing 0.7 grams per 100 grams and unripe mangoes containing 1.2 grams [17][18]. Dietary fibre, a complex carbohydrate, comes in both soluble and insoluble forms. Blood sugar levels are controlled by fibre, and fibre aids in weight loss. It helps to maintain regular bowel movements, avoid constipation, and promote healthy gut microbiota. Because some fibre may disintegrate or change into other forms as fruits mature, unripe mangoes have a higher fibre concentration.

## 2.7. Energy

Mangoes also have a comparatively low calorie and fat content. In comparison to immature mangoes, which provide 44 calories and 0.1 grams of fat per 100 grams, ripe mangoes offer 74 calories and 0.4 grams of fat [17] [18]. These qualities add to the attraction of mangoes as a healthful fruit that may be included in a balanced diet, especially for people who are cautious of their calorie and fat intake. It is crucial to keep in mind that the nutritional makeup of mangoes might change depending on the variety, growth circumstances, and post-harvest management. The particular numbers listed in Table 1 serve as a guide for comprehending the

overall nutrient profile of mangoes and indicate an average nutritional composition. Even though the results show the nutritional advantages of mangoes, it is important to remember that these values can change slightly based on the geographical area, fruit freshness, and farming methods. Mangoes' nutritional makeup can also be affected by post-harvest processing techniques, including handling and storage conditions. Mangoes have several health advantages, but it's vital to keep in mind that they should only be consumed as a part of a balanced diet that also includes a variety of fruits, vegetables, whole grains, lean proteins, and healthy fats. Including mangoes in a balanced diet helps improve overall health.

Nutrients	Ripe mango	Unripe mango
Protein (g)	0.6	0.7
Fat (g)	0.4	0.1
Minerals (g)	0.4	0.4
Fibre (g)	0.7	1.2
Carbohydrates (g)	16.9	10.1
Energy (kcal)	74	44
Vitamin C (mg)	16	3
Total carotene (mcg)	2,210	90
Beta carotene (mcg)	1,990	-
Potassium (mg)	205	83
Sodium (mg)	26	43
Calcium (mg)	14	10
Iron (mg)	1.3	0.33
Phosphorus	16	19

**Table 1.** Analytical nutritional composition of mango per 100g

(Source: <sup>[17]</sup> cite in <sup>[18]</sup>)

### 3. Basics of Immune Health

The immune system is an intricate network of tissues, cells, and chemicals that protects the body from infections and promotes general health <sup>[1]</sup>. The lymphatic system, white blood cells (such as lymphocytes and phagocytes), antibodies, lymphoid organs (such as the thymus and spleen), and other bodily systems make up the immune system. These elements work in close coordination to elicit immunological responses and maintain immune surveillance throughout the body. An individual's general health and well-being are directly impacted by the immune system's capacity to prevent and treat infections, allergies, and chronic disorders. A healthy immune system contributes to long-term disease prevention, quicker healing, and protection against illness. Thus, enhancing immune function is essential for fostering a healthy and durable physique.

The prevention of chronic diseases and the maintenance of good health both greatly benefit from a robust immune system <sup>[38]</sup>. In addition to supporting

general health and vigour, the immune system is essential for tissue regeneration and repair <sup>[1]</sup>. According to psychological research, having a strong immune system improves mental and emotional well-being by lowering levels of stress and anxiety <sup>[38]</sup>. The amazing immune systems in the human body protect us from illnesses. Our immune system uses three different types of defence mechanisms—innate immunity, adaptive immunity, and passive immunity—to protect our bodies from pathogens. These defence mechanisms all work in different ways to keep us safe from dangerous outsiders. Our bodies' innate immunity serves as a quick reaction system and initial line of defence <sup>[39][40]</sup>. According to <sup>[41]</sup>, it is present from birth and offers instant defence against a variety of infections. Innate immunity includes both chemical and physical barriers, such as antimicrobial proteins and enzymes, as well as physical barriers like the skin and mucous membranes <sup>[42]</sup>. These defences provide constant protection against a variety of infections <sup>[43]</sup> <sup>[44]</sup>. Following innate immunity, adaptive immunity is activated. It is a highly specialized defence mechanism that evolves with time. Adaptive immunity involves the activation of particular immune cells, such as T and B

lymphocytes, which create antibodies tailored against particular diseases [39]. Although it takes longer, this procedure offers long-term protection and memory against previously met infections. As the name implies, passive immunity refers to the brief transmission of already-formed antibodies from one person to another. This transfer can happen spontaneously, such as when a woman breastfeeds her baby, or artificially, such as when immunological serum or antibodies are given to a patient [1][45]. Passive immunity offers immediate, albeit transitory, defence against some infections. To talk about the unique reaction to eating mangoes, mangoes include a variety of minerals and phytochemicals that are beneficial to health, but their effect on immunity has garnered particular attention. Evidence gathered via scientific investigations and research suggests that some mangoes' nutrients, including vitamins, minerals, and bioactive substances, may have immunomodulatory effects that could help innate immunity operate and be strengthened. The following sections will discuss the special ways that mangoes assist our immune system. Get ready to find out the truth about the connection between mangoes and the body's first line of defence, which is advantageous.

### *Mango and Immune System Interaction*

Research suggests that mango may include several bioactive compounds that support immune system health. Antioxidants and anti-inflammatory agents are among the chemicals that can support the immune system's defenses and combat oxidative stress, both of which are advantageous to immunological health. Scientific studies on how eating mangoes affects immune function have shown hopeful findings. Numerous studies have been conducted on the bioactive components of mangos and their potential health benefits [46][47][48][49][50][51]. Recent studies have shown the fruit's additional health benefits, including crucial components that assist in healthy weight management, disease prevention, and even some anti-ageing properties [52]. Mango is rich in polyphenols like mangiferin, which have been shown to have therapeutic and nutraceutical significance in the treatment of degenerative diseases like cancer and heart disease [53].

A healthy heart is supported by the nutrients that mango contains. For example, it is said to include magnesium and potassium, which support lower blood pressure by assisting blood vessels in relaxing [52]. Mangoes are also a high source of fibre and antioxidants, such as vitamin C, thus they may help

combat chronic and inflammatory disorders [54] and support a healthy immune system. Pulp, peel, and kernel make up the fruit's three main components. The peel and kernel are typically discarded, whereas the pulp is the component that is consumed the most. The kernel of the mango has higher antioxidant and polyphenolic levels than the pulp and peel, whereas mango pulp is a source of a range of reducing sugars, amino acids, aromatic compounds, and functional compounds, such as pectin, vitamins, anthocyanins, and polyphenols [11]. Peels and kernels from mango processing are biowaste; however, they also have nutritional value but are not fully covered in this chapter. Protocatechuic acids, mangiferin, and beta-carotene are examples of functional chemicals found in the peel that have been shown to have antibacterial, anti-diabetic, anti-inflammatory, and anti-carcinogenic characteristics [11]. Mango pulps are a good source of antioxidants, particularly vitamin C, and fibre, which help to maintain a healthy immune system and may help combat inflammatory and chronic diseases [52][55]. Additionally, they are a beneficial component of a diet rich in healthy foods and include elements that support the health of the skin and eyes [52]. Mangoes and the bioactive compounds they contain may provide several health advantages, including anti-inflammatory properties, improvements in mitochondrial bioenergetics, and improved exercise capacity. These include lowering the risk of developing cancer, improving skin quality, lowering the risk of developing heart disease, enhancing sexual function, promoting brain health, slowing the ageing process, alkalizing the body, enhancing eye health, maintaining heart health, boosting bone health, and promoting digestive system support [56]. Mango pulps are also rich in polyphenols, such as mangiferin, which have been shown to have nutraceutical and pharmaceutical significance in combating degenerative diseases like heart diseases and cancer. Mangiferin is a special polyphenol in the mango that has been extensively demonstrated and continues to attract much attention, especially in its potential to combat degenerative diseases like heart disease and cancer [57][58][59][60].

In inflammatory cells, mango polyphenols have been shown to reduce the release of pro-inflammatory cytokines while increasing the secretion of anti-inflammatory cytokines [61][62]. Additionally, it has been shown that mango's anti-inflammatory action reduces or eliminates inflammation as well as other symptoms linked to leaky intestines, colon cancer, and constipation by inhibiting the production of pro-

inflammatory cytokines. This anti-inflammatory impact has been linked to the signalling axis miR-126/PI3K/AKT/mTOR [63]. Antioxidants found in mangoes can boost immunity and the body's ability to provide anti-inflammatory effects [64]. Mangiferin, a polyphenolic molecule abundant in mangoes with antioxidant and anti-inflammatory properties, can, however, cause unpleasant muscle cramps if mango is consumed in excess [64].

#### **4. Recipes and Mango-Based Processed Foods for Immune Health**

This section on dishes using mango and products made from processed mango is a real treasure trove of culinary ideas, providing a great variety of recipes that

highlight the incredible adaptability of mango. Readers will learn numerous methods for processing mango into a variety of mango products that may be incorporated into their daily meals, from energizing ripe mango products to unripe products. These dishes are tantalizing to the taste senses and supportive of overall immune health because they not only highlight the inherent sweetness and vivid flavour of mango but also harness the power of other immune-boosting ingredients. Mangoes are a great source of vitamin C, which is crucial for boosting immunity and preventing disease, as was already discussed. Non-fibrous fleshy kinds are primarily employed for processing these recipes and give a potent immune-boosting punch, while succulent juicy types are used for dessert applications [18]. Table 2 provides a summary of how these recipes can be prepared.

Ripe mango Product	Description	Source
Mango pulp	By adding sugar syrup and citric acid, mango pulp is typically standardized to 14–18oB and 5–6.5% acidity as citric acid, and it is then kept during the peak season of the mango crop for later usage in a variety of goods.	[18][65][66] [67][68][69] [70][71]
Mango beverages	To prepare mango beverages, start by blending ripe mangoes with water for mango juice or keeping the pulpy consistency for mango nectar. For mango squash, combine mango juice, sugar, and water, then dilute before serving. Mango wine requires fermentation. Milk-based options like mango lassi can be made with mango, yoghurt, and milk, while carbonated mango beverages involve combining mango juice with sparkling water. Customize these recipes to enjoy a variety of refreshing mango beverages at home.	[66][72][73] [74][75][76] [77][78][79]
Dry mango products	In the ice cream, bread, and confectionery sectors, dried mango powder is a useful auxiliary ingredient. After concentration, mango pulp or juice is combined with powdered sugar and dried.	[2][80][81] [82][83][84]
Mango leather	Indian cuisine traditionally uses large amounts of pulp from the sour and seedling types that have been extensively sun-dried to add flavour.	[2][17][85] [86][87][88] [89]
Mango jam	Pulp from dehydrated mango slices is heated with an equal quantity of sugar to 65–68oB and citric acid is added at the end to get 0.6–0.7% acidity in the final product score for colour and flavour	[66][90][91]
Mango toffee	According to the following recipe, mango pulp can be used to make mango toffee together with other ingredients: mango pulp: 53 kg, sugar: 30 kg, glucose: 4 kg, skim milk powder: 8 kg, hydrogenated fat: 5 kg, with appropriate essence and colour in the required amounts.	[78][91][92]
Mango yoghurt	Mango yoghurt can be prepared with mango posser and boiled cooled milk in the presence of starter culture (curd)	[83][93][94]
Mango custard powder	Mango powder, sugar, skim milk powder, corn starch, lime juice, cream, salt, and water can be combined to make a nutrient-dense food for the kids.	[18]
Mango ice-cream	Mango powder can be added to sweetened, boiled, and cooled milk to make mango shakes.	[95]
Mango shake	Mango powder can be added to sweetened, boiled, and cooled milk to make mango shakes.	[96]
Mango Lassi	Mango lassi can be prepared with mango powder curd and other ingredients	[97]
Mango cereal flakes, vermicelli, and powder	Vermicelli and powder made from mango cereal can be made by mixing cooked wheat flour into a dough that is appropriate for extrusion through a vermicelli press or by drying the vermicelli directly on trays.	[98]
Strained baby food	A 60-mesh sieve is used to filter the fibre out of mango pulp. This pulp is blended by adding sugar to it; after homogenizing the mixture, it is then canned	[98]
Mango tablet	Ripe and unripe mangoes are used to make the mango tablet. Mango pulps are freeze-dried to create mango powder and then moulded to a desired shape	[99]
Unripe mango products		
Mango pickle	They are produced with fruit that has either been peeled or left unpeeled, with or without stones, and with varying ratios of spices.	[2][66][92] [94][100]



Ripe mango Product	Description	Source
		[101][102]
Mango chutney	Unripe or semi-ripe mangoes are peeled, sliced, or shredded and cooked to a thick consistency with spices, salt, onion, garlic, sugar/jaggery, vinegar, or acetic acid to make mango chutney.	[66][91][103]
Green mango powder	After being milled into powder and sun-dried (16 hours in the sun at 35–40°C for thorough drying of the slices), green mango slices can be created.	[6][103][104] [105][106] [107][108] [109]
Green mango beverage	Many processing methods have been devised for beverages made from green mangoes.	[90][110][111] [112][113] [114][115]

Table 2. Diversity of processed mango products and their preparation methods

Source: Modified from [18]

## 5. Conclusion

This extensive examination of mangoes has revealed their exceptional potential as an important booster of immune function. Mangoes are an excellent source of vitamins, minerals, and antioxidants that help to support the immune system and lower oxidative stress. Mangoes are special in that they contain considerable amounts of vitamins A, C, and E, which are essential for the synthesis of white blood cells and antibodies, both of which are necessary for a healthy immune system. In addition, mangoes contain antioxidants that not only help to lower inflammation but also protect the body from potential threats by scavenging dangerous free radicals. Mangoes also contain beneficial substances including carotenoids and polyphenols, which have outstanding anti-inflammatory and immunomodulatory capabilities. These substances affect how immune cells operate and support the development of a balanced immunological response. Mangoes' fibre content is also essential for promoting a healthy gut microbiome, which is essential for maintaining normal immunological function. Mangoes can unquestionably improve immune function when included in a balanced, healthy lifestyle. By embracing the delightful flavour and potential immune-boosting properties of mangoes, individuals can take a proactive step towards a holistic approach to well-being and fortified immune health. Although the evidence presented here suggests that mangoes may be good for your immune system, one should still get specific

advice from qualified dietitians or medical experts. They can offer tailored advice depending on client requirements and medical situations, resulting in the greatest outcomes.

## Statements and Declarations

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