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Effect of Dietary Factor on Response of the Immune System Numerically

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Abstract. Dietary habits are one of the main causes of fatal diseases such as cardiovascular disorder, cancer and diabetes. This paper aims to illustrate a proportional relationship between diet and behaviour of the immune system which responds when a human body is being attacked by pathogens. However, if a person's diet is well balanced their immune system will improve and vice versa. Nonlinear ordinary differential equations are formulated to describe the behaviour of the immune system and its response when a human body gets infected by a pathogen. This model considers two populations: normal cells and immune cells. In addition, the model has been monitoring the behaviour of the immune system for thirty days using Mathematica 10.0 software. The results prove that well balanced and regular diet can boost the immune system and improve its response to protect a human body from diseases. In conclusion, a balanced diet plays a huge role in reducing the percentage of lethal diseases.
Keywords: Malnutrition; Supplement dietary; Immune system; Normal cells.

1. Introduction

The immune system is a complex system which comprises of a nexus of cells, tissues and organs which works as a defence for the body. Certain essential nutrients are required to enable optimal function of the immune system to carry out the defence against invading viruses, bacteria and to clear up dead cells. Immune cells utilize substrates like amino, fatty acids, glucose and further uses various other nutrients to divide and produce antibodies to destroy pathogens. It also produces proteins like cytokine, immunoglobulins and lipid mediators, for instance, leukotrienes, prostaglandins and specialized pro-resolving mediators. Multitudinous enzymes are involved in critical roles which avial zinc, iron, copper, selenium, magnesium, vitamins A, C, D, E and group of vitamins B and others. Dietary extremes, especially protein-energy malnutrition (PEM) have a significant impact effects in decreasing the immune system functions and also increases the risk of opportunistic infections [1].

A Global Nutrition report (2016) summarized that between three people there is one who is malnourished in the worldwide [2]. Currently, nutritionist focus on a diet pattern as one of the main risk factors which cause deadly diseases, especially cancer. Where they are observed that

the risk of breast cancer is reducing among premenopausal and postmenopausal women if they take a higher amount of beta-carotene. However, the effect of intake vitamin C is associated with reducing the risk of breast cancer for just premenopausal women [3].

Moreover, ordinary differential equations, partial differential equations and delay differential equations are used to describe the interaction between immune cells and a bacterial infection, viruses and cancer cells. Several mathematical models have been applied to illustrate the growth of tumor cells dynamically also displaying the interaction between the immune system and tumor cells. Most of these models have been described the interaction by three variables which are tumor cells and immune cells, tumor cells and normal cells [4] or an interaction of immune cells and tumor cells undergoing a treatment of chemotherapy [5]. Another paper discussed the correlation between cancer and estrogen [6] however an impact of modern lifestyle on health has been studied mathematically [7]. This paper presents the dynamical model of reactivity between the immune system and normal cells when there is abnormal division which may lead to cancer.

2. Materials and Methodology

In this paper, ordinary differential equations are used to elucidate the effect of dietary habits with the appearance of abnormal cells on the response of immune system. This model is formulated as follows:

$$\begin{aligned} \frac{dN}{dt} &= N(r-\beta N)-\eta IN, \\ \frac{dI}{dt} &= \sigma+\frac{\rho IN}{m+N^2}-\delta I-\mu IN, \end{aligned} \tag{1}$$

with initial point $N[0]=1$[6] and $I[0]=1.22$ [8], where N and I are the populations of normal cells and immune cells, respectively. The parameter r represents the growth rate of normal cells which is associated with the carrying capacity of the tissue. Normal cells sometimes become abnormal cells during cell division and the rate of this change is given by β. While the properties of these cells differ from normal cells and the presence and spread of these cells trigger the rise of tumor cells. In this case, the immune system is active in the inhibition and elimination of these abnormal cells by using the parameter η. This interaction leads to a reduction of immune cells by the parameter μ.

The constant natural rate of immune cells is represented by σ and their natural death in the absence of abnormal cells is showing by rate δ. Finally, abnormal cells can be eliminated by the Michaelis-Mentent term where the immune cells grow as a result of a stimulant in the form of abnormal cells; whereas the constant rate of response of the immune system is represented by ρ and the threshold rate of immune cells can be described by the function $m=(\sigma-\rho t)a$ where $t=30$ years [9]. All values of these parameters are defined from the literature see Table 1.

Moreover, the comparison between the effect of healthy and unhealthy dietary habits on the response of the immune system has been studied by exchanging two parameters that have been related to engulfing and attacking abnormal cells.

3. Discussion and Results

In this paper, we used Mathematica 10.0 software to demonstrate the relationship between the dietary intake and the behaviour of the immune system. The first is a control case where it describes the behaviour of the immune system and its response when a person follows a regular and a healthy diet which co-relates the food pyramid, see Figure 1. The numerical solutions of the model (1) showed that response of the immune system is dependent on the change in the parameter η which is called the rate of inhibition or elimination of the abnormal cells by the immune cells such as T-cells and natural killer cells NK. However, the numerical solutions proved that the immune system could recognize and eliminate the abnormal cells within the

Table 1. Parameters of the model and references.

Parameter	Value	Definition and reference
r	0.431201	Rate of growth normal cells [10]
β	$2.99 * 10^{-6}$	Rate turn norma cells to abnormal cells [11]
η	0.2	Rate of repaired abnormal cells [5]
σ	0.7	Fixed of immune source [9]
δ	0.57	Rate natural death of immune cells[Evaluate]
ρ	0.003	Response rate of immune cells [12]
m	0.427	Threshold rate of immune cells [9]
μ	0.82	Rate in decreasing of immune cells as a result of interaction with abnormal cells [10]
a	0.7	Amplitude of immune alteration [9]

interval $0.6 \leq \eta \leq 0.82$. The first ten days from the appearance of pathogens the immune cells decreased as a result of interaction between the immune cells and abnormal cells. The initial response of the immune cells was to repair or fight the abnormal cells thus preventing them from turning into cancers cells. After ten days the rate of immune cells returned to its initial value of 1.2 of the immune cells after elimination of the abnormal cells, see Figure 2.

Therein, positive behaviour of normal cells is observed where the numerical solutions showed that the population of normal cells reached 19×10^4 cells when $\eta = 0$ which may trigger the appearance of the cancer cells. But when the immune cells are active, the normal cells decrease to a zero value within an interval $0.6 \leq \eta \leq 0.82$ indicating that the immune cells were activated to inhibit and eliminate the pathogens, see Figure 3. One of the precipitates in the emergence of cancer cells is partly due to the continuous division of normal cells leading to cell mutation. The decrease in normal cells proved to have a positive impact as the nervous system signals the normal cells to cease or die off [13, 14].

The numerical solution of the model showed that the behaviour of the immune system and its response differs when the person follows an unhealthy dietary pattern such as junk food, sugary and fatty food, Figure 4. This figure presents the response of the immune system with the differential value of μ (the decreasing rate of immune cells as a result of the interaction between immune cells and abnormal cells) when a pathogen is present. It is clear that, the population of the immune cells did not change when $\mu = 0$ that means there is no response if there is appearance of the pathogen. But when the immune cells begin to fight the effects of pathogen as abnormal cells, they will dramatically decease to reach zero specifically when $0.6 \leq \mu \leq 0.82$. In addition, the abnormal cells have a chance to divide and grow. Sometimes this growth and division can turn to tumor cells.

Not only this but unhealthy diet is a risk factor for normal cells as well, where Figure 5 proved that the population of the normal cells increased continuously and reached to 14×10^4 cells whenever the immune cells tend to be zero. Also, all tissues have a fixed amount of cells, thus the normal cells can continuously divide but when increased in number of normal cells can lead to the occurrence of mutated cells in the tissue which may cause carcinoma.

In the end, dietary pattern is one of the main factors which increases the risk of deadly diseases not only in the western countries but also in the developing countries. The present study confirmed that the dietary habits have been significantly associated with the spread of fatal diseases. The immune system plays a vital role in protecting the human body against diseases as thus it needs to be in a fighting fit state to carry on.

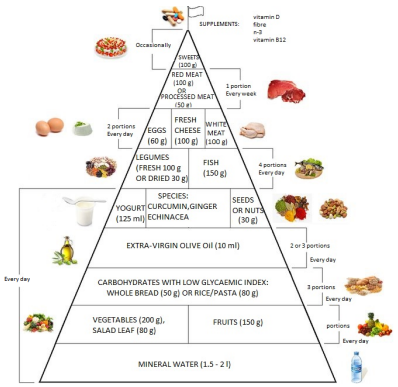

Figure 1. The dietary management co-relates food pyramid [15].

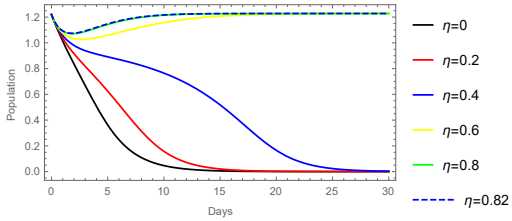

Figure 2. The behaviour of the immune system with healthy diet pattern .

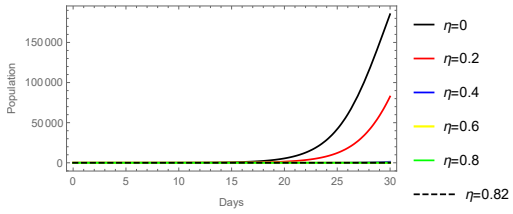

Figure 3. The behaviour of normal cells with healthy diet pattern.

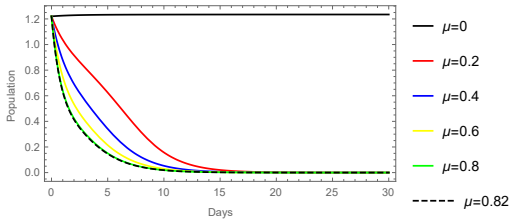

Figure 4. The behaviour of the immune system with unhealthy diet pattern.

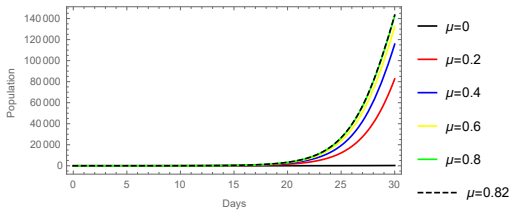

Figure 5. The behaviour of normal cells with unhealthy diet pattern.

4. Conclusion

This study indicated that dietary habits had a significant impact on the behaviour of the immune system and its response dynamically. The numerical solution showed that a regular and balanced diet based on the food pyramid could boost the immune system and modify its response to protect the body from developing diseases. However, modern diet is one of the risk factors causing lethal diseases. Diet pattern also has an impact on the behaviour of normal cells. It is further observed that a balanced diet helps the nervous system to prohibit the normal cells from dividing continuously or they can turn the normal cell into a quiescent, thus it protects the human body from cancer. Eventually, it is revealed that an unhealthy dietary pattern serves as a pathway for fatal diseases such as cardiovascular diseases and cancer by the rapid cell multiplication of normal cells.

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