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NUTRITION CONSULTANT BASED ON MACHINE LEARNING FOR PREECLAMPSIA COMPLICATIONS

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Abstract

The current study aims to advise the alimentation of pregnant women who suffer from preeclampsia, because we live in a society which is characterized by speed and an impact needs to be done over the nutritional behaviour of the women expecting babies. Pregnant women should take care of their alimentation and acknowledge the health consequences which might appear. Fast food and soft drinks have to be avoided for a healthy life style, as well as during pregnancy. The statistical data regarding the nutrition and medicine for the prevention and treatment of preeclampsia is retrieved from the World Health Organization. In the paper have been analyzed several trials done on a number of persons which varied according to the comparison criteria. Machine learning is used for the pregnant women to assess their dietary habits based on their daily meals and taken medicine descriptions which are written in natural language. As a conclusion, salt restriction, antioxidants, calcium, vitamin D supplementation, antiplatelets have been some of the most frequent recommendations.

Keywords: *preeclampsia, nutrition, consultant, natural language processing, machine learning.*

INTRODUCTION

We live in a society where everything develops fast and people should be aware of their nutritional behaviour in order to be healthy. Pregnant women need to change their alimentation and be conscious regarding the health evolutions which can appear.

Fast food and soft drinks have to be excluded from the alimentation, mostly during pregnancy. A study done on 200 pregnant women from Downey, California, United States, reported that 96% of them did eat fast foods, namely burgers, French fries, chicken (Santiago et al., 2013). As a soft drink, Cola was consumed by 60.2% of the studied persons. The prenatal diet which contains mostly fast food endangers the fetus, because the level of fat and salt increase. In this case, the offspring is most likely to develop obesity in life and have altered genes that promote the eating behaviour (Tamashiro et al., 2009).

The content of caffeine from Cola can provoke miscarriage (American Pregnancy Association, 2019). Based on a study done at the Aarhus University Hospital from Denmark, high levels of caffeine promoted the occurrence of stillbirth after the second trimester (Wisborg et al., 2003). Based on studies done on first-time mothers, the consumption of vegetables and fruits is low (Wen et al., 2010). A poor nutrition leads to cardiovascular diseases, diabetes, cancer and weight gain (World Health Organization, 2019).

A 10 years study performed in Norway based on the New Nordic Diet which consisted on eating the main meals, as well as consuming fruits, root vegetables, cabbage, potatoes, whole grain bread, oatmeal, fish, milk and drinking water six times more than sugary drinks (Hillesund et al., 2014). The outcome of respecting such a diet was a lower risk of preeclampsia (Hillesund et al., 2014).

52% of the pregnant women prove to have iron deficiency (Abu-Ouf et al., 2015). Iron influences the haemoglobin value. Based on a study done in India at the Navodaya Medical College, a high maternal haemoglobin value is associated with a greater risk of developing preeclampsia (Manjunatha et al., 2015).

A high intake of fat, sodium and a low consumption of fruits, fibers, vitamin A, C and olive oil influence the occurrence of preeclampsia (Yusuf et al., 2019). Magnesium taken from dairy products, bread, cereals, vegetables and meat, as well as supplements which contain it, reduce the risk of fetal growth restriction and preeclampsia (Zarean et al., 2017).

In the next section is presented a study done on the nutritional ingredients, along with the paper's algorithm which suggests the best diet. The later mentioned feature is done using the nutritional ingredients, their quantities and the list of medicines which are taken by the pregnant women. Section 3 describes the obtained results. The last section outlines the conclusions and the future work.

MATERIALS AND METHODS

In 2018, the World Health Organization performed a study which comprised 11 trials, having in total 5162 pregnant women (World Health Organization, 2018). The study demonstrated that diet and exercises prevent hypertension in pregnancy. A healthy diet comprises an intake of energy, vitamins, proteins, minerals in adequate quantities.

Several nutritional ingredients are analyzed in Table 1 according to the maximum advised quantity, along with their advantages and overdose disadvantages.

Table 1. Prevention and treatment of preeclampsia

Nutritional ingredient	Quantity	Advantages	Overdose problems
Alpha-linolenic acid (Pan et al., 2012; Phang et al., 2019)	< 1.10g/day	Lower risk of cardiovascular disease	Preeclampsia, higher infant birth weight
Salt (Scaife et al., 2017)	5g/day	Helps the thyroid, maintains the body hydrated	Hypertension, plasma volume expansion
Caffeine (American Pregnancy Association, 2019; Wisborg et al., 2003; Morgan et al., 2013)	300 mg/day	Treats headache, is efficient for weight loss, stimulates of the central nervous system	Miscarriage, stillbirth
Organic vegetables (Torjusen et al., 2014)	Up to 95% of the consumed food per day	Low risk of atopic diseases, reduced risk of preeclampsia	Higher hemorrhagic stroke risk
Fruits (Brantsaeter et al., 2009)	> 255 g/day	Reduced risk of preeclampsia	High level of fructose, can lead to diarrhoea
Fibres (Qiu et al., 2008)	>= 21.2 g/day	Reduced risk of preeclampsia, attenuate dyslipidemia	Bloating, gas, constipation
Fish (Imperial College London, 2019)	2 portions/week	Low high blood pressure	Depending on the fish origin, can lead to mercury poisoning, vomiting, diarrhoea, cramps, headaches, fatigue, fainting
Dairy products (Miller et al., 2019)			
Calcium	500 mg/day	Bone calcium balance, low risk of preeclampsia	Creates kidney stones, weaken the bones
Iron (Fisher et al. 2017)	1040 mg/day	Creation of extra blood, moves oxygen from lungs to the entire body	Vomiting, diarrhoea, pain, dehydration
Water (Parent, 2012)	2 L/day	Physical and mental health stability, normalized cholesterol and blood pressure	Nausea, vomiting, headache, low level of sodium, weakness, seizures
Olive oil (Assaf-Balut et al., 2019)	40 mL/day	Less urinary tract infections, low risk of premature birth	Weight gain, vitamin E overdose
Vitamins			
Folic acid (Liu et al., 2018; Slomski, 2018)	800 µg/day	Reduced risk of preeclampsia	Does not prevent preeclampsia
Vitamin A (Maia et al., 2019)	800 µg/day	Growth of embryonic cells	Drowsiness, irritability, vomiting, blurry vision
Vitamin C (Fu et al., 2019)	1 g/day	Reduced risk of prelabour membrane rupture	Diarrhoea, vomiting, heartburn, cramps, headache, insomnia

Through antioxidant, anti-inflammatory or vasoactive proprieties, micronutrients are good candidates for preeclampsia prevention.
Micronutrients are represented by essential elements which are needed by the body in small quantities, namely vitamins and minerals. Based on a study done on 65,220 pregnancies in Denmark, the alpha-linolenic acid which is an omega 3 fatty acid, proved to be present in the alimentation of the women who suffered from severe preeclampsia (Arvizu et al., 2019).
A study done in Netherlands proved that caffeine determines the increase of the systolic blood pressure during the first and third trimester, but it does not determine the presence of elevated diastolic blood pressure values (Bakker et al., 2011).

According to the Danish National Birth Cohort study which consisted on 55,138 pregnant women who were analyzed, it was observed that a diet of vegetables and fish decreased by 21% the risk of preeclampsia development (Imperial College London, 2019). Adequate intake of calcium taken from dairy products proved that the risk of preeclampsia occurrence reduced by 62% (Miller et al., 2019). The calcium intake (> 1 g/day) may reduce the risk of preeclampsia in women with low-calcium diet (Cormick et al., 2019).
Multivitamins proved to decrease the risk of preeclampsia, the confidence interval reaching 95% for evaluating the connection between the supplementation with folic acid and the risk of developing preeclampsia (Liu et al., 2018).
The folic acid can also be given to pregnant women, being the created form of folate which is a B vitamin. The intake of folic acid before and at the beginning of the pregnancy proved that it might lead to giving birth to infants with neural tube defects. Due to this cause, the dose has been lowered to 400, up to 800 μg per day (Dolin et al., 2018). Folic acid deficity and anemia influence the occurrence of stillbirths (Yakoob et al., 2009).
The iron quantity needed during pregnancy is cause by the requirements of the fetus (270 mg/day), the placenta (90 mg/day), the loss of the iron in the maternal body (230 mg/day), the expansion of the maternal red blood cell (450 mg/day) (Fisher et al. 2017).

SmartCarb is a mobile system which assists the pregnant women who suffer from gestational diabetes to monitor their diet (Hu et al., 2018). The application uses deep learning neural networks for recognizing food images which were taken using the mobile phone's camera. After the image is analyzed, the value of carbohydrates is displayed and in this way, the amount of food which should be consumed is suggested.
Another web and mobile application solution comprises a corpus for machine learning that diagnoses and offers health tips based on surveys that are completed by pregnant women (Saranya et al., 2017). The corpus comprises the previous responses taken from doctors and dietitians. The solution uses decision trees and cluster analytics which are part of supervised machine learning.
The solution of the current paper consists in an application which advices the diet of the pregnant women who suffer from preeclampsia. The algorithm takes as input from the pregnant women the list of food ingredients, along with their quantities and the list of medicines which are taken by them.
The outcomes determine the classification of the persons based on their alimentation into healthy diet, being grouped into two subsequent batches corresponding to true positive and false negative diagnosis. There is also the case when the users were detected as not having a healthy diet, being grouped into two batches corresponding to true negative and false positive diagnosis.
The Viterbi machine learning algorithm was used to assess if the diet of the pregnant women who suffer from preeclampsia is healthy or not. The algorithm computes the most possible path through the use of the hidden Markov model series (Brown et al., 2010). The input dataset comprises the nutritional ingredients, their quantities and the list of medicines which are taken by the pregnant women. The states of the hidden Markov model contain the probabilities for emissions and transitions.
Initially, the sequence contains the states when the person who is ill because of preeclampsia. The Viterbi algorithm creates new states that close to the ones of the provided input. The most similar sequence of states is calculated up to the point when the final state is reached. This

is done by utilizing the transitions from the state which was before and the most probable one that results, as well as the probability of the noticed state which is related to a hidden state.
Every transition state determines the computation of a triple that consists of the probability of the entire paths from the start state until the reached one, the Viterbi sequence and the state's probability.
The probability of the following state is computed by adding the probabilities of the entire paths that go to itself. Each source state has the total probability calculated for the entire paths which lead to itself. The triggered value is multiplied by the probability of the emission if the present state changed and the transition probability beginning from the source state that goes to the following one.
Preeclampsia and nutrition knowledge influence the process of training when the source states are determined. According to the tuples which have information about the consumed nutritional ingredients, their quantities, and the list of medicines which are taken by the pregnant women, the algorithms determines a sequence of observations that have been created by the most probable states. The following formulas are used:

$$M_{1,healthy} = P(y_1|healthy) * InitP_{healthy}$$
$$M_{t,healthy} = max\ (P(y_t|healthy) * T_{x,healthy} * M_{t-1,x}) \quad (1)$$

where $M_{1,healthy}$ is the probability of the most probable initial state which depends on the probability of being healthy, $InitP_{healthy}$. $M_{t,healthy}$ belongs to the probability of the most probable state sequence $S(x_1, ..., x_t, y_1, ..., y_t)$ where the states are x and the observations are y for the first t observations which have healthy as its final state, namely the right diet. $T_{x,healthy}$ is the transition matrix that contains the transition probabilities from a state x towards the final state, healthy diet. The triggered sequence of states is the one which contains the greatest values for $M_{t,healthy}$, where t takes values from 1 to healthy.
The pregnant women who suffer from preeclampsia have an elevated blood pressure, respectively over 140/90 mm Hg. An increased sensitivity is useful for the early detection of an healthy diet. According to this, the doctor can decide upon the alimentation of the pregnant woman.

The proposed algorithm for detecting a healthy diet for the pregnant women who suffer from preeclampsia has two stages. At the first step are determined the optimal number of hidden Markov model states. The next step contains the addition of the new hidden Markov model states by applying the Viterbi algorithm and the event log which contains the tuple of ingredients, their quantities and the list of medicines which are taken by the pregnant women. Every event can be assigned to multiple states. A hidden subprocess is represented by a hidden Markov model state. An event is a consideration of the subprocess. A group of hidden subprocesses realizes a complex system which is a deep neural network that represents the full target system utilized for the early detection of healthy diet for the pregnant women.

RESULTS AND DISCUSSIONS

The current paper utilizes approximate values of the hidden Markov model and the novel determined metrics are included to evaluate the transition values.
For demonstration purposes, the input sets were split into groups, like the data which belongs to the patient who visit a clinic from Bucharest, Romania. The input sets contain information about the nutritional ingredients, their quantities and the list of medicines which are taken by the pregnant women. According to this, the healthy diet is determined. The control batch contained 10 sets and the experimental batch had 100 sets.
It was considered that a part of the pregnant women participated actively. On the other side, 6 of them, had incomplete presence and they have been excluded. For the rest of the pregnant women who participated actively, namely 104 persons, there are two cases when the detection of the healthy diet has been determined as being positive, as well as negative. The positive detected pregnant women have been divided into two groups: true positive (TP) for 38 persons and false negative (FN) diet identification for 2 persons. It has been noticed that the women who had a diet characterized by salt restriction, antioxidants, calcium, vitamin D supplementation, and the use of antiplatelets, the healthy diet was most

likely to be identified. Similarly, for the negative detected pregnant women are other two cases: true negative (TN) for 45 persons and false positive (FP) diet identification for 19 persons.

For the group of 104 pregnant women, the overall accuracy was of 79%, with a sensitivity of 95% and a specificity of 70%. The obtained values are better compared to the ones triggered by the detection of seizures for pediatric cardiac arrest (Du Pont-Thibodeau et al., 2017), having the sensitivity equal to 77% and the specificity equal to 65%. The results demonstrate that the described model is good for determining a healthy diet for the pregnant women who already suffer from preeclampsia.

CONCLUSIONS

In this paper has been described the Viterbi algorithm for determining a healthy diet for the pregnant women who have preeclampsia. This was done using the list of food ingredients, along with their quantities and the list of medicines which are taken by them.

The presented solution allows the user to analyze the evolution of their diet. The proposed healthcare solution for the observation of the diet changes enhances the user's quality of life and the probable unwanted outcomes can be avoided successfully. The results are encouraging for the analyzed control and experimental batches.

The next step of the presented work is the enhancement of the early automatic detection of gestational diabetes. This unsupervised detection will be good in the future for the staff from the healthcare domain.

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