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Development of a Medical Expert System for Hypertensive Patients Diagnosis: A Knowledge-Based Rules

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ABSTRACT

Early detection of ailment or diseases in human has called for smart intelligence system healthcare development. Some of the major problems that both populated and less populated countries are facing is the difficulties in early ailment detection and treatment of ill health people. This is due to minimal number of medical expertise and resources available in various hospitals which leads to spending of huge affluence of their resources to meet those challenges, but still demanding for adequate medical services provisions. Therefore, this paper proposed a medical expert system for early detection of hypertensive patient, ailment diagnosis and characterisation with medical advice based on decision-making. The developed medical expert system is proficient, accurate and avoid time-waste in patient diagnosis with adequate professional advice on the ailments.

1. Introduction

Over the years, effort has been made to improve healthcare services approaches in the area of remote human health monitoring, ailment diagnosis, patient records and clinical data management. This resulted in different techniques of medical diagnostic system development which includes expert system, healthcare automation monitoring and alarm system, decision making support system and various computerised system.

Human health monitoring and diagnosis is very important, which required frequent checking for early stage of illness or disease like hypertension, diabetes, and many other ailment that are deadly or dangerous to human health. There are four healthcare body vital signs that required frequent inspections to keep the body system healthy and to sustain life functions. These includes body temperature, human heart rate/pulse rate, human blood pressure and human respiratory rate (breathing rate). The National Institute for Health and Clinical Excellence (2007) warned that vital signs of individual combination into a single score is recognised as deteriorating signs that can lead to (precede) cardiac problem or serious deteriorating patient health.

Hypertension is a common ailment that threatens human health condition as a result of part of body system infections (heart), mental stress, pregnancy, deficient of body nutrients and others (Gudu *et al.*, 2012). Hypertension is a treat to medical personnel, especially human in pregnancy (HIP), obesity human (OH), diabetic patients and many others. This illness usually lead to maternal deaths in women, strokes in both men and women, heart attack or sudden death. Research showed that not less than two pregnant women are diagnosed with hypertension in pregnancy daily or more (WHO, 2010).

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There are numerous cases of ineffective drug prescription as a result of inaccurate diagnosis in an attempt to carryout self-medication or medical prescription. Also, it is found that body mass index (body weight) of human greatly contribute to the adverse effect of hypertension diseases due to high level of cholesterol presence in the human body. This usually resulted in coagulation of blood, blockage of artery and pulmonary veins of the body system which ensue hypertension (Toshiyo *et al.*, 2016).

Many advanced technology for medical diagnostic systems have been designed to help medical personnel in areas like human illness diagnosis, drug prescription, remote health monitoring, patients registering and database records updating. Rupinder & Amrit (2014) and Guzman *et al.* (2017) developed medical diagnostic systems using fuzzy logic techniques to enhance the accuracy and precision of medical test aids. Wireless Sensor network were also developed as ways of diagnosing patient ailment in remote areas, which was due to the absence of expert medical personnel in rural areas (Agajo *et al.*, 2016)

However, the advent of artificial intelligence (AI) has made the invention of human engineered systems which show intelligent behaviour or features possible (Ajao *et al.*, 2018). Artificial intelligence helps to merge knowledge and science and form system around human engineered features. The term "intelligence" in this concept refers to the utilisation of engineering techniques that consist of one extent or another, an act borne out of human reasoning, adaptation or learning, biological cognitive structures or principles of evolution, natural physical or chemical processes. In this paper, a medical expert system for early detection of hypertensive patient, ailment diagnosis and characterisation with medical advice was developed on the basis of artificial intelligence.

2. Methods

The methods adopted to achieve this work is divided into two categories. Redesign embedded hardware system for acquiring hypertensive vital sign parameters and software development system based on knowledge rules techniques for patient diagnosis, and decision making.

2.1 Hardware System Development

The hardware system development used C language in the programming of ATmega328 microchip, which is implemented on Arduino Uno board. This system was employed to acquire hypertensive human health parameters and conditions based on the systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart beat rate (HBR). The body mass index (BMI) parameters depend on an oral enquiry includes patient height (m) and weight (kg). The hypertensive blood pressure (HBP) system (Sphygmomanometer) comprises of blood pressure sensor with cuff, microcontroller unit (MCU), heartbeat sensor, liquid crystal display (LCD), switch buttons and so on. Figure 1 shows the block diagram of hypertensive patient monitoring system.

2.2 Software Development System

The software system development for the knowledge-based rule expert system for hypertensive patient diagnosis is coded using java program. The forward chaining inference techniques is used in the system, where the system starting process with fact and forwarded to conclusions. Figure 2 shows the flow chart operation of the blood pressure monitoring system.

2.3 Knowledge-Based Rules Expert System

A decision support or an expert system is an interactive computer programs designed to assist physician or health professionals with fitness of patient decision-making activities. This system is capable of allowing both medical expert and non-medical professional to interact with the software about their health condition using combined medical expert knowledge and the inference (software rules) to make a better analysis of the patient's data. Figure 3 illustrates the block diagram of an expert system model.

Expert system development comprises of many rules that are applicable and responsible for prediction of the following hypertensive ailment in the expert system developed which includes (Hypertension (Hy), Hypotension (Ho), Normal (N), Pre-hypertension (Ph), Hy stage 1, Hy stage 2, and Hy urgency with medical advice for each stages occurred. Figure 3 depicts a block diagram of knowledge base rules expert system (Ajao *et al.*, 2018).

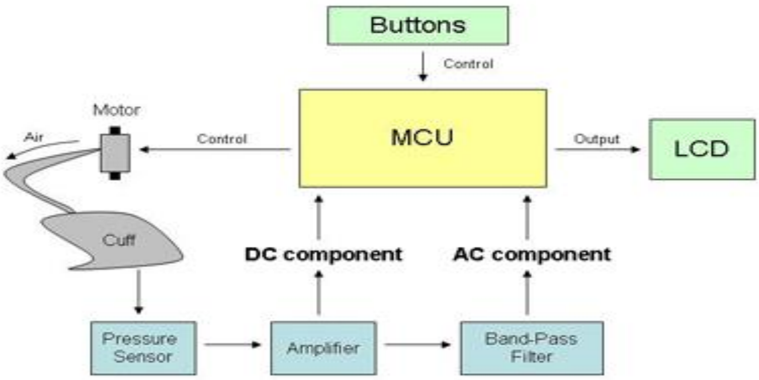

Figure 1: Block diagram of hardware system development

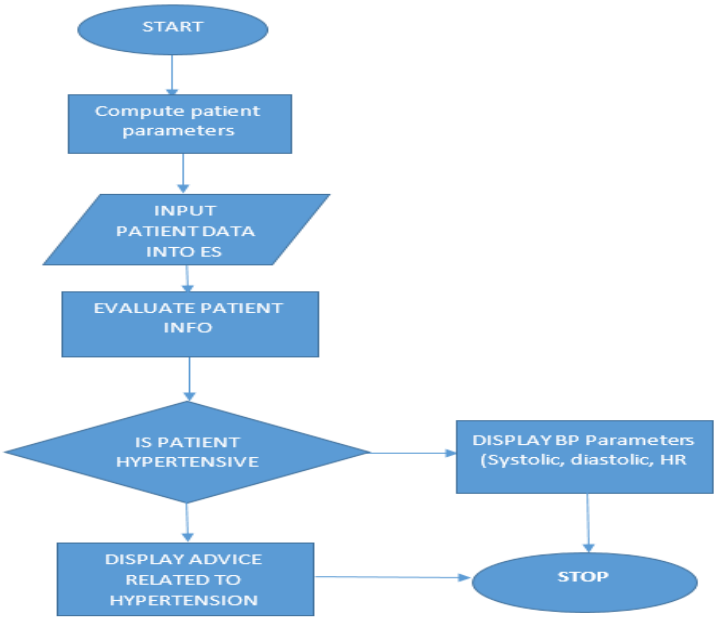

Figure 2: Flowchart of blood pressure monitoring system

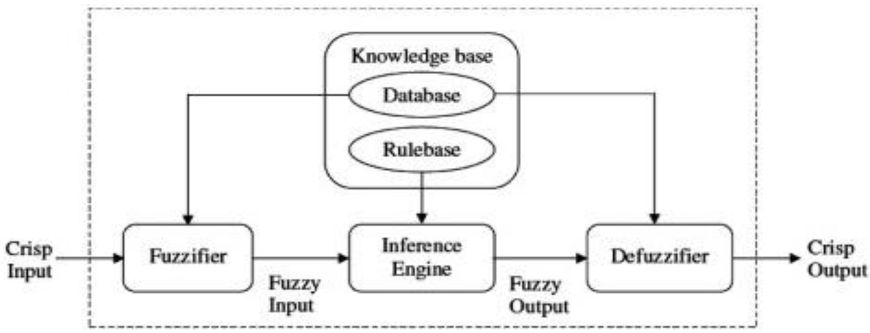

Figure 3: Block diagram of expert system development

2.4 Expert System Model

The knowledge based rule for ES is developed and modelled to determine the different stages/conditions of hypertensive patient after diagnosis, which can be expressed as in (1).

$$T_{total\ number\ of\ possible\ rules} = \prod_{i=1}^{n} m_i, \tag{1}$$

where m_i is membership functions for input i and n is the number inputs.

The mathematical modelling of knowledge based rule representation to determine crisp output of the hypertensive BP condition (systolic BP, diastolic and heartbeat rate) can be expressed as given in (2) and (3).

$$ES_{input} = BPi.BMi. \tag{2}$$

$$ES = \frac{\sum_{i=1}^{r} ES_i.Li}{\sum_{i=1}^{r} Li} \tag{3}$$

where, ES_i is crisp output of blood pressure IF-THEN rule, Li is firing level, r is number of rules fired, BP_i is blood pressure parameters (systolic and diastolic), BM_i is body mass index (height and weight).

The triangular curve function of a vector x, depends on three scalar parameters a, b and c, and is expressed as given in (4).

$$f(x;a,b,c) = \begin{cases} 0, & x \le a \\ \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & c \le x \end{cases} \tag{4}$$

3. Results and Discussion

Figure 4 illustrate the redesign embedded system-based hypertensive measuring system.

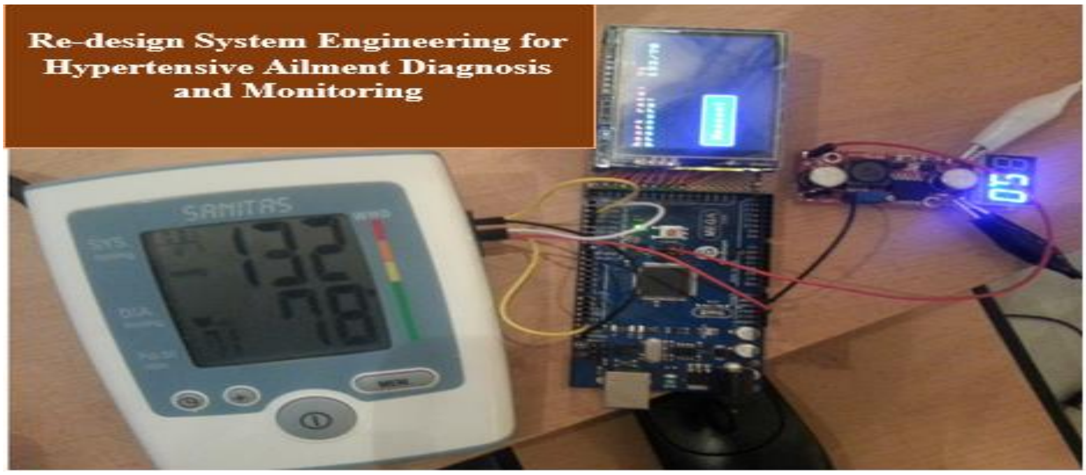

Figure 4: Hardware system implementation

The signals from the pressure sensor is conditioned with an op-amp circuit before data conversion by an analogue-to-digital converter. The systolic pressure, pulse rate and diastolic pressure are then computed in the digital domain using an appropriate technique for the type of monitor and sensor used. The resulting systolic, pulse-rate and diastolic measurements are displayed on an LCD, time/date-stamped, and stored in non-volatile memory.

3.1 Hypertensive Data Evaluation GUI

The patient data is evaluated using the developed expert system based on Android operating system. Figure 5 shows the evaluation page of the expert system where the patient inputs all the necessary data such as the pulse rate, systolic pressure, diastolic pressure and BMI and Figure 6 illustrates the patient evaluation pages.

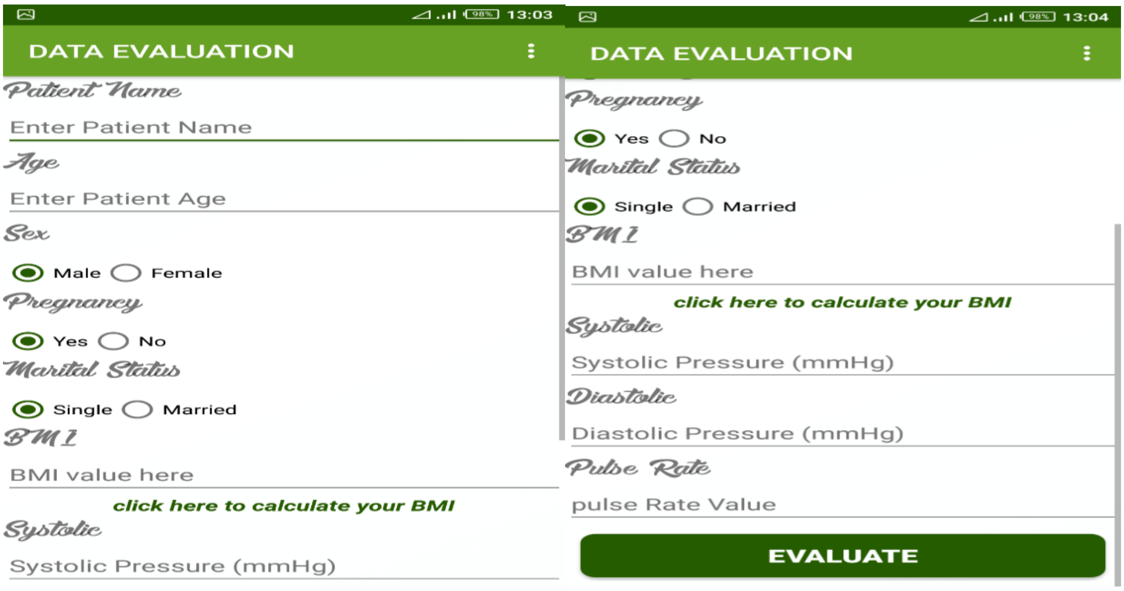

Figure 5: Data evaluation GUI for the expert system

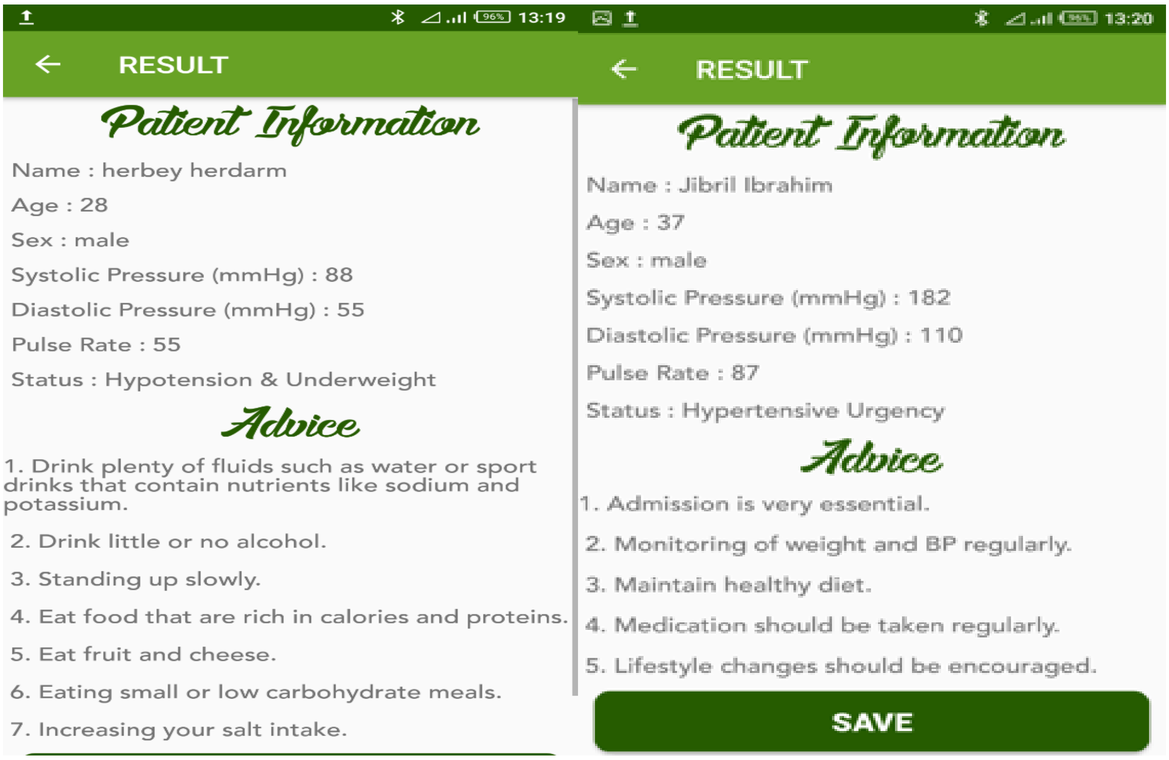

Figure 6: GUI result for hypertensive patient diagnosis with expert system

3.2 Result Analysis of Hypertensive Ailment Diagnosis

The statistical analysis for the research was done using Python programming language, data were analysed in anaconda environment. Continuous variables were expressed using mean. Categorically variables were presented as frequencies. Logistic regression analysis was used to test the significant determinant of hypotension, normal-tension and hypertension of the male participants of about 626 and 464 female in the survey that took place in the city of Minna as contained in Tables 1 – 3 and Figures 7 – 9 respectively.

Table 1: The summary of hypotension, normal-tension and hypertension of the male participants.

Variables	N	Hypotension	Normal-tension	Hypertension
Total	624	100	240	284
BMI (*kg/m2*)				
Underweight	53	35	15	3
Normal	350	21	200	129
Over weight	112	14	18	80
Obese	60	18	4	38
Extremely Obese	49	12	3	34
AGE (*year*)				
18-24	102	36	60	6
25-34	215	17	135	63
35-44	110	19	27	64
45-54	80	12	9	59
55-64	76	11	7	58
65-79	41	5	2	34
MARITAL STATUS				
Single	317	53	195	69
Married	307	47	45	215

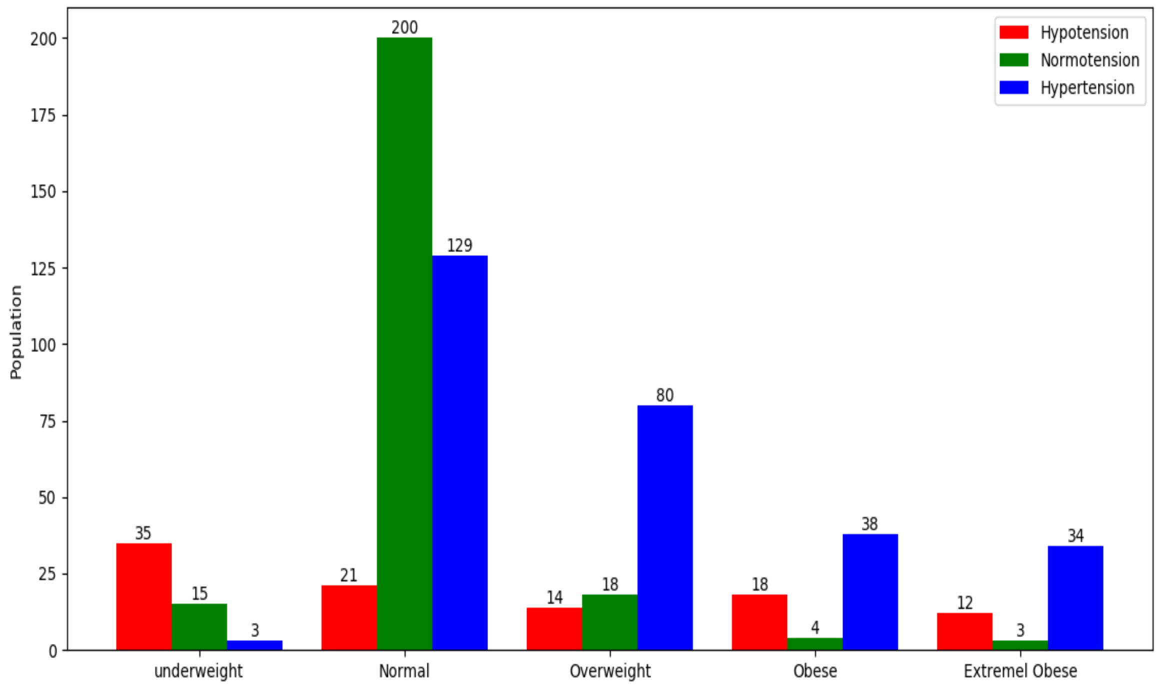

Figure 7: BMI specific summary of Hypotension, Normal-tension and Hypertension of Male

Table 2: The summary of hypotension, normal-tension and hypertension of the female participants

Variables	N	Hypotension	Normal-tension	Hypertension
Total	376	76	190	110
BMI (*kg/m2*)				
Underweight	33	20	9	4
Normal	200	31	112	57
Over weight	86	14	40	32
Obese	30	6	20	4
Extremely Obese	27	5	9	13
AGE (*year*)				
18-24	80	36	40	4
25-34	93	19	52	22
35-44	75	11	47	17
45-54	60	5	25	30
55-64	38	3	16	19
65-79	30	2	10	18
MARITAL STATUS				
Single	173	60	92	21
Married	203	16	98	89
PREGNANCY				
Yes	35	1	7	27
No	341	75	181	83

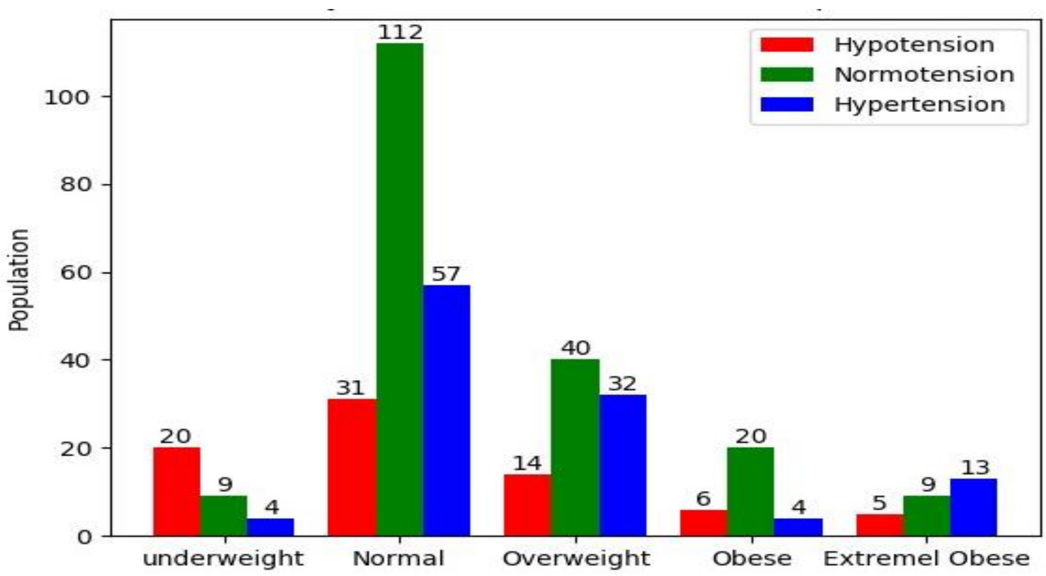

Figure 8: BMI specific summary of Hypotension, Normal-tension and Hypertension of Female

Table 3: The overall social-demographic characteristics of hypotension, Normal-tension and hypertension in the City of Minna, Nigeria.

Variable	N	Hypotension, n (%)	Normal-tension, n (%)	Hypertension, n (%)	Mean
Total	1000	176 (100.0)	430 (100.0)	394 (100.0)	
AGE (*year*)					47.7
18-24	182	72 (40.9)	100 (23.3)	10 (2.5)	
25-34	308	36 (20.4)	187 (43.5)	85 (21.6)	
35-44	185	30 (17.0)	74 (17.2)	81 (20.5)	
45-54	140	17 (9.6)	34 (7.9)	89 (22.6)	
55-64	114	14 (7.9)	23 (5.3)	77 (19.5)	
65-79	71	7 (3.9)	12 (2.9)	52 (13.2)	
BMI (kg/m2)					28.4
Underweight	86	55 (31.3)	24 (5.6)	7 (1.7)	
Normal	550	52 (29.5)	312 (72.6)	186 (47.2)	
Over weight	198	28 (15.9)	58 (13.5)	112 (28.4)	
Obese	90	24 (13.6)	24 (5.6)	42 (10.7)	
Extremely	76	17 (9.7)	12 (2.7)	47 (11.9)	
GENDER					495.6
Male	624	100 (56.8)	240 (55.8)	284 (72.1)	
Female	376	76 (43.2)	190 (44.2)	110 (27.9)	
MARITAL STATUS					495.6
Single	490	113 (64.2)	287 (66.7)	90 (22.8)	
Married	510	63 (35.8)	143 (33.3)	304 (77.2)	

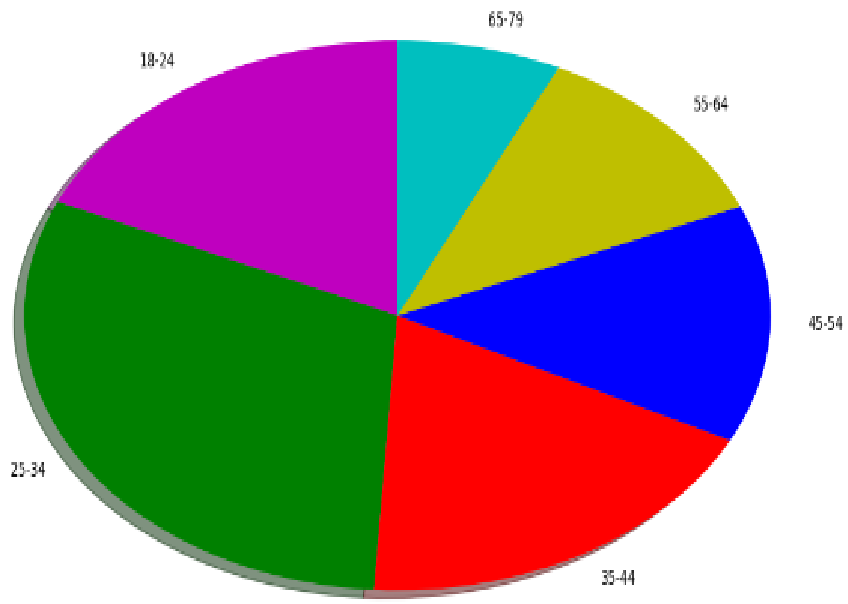

Figure 9: Age specific summary of the participants in Minna City

4. Conclusion

This paper proposed a medical expert system for early detection of hypertensive patient, ailment diagnosis and characterisation with medical advice based on decision-making. Early detection of ailment or diseases in human has called for smart intelligence system healthcare development. Some of the major problems that both populated and less populated countries are facing is the difficulties in early ailment detection and treatment of ill health people. This is due to minimal number of medical expertise and resources available in various hospitals which leads to spending of huge affluence of their resources to meet those challenges, but still demanding for adequate medical services provisions. The developed medical expert system is proficient, accurate and avoid time-waste in patient diagnosis with adequate professional advice on the ailments.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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