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Design an Archetype to Predict the impact of diet and lifestyle interventions in autoimmune diseases using Deep Learning and Artificial Intelligence

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Abstract: Deep Learning Algorithms are used extensively for diagnosis and to predict various health factors in the healthcare system for better accuracy and precision. Due to recent developments in Artificial Intelligence, the prediction accuracy rate is high with Deep Learning models. Autoimmune diseases are about 80 different types; 8% of the global population is suffering from these conditions nowadays, and 3 quarters are women amongst these sufferers. Autoimmune diseases are chronic inflammatory diseases caused due to persistent inflammation; the traditional treatments result in various side effects and eventually damage the tissues and organs. Diet and lifestyle interventions help to relieve the disease symptoms, increase mobility, enhance wellbeing, and expedite treatment process. A healthy diet recovers the gut and reduces inflammation in the body which aids to relieve the symptoms of the disease, reducing pains, and increasing strength. Healthy lifestyle choices are beneficial for stress reduction to provide a positive environment for the body and mind to heal naturally. There is a lot of research yet to be done in this area based on Deep Learning techniques. This paper intends to find the impact of diet and lifestyle interventions in autoimmune diseases using Deep Learning algorithms for better understanding to individuals who are seeking help to lead a healthy life. WEKA open-source software tool is used in this article to create models based on Deep Learning techniques such as ANNs, CNNs, and RNNs. Datasets were downloaded from Centres for Disease Control and Prevention (National Center for Chronic Disease Prevention and Health Promotion).

Keywords— Deep Learning, Artificial Intelligence, ANN, CNN, Algorithm, Diet, Lifestyle, Autoimmune.

I. INTRODUCTION

A. Background:

Technological developments in the last decade in Artificial Intelligence (AI) have given a scope to improve the healthcare system in various aspects such as robotic surgeries, adaptive learning systems, predictive and recommendation systems, innovative drug discovery, and smart systems adaptation. Relentless research and development in Machine Learning (ML) and Deep Learning (DL) unravelled faster and smarter way of dealing with complicated diseases. DL algorithms have the potential to process huge datasets to find meaningful data patterns. DL algorithms are the finest to diagnose images and speech in healthcare. Unabated efforts of engineers, physicians, governments, and associated authorities are making a huge difference in the health care systems in the modern world. The research and development in open-source applications have led to experimenting with DL models to work efficiently to improve the accuracy and precision of results.

Autoimmune diseases are chronic conditions caused due to genetics, infections, food sensitivities, and imbalance of the gut microbiome. The leaky gut syndrome causes sensitivity to many foods hence the immune system attacks own body tissues lead to pathogenesis of Autoimmune Disease (AID) and comorbidity. The imbalance of the immune system for years continuously affects the body cells, tissues, joints, skin, muscles, and organs. Chronic inflammation is associated with disease symptoms, increased pains, immobility which contributes to psychological conditions. Inflammatory foods increase the inflammation due to which the disease symptoms raise, even the high doses of anti-inflammatory drugs are ineffective until these foods are removed from the diet. In conventional treatments, steroids are used in treating these conditions, which leads to severe side effects. Long-term usage of steroids contributes to major concerns such as suppressing the immune system, hypersensitivity reactions, prone to infections, and comorbidities. The most important factors of treatment in autoimmune conditions are adapting to healthy diet and lifestyle changes in addition to medications. If autoimmune conditions are not properly diagnosed and treated on time, it might lead to comorbidities and life-threatening diseases. There are about 8% population is suffering from these conditions and 80% are women sufferers, AID being 3rd top disease in the world [1]. AIDs are commonly seen in children and youth nowadays, hence this area of research is critical to have a healthier life for a younger generation. With the awareness of these conditions and precautionary measures, anyone can avoid suffering from AID and improve the quality of life.

B. Problem:

To treat AID, physicians prescribe medications to suppress the immune system, which in turn creates plenty of side effects. AID symptoms vary based on quality, digestion, and absorption of food, gut health, quality of sleep, stress management, many other lifestyle habits. Artificial Intelligence technology used to create applications for measuring food nutrition levels with Image recognition process, which takes the food items as input, then acts as a food journal to follow healthy eating habits easily. [2] Most autoimmune conditions occur due to unhealthy diet, environmental factors, and genetics. Diet is the easiest component to modify for disease remission, hence dietary factors are the most important in reversing autoimmune conditions. Individuals despair to follow a healthy diet and lifestyle since immediate remission is not noticeable therefore, they are not able to implement the diet effectively with customizations. In most of the cases, patients are unaware of AID symptoms, they visit the physician after worsening their mobility and cannot perform daily routine activities. According to research, autoimmune conditions are affected one or two decades before the disease onset. If anyone in the family is suffering from autoimmune conditions, they need to be extra cautious towards unhealthy diet and lifestyle habits. With the advent of analytics and AI, further studies are to be done in this most important area to evaluate the benefits of a healthy diet and lifestyle changes. Enormous developments that took place in ML and DL algorithms in this decade have led to the feasibility of additional research in this area. The relativity between the healthy diet and lifestyle factors in association with AIDs needs to be studied with the best model predictions in DL. Combining the technological advancements in AI and healthcare facilities is the need of the hour now.

C. Contribution:

There is dominant research of studies and inventions to recognize food as input to applications using AI techniques to maintain diet and nutrition values, but there is yet to do a lot of research to prove that various diets and lifestyle changes drastically improve the disease symptoms and provide remission to AID prevalence, which can promote the individuals to follow a healthy diet and lifestyle choices to progress towards the good prognosis of health. There are research articles available on ML Algorithms, but there is not enough research done with DL models as

the datasets required for DL must be large enough to experiment. Various healthy diets have been recommended for AID, still, more research yet to be done to know the influence of these interventions for validating disease symptoms improvements. This paper investigates the relationship between diet and lifestyle changes with disease symptoms progression in AID using DL techniques.

D. Deep Learning:

Deep Learning techniques simulate the human brain neurons and signaling mechanism. In DL there are 3 main components like Neuron is the center of a network, Dendrites is like branch and receiver, Axon is like a transmitter. DL algorithms work with supervised and unsupervised data. Artificial Neural Network (ANN) is connected to synapses which are like connectors from input layers to neurons with assigned weights. In ANN, weights are adjusted and trained in the gradient descent optimization technique which back propagates errors in the network, adjusts the weights accordingly to reduce the error for accurate results. ANNs are used mainly for regression and classification mechanisms. The activation function applied in the 2nd step by adding weights to input values which will pass the values to 3rd step to yield output values as shown in fig. 1:

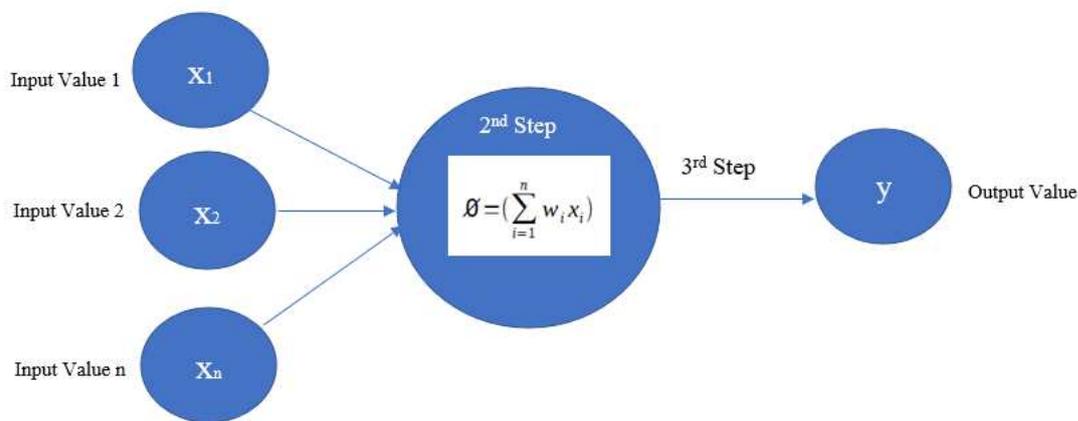


Fig. 1: To illustrate the activation function

Primarily DL consists of 4 activation functions used widely: Threshold, Sigmoid/Logistic (fig. 2), Rectifier, and Hyperbolic Tangent (fig. 3). Threshold function is simple to apply, if the value is less than 0 it passes 0, if value is more than 0 then it passes 1:

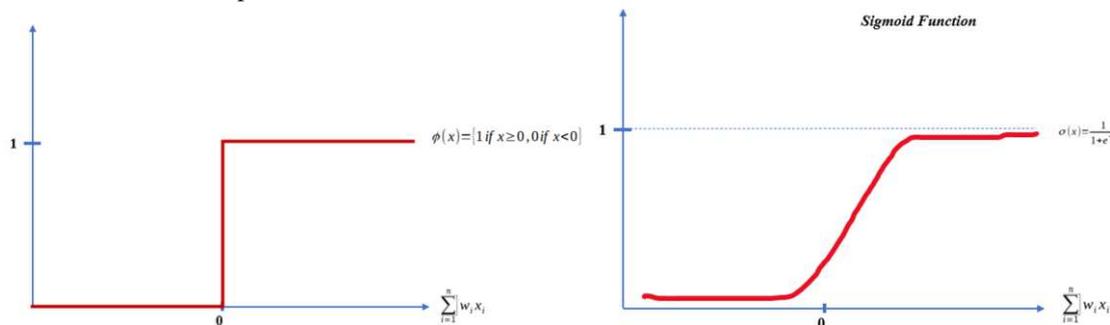


Fig. 2: To illustrate Threshold function and Sigmoid Function

Sigmoid function is the easiest to apply and it is useful in predicting probabilities. Sigmoid Function formula [3]:

$$\sigma(x) = \frac{1}{1+e^{-x}}$$

Typically, the Rectifier activation function implemented with hidden layers, most widely used in ANNs and the Sigmoid activation function implemented with output layers.

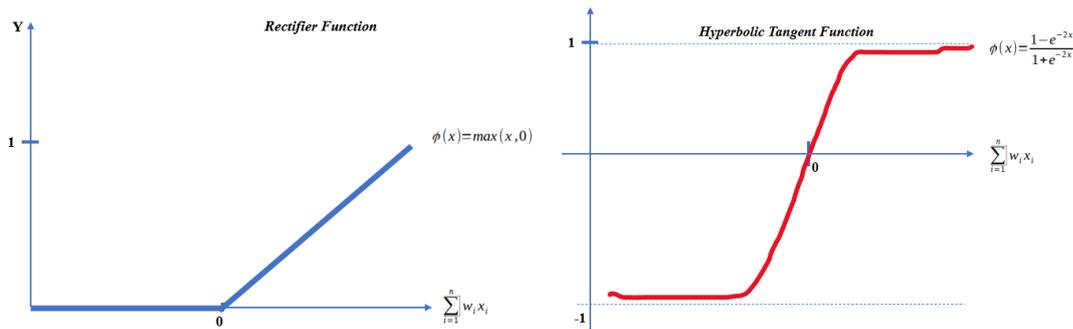


Fig. 3: To illustrate Rectifier function and Hyperbolic Tangent Function

The difference between ANNs and CNNs, the hidden layers are fully connected in CNNs. CNNs are used in Computer vision projects; they are popular due to their extended usage in many industries such as self-driving cars, social media, and healthcare. In CNN, Feature detectors, Feature maps, Pooling, and Flattening aid to find features in the images faster and avoid overfitting of data by maintaining the main structure of an image. Pooling attains invariance by lessening resolution of feature maps. Max pooling and subsampling are 2 different pooling techniques. “The subsampling function,

$$a_j = \tanh\left(\beta \sum_{N \times N} a_i^{n \times n} + b\right)$$

takes the average over the inputs, multiplies it with a trainable scalar β , adds a trainable bias b , and passes the result through the non-linearity. The max-pooling function,

$$a_j = \max_{N \times N} (a_j^{n \times n} u(n, n))$$

applies a window function $u(x, y)$ to the input patch and computes the maximum in the neighborhood”. [4]

Recurrent Neural Network (RNN) used for time series analysis, hidden layer feeds itself to facilitate analysis of temporal data. ANN, CNN, and RNN algorithms can be implemented with Supervised data. Rectifier functions are used as a filter to reduce linearity and to increase non-linearity in a network. In Fully connected NN, each node connects in one layer to other layer nodes; they are structure agnostic hence no assumptions are required to form regarding input. [5]

Unsupervised learning includes Self-organizing Maps (SOMs), Boltzmann Machine (BM), and Autoencoders popularly used in various industries due to the nature of data; DL provides the opportunity to analyze this type of data. SOMs reduce the dimensionality to understand the data better. Boltzmann Machines are undirected model nodes that are interconnected with each other, bidirectional without an output layer. BM types include Energy Based Model (EBM), Restricted Boltzmann Machines (RBM), Deep Belief Networks (DBN), Deep Boltzmann Machines (DBM). In RBMs hidden nodes and visible nodes cannot connect to each other, this learning model is like CNN. The contrastive Divergence algorithm grants RBM to learn. BM does not work successfully with scaled-up data. RBMs are used to construct Deep Belief Networks using Boltzmann Machines, there is no output layer, there is no interactivity between same layer units with different layer units. DBN model uses multiple layers of RBM, RBMs are trained with Greedy layer-wise algorithm and wake-sleep algorithm. Unlabelled smaller no. of layers architecture such as Autoencoders which encodes itself; it uses directed type of network. Autoencoders aim for the output identical to inputs, hence they are not fully unsupervised algorithms, these are used for feature extraction, and to build strong recommendation systems. In autoencoders, target output represents input itself using stochastic gradient descent. There are 3 autoencoder regularization techniques; Sparse autoencoder, where the larger hidden than input layer, and technique implemented to prevent over-fitting or stabilize the algorithm. Denoising autoencoders depend on random generation of values. Autoencoders are designed to counter the problem when over-complete the hidden layer in the autoencoder, it extracts features without learning important features. Contractive autoencoders add the penalty to loss-function which propagates back through the network. Stacked autoencoders are normal autoencoders stacked up; Deep autoencoders are RBMs stacked on top of each other, and they have more hidden layers to achieve an autoencoding mechanism.

II. Literature Survey

A. Existing Research:

Contribution of AI, ML, and DL algorithms in Autoimmunity:

Infections, Ecology, and Nutrition are the reasons for increasing AID. The rate of occurrence and prevalence is increased to 12.5-19.9% and 19-62.2% worldwide respectively in the last 30 years (fig. 4), Celiac Disease is being highest in European countries. Neurological, gastrointestinal, endocrinological, and rheumatic disease groups are affected by AID. These diseases can be prevented by changing diet and lifestyle. [6]

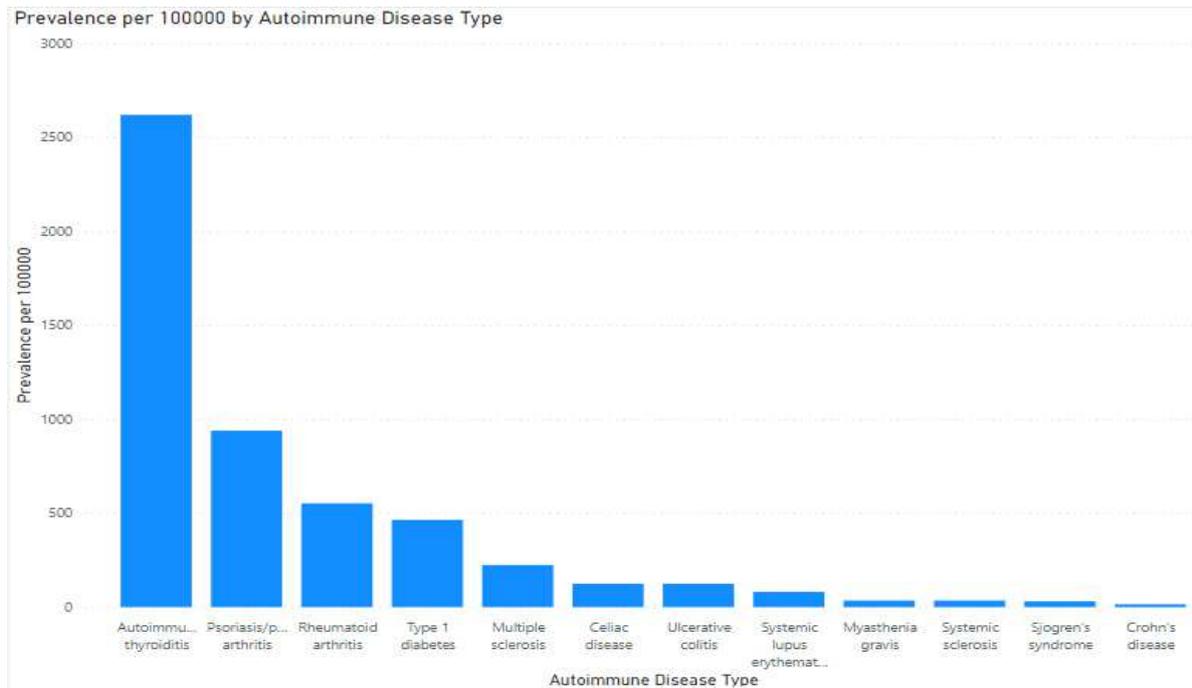


Fig. 4: Illustrates the prevalence of autoimmune diseases per 100000 population [7]

Individual nutritional health status depends on nutritious food, diet habits, phenotype, physical exercise, and metabolic rate parameters. Customized Nutritional protocols are provided using technologies such as genomics, metabolomics, proteomics with the systems biological integration. Personalized diet recommendations are proven to be having a greater effect than generic diet plans. Data-driven methods measure the effect of nutrients on gene expression, genetic disparity, and lifestyle factors on gut microbiota reactions, which enabled us to understand individuals' diet requirements. Bigdata and ML algorithms enabled with static data such as Electronic Health Records (EHR) and dynamic data such as meal details, gut microbiota structure, metabolism, stress management, and sleeping hours as parameters to create personalized dietary recommendations, which could prevent further diseases for better disease management. Wearable sensor devices with data input, integrated with EHRs enable the process of creating automated systems using ML and AI technologies. ML models are created for predictive mechanisms of 10,000 virtual Crohn's disease patients based on immunological changes using genotype and metabolic features. Advanced approaches of ML Techniques identified new molecular biosignatures as biomarkers to create specified diet plans. [8] Among AI Algorithms Artificial Neural Network (ANN) models proved to be popular in nutritional research. ML algorithms are used widely in the clinical studies of nutrients and their effects on the human body in health, disease, and gut microbiome areas. Fuzzy neural networks are used by converting into neural networks extending to achieve better accuracy, precision, and simplification of the models [9]. ML algorithms were used to predict people's overeating habits as accurately as 71.3% and dietary lapses were predicted using Decision Trees with 0.72 accuracies [10]. Deep Learning-based tools such as FoodAI are available to calculate total calories and diet recommendations based on food images input entered by users easily. [11] Inadequate diet and inactive lifestyle impact disease treatment and progression in asthma patients. [12] Proper nutrition, supplements, adequate sleep, exercise, and techniques to reduce stress will improve the women's (as shown in fig. 5 women sufferers are high with AID) endocrine system and fertility rates. [13]

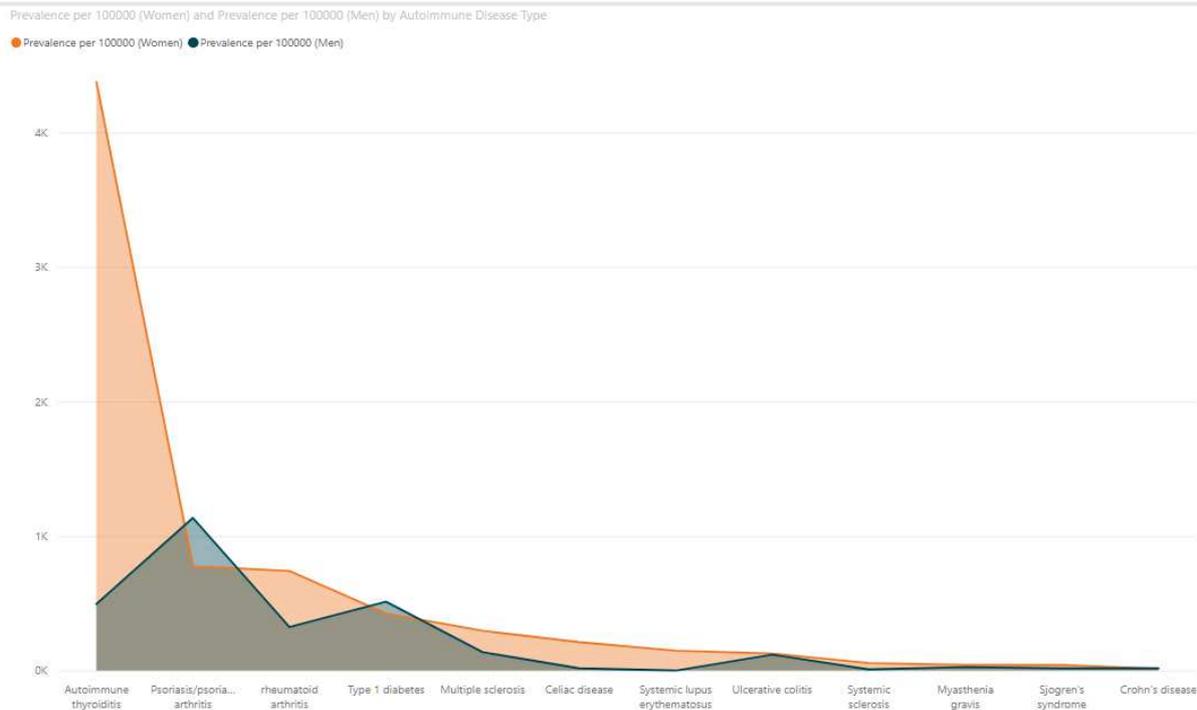


Fig. 5: To illustrate Autoimmune diseases among Women are high [7]

ML and DL algorithms are used essentially in healthcare diagnosis to arrest the disease progression and provide treatment options like primordial prevention. Early diagnosis of disease will lead to greater benefits; AI is playing a big role in predicting the models with the biomarkers and other pathological tests based on which the clinicians can make better decisions for the prognosis of the disease. AI technology is being pioneered in healthcare in terms of diagnosis, prediction, recommendation, and automation. AID shows the symptoms after a long period of manifestation of the disease. Early detection of disease is essential to avoid delays in treatment and organ level damages. Precision Healthcare (PH) techniques are considered to prevent and reduce disease progression. The cost of the treatment to serious illnesses such as Inflammatory Bowel Disease (IBD), RA, Systemic Lupus Erythematosus (SLE), Multiple Sclerosis (MS), and Psoriasis is too high to control the symptoms as the disease grows older hence early detection and treatment will reduce the cost of treatment for patients. DL algorithms are extremely helpful for classifying diseases and segregating patients depending based on their molecular structure. Antibodies test reports are the basic feature to classify the disease and potential risk factors of other diseases in co-morbidity cases. DL algorithms and predictive models classify these conditions faster and provide quick recommendations to clinicians for further treatment processes based on antibodies, biomarker's test reports, and patient's disease history. Research shows that many healthcare professionals are interested in treating advanced cases rather than preventing the diseases at an early stage, hence PH to be trained to clinicians as well. This research paper suggests that the PH system highly recommends healthy lifestyle interventions to increase the effectiveness of the treatment. Few antibodies such as anticardiolipin are linked with Anti-Phospholipid Syndrome (APS) and SLE disease, by finding this test results positive indicates that the patient is likely to get SLE in a few years. DL algorithms can detect markers such as mean, max, and correlation coefficient values to recommend the clinicians appropriate treatment plans to eliminate co-morbidity in AID. Glycoengineered Antibodies is the new and emerging treatment options in AID according to recent research. Patients' categorization and appropriate treatment options are key factors to arrest the progress of autoimmunity in individuals using DL algorithms at an early stage. Companion diagnostic approach is helpful to predict the outcomes of treatment, which can contribute to developing beneficial therapeutics and to develop drugs with a high success ratio. [14]

Deep learning (DL) algorithms can analyze an enormous amount of unlabelled and uncategorized data with high computing resources on large datasets. These models' prediction and accuracy rates are higher than ML algorithms since the models can train repetitively to obtain the best results. In recent years, enormous development has taken place in DL algorithms due to open-source software availability, cloud storage, infrastructure cost reduction, and increased availability of high-performance computing solutions. DL algorithms provide a solution for analytics of large data to extract intricate data patterns, categorization, high-speed access, and faster processing. DL models learn the features of legendary movements with multi-modal data to advise fascinating content including different types of emojis. DL algorithms can analyze live streaming data in addition to static data. DL algorithms perform

distinctively on automated extracting of intricate data features using hierarchical learning architecture methodology to train the models in deeper layers. DL models are enormously used in Natural Language Processing (NLP), accurate speech recognizing, and computer vision such as image categorization, detecting objects and recognizing faces. DL algorithms are essentially used to extract the data abstractions of huge and intricate raw datasets, whereas ML algorithms are insufficient to obtain the outputs with high accuracy. DL models learn the data patterns and correlations beyond neighbor nodes in multiple layers with hierarchical architecture by passing the output to the next layer to get the best outputs in a nonlinear fashion. The final node output transforms to result with more accuracy in terms of features to classifiers, and data indexing. Huge amounts of Bigdata datasets are the perfect match for DL algorithm models to train by using cloud resources and Graphics Processing Units (GPU) with parallel computing resources. [15] The robust scalability and adaptability of the DL algorithms are incomparable to ML algorithms with heavy processing capabilities.

Developments in AI technology can detect data patterns even with complex, unsupervised, and huge datasets in medical care systems. AI usage in the pharmaceutical industry for new drug discovery due to the technological advancements recently in ML and DL models. Many clinics are implementing targeted therapies using AI technology. AI-based systems are competing with humans in classification, image categorization, and games. DL algorithms are used extensively in aging research projects essentially in biomarkers such as pathological tests, image segmentation, speech recognition, scanning, and MRIs. [16] DL algorithms experimented with supervised and unsupervised data in lung and pancreas cancers to categorize malignancy. These types of cancers are detected based on the kind of nodule, intensity, size, shape, and texture; 3D CNNs are appropriate to extract the attributes without losing important content of data from scan reports.

Holographic images are categorized and segmented accurately with 3D CNNs. SVM and RF classifiers are used to predict the risk assessment by categorizing and segmenting the images in addition to CNNs on unsupervised data. Unsupervised algorithms are deemed remarkable in image, and voice categorization for large datasets where labeling data is a cumbersome process. [17]

AI technology's contribution is remarkable in achieving the highest accuracy in predicting meal images by segregating the foodstuffs. DL algorithms are used extensively to stratify the foodstuffs for applications to calculate the total calories of a meal including micronutrients count due to efficient categorization algorithms. CNN's are most widely used for image categorization in numerous sectors such as healthcare, finance, and automobile industries. [18]

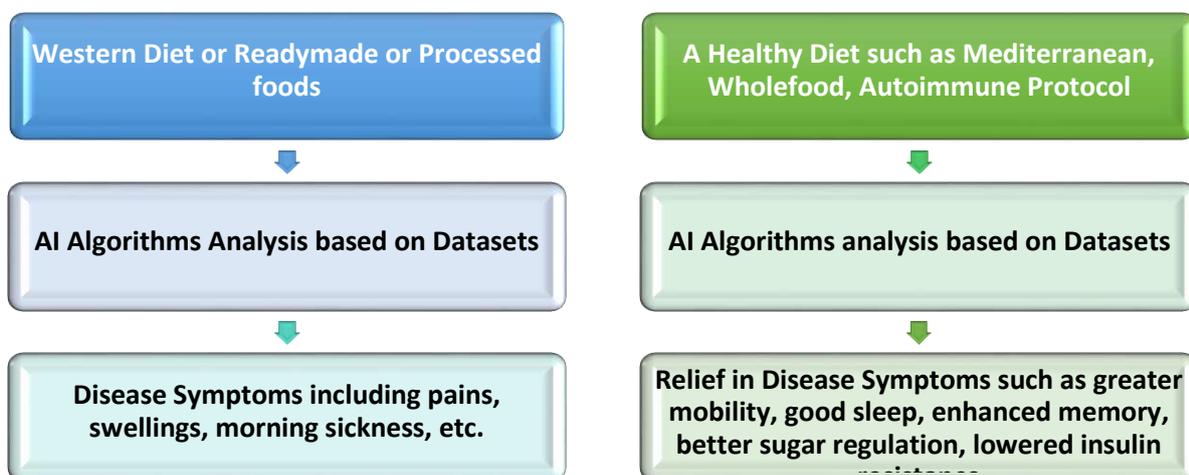


Fig. 6: To illustrate the analogy of AI Algorithms can detect Datasets based on Diet type to validate the improvements in disease symptoms

Data collected from various online platforms such as virtual communities in healthcare are fed to DL algorithms to generate the best accuracy and precision, models (fig. 6 for illustrative purpose). Many online applications and groups are supporting patients virtually to tackle AIDs which is not only affected physically but mentally and financially as well. Numerous health gadgets integrated with IoT technology provided the opportunity for patients to share their illness-related data, and to get primary healthcare support. Online data is processed with variables by DL algorithms such as NLP, Clustering to identify the important data patterns to variate the diseases, diagnosis methods, and treatment options. [19] The data fed to IoT devices and online platforms are used for analytical purposes by ML and DL models to train, learn, predict, diagnose, and provide recommendations to clinical practitioners. Guided therapies and preventive mechanisms allow the practitioners to help the patients to keep the chronic diseases away.

Autoimmune disease manifestation, potential causes, consequences, and remedies:

Autoimmune diseases are manifested by gut dysbiosis caused due to increased intestinal permeability. Genetic predisposition, environmental factors, and an unhealthy diet could contribute to the susceptibility of AID in children and adults, diet is the most integral part of the human body. Processed or fast foods consumption leads to gut lining tear off that causes waste or food particles to enter the bloodstream leading to many diseases, if this continues for a long period, it might result in chronic inflammation and AIDs. High amounts of salt added to enhance the food flavors, to increase products shelf life, and processed sugars to attract the taste goblet make young population eat food in excess even if they are not hungry. High sugars in processed foods make the children obese at early age manifests to other ailments in adult life. An unhealthy diet for a prolonged period from an early age can lead to severe health conditions such as autoimmune co-morbidities. Due to the modern busy lifestyle and time constraints, many people buy readymade foods for easy access, which has led to consuming a lot of packaged foods loaded with preservatives and nutritionally deprived in comparison with freshly prepared food. Conversely, nutrient-dense food nourishes the body, repairs the cells, and balance the immune system. Anti-inflammatory diets have shown greater results in promoting good health and vitality. Quality food choices provide an opportunity to revert the autoimmunity and possibly can prevent further co-morbidities associated with autoimmune. Readymade gluten-free processed and packaged products have a more adverse effect on children due to lack of micronutrients and high sugar contents, hence advisable for them to adopt a diet with whole and natural ingredients to reduce Celiac Disease symptoms. Highly processed foods impact insulin resistance which may cause high blood pressure, obesity, and diabetes. Gut flora impact largely the bacterial growth ratios and imbalance in the digestive system. Breakfast granola, cereals, many readymade foods for infants, toddlers may imbalance the gut micro-flora and promote an inflammatory response in the body to embark on irreversible diseases. Resistant starches are believed to be an important factor to stimulate digestive health. Following a healthy diet from childhood could ward off the effects of genetic predisposition and provide good health for the long term. A well-balanced diet with natural whole grain-based and minimum processed foods promotes healthy bacteria growth in children's gut to avoid long-term diseases. Excessive usage of meat products and processed meats could develop a pro-inflammatory response from the immune system. Whole foods such as vegetables, fruits, and whole grains free of additives, preservatives, or artificial flavors with natural salt and sweets provide a healthy gut microflora. Fiber-rich foods are beneficial for good bacteria in the gut which reduces the chances of getting sick. Trans fats and high Omega-6 ratios from fried foods elicit serious health hazards for example diabetes, cancers or heart relevant diseases. [20] An adequate amount of nutrients should be the goal of a daily diet to repair the gut and avoid potential health risks. High salt intake promotes a pro-inflammatory response in the body, which eventually aggravates AIDs. Processed foods are loaded with high salt for shelf life and taste, which are harmful to healthy or unhealthy individuals. [21] Emulsifiers found in Processed foods cause an imbalance in the gut microbiome which eventually may lead to inflammatory diseases, heart failures [22], or cancers, whereas a well-balanced diet such as the Mediterranean diet proves to maintain a healthy gut environment. [23] Healthy fats such as clarified butter, extra virgin coconut oil may soothe the stomach and calms down the gut.

Cytokines and inflammatory responses are closely associated. Cytokines are released in the body to treat infections, but in the cases of chronic inflammation, an imbalance of cytokines produces AID and takes over the immune system. [24] In the Pharmaceutical industry, research is enhanced to find effective drugs for chronic inflammation with minimal side effects for example how to target cytokines and their proliferation to treat chronic diseases. [25] Along with dietary changes, supplementation is beneficial for autoimmune thyroid patients to protect thyroid gland tissues and improve the symptoms. [26] As Iron, vitamin C, and D deficiencies are very common in AID patients hence appropriate supplementation may benefit to replenish these essential vitamins and minerals. Supplementation such as antioxidants, vitamins, probiotics, amino acids play a vital role in AID patients' recovery protocols. In addition to nutrient food, supplementation aids to absorb the nutrients properly to reduce oxidative stress. Metabolomics are metabolic pathways useful to find out the AID levels and to monitor the treatment progress. Psoriasis and Hashimoto's Thyroid AIDs remission could be possible with nutrient-dense food and appropriate supplementation. In the case of Hashimoto's, Vitamin D levels are crucial to controlling TSH and thyroid autoantibodies. There are various studies regarding diets such as intermittent fasting proven to be beneficial for controlling insulin resistance issues in obese and AID patients. [27] Metabolomics can be used as inputs along with nutrients and disease-related biomarkers such as anti-TG, anti-TPO to analyze with ML or DL algorithms to train the models for diagnosis and prediction of the results. In AIDs the early diagnosis and treatment, protect the organs from further damage and comorbidities.

As per various studies in medical literature, chronic inflammation manifests AID and life-threatening diseases. Diet is the single most important factor which can be modified easily by individuals and benefitted not only AID patients but inflammatory responsive diseases such as various types of cancers, heart-related diseases, liver diseases, and diabetics. [28] Recurrent studies have shown that diets such as vegan, vegetarian, Mediterranean,

whole-food-based diets have beneficial effects on health to reduce inflammation and associated illness. Not only reducing the symptoms but also preventing these diseases in healthy individuals and co-morbidities in diseased persons (as shown in fig. 7).



Fig. 7: To illustrate the various factors to improve good health in addition to treatment

Rheumatoid Arthritis (RA) prevalence among youth especially female population is high in modern societies leading to one of the top diseases in the US and around the globe, which affects the joints due to chronic inflammation. Rheumatism is an AID due to systematic inflammation; it affects joints, ligaments, bones, muscles, and tendons causing discomfort and immobility which makes it difficult to perform routine activities, significantly affects the quality of life. Genetics and environmental factors are inescapable parameters, but dietary factors and poor lifestyle habits are playing a major role that can be controlled and monitored for the good prognosis of RA. A study has taken place in Iran under the observation of a Rheumatologist to assess the significant association between unhealthy diet and probability of rheumatism using statistical analysis with SPSS, an IBM tool in local population using factor analysis methodology and multivariate logistic regression model. Healthy diets such as the Mediterranean, low fat, vegetarian diets prove to help reduce the disease symptoms and elevate the quality of life. The underlying studies have enough evidence to prove a strong association between chronic inflammation, Insulin Resistance (IR), and RA, hence inflammation and IR can be controlled to reduce the disease symptoms by adapting to healthier diets [29]. To enhance this kind of research large datasets are to be considered for deeper analysis using robust technologies like DL. Consumption of processed foods, lack of nutrients, and physical inactivity annihilate the joints faster. The imbalanced immune system spreads the autoimmunity to other organs, tissues which turn to co-morbidities. Conventional treatments include non-steroidal or disease-modifying anti-inflammatory medicine. Steroids and biologics help reduce the disease progression, but these medicines have various side effects due to immune suppressive mechanisms. Biologics have lesser side effects, but they are very expensive, and usually they are not covered in the insurance due to high cost. In this study prescribed drug types and blood tests are considered as variables for the best prediction algorithm model on patients with two different groups one with RA conditions and another one with RA and other complications. Decision Trees are proved to be the best in terms of efficiency and accuracy for prediction models than other classifiers, and these algorithm-based techniques can be adapted easily by the clinical practitioners for treatment purposes. Among Statistical Classifiers, the J48 classifier is the best compared to SVM and Logistic regression to analyze the rate of accuracy. Data mining and AI branches such as ML and DL conform to extract meaningful patterns of data from a large volume of datasets with an advanced level of algorithms. [30] Many studies suggest that following nutrient-dense

food habits and adapting healthy lifestyle factors lead to a reduction in the disease symptoms in addition to the conventional treatments to have a pain-free and contented life.

One prevalent disease in the autoimmunity group is Celiac Disease (CD), which usually, occurs due to genetic predisposition, possibly inflict at any age, and is mostly underdiagnosed. Irrefutable that AI technology generates the best diagnostic results in processing digital images to diagnose CD in adults and children. Endoscopy is the diagnostic method to detect CD in adults by taking a sample of stomach tissues, but there are challenges to detecting gastric surface epithelium in mild cases. Computer-aided diagnostics are beneficial to find the CD biomarkers using the images of capsule or standard endoscopy with lesser resource utilization in terms of money and human efforts to produce accelerated yet higher efficient and accurate reports. AI technologies, ML, and DL algorithms have provided the efficiency to diagnose an enormous number of images with Bigdata computing resources to enhance the chances of detecting CD using advanced techniques such as chromoendoscopy and modified immersion. CNN is essentially used in image analysis, fusion, and segmentation. AI computer vision branch has enhanced to a greater level in pre-surgical, post-surgical procedures, and image-guiding therapies. Feature extraction techniques are used for the categorization of CD into 4 categories such as spatio-domain, spatio-temporal, transform domain, and scale-invariant features. CNN such as FFT layers elucidated 97% accurate results in transform-domain category features. Extracted new features are used in numerous classifiers such as Logistic Regression, Random Forest, Support Vector Machine, Naïve Bayes, and K-Nearest neighbor. [31]

Primary immune deficiency diseases (PIDD) are also linked with inflammation and autoimmunity. The imbalance of gut microbiota is suspected to be the worst offender of immune response dysfunction. PIDD patients' symptoms are identical to AID such as IBD, Celiac, and Crohn's Disease. Damage of intestinal barrier causes the immune system dysfunction to develop AIDs. Gut health and food intolerances play a vital role in immune balance. Higher rates of good bacterial in the gut have fewer chances to get AID in genetically predisposed individuals. Immunoglobulin A, IL-10 deficiency, and gut dysbiosis may lead to T cells dysfunction. Damage to the gut barrier and excess mucus cause autoantibodies production and food intolerances against a few proteins. Balancing the gut microbiome with good bacteria such as Lactobacillus hinders spreading inflammation to multiple organs thus reducing the chances of co-morbidities. Inflammation affects organs such as the digestive tract, lungs, colon, skin, liver, brain, and kidneys which could lead to AIDs. Dietary interventions could potentially correct the microbiota to improve the immune system function to get relief from disease symptoms. [32]

During the Covid-19 Pandemic, one study proposed on drugs repurposing to treat Covid-19 patients as part of a Drug repurposing strategy using DL multi-modal RBM approach. The drug repurposing process is required during the pandemic as it's a quick process and reduces the manufacturing cost and time to avail medicine faster. In this study, DL provided the best algorithms to study datasets based on chemical structures and drug-induced perturbations in cell lines. Complicated data relationships in each modality are encoded to obtain Specific Clusters which enabled to unveil of the new drugs related to Covid-19 medicines. This approach designates combining data contributes to specific clusters. Data are clustered according to drug type to fingerprint and DEG (Differentially Expressed Genes). Hidden layers are central in modalities to find relationships between discrete modalities to obtain accurate results. Drugs are categorized using contrastive divergence algorithms and clustering approaches to train the models on 12 different clusters. Properties are implemented in groups rather than separately to have better segregation of clusters. Hyperparameter optimization, RELU functions are used in this experimentation to introduce antiviral drugs for Covid-19 treatment. [33]

In this article, a proven diet application is developed by authors called "Diet4Hashi" to benefit Hashimoto's Thyroid patients. In this protocol, it's advised that processed foods, sugars, junk foods, and simple carbohydrates be avoided instead of healthy quality foods to be included in the diet. The successful implementation of this protocol in the female population gave good results in Hashimoto's Thyroid patients. This protocol is intended to support patients and provide guidance to nutritionists and physicians. [34]

Unhealthy eating habits and poor lifestyle conditions such as anorexia, binge eating is prone to raise the chances of AID in youth and adults. These habits could be due to genetic history or environmental factors. Psychological therapies help individuals to control their eating habits by following techniques to avoid unhealthy foods. [35] Immune imbalance and psychological disorders are interrelated; hence the psychological therapy sessions help the individuals during and post-treatment.

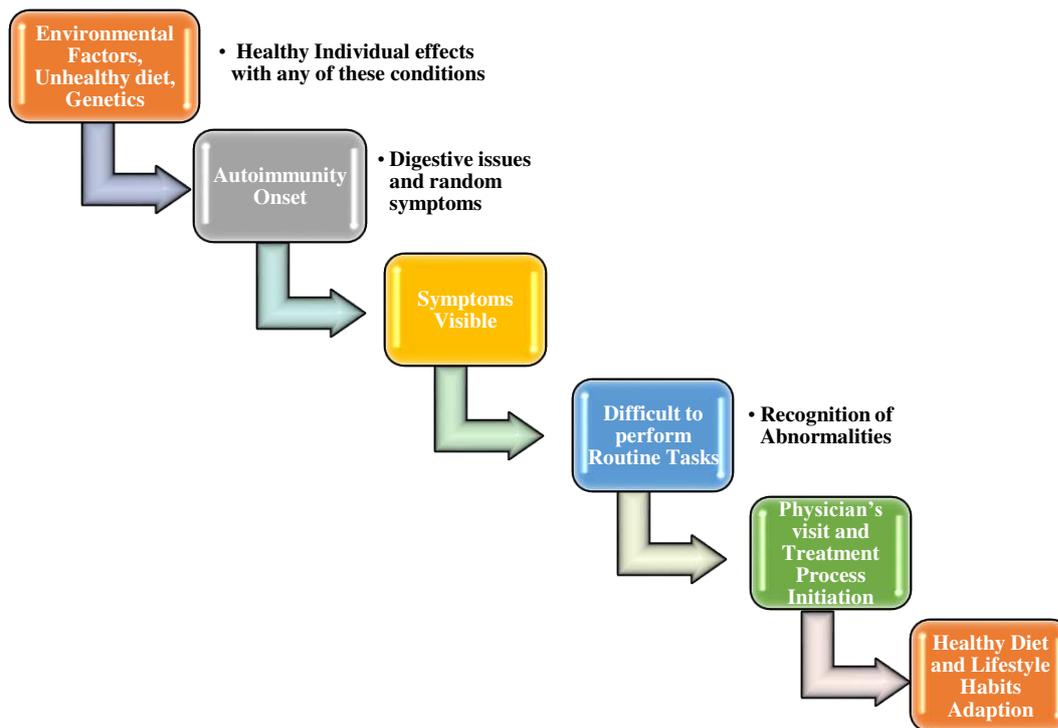


Fig. 8: To illustrate the manifestation of Autoimmune diseases

The high amount of salt in many processed and packaged foods gets attracted for tasty flavors but at the cost of the pathogenesis of several diseases including AIDs. In this review article, the authors elucidated the harmful effects of salt in AIDs and many other serious diseases. The human immune response depends on diet and lifestyle factors largely (as shown in fig.8). A high level of salt intake leads to cell-mediated immune diseases due to a heavy load on organs such as the liver. [36] Most modern societies use packaged foods for quicker access and tastier alternatives, but it puts a lot of pressure on the digestive system and important organs such as the liver and kidneys yield to many diseases.

This study revealed that there is a strong co-relationship between heart disease and the Mediterranean diet along with an active lifestyle. The pathological tests relevant to heart disease biomarkers such as lipid profile, AIP, LAP, FLI, CRP, ESR improved with guided customized diet plans and exercise sessions. [37] Obesity causes morbidity and heart-related diseases, hence keeping the body fat in optimal ranges is necessary to lead a healthy life. Even though heart-related diseases are not AID, the underlying reason is chronic inflammation. AID patients are vulnerable to heart diseases if they are not maintaining a healthy diet and lifestyle despite taking medications.

Personalized medicine is the new trend of treating patients in most of the developed countries to provide effective results based on their genetic profile, environmental, lifestyle, and diet factors. With a massive increase in data and storage capacities due to technological advancements and data revolution, personalized treatments getting explored unlike ever before. Customized treatments are a necessity to the modern world since the changes in socio-economic factors vary for everyone. Medical prescriptions and therapies are recommended based on individual diagnostic tests subject to environmental, phenotype, and lifestyle factors for even the same disease patients. Disease risk predictive models could provide accurate results by considering the diet and lifestyle factors as input since these features are potentially alterable determinants that have a high impact on the results. Optimized treatments provide many accurate results and are feasible to predict the outcomes. Biomarker tests are the most important part of diagnosis in personalized medical treatments. Disease prevention, diagnosis, and treatment are crucial steps. Environmental factors, Phenotypes, genomics, metabolomics are a few other important factors to be considered as features for predictive models in medical care. Genetic screening can be done to predict the disease risk, but they are not providing enough results due to the limitations in design, replication, and statistics. Limited algorithms are suggested for Gene expression, and there are no efficient methods analytically. Along with genetics, dynamic factors like diet and lifestyle must be considered for analysis periodically to get timely and appropriate predictions and disease classification. Data collection is one of the expensive tasks in the medical industry due to which sample sizes are not enough to study and train the models based on advanced DL algorithms; DL models' prediction rate is highly accurate and faster. The social media platform is popular to make awareness of diets and lifestyle habits to improve health conditions in an easily accessible way and free of cost, but the data

is challenging to transform and analyze. The data is derived from various platforms used for research and analytical purposes as well. Data protection and security measures [38] are prioritized on big projects initiated by governments since online threats are steadily increasing. Health records information is stored for easy access which is integrated across health providers in various cities to share the data and avail faster diagnosis process with the invention of many AI and IOT based tools in the health industry; governments are initiating the projects to integrate EHR data. Integration of streaming data and static data from various sources poses a challenge on Bigdata due to variance in features, variants, formatting, data mapping, and data interpretation techniques. A diversified approach is needed to customize the model to resolve certain issues and requirements, it cannot be one fit for all. In Big data, top-down and bottom-up approaches help design, test, and define the hypothesis, however, there are challenges and improvements needed in this field. [39] The invention of Cloud storage and Bigdata expansion [40] led to load and store ample of EHR data, which provides the opportunity to learn and train models and to create better models for the growth of health care system in terms of patient's care and new medical equipment inventions and therapeutical solutions provided for the good prognosis of various diseases across the globe. Since the farming revolution and modern techniques to yield higher crops brought many changes in food throughout the world, makes every nation must build health standards to protect the younger and older generations from innumerable diseases caused by pesticides, herbicides, hormones, antibiotics, and other chemicals. These formulated foods and various stages of processing will make the food lose its nutritional values hence instead of recovering the body, food is the reason for countless medical conditions in the human population. Improving and maintaining a balanced immune system has become a necessity to tackle new bacteria or viruses such as Covid-19; this pandemic made individuals realize that being in good health is a basic requirement.

Research suggests that Targeted Therapeutics are considerable for preventing and curing RA in patients. DL algorithms are effective to predict disease occurrence and level by training the models with appropriate datasets. Inflammation in the mouth, gut, and lungs, environmental factors including diet and stress, and genetics are suspected to be the reasons for systematic inflammation. Gum diseases must be addressed in RA onset patients as well as high-risk individuals. AI-based tools enable the prediction of personalized disease risk levels such as severe, moderate, or mild based on an individual's biomarkers (anti-ccp and RA factor) and pain symptoms. Risk classification based on mucus inflammation and dysbacteriosis is useful to find the disease prediction in genetically predisposed individuals. Healthy lifestyle changes such as diet, avoiding smoking, and stress management are more potent in preventing autoimmunity without side effects compared to immunomodulatory drugs. [41] Smoking is the biggest promoter of AID; it increases lung infections and aggravates RA symptoms. Infections, pollutants, and urban lifestyle are other factors of RA outbreak. Mediterranean diet is rich in omega-3 associated to reduce the risk of RA. [42] Research in new drugs invention and precision medicine therapies may contribute to treating the patients without any side effects, but the role of diet and lifestyle changes has a big impact to consider as a primary step since it's the easiest to adapt and inexpensive compared to any other clinical methods.

III. Methodology

Deep Learning has the potential to build and train models based on various nutritional and physical activity factors data. In this article, we have developed models based on DL algorithms such as multilayer perceptron neural network, SMO, Deeplearning4j, RBF Network and decision trees such as J48 and Random Forest to investigate the potential impact of dietary, physical activity and Arthritis disease symptoms.

Dataset is acquired and downloaded from Centres for Disease Control and Prevention (U.S. Chronic Disease Indicators (CDI)), National Centre for Chronic Disease Prevention and Health Promotion. Nutrition and Physical Activity Dataset consists of 80929 records and 27 data attributes. Arthritis Dataset consists of 62640 records and 17 data attributes. Data attributes selection done based on the meaningful data required for this study. The no. of hidden layers changed to 2, 4, 6, 8, and 10 to run the models for best predictability in MLP Algorithm. Noisy features have been removed from datasets to reduce overfitting, enhance accuracy, and reduce the time for training the models. Filter Method used to select the features; assigned the rank score to the features.

WEKA 3.8.5 open-source software tool is used to process and classify datasets. WEKA tool has a Graphical interface used for data science projects, data analysis, data mining, statistical analysis, predictions, and visualizations using ML and DL algorithms. WEKA tool can be integrated with R and java libraries. This tool evolved in the University of Waikato, New Zealand for internal research objectives. It's a NO CODE tool, easy to install, load the datasets, navigate, pre-process the data, run algorithms, visualize, and interpret the reports.

Wekadeeplearning4j 1.7.2 was installed for DL algorithms to train the models. In DL4jMlpClassifier, layer specification is chosen to use various DL techniques. In the network configuration, the optimization algorithm

selected Stochastic Gradient Descent; epochs set to 5. AutoWEKA classifier finds the best model to run the dataset with appropriate parameter settings.

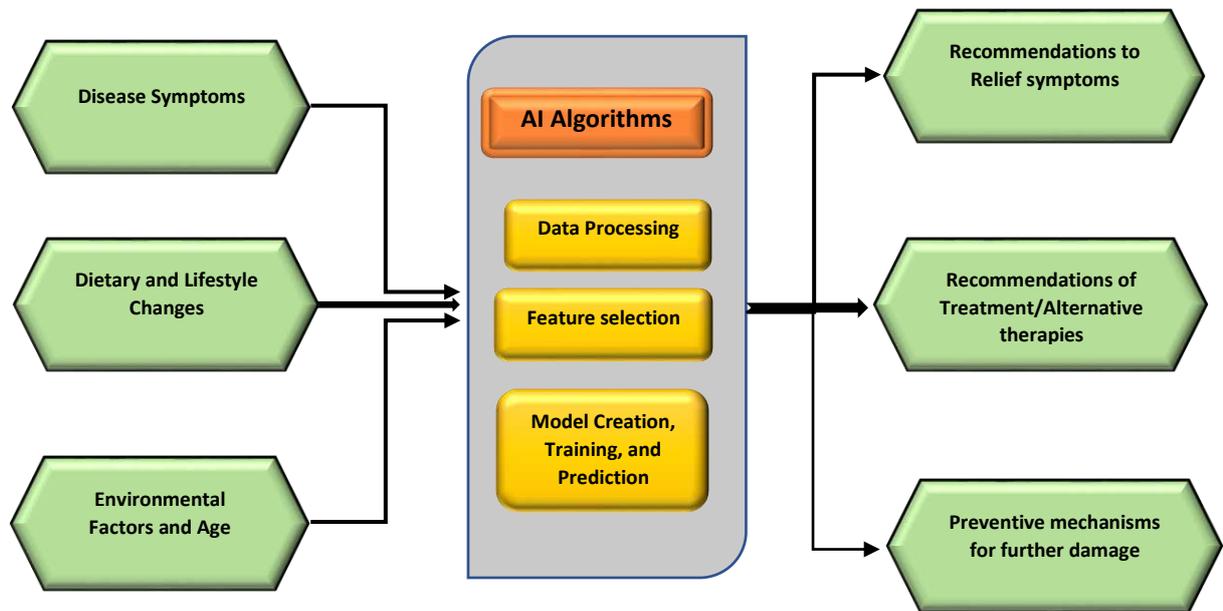


Fig. 9: To Illustrate the model using AI Algorithms

Awareness and finding the root causes of autoimmune diseases is an intricate process which has little explained in conventional medicine, hence various treatments and therapies differ based on treatment type such as conventional, functional, natural, and wholistic to correct the nutrient deficiencies, increase the energy levels, treat the gut and eventually treat autoimmune disease. fig. 9 displays the framework of AI algorithms input, output variables, and DL models activity.

Datasets were downloaded, converted files from CSV to ARFF format. Data is pre-processed with no. of instances and attributes selection required to consider for this experimentation. Weka tool displays statistics such as minimum, maximum, mean, and standard deviation calculated values on attributes section and filters used to normalize the data as shown in fig. 10.

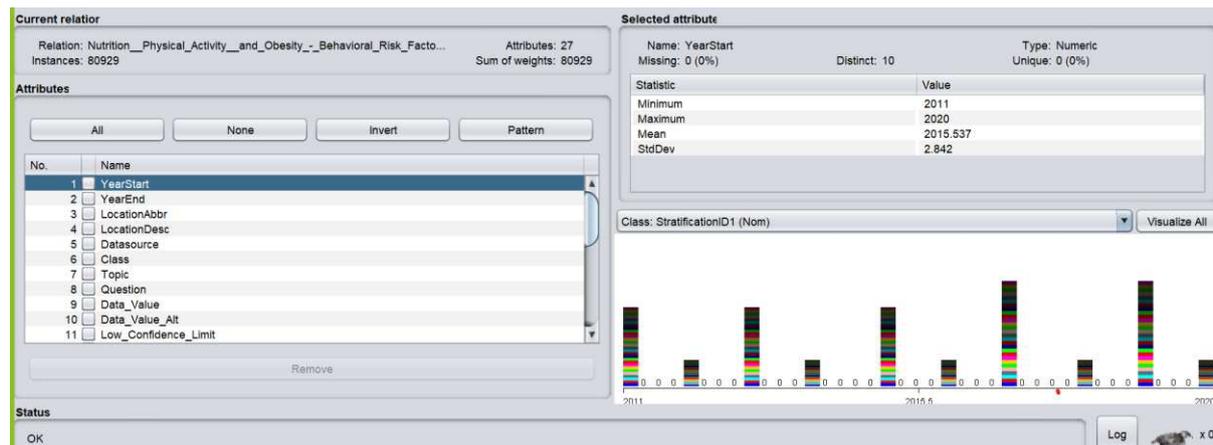


Fig. 10: To illustrate Dataset instances, attributes, weights and statistics

Multilayer Perceptron (MLP), RBF Network, Non-negative Logistic Regression, SMO, Simple Logistic Regression, SVM and decision trees such as J48 and Random Forest are considered to run the models with cross-validation 10 folds and percentage split 80 and 20 to classify the data as shown in fig. 11. Trained the models with the D14jMlpClassifier algorithm.

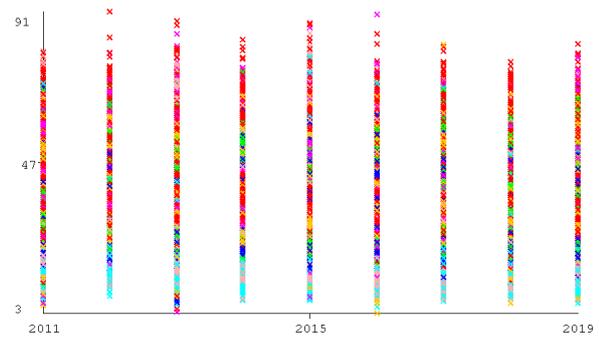
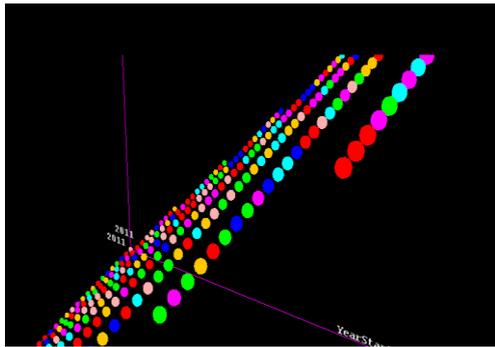


Fig. 11: Visual 3D display of Nutrition and Physical Activity Dataset model and classification based on year

The Result-list panel consists of the models run with different classifiers displayed. Out of considering the best-run model based on no. of instances correctly classified, Mathews Correlation Coefficient, Precision, ROC Curve and confusion matrix as displayed in below fig.12 and fig. 13.

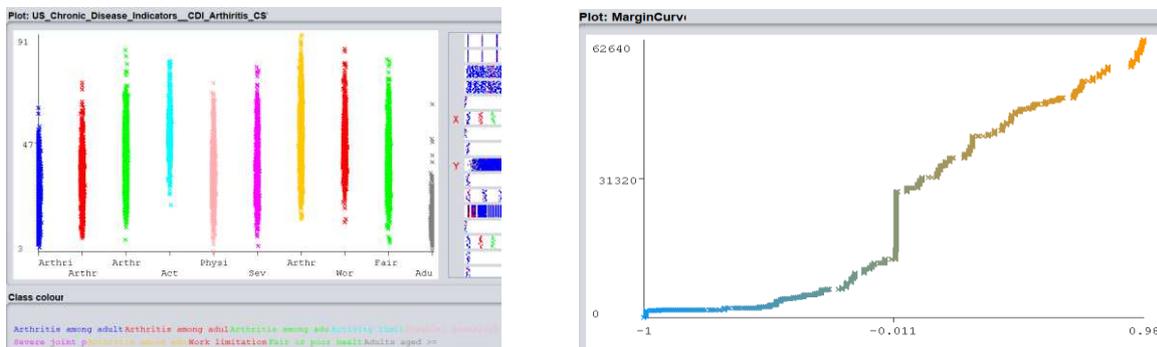


Fig. 12: Visualization of data classification and Margin curve of Arthritis disease symptoms

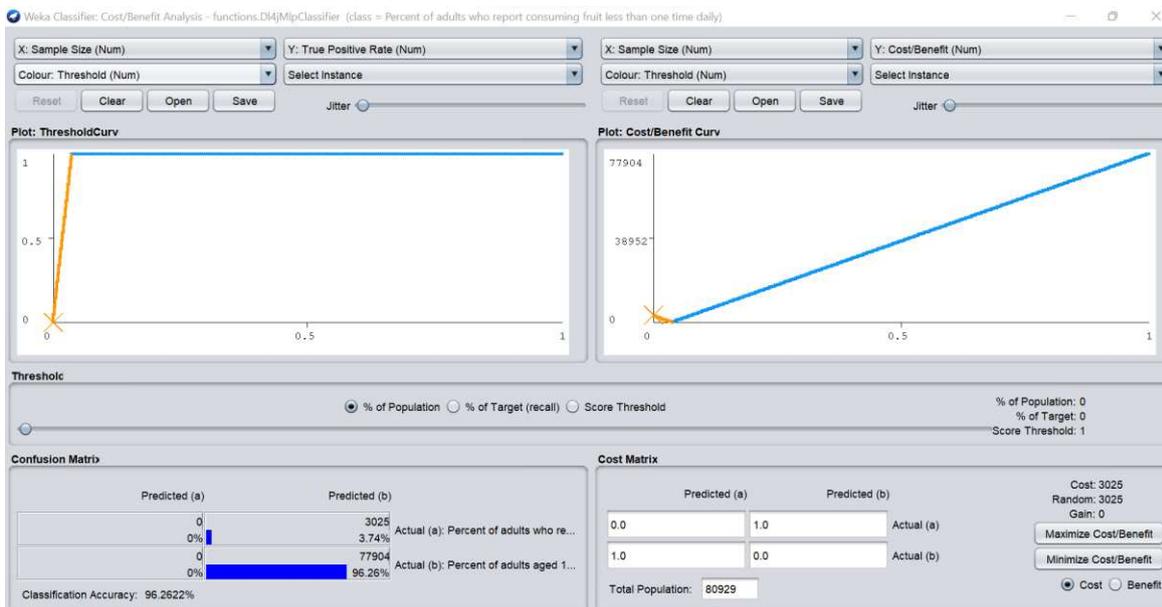


Fig. 13: To illustrate Cost/Benefit analysis of Percentage of adults consuming less fruits and confusion matrix

IV. Results

The best model prediction has been done with DL4J Multilayer Perceptron classifier with precision 1, MCC 1, and ROC Area 1 in comparison with other classifiers RBF Network, SMO, Logistic Regression, SVM and Random Forest. Based on this experiment the results show that following a healthy diet, physical activity, and

stress management has greater benefits along with treatment medications and it could potentially reduce the risk of further co-morbidities and relieve the AID symptoms in autoimmune patients.

US Chronic dataset has been used to experiment in this model of study with data values of diet and physical activity in various states of USA to classify based on Percentage of adults aged above 18 years who are obese, Percentage of adults who engaged in physical activity, Percentage of adults who engaged in muscle strengthening activity, Percentage of individuals who consumed fruits and Percentage of individuals who consumed vegetables. Among all the algorithms, DL4JMLP Classifier displayed the best output as shown in table 1.

Algorithm	Root Mean Squared Error [43]	Root relative Squared Error [43]	Precision	MCC	ROC Area
MLP Classifier	0.26	84.36%	0.876	0.744	0.982
DL4jMlpClassifier	0	0	1	1	1
SMO	0.28	90.82%	1	1	1
J48	0	0	1	1	1
Random Forest	0.05	17.59%	1	1	1
Simple Logistic Regression	0.06	19.41%	1	1	1
RBF Network	0.07	23.84%	0.972	0.968	0.998
SVM	0.07	23.84%	0.972	0.968	0.998

Table 1: Displays the algorithms performance metrics of Lifestyle factors impact data

US Chronic dataset has been used to experiment in this model of study with data values of Arthritis disease symptoms in various states of USA to classify based on Percentage of adults aged above 18 years and suffering with obesity, diabetes, heart disease, and old age. Percentage of adults who have disease symptoms such as activity limitation, physical inactivity, severe joint pain, work limitation, and poor health. Out of all the algorithms DL4J MLP Classifier showed the best results in addition to J48 Decision Tree algorithm as shown in table 2.

Algorithm	Root Mean Squared Error [43]	Root relative Squared Error [43]	Precision	MCC	ROC Area
MLP Classifier	0.23	72.19%	0.623	0.544	0.932
DL4jMlpClassifier	0	0	1	1	1
SMO	0.28	87.58%	1	1	1
J48	0	0	1	1	1
Random Forest	0.02	8.87%	1	1	1
Simple Logistic Regression	0.06	20.33%	1	1	1
Linear	0.23	79.57%	0.798	0.708	0.845
SVM	0.03	10.59%	0.995	0.994	0.997
RBF Network	0.01	4.04%	0.999	0.999	1

Table 2: Displays the algorithms performance metrics of Arthritis Disease data

V. Conclusion

Deep Learning algorithms displayed the best output in terms of MCC, precision, accuracy, ROC Area, and correct classification of data. Out of various algorithms experimented with, the DL4J Multilayer Perceptron algorithm has yielded the best results for classifying the disease symptoms and to classify data based on diet, physical activity and associated health issues. Each type of AID has different symptoms for everyone based on parameters such as age, weather conditions, symmetric or asymmetric symptoms, affected area, pain levels, immobilization, stiffness, energy levels, and memory issues. The diet elements are based on the availability, quality, and affordability of foods in their regional areas. The lifestyle factors are based on their living conditions such as urban, rural, or hilly areas, and personal status in terms of economic, social, geographical, and ethnic conditions. It's challenging to consider all the factors mentioned together to train the models to conclude the results due to data limitations, but as per the data available currently, the models executed gave the best of possible outcomes.

The goal of this experiment is to provide the best possible prediction model with DL techniques based on data of disease symptoms, diet and lifestyle changes to inspire and promote AID patients to spend a healthier life without strong medications. We conclude that Neural Networks outperform over all algorithms with these datasets. We expect future research could involve more elaborative data sets in relevant to AIDs and various types of diets implemented with AID patients' communities based on the type of disease and individual indigenous category to do more extensive experiments and studies based on their diet and lifestyle conditions.

Data availability/Availability of Data and Materials:

All data generated or analysed during this study are included in this published article [and its supplementary information files] as follows:

1. Nutrition_Physical_Activity_and_Obesity_-_Behavioral_Risk_Factor_Surveillance_System_edit_3.csv
2. US_Chronic_Disease_Indicators_CDI_Arthritis_CSV.csv

Contact Details for Data requisition:

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Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [NutritionPhysicalActivityandObesityBehavioralRiskFactorSurveillanceSystemedit3.csv](#)
- [USChronicDiseaseIndicatorsCDIArthritisCSV.csv](#)