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Prediction of Myopia Progression Based on Artificial Intelligence Model

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Abstract. This study gives an idea about myopia which become a leading health concern and socio-economical issue with a big threat to the pediatric population. Also, give an idea about some genetic and environmental factors for myopia progression. Clinical, environmental markers for predicting this visual threatening disease. Involvement of corneal biomechanics, a different mode of managing myopia, most important, different approaches for predicting myopia and an efficient model selection for handling such huge data from EMR and predicting the disease perfectly with the help of AI.

Keywords. Corneal biomechanics, EMR, AI, clinical and environmental markers.

1. Introduction

Myopia is a leading socio-economical issue that gives a threat mostly to the pediatric population. This issue can lead to visual impairment as well if the prediction and prevention are not done properly. According to the World Health Organization (WHO) around 27% of people all over the world's population are suffering from myopia. By considering the population of the united nation maximum of 52% of the population is suffering from myopia. Considering the pediatric population maximum of 80%-90% of the population is suffering from different stages of myopia [World Health Organization–Brien Holden (2015)]. The increasing rate of myopia is having a distinct amount of reason behind it. As children are more prone to this visual error, time spent on the electronic system (TV, smartphone) and for studying, reading can also be one important cause of myopia. Also, some genetic and environmental factors can be considered as one of the causes. According to many types of research in ophthalmology, the field shows that the structural changes in a visual component can

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also lead to myopia. If the cornea is a little more curved than the normal eye then, the light ray focused incorrectly which leads to myopia [Andrzej Grzybowski et.al. (2020). A review on the epidemiology of myopia in school children worldwide, BMC Ophthalmology]. A term i.e. Spherical Equivalent Refraction (SER) is having a major impact on determining the degree of myopia. If the SER is between -0.5 D to -6.00 D then it defined as low myopia. If SER is more than -6.00 D then it is considered as high myopia [Daniel Ian Flitcroft (2019). IMI – Defining and Classifying Myopia: A Proposed Set of Standards for Clinical and Epidemiologic Studies, Investigative Ophthalmology & Visual Science, Vol.60, issue 3, pp. M20-M30]. As we know cornea is an important visual component its properties are playing an important role. The cornea is a biomechanical tissue which is having a certain type of biomechanical characteristics. For a normal eye these biomechanical characteristics are within a normal range but for eyes with some visual error including myopia the biomechanical properties changed. Staring from the thickness of the cornea, viscoelasticity, Intra Ocular Pressure (IOP), curvature etc. plays a major impact on the myopic eye. The axial length of the eye is also an important factor. The normal eye is having a certain range of axial length than the myopic eye. If axial length is more then it can easily lead to a myopic condition (axial myopia) [NeryGarcia-Porta et.al. (2014). Corneal Biomechanical Properties in Different Ocular Conditions and New Measurement Techniques, ISRN Ophthalmology, Vol.2014, pp. 1-19]. As myopia already started to lead the entire world by threatening mostly the pediatric population and becoming the leading health concern it needs to be addressed properly. In recent days health care department is having huge data regarding a patient that is required while proceeding for any treatment or any kind of clinical prediction. Handling these huge data manually is very tedious so nowadays health care department is switching to automated handling and prediction after a patient's regular check-up by the ophthalmologist for clinical prediction. After the clinical data are collected then this can be used as the input for the automated system. Artificial intelligence is a boon to the health care department when it comes to handling huge data of electronic medical records (EMR). Artificial intelligence is all about train the machine with all the intelligence of a human begin so that they can also do the job of a human. (Guoguang Rong, et.al. Artificial Intelligence in Healthcare: Review and Prediction Case Studies, Chinese Academy of Engineering and Higher Education Press, 2020) As AI trained machines, machine learning can be a subset of AI. There are many subtypes of machine learning algorithms that are efficiently used in the health care domain**.** Machine learning algorithms like random forest algorithm (RFA), support vector machine (SVM), decision tree, k-nearest neighbour (K-nn) etc are frequently used algorithms in the progression of myopia. For this study RAF algorithm is mostly focused on prediction [Yahan Yang et.al. (2019

2. Literature survey:

Myopia: clinical rudiment and degree

As myopia is a leading socio-economical issue knowing the degree of myopia is very important for efficient prediction and treatment. For knowing the degree few clinical parameters are required. Among which spherical equivalent refractive error is the most common one. The axial length of the eye can also predict myopia figure 1.

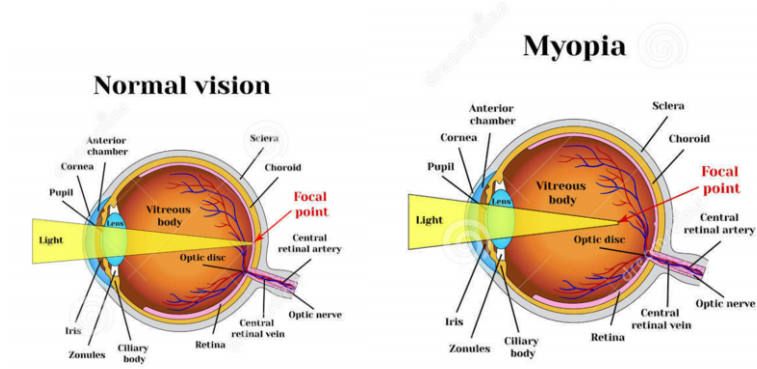

Figure 1. Image describing the visual process in normal vs. myopic eye (Courtesy: ID 80086526©Mrsbazilio|Dreamstime. com)

Myopia can broadly classify into three subtypes i.e. Simple myopia, high myopia and pathological myopia.

- Simple myopia: If the spherical equivalent refractive error of eye range within 6 or less than 6 D (Diopter) then it's called simple myopia [Daniel Ian Flitcroft (2019)].
- High myopia: If the spherical equivalent refractive error is more than 6D then it's called high myopia,
- Pathological myopia: this is a very high degree of myopia. It can also be called degenerative myopia. This can also lead to axial length elongation and retinal detachment further leads to complete vision loss [Kyoko Ohno-Matsui (2018)].

Changes in image forming system of the eye during myopia:

As discuss structural changes of many visual components of the eye can lead to refractive errors like myopia. Mostly corneal structural changes lead to myopia. As the cornea is a biomechanical tissue with certain biomechanical properties. As the cornea is a little curved originally it refracts the light rays coming from the object and focus it on the retina with the help of a lens. If the cornea is curved more then the light ray is not refracted properly and instead of focusing on the retina it focuses in front of the retina and makes the far vision blur by causing myopia. Also, elongation of axial length can lead to myopia by changing the focus point of the eye. Biomechanical properties of the normal cornea are having a certain range than the abnormal or myopic eye. Axial length, central corneal thickness (CCT), corneal endothelial cell density, viscoelasticity, the curvature of the cornea, depth of the vitreous layer etc. are some biomechanical properties are having some specific values for a healthy eye, if the eye is myopic then this range can alter and can be treated as a marker for early detection and prediction [Hema Radhakrishnan et.al. (2012)]. These parameters can be measured with the help of a non-invasive instrument. Some parameters from the instrument like deformation amplitude (DA), A1&A2 time, A1&A2 length, A1&A2 velocity, HC time, PD, HC, IOP, Ks, Kf, CV, ACD can also indicate the difference in the normal eye and myopic eye. Corneal stiffness is a very important factor as the cornea is less stiff when the eye is myopic. So, DA can symbolize that if DA is higher then corneal stiffness is lesser and it symbolizes the eye is suffering from myopia Figure 2 [A-Yong Yu, et.al. (2020)].

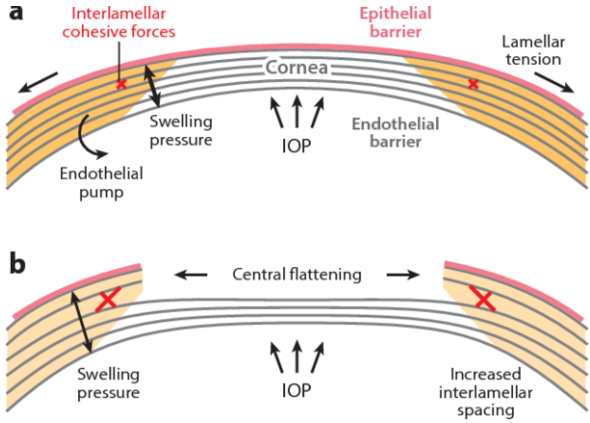

Figure 2. Corneal biomechanics

Myopia: Threat to the pediatric population

According to many research surveys, degrees of myopia can be progressed from low to high during a certain age i.e., mostly in the pediatric population. For a child aged from 5 to 7 years old, there is a chance of 14.7% getting affected with progressive cases of myopia and children aged between 17 to 19 have 59.0% chances of getting progressive myopia [Christos Theophanou et.al. (2018)]. According to the ***"*Investigative Ophthalmology and Visual Science *journal"*** around the globe, 32% of the pediatric population are suffering from myopia which can lead to visual impairment at max.

Other than clinical causes some genetic and environmental factors may be the root of myopia [Gabrielle James et.al. (2018)]. As it hits more on the pediatric population environmental factors including time spent on an electronic system, near work time spent in study and doing tasks may be the leading influencer in myopia. In recent days children spent maximum time in front of electronic system it causes the elongation of the eyeball which may lead to axial elongation ending with myopia. Many types of research give some evidence that time spent outdoors can reduce the progression by secreting more amount of dopamine, a hormone that can slows down the elongation process of the eyeball [Aisha Mohammed Alemam et.al. (2018), Jin Tao Sun et.al. (2018)] figure 3.

Myopia management:

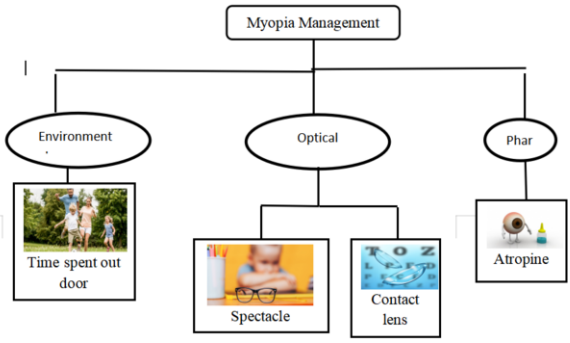

Figure 3. Myopia management

Myopia can be managed in 3 ways; it can be managed by reducing the time spent on electronic systems and increasing the time spent outdoors. This can be managed optically by using spectacles and contact lens which is very common nowadays, also by using some clinically prescribed eye drops.

Clinical Countermeasure:

According to many ophthalmology types of research some clinical drugs are used to suppress the progression of myopia. Drugs like atropine, pirenzepine etc. are broadly used for clinical medication. Atropine is affecting the reduction of accommodation of the eye and results in pupil dilation. Usage of different percentage concentrations of atropine in 6-12-year children with moderate myopia can reduce the progression after continuous use for 2 years [Matthew Recko and Erin Durrie Stahl (2015)].

Optical Medication:

Bifocal lenses can also be used for the reduction of myopia but the results are clinically insignificant. Orthokeratology is another way in which an ophthalmologist uses a specific contact lens to temporarily flatten the cornea. But still, it having some complications including vision threat so cannot be generalized for everyday use [Matthew Recko and Erin Durrie Stahl (2015)] figure 4, figure 5.

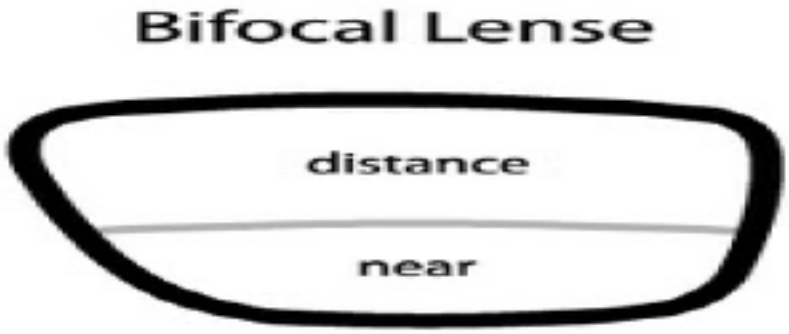

Figure 4. Biofocal lens

(Courtesy: https://youreyesite.com/bifocal-glasses-multifocal-lenses/)

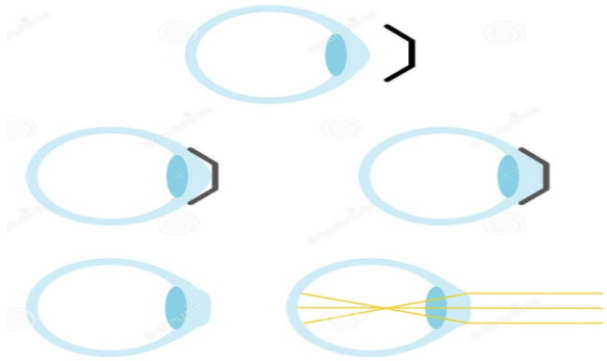

Figure 5. Orthokeratology

(Courtesy: ID 87374079©NatalliaYatskava|Dreamstime.com)

Surgical Management of myopia:

Many surgical approaches can be performed to reduce the myopic power as some people are not much interested in spectacles and contact lens. This can be subcategorised according to the mode and site of the surgery procedure. This can be incisional refractive surgery, excimer laser refractive surgery and intraocular surgery. In incisional surgery radial keratotomy (RK) is used to treat myopic eyes but due to some complications like infection, problems in night vision, weakening of cornea made this procedure less appropriate for people. Same to intraocular surgery which is useful for a very high degree of myopia i.e. more than -10D but also having some post-surgical complication. In recent days all the procedures of the excimer laser technique are used in many ophthalmology centres. This involves LASIK, PRK, LASEK, and EPI-LASIK. In PRK clinician scrap out the tissue from the cornea to make it perfectly bend so that the light ray can refract properly and form a focused image. Lasik surgery is pretty much common in recent days as it is having less discomfort for the patient than PRK. In this procedure, doctors make an 83 to 200 mm flap and with the help of a computer-assisted cold laser beam and remove some tissue and place the flap back. This can correct the power of the eye to make a focused image [Javed Hussain Farooqui et.al. (2019), Dieudonne Kaimbo Wa Kaimbo (2016)] figure 6, figure 7

Figure 6. Lasik eye surgery (Courtesy- ID 79302660©Gdmohamed|dreamstime. com)

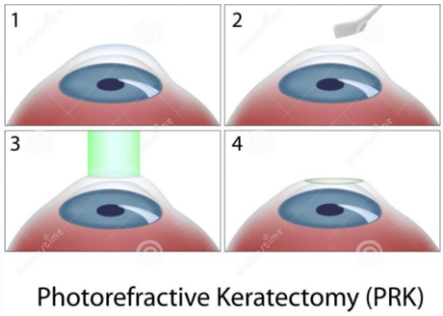

Figure 7. PRK surgery procedure (Courtesy:ID 23173857©lila07|Dreamstime)

Prognosis of myopia:

By considering a few parameters myopia can be subcategorized according to its degree. It can be low, high, stable, progressed etc. As discussed before few crucial environmental factors can be an early marker for predicting myopia. Time spent in front of an electronic system, parental myopia and time spent outside can be treated as environmental predicting factors. Some clinical parameters such as axial length, corneal & lens power, corneal &lens thickness etc. parameters like spherical equivalent refractive error (SER) can also predict the degree of myopia [Karla Zadnik et.al. (2015)]

Statistical prediction:

In recent days so many people are into customizing their medication for many diseases. So genetic prediction of myopia can also be done by the genetic council by

a clinician for developing customized medication. Statical parameters like mean median and standard deviation its easier to the distribution, variability of all the myopic data points. Calculating the root mean square error of a myopic population also myopia progression can be predicted. But these methods cannot be efficient enough to handle huge medical records and to predict the progression for each person [Siyu Jiang, et.al. (2019)].

AI-based prediction:

Artificial intelligence refers to train machines to perform tasks like a human without human supervision. As it trains a machine so machine learning can be a subset of AI. In recent days Electronic Medical Records (EMR) contains a huge number of data which need an efficient way to handle these data. For this task handling, the manual procedure is tedious. So AI is like a boon to the health care department. This machine learning approach is broadly subcategorized into 3 types i.e. supervised learning algorithm, unsupervised learning algorithm and reinforcement learning [Tao Tang et.al. (2020)].

Supervised algorithm:

Supervised learning is a learning in which it needs external supervision. The input of the model can have both a training set and a test set that need to be predicted. This algorithm model is trained by labelled data and tested by the test set to get the result efficiently. This again can be categorized into classification and regression. The classification approach is for classifying between two groups where regression models are for predicting continuous data points. Decision Tree, Naïve Bayes, Support Vector Machine, logistical regression, artificial neural networks, and random forests are few important algorithms used in supervised learning. As this algorithm is giving the result from previous experience then the user is having an exact idea about the classification and category. But to handle complex data might take a lot of computation time. [Ayon Dey (2016)].

Unsupervised learning:

This algorithm does not require external supervision. This model learns some features from the input training data and applies the same when the test data come. This model can be trained with unlabeled data and can solve a complex problem. Unsupervised learning can be divided into 2 one is clustering and another is association. With the help of the clustering approach, one can be able to identify the similar and non-similar types of data in a whole input data folder. The association approach is very efficient to know the relationship between the data points. Clustering, KNN (k-nearest neighbours), Hierarchal clustering, Anomaly detection, Neural Networks, Principle Component Analysis, Independent Component Analysis are some algorithms coming under this. The clustering algorithm can able to differentiate the dataset into a separate group based on their similar parameter. An anomaly algorithm can find unusual data present in datasets. It's having more efficiency to handle complex data but it is very difficult to compute rather than supervised learning and the result might be not accurate as the data are not labelled. [Ayon Dey (2016)].

Reinforcement learning:

Reinforcement learning is suitable for giving results for a particular situation. This method can set its own ideal set of values for a particular situation to increase the efficacy of the result. It takes a feedback approach for further betterment. This approach can correct the errors by using the feedback approach during training. It can help handle complex data. More frequent use of reinforcement algorithms can

lead to overload the data. It's not suitable for solving a simple problem. As it requires a lot of data then it might lead to a decrease in the efficacy due to fewer amounts of data. By considering the previous research survey supervised learning algorithm can train the model with the correct prediction data but in the reinforcement approach the agent is helpful to decide how to solve the particular problem in a particular environment by using the experience and the feedback of each error that the model makes. The reinforcement algorithm is having 3 main terms used in the model i.e., agent, path and reward. The agent is the one who helps to find the suitable and efficient path to get the reward and reward is the final result that the user wants. Final after the model get the final reward then the total reward of the model is calculated. There are two types of reinforcement learning i.e., positive and negative. Positive reinforcement learning as the name suggests it add some distinct feedback to the model. Similarly, negative reinforcement learning deducts some distinct feedback to maximize the performance of the model [Richard S. Sutton and Andrew G. Barto (2015), Ahmad Hammoudeh (2018)].

All these above algorithms are efficient to do the task accordingly. In recent days in the health care department for clinical prediction, a supervised learning algorithm named Random Forest Algorithm (RFA) is quite popular due to its efficiency. RFA is an algorithm that uses the same concept of a decision tree but a better version of it. As the name suggests it build a forest by merging many decision trees. Only one decision tree gives a result that may not be accurate but by combining many decisions trees result is more accurate. in a random forest algorithm, it only selects the specific features and make multiple decision trees and average it for the result. RFA randomizes the decision tree and randomly chooses the features to make it more efficient. By combining multiple decision trees, the particular algorithm can give a better prediction. RFA can select random samples from a given dataset then it constructs a decision tree for each sample. Each decision tree gives prediction results and performs voting for each predicted result then the algorithm chooses the most votes as the final prediction. This can be an efficient result for prediction. [Haotian Lin et.al. (2018)] figure 8.

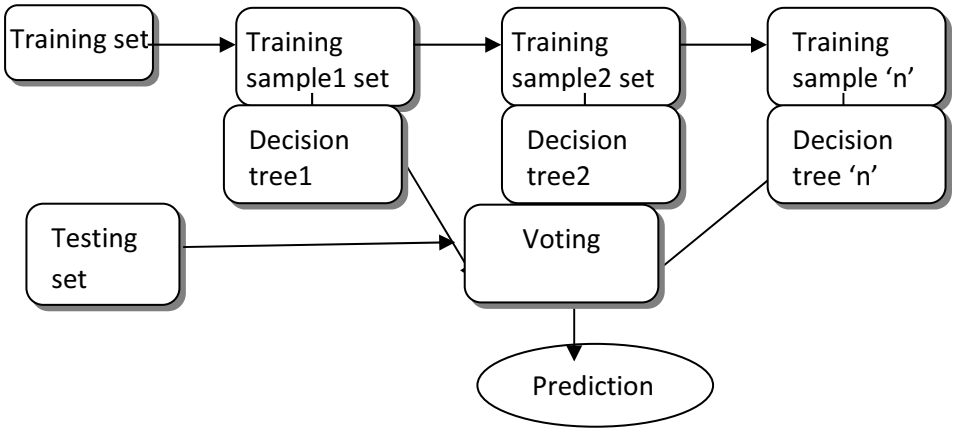

Figure 8. Schematic describing prediction methodology of random forest algorithm (RFA)

Performance of a prediction model:

After building an AI model for prediction or any other task it's very crucial to check its performance including its accuracy, sensitivity and specificity. There are few methods of evaluating a model before finalizing it for clinical or any other workplace use table 1.

Confusion matrix:

A confusion matrix is a table consisting few parameters that describe them correctly and incorrectly classified data [Jasmina Dj. Novakovi et.al. (2017)]

1.True positive- Data those are positive and model also predicted it as positive (correctly predicted)

2.False-negative- Data that are positive, but classified as negative

3.True negative- Negative data those classified also as negative (correctly classified)

4.False-positive- negative data but classified as positive

Table 1. Confusion matrix

		Predicted values	
		Positive (1)	**Negative (0)**
Actual values	**Positive (1)**	TP	FN
	Negative (0)	FP	TN

By using these above parameters accuracy of the model can be calculated easily. [Tao Tang et.al. (2020)].

$$Accuracy = \frac{TP+TN}{TP+TN+FP+FN} \quad (1)$$

Specificity and sensitivity:

By calculating these parameters anyone can know how well a model is predicting and giving the results. By calculating the specificity of a model it's easy to know how efficiently a model predicts the negative data points as negative. If the sensitivity of a model is more than, the model is more efficient to predict the results.

$$Sensitivity \frac{TP}{TP+FN}, \; Specificity = \frac{TN}{TN+FP} \quad (2)$$

Receiver Operating Characteristic Curve (ROC):

A graph plotted between true positive rate (Y-axis) and false positive rate (X-axis).

$$TPR = \frac{TP}{TP+FN} \;\; , FPR = \frac{FP}{FP+TN} \quad (3)$$

With the help of this graph, we can know the performance of the model at each threshold point [Xu Yang et.al. (2020)] figure 9.

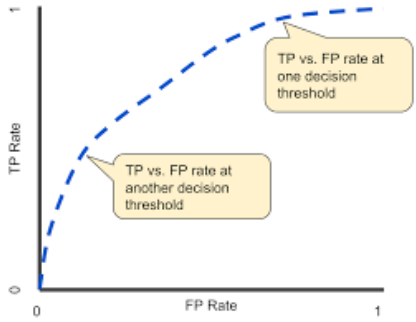

Figure 9. An ideal ROC curve (Courtesy-https://developers.google.com/machine-learning/crash-course/classification/roc-and-auc)

Area Under Curve (AUC):

The area under the ROC curve symbolizes the efficacy of an AI model. This parameter ranges from 0 to 1. More the AUC value more the model is efficient to predict the class [Yahan Yang et.al. (2020)] figre 10.

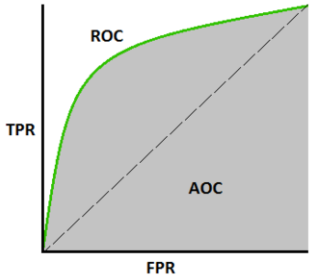

Figure 10. Area under ROC curve (Courtesy: https://towardsdatascience.com/understanding-auc-roc-curve-68b2303cc9c5

3. Conclusion:

From this overview, we conclude that myopia is a very serious socio-economical issue and recently became the leading public health problem mostly a threat to the pediatric population. Which need an efficient clinical prediction method for cure and precaution. In recent days huge medical record AI is a boon to medical science. With the help of an efficient AI model, it is possible to predict myopia with greater efficacy than manual prediction.

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