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Original Article

New Age Borders Obtained from Spot Photoscreener by Using Multivariate Cluster Analysis

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ABSTRACT

Objective: The aim of this study is to analyze all the variables obtained from photoscreener using hierarchical cluster analysis to create more homogeneous age groups for more reliable and consistent measurement by photoscreener.

Methods: The variables obtained from photoscreener examination of consecutive children who attended the ophthalmology department were evaluated. Medical records of the children were evaluated to ontain data including refractive parameters, deviation angle, pupil diameter variables and the calculated spherical equivalent, the cylindrical power vector J0, J45 values. These variables were analyzed by the multivariate cluster analysis.

Results: Based on a dendrogram, 4 main clusters of similar quality variables were created. The calculated spherical equivalent decreased gradually from cluster I to IV, from 0.745 D to −0.235 D. The average pupil size in the Ist cluster was 5.06 mm, while in the IVth cluster, it was 6.38 mm. The proposed new age borders are distinct and statistically significant ($P < .001$). The ultimate proposed new age borders were found as 1-20, 21-64, 65-101, and 102-120 months, respectively.

Conclusions: We proposed new age borders for the evaluation of refraction and pupil size of children which create new groups with a statistically different and homogeneous distribution. The proposed new age borders in this research would provide more reliable and consistent measurement results for clinical diagnosis.

Keywords: Age border, classification, cluster analysis, dendrogram, photoscreener

INTRODUCTION

Refractive errors are still a well-known public eye health problem frequently diagnosed in daily practice. Refractive error detection is critical for the prevention of amblyopia, especially in the pediatric age group. Various refractive error measurement techniques, such as retinoscopy, autorefraction, and photorefraction, have developed from the past to the present.[1]

Photorefraction was first described by Howland in 1974. The MTI photoscreener (Medical Technology and Innovations Inc, Lancaster, PA) was the first device introduced in 1995.[2] Due to short measurement time, ease of use, and portability, photoscreeners have been commonly used in refraction scans and measurements. They identify refractive errors by analyzing reflected (red) reflex images of the pupils using the infrared camera as a working principle. With these devices, which can take binocular measurements from a distance of about 1 m, the heads of pediatric patients do not need to be fixed and are believed to be able to eliminate accommodation due to short measurement times. For these reasons, photoscreening may be a good option for young children and groups of patients who cannot cooperate.[3]

Studies have shown that photoscreeners have acceptable sensitivity and specificity to detect refractive errors and risk factors for amblyopia.[4] Many different devices have been developed and presented along the way from past to present by different companies for clinical use. These devices can measure refraction errors as well as the deviation angle, the pupil size, and the interpupillary distance.

It is well known that many photoscreening devices which are currently used clinically assess the parameters obtained by age-based measurements. As a result of this assessment, it provides a report to the clinician that includes information that measurements are within normal limits or a full eye examination is required. These devices analyze the measurement results based on the age criteria defined in the software installed on the device.[5] Although there is no particular standardization of age classification, each company uses its own distinct age classification system in the photoscreening device software.

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Table 1. Descriptive Statistics for Continuous Variables of Children

	Minimum	Maximum	Mean	Standard Deviation
Spherical value (D)	−5.5	7.000	1.013	1.369
Astigmatism (D)	−3.000	0.000	−0.984	0.715
Spherical equivalent from Spot Vision	−5.500	6.250	0.528	1.308
Calculated spherical equivalent (D)	−5.625	6.500	0.521	1.299
Vector presentation of cylindrical power J0 (D)	−0.887	1.499	0.364	0.425
Vector presentation of cylindrical power J45 (D)	−1.042	1.149	0.003	0.237
Pupil diameter (mm)	3.90	8.80	5.674	1.0000
Angle of vertical deviation (°)	0.0	5.0	1.193	1.068
Angle of horizontal deviation (°)	0.0	5.0	1.329	1.166

D, diopter; (°), degree; mm, milimeter.

The aim of this study is to analyze all the variables obtained from photoscreener in order to create more homogeneous age groups for more reliable and consistent measurement by photoscreener. In this analysis, hierarchical k-means cluster analysis of multivariate statistical methods that considers the variation in all variables as a whole was used to obtain more sensitive and more powerful methods instead of univariate statistical methods.

METHODS

Patient Data Collection and Exclusion Criteria

In this retrospective study, children attending the ophthalmology department either for vision screening or routine ophthalmic examination within the age group of 1 to 120 months were recruited in this study from March 2018 to December 2018. The data were extracted from medical records of children undergoing vision screening with photoscreener. The data included age, gender, and measurements obtained by the photoscreener (Welch Allyn Spot Vision Screener Skaneateles Falls, NY software: 3.0.05.00) including the pupil diameter, cylindrical (C), spherical (S) and spherical equivalent (SE) values, cylindrical axis (α), and angle of ocular deviation with direction. Spherical equivalents, vector presentation of cylindrical power referred as J0 and J45 were calculated by the following formulas: $SE = C/2$, $J0 = (-C/2) \cos (2\alpha)$, $J45 = (-C/2) \sin (2\alpha)$, respectively. Myopia was defined as SE ≤ −0.5 diopter (D) and hypermetropia ≥ 0.50 D. Emmetropia was defined as SE between >−0.5 D and <+0.50 D. The same medical technician performed all the refraction measurements. It was ensured that the room was in dim light during the measurement and the device was at the same level as the patients' eyes from a distance of 1 m. All children underwent complete ophthalmological and orthoptic evaluations. Strabismus cases (>5 degree/10Δ diopter prism), media opacity, retinal disease, nystagmus, previous ocular surgery, and history of eye-head trauma were excluded from the study. Additionally, cases with refractive errors outside the limits of the recommendation by the manufacturer guidelines (spherical value interval +7.5/−7.5 diopter (D), cylindrical value interval +3/−3 D) were not included in the study.

Main Points

- Photoscreeners have acceptable sensitivity and specificity to detect refractive errors and risk factors for amblyopia.
- There is no particular standardization of age classification, and each company uses its own distinct age classification system in the photoscreening device software.
- Hierarchical cluster analysis of multivariate statistical methods is useful for many applications in terms of classification.
- New age borders were proposed with a large data set with high clinical evidence by using a hierarchical cluster method of multivariate statistics, which is an advanced analysis to obtain valid and reliable results.
- The proposed new age borders would provide more reliable and consistent measurement results for clinical diagnosis.

Statistical Analysis

The data obtained were evaluated with hierarchical cluster analysis of multivariate statistical methods, which is useful for many applications in terms of classification. Using this method, the relationships among variables and clustering trends were determined by dendrogram, allowing us to obtain greater detail to the clinical interpretation. The data were analyzed using "R programming, version 3.6.2 (2019-12-12)—CRAN" adapted by statistical experts as a standard software package for data analysis.

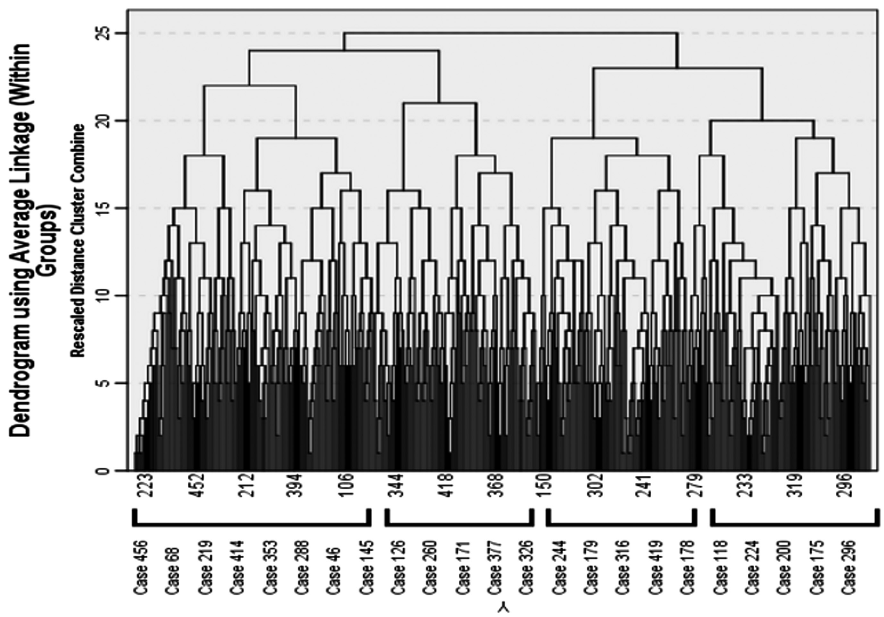
Power Analysis

Based on literature information, photoscreener has 87% accuracy in refraction in children.[6] In our study, it was calculated that when this rate was accepted as 0.05% higher, than 92% and according to 85% power, the sample size was calculated as 406 patients by using R programming. The sample size included in the current study was 458.

Ethical Statement

The study was approved by the Ethics Committee of Health Sciences University, Istanbul Training and Research Hospital on January 18, 2019, with the number 1641. The study was carried out in line with the principles of the World Medical Association Helsinki Declaration.

Figure 1. The dendrogram for the measurements of the children by using "hierarchical cluster method."



RESULTS

Nine hundred sixteen eyes of 458 children (222 boys, 236 girls; average age, 43.37 ± 34.91 months; range, 1-120 months) met the inclusion criteria and were included in this study. Descriptive statistics (minimum, maximum, mean, and standard deviation) for continuous variables of patients are presented in Table 1. The distribution of refractive error according to the calculated SE in 916 eyes was as follows: hypermetropia, 436 eyes; myopia, 124 eyes; and emmetropia, 356 eyes.

The clusters and subclusters formed by the related variables were shown by dendrogram using cluster analysis (Figure 1). The dendrogram allowed us to see how clusters were combined and at the same time determined the appropriate number of clusters formed by the variables. Based on the dendrogram, 4 main clusters of similar quality variables were created. Based on the results of the dendrogram, the "hierarchical clustering method" demonstrated that children form 4 very smooth and different clusters according to their ages (months) in Table 2 and Figure 2. Descriptive statistical values (number of individuals, mean and standard deviation values) and analysis results related to the distribution of variables in 4 different sets are presented in Table 3. From cluster I to cluster IV, the calculated SE decreased gradually from 0.745 D to −0.235 D. The average pupil size in the Ist cluster was 5.06 mm, while in the IVth cluster, it was 6.38 mm.

Table 2. Ultimate Border Values Obtained for the Ages (in Months) of the Children in 4 Different Clusters to be Considered in Clinical Diagnosis

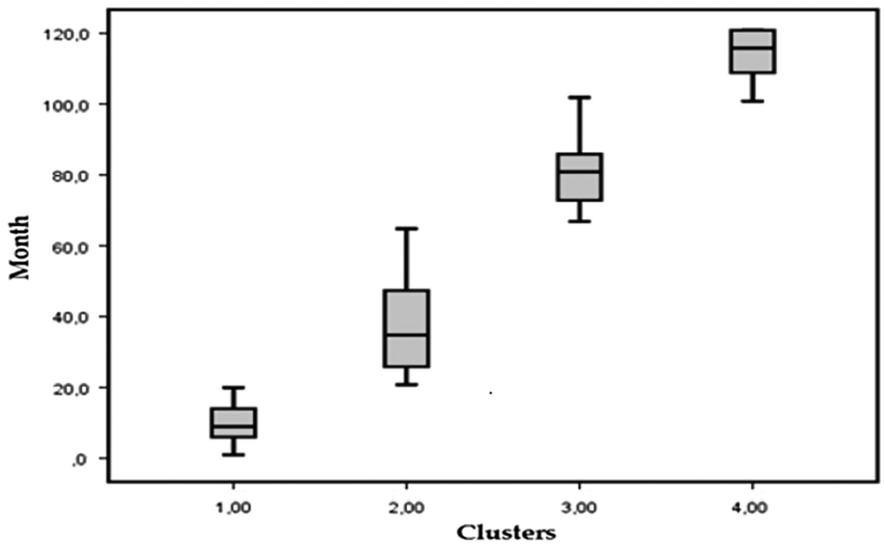
	Month	
Main Clusters	**Minimum**	**Maximum**
I	1	20
II	21	64
III	65	101
IV	102	120

DISCUSSION

The most common cause of visual impairment affecting all age groups is refractive errors.[6] Thus, early detection of refractive errors and risk factors of amblyopia in children may lead to better and more stable final visual results, with shorter treatment times and more rapid improvement in visual acuity.[7,8]

In the pediatric age group, photoscreeners are now commonly used to evaluate refractive parameters and perform community vision screening programs. Photoscreeners allow a large number of children to be screened in a short period of time in a wide geographic area and provide time advantage over conventional methods such as cycloplegic retinoscopy.[9] In addition, some studies reported that these devices are effective and reliable in detecting refractive erors.[4,6] Panda et al.[6] reported that the difference between the measurements of photoscreener and cycloplegic retinoscopy was -0.3 D and stressed that this difference in measurement was not clinically significant. Therefore, the frequency of clinical use of photoscreener devices is increasing day by day. The fact that each producer company uses a different age classification is the most important proof that no consensus exists in this regard. To the best of our knowledge, there is no specific study done so far to classify the age borders according to the variables used by photoscreener. As a result, the age limits used in photoscreeners in clinical use are not based on evidence, especially in the pediatric age group. In order to obtain more reliable and consistent photoscreener measurements, we believe

Figure 2. The distribution of the minimum and maximum values obtained for the age (in months) of the children in 4 different clusters to be considered in clinical diagnosis.



that it is necessary to establish homogeneous age groups. Therefore, using the hierarchical cluster method of multivariate statistics and advanced analysis, we proposed 4 age ranges for children aged 120 months and below.

In this study, 4 clusters were determined according to variables that including refractive error, pupil size, angle of ocular deviation, and direction obtained from children aged between 1 and 120 months. The distribution of age ranges in these 4 clusters is 1-20, 21-64, 65-101, and 102-120 months, respectively (Table 2). In the cluster I consisting of children under 20 months, SE and J45 values were the highest, while pupil diameter was the lowest. From cluster I to cluster IV, there was a gradual decrease in SE and J45, as well as an increase in pupil diameter. Cluster IV, which included children aged 102-120 months, had the lowest SE and J45 as well as the highest pupil diameter. Ocular structures are constantly changing in childhood, so it is important to determine the characteristics of this change by assessing the visual system and refractive parameters that are still developing according to the age of children. It is a well-known fact that refraction changes with age and hyperopia are the predominant refractive status in early childhood.[10] Myopic shifts become more evident as the age progresses.[11] Consistent with other studies, our study showed that SE was gradually decreasing among these 4 groups. The SE values obtained from the device and calculated were found to be the same (0.74 D) in cluster I that included children aged 1-20 months. In cluster IV, children aged 102-120 months, these values were-0.24 and-0.23, respectively, and a shift in myopia was observed.

Studies show that the prevalence and amount of astigmatism decrease as the child grows and the greatest change occurs between the ages of 2 and 4 years.[12,13] Dobson et al.[12] found the highest prevalence of astigmatism in infants and toddlers in their

Table 3. Descriptive Statistical Values and Analysis Results of the Variables Measured in 4 Different Clusters Obtained by the "Hierarchical Clustering Method"*

KMC		A	S	SE	CSE	J0	J45	VD	HD	PD
I	$\bar{x}$	9.820	1.345	0.745	0.745	0.445	0.025	1.390	1.570	5.065
	SD	5.140	1.325	1.270	1.280	0.470	0.285	1.185	1.245	0.715
II	$\bar{x}$	36.29	1.060	0.610	0.585	0.345	−0.005	1.110	1.205	5.750
	SD	11.97	1.240	1.195	1.170	0.410	0.210	1.030	1.105	0.915
III	$\bar{x}$	80.38	0.880	0.435	0.425	0.345	−0.030	1.195	1.410	6.195
	SD	9.550	1.470	1.445	1.435	0.380	0.240	1.025	1.480	1.040
IV	$\bar{x}$	112.6	0.090	0.240	−0.235	0.215	0.005	0.960	1.060	6.380
	SD	7.490	1.395	1.360	1.345	0.345	0.165	0.875	1.070	0.985

*The mean values of the variables obtained in 4 different clusters were found to be significantly different with the ANOVA test (P <.001).
n, Number of individuals; $\bar{x}$, mean value, SD, standard deviation; KMC, k-mean cluster no, A, age (month); S, spherical value, SE, spherical equivalent from Spot Vision; CSE, calculated spherical equivalent; J0 and J45, vector presentation of cylindrical power; VD, vertical deviation; HD, horizontal deviation; PD, pupil diameter.

study between the ages of 0 and 9.5 years and reported that astigmatism disappeared at school age. Our research has demonstrated that the importance of astigmatism decreases with growing age. The J0 value of astigmatism had the highest value (0.44 D) in cluster I, and it decreased with age. It was found 0.34 D in the IVth astigmatism was measured as close to zero and did not change significantly with age.[14] According to our findings, the importance of astigmatism decreases with age. Photoscreener devices provide information about the pupil size, angle of ocular deviation and direction as well as refractive error.[15,16] Silbert et al[17] in their study with photoscreener showed that pupil size increased with age in children between ages 0 and 16 years. However, they did not report any specific pupil size values for these age groups. In our study, the average pupil size was found as 5.06 mm in the Ist cluster, and it significantly increased with age and reached 6.38 mm in the IVth cluster. In addition, pupil diameter in children shows similar characteristics in 4 different groups according to age.

The spot vision photoscreener performs all measurements based on age groups in the software of the device and the corresponding age range must be selected prior to patient screening. For children under 10 years of age, the age groups defined in the software device are 6-12 months, 12-36 months, 3-6 years, and 6-20 years, respectively (Figure 3). However, no research or paper can be found demonstrating the criteria by which these age limits have been defined. In addition, when the age limits of 1-20, 21-64, 65-101, and 102-120 months determined in our study are compared with the age limits in the software of the device, it is observed that there are significant differences between the age limits. When these findings are evaluated, the recommended age limits can be used to create a more homogeneous age group.

One of the limitations of this study is that the results are based on data related to a single population. Different results may be obtained in different populations due to differences in ethnicity. In addition, we did not include ocular biometric parameters associated with refraction such as axial length, corneal radius, anterior chamber depth, and personal characteristics such as body weight and height. Further studies in different ethnic groups and that contain more parameters will provide additional information.

Figure 3. Spot vision photoscreener age classification.

CONCLUSION

In this current study, new age borders were proposed with a large data set with high clinical evidence by using a hierarchical cluster method of multivariate statistics, which is an advanced analysis to obtain valid and reliable results. As a result, new age borders for the evaluation of refraction and pupil size of children which create new groups with a statistically different and homogeneous distribution are proposed. The proposed new age borders in this research would provide more reliable and consistent measurement results for clinical diagnosis.

Ethics Committee Approval: Ethics committee approval was received from the Ethics Committee of Health Sciences University, Istanbul Training and Research Hospital (Date: January 18, 2019, Decision no: 1641).

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