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Original Article

Forensic Section

Study of Pattern of Change in Handwriting Class Characters with Different Grades of Myopia

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ABSTRACT

Introduction: Handwriting is a visuo-motor skill highly dependent on visual skills. Any defect in the visual inputs could affect a change in the handwriting. Understanding the variation in handwriting characters caused by visual acuity change can help in identifying learning disabilities in children and also assess the disability in elderly. In our study we try to analyse and catalogue these changes in the handwriting of a person.

Materials and Methods: The study was conducted among 100 subjects having normal visual acuity. They were asked to perform a set of writing tasks, after which the same tasks were repeated after inducing different grades of myopia. Changes in the handwriting class characters were analysed and compared in all grades of myopia.

Results: In the study it was found that the letter size, pastiosity, word omissions, inability to stay on line all increase with changes in visual acuity. However these finding are not proportional to the grade of myopia.

Conclusion: From the findings of the study it can be concluded that myopia significantly influences the handwriting and any change in visual acuity would induce corresponding changes in handwriting. There is increase in letter size, pastiosity where as the ability to stay on line and space between the lines decrease in different grades of myopia. The changes are not linear and cannot be used to predict the grade of myopia but can be used as parameters suggestive of refractive error.

Keywords: Pastiosity, Refractive errors, Writing disability, Visual acuity

INTRODUCTION

Blindness and diminution of vision in any of its forms has a significant effect on the lifestyle and livelihood of every one affected. Uncorrected refractive errors are the most common cause of reversible blindness in India [1]. Studies from urban India suggest that 49.3 million of those aged >15 years may have refractive errors [2]. However there are a very few population based statistics available. Most of the studies done are in adults.

Myopia is considered to be the most common correctable refractive error [3]. Studies in urban Indians suggest that 42.16% of the adults have refractive errors. Among these 17.8% in the 40 to 49 year age group, 29.6% in the 50 to 59 year age group, 44.8% in the 60 to 69 year age group, and 50% in the >70 year age group have myopia [2]. The statistics are different in the rural population. Studies report 38% of people has myopia and the percentage increases with age due to nuclear cataract [4].

People suffering from refractive errors not only have to bear the physical burden but also the social and financial consequences. Vision significantly has influenced the career choices and social activities a person can engage. A significant number of people suffer for a long time before being diagnosed. Up to 25% of children have refractive errors significant enough to impair academic performance. Nearly 60% for children already labeled as having learning problems have problems with visual acuity [5].

Handwriting skills in man are not inherited as an innate process. These are skills which are taught to every person. Initially these skills are learnt and practiced as a conscious process but as one matures these skills mature and become more of a subconscious event [6].

The development and progress of handwriting passes through four stages in the course of a lifetime. At a very young age as writing skills develop there is a sequential change in handwriting which reaches a plateau at middle age only to degenerate as age advances due to various intrinsic and extrinsic factors [7].

Handwriting is a visuo-motor skill which requires continuous processing of the visual perceptions to execute effectively the fine hand movements. Any defect in the visual inputs could affect a change in the handwriting. Learning disorders in children are documented to be present in 2-10% of the population, and in 80% of cases it is due to the defect in visual perceptions. Even deterioration in handwriting at the extremes of age though is primarily because of neuro-muscular degeneration can also be because of decreased visual acuity [8,9].

Understanding the variation in handwriting characters caused by visual acuity change can help better diagnose these learning disabilities in children and also assess the disability in elderly. We have attempted to catalogue changes in different class characters of handwriting at different grades of artificially induced myopia so as to have an authentic objective data. The data thus collected will provide better insight on this relatively less studied area. This study will be of benefit to researchers in disability assessment, rehabilitation of children with learning disorders and in Forensic question documents.

MATERIALS AND METHODS

The study was conducted in Shri Sathya Sai Medical College and Research center, Ammapettai, Chennai, India. After the Institutional Ethical committee clearance was obtained an advertisement was put up in the college campus asking for volunteers. A total of 100 subjects were selected from faculty, office staff, technical staff and students on first come first serve basis.

The participants were informed of the procedure and purpose of the study and informed consent was obtained in writing. Only subjects with visual acuity of 6/6 were selected for the study. The subjects were asked to perform a set of writing tasks in the space provided in the proforma.

Myopia was induced in the participants by giving plus spherical lenses from the trial set starting from +0.5 D power with serial increments of +0.5D up to 4 D as the subjects reported significant diminution of vision preventing them from continuing further. The tasks were repeated for each of the plus lens given. Pens to perform

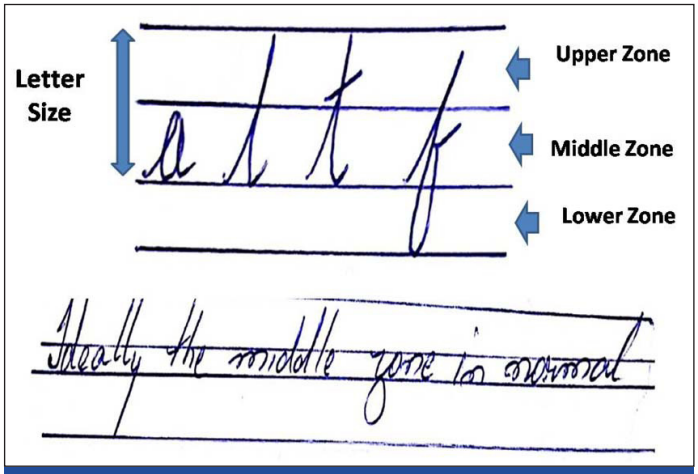
the task were provided to maintain uniformity in the data collected and avoid error introduced by defective pens.

After the performance of all the tasks the proforma were collected and assessed for a set of class characters. Class characters like font size, orientation, style, curvature, letter form, stability, slant, fluency, copying skills, etc were evaluated. For the purpose of the study 13 standard variables for the handwriting were analysed repeatedly with every increment of plus lens given. The data was compiled & statistically analysed using SPSS (Statistical Package for Social Sciences) computer software (version 16).

RESULTS

The sample of the study consists of 100 (68 male & 32 female) subjects between 18-38 years, with the mean age of the participants being 23.3 years. As the study is planned in Chennai most of the participants are Tamil (78%) speaking.

As required in this study 13 variables were repeatedly measured in the handwriting with every 0.5 D increment of the plus lens. The changes in the variable were compared to the handwriting character of the subject when the task was performed for normal vision. The difference in their means was studied. To check for the variance and its statistical significance multivariate analysis (MANNOVA) was used. The results of the same for relevant variables are presented in [Table/Fig-1-9].



[Table/Fig-1]: Figure showing the different zones of letters in cursive writing and the measurement of letter size

Letter size with induced myopia	Minimum	Maximum	Mean	Std. Deviation	Variance
Letter size normal	2.00	7.35	4.5615	1.10584	1.223
Letter size at 0.5D	2.00	7.90	4.5750	1.23308	1.520
Letter size atD1D	2.00	6.90	4.6730	1.14142	1.303
Letter size at 1.5D	3.00	7.61	4.8045	1.16186	1.350
Letter size at 2D	2.00	7.10	4.8340	1.17578	1.382
Letter size at 2.5D	2.00	8.10	5.0140	1.36375	1.860
Letter size at 3D	2.00	7.90	5.1690	1.34410	1.807
Letter size at 3.5D	2.00	7.90	5.0440	1.32294	1.750
Letter size at 4D	3.00	8.40	5.1440	1.15988	1.345

[Table/Fig-2]: Descriptive statistics of the average letter size in handwriting with different grades of myopia

DISCUSSION

Letter size: For the purpose of handwriting analysis in cursive writing the letters are said to have three zones, usually termed as the upper zone, middle zone and lower zone. Normally this corresponds to the four line book used by children to practice writing. The average size of the letters in ones cursive writing was measured with calipers in letters having both upper and lower zone like letters 'L' & 'T' [Table/Fig-1]. The mean letter size [Table/Fig-2] in all grades of myopia is larger compared to that in normal vision. There is a statistically significant difference [Table/Fig-3] in the average letter size of the handwriting with serial increments of myopia, $F(200, 528) = 2.144$, $p < .0005$; Wilk's A=0.011.

Further supporting the above findings [Table/Fig-4] shows that the mean upper zone and lower zone size of the handwriting at different grades of myopia is higher compared to that in normal vision. As size of objects visualised proportionally increases with serial increments in myopic lenses, the writing size also increases probably due to this perceptual defect. However as these changes are not proportional to the grade of induced myopia they can't be used to predict the same. Change in the writing size can be clinically considered as an indicator of myopia.

Ideally the middle zone in normal adult writing would measure to be 3mm [7]. This is an accepted international norm. Thus the middle zone can be divided into three probable types [Table/Fig-5]. Multivariate analysis ($F(104, 554)= 2.89$, $p < .0005$; Wilk's A= 0.051, partial $\eta 2 = 0.311$.) shows a statistically significant variation in the mid zone size but from the [Table/Fig-5,6] it is not very clear if the size primarily increases in a graded manner. The extent of change noted with every grade of myopia is variable and inconsistent. But what can be safely concluded is that the size of letters in all zones increases with change in the visual acuity and the change is not proportional to the grade of myopia. This finding finds support in various studies [7,9,10-13] quoted in the references.

It has been found that visual perceptions contribute significantly to the perceptual skills necessary for writing. The visual-motor coordination is the ability to match motor output with visual input. It is a process of integrating information derived from both visual and the motor systems to optimize the movement pattern, to reduce the amount of time and energy spent to reach the desired writing outcome [14]. While writing, the visually impaired have to judge the form, length, and location of strokes without references. Partial vision can provide a few guides and the availability of these reference points may determine the quality of the writing or lettering. There is misalignment of letters, words with one another and of writing with respect to a ruled or implied baseline. There is some increase in letter sizes compared to the previous handwriting. Also, documented are overlapping of words, infrequent pen lifts and absence of "t" crossings in cursive writing and unrepaired occurrences of pen failure creating voids in ink deposits. A lack of fluency and infrequent introduction of hesitation marks or scratches are also noted [7,9-13].

Space between lines: - When writing in an unruled surface the writer has to judge his relative positioning based on his own letter spacing. Space between the lines was measured in millimeters

Multivariate Tests[d]								
Effect		Value	F	Hypothesis df	Error df	Sig.	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.975	3.333E2[a]	8.000	67.000	.000	2666.695	1.000
	Wilks' Lambda	.025	3.333E2[a]	8.000	67.000	.000	2666.695	1.000
	Hotelling's Trace	39.801	3.333E2[a]	8.000	67.000	.000	2666.695	1.000
	Roy's Largest Root	39.801	3.333E2[a]	8.000	67.000	.000	2666.695	1.000
lettersize	Pillai's Trace	2.742	1.544	200.000	592.000	.000	308.704	1.000
	Wilks' Lambda	.011	2.144	200.000	528.038	.000	403.981	1.000
	Hotelling's Trace	9.290	3.031	200.000	522.000	.000	606.184	1.000

[Table/Fig-3]: Results of Multivariate (MANNOVA) test for letter size with serial increments in myopia
a. Exact statistic, b. Computed using alpha = .05, c. The statistic is an upper bound on F that yields a lower bound on the significance level., d. Design: Intercept + letter size

Visual acuity	Mean upper zone size (mm)	Mean lower zone size (mm)
Normal vision	3.0400	4.5485
Myopia of 0.5 D	2.9525	4.8300
Myopia of 1 D	3.1450	4.5965
Myopia of 1.5 D	3.1800	4.7265
Myopia of 2 D	3.2340	4.4687
Myopia of 2.5 D	3.2590	4.6990
Myopia of 3 D	3.5490	4.5540
Myopia of 3.5 D	3.4090	4.9140
Myopia of 4 D	3.4440	4.8890

[Table/Fig-4]: Mean upper zone and lower zone size of handwriting at different grades of myopia

Mid zone type	Normal vision	Myopia 0.5D	Myopia 1D	Myopia 1.5D	Myopia 2D	Myopia 2.5D	Myopia 3D	Myopia 3.5D	Myopia 4D
Size >3mm	0	0	0	0	0	0	0	0	5
= 3mm	5	0	4	0	4	10	20	5	5
Size < 3mm	95	100	96	100	96	90	80	95	90

[Table/Fig-5]: Distribution of subjects based on the mid zone size of the handwriting in different grades of myopia

	Minimum	Maximum	Mean	Std. Deviation	Variance
Mid zone size normal	1.00	3.90	1.9290	.67976	.462
Mid zone size 0.5D	1.00	3.72	2.1100	.63952	.409
Mid zone size 1D	1.00	3.41	1.8845	.62628	.392
Mid zone size 1.5D	1.00	3.70	1.9840	.65808	.433
Mid zone size 2D	1.00	3.90	2.0240	.70812	.501
Mid zone size 2.5D	1.00	3.90	2.0890	.74331	.553
Mid zone size 3D	1.00	3.90	2.0390	.82240	.676
Mid zone size 3.5D	1.00	3.40	1.9340	.61005	.372
Midzone size 4D	1.00	3.90	1.9690	.66099	.437

[Table/Fig-6]: Mean mid zone letter size of handwriting at different grades of myopia

[Table/Fig-7]. Statistically significant ($F(189, 460) = 3.165$, $p < .0005$; Wilk's A= 0.003) variation in the spacing of the lines is noted, similar to that noted by Huber [7] and various other researchers [9-14]. However the change is inconsistent, with the spacing decreasing in some grades of myopia and increasing in some.

Ability to stay on line: - From [Table/Fig-8] it is clear that the ability to stay on line while writing decreases with serial increments of myopia. This could be due to blurring of vision with higher grades of myopia affecting one's ability to perceive the base line. This is consistent with findings of Huber [7] and various other researchers [9-15]. Mischio writes that there are several vision-related skills that are critical to good handwriting that may be underdeveloped in a student with vision problems [13]. Peripheral awareness & spatial concepts are required to know, plan and write in a straight line. Visualization is required to remember the word form. Good laterality and directionality are required for recognizing similar patterns.

Omission of words: - With progressive blurring of vision it is expected that the writer face difficulties in reading and hence omit words while copying. At higher grades of myopia (>2.5D) few (9%) subjects omitted words in the sentences they were copying. Similar findings were reported by Huber et al., Wilson et al., William et al., Tukel S et al., & Sanghvi et al., [7,9,12,14,15]. Literature published from experience in learning difficulties in children does suggest the influence of vision on the writing outcome. The following writing tasks were observed to be significantly difficult in children with visual impairment. Children had difficulty copying from whiteboard or book. They omitted or repeated letters, words, or phrases, had poor eye-hand coordination including poor writing & wrote too slowly. These children were found to have poor finger movement in writing [16].

Serial increments of myopia	Minimum	Maximum	Mean	Std. Deviation	Variance
Space between lines normal vision	.00	8.90	4.7110	2.65996	7.075
Space between line 0.5D	.00	8.90	4.7565	2.68968	7.234
Space between lines1D	.00	10.90	5.2935	3.07509	9.456
Space between line1.5D	.00	7.90	4.5865	2.56400	6.574
Space between line 2D	.00	9.90	5.2740	2.71746	7.385
Space between line 2.5D	.00	9.90	4.8290	2.87459	8.263
Space between line 3D	.00	8.90	4.2090	2.54880	6.496
Space between line 3.5D	.00	8.90	4.7890	3.06538	9.397
Space between line 4D	.00	8.90	4.0790	2.76940	7.670

[Table/Fig-7]: Mean space between the lines in the handwriting at different grades of myopia measured in mm

Ability to stay on line	Normal vision	Myopia 0.5D	Myopia 1D	Myopia 1.5D	Myopia 2D	Myopia 2.5D	Myopia 3D	Myopia 3.5D	Myopia 4D
Present	49	49	54	53	52	45	44	32	35
Absent	37	42	37	38	29	34	24	42	42
Partially present	14	9	9	9	19	21	32	26	23

[Table/Fig-8]: Distribution of subjects based on the ability to stay on line while writing at different grades of myopia

Pastiosity count	Normal vision	Myopia 0.5D	Myopia 1D	Myopia 1.5D	Myopia 2D	Myopia 2.5D	Myopia 3D	Myopia 3.5D	Myopia 4D
Absent (0)	28	23	19	14	24	14	24	9	14
1 time	18	4	0	10	0	19	0	5	10
2 time	13	23	3	10	13	4	4	14	4
3 time	12	9	27	12	18	13	27	13	17
4 time	14	26	8	17	16	17	4	13	19
5 time	10	5	23	18	0	19	12	18	9
6 time	5	5	0	5	14	5	5	13	12
7 time	0	7	5	5	10	0	14	5	0
8 time	0	0	5	9	0	5	10	5	10
9 time	0	0	0	0	5	4	0	5	5

[Table/Fig-9]: Distribution of subject's base on Pastiosity count of the writing at different grades of myopia

Pastiosity:- Fatigue in writing and difficulty in maneuvering the pen sometimes cause a delay in the flow of writing. This causes the pen to blotch due to excessive flow of ink. The transient phenomenon causes repeated marking on the letters termed as pastiosity. Pastiosity count is the number of times this phenomenon occurs in a particular word [7]. One particular word was selected for this purpose and studied in all grades of myopia and compared in the [Table/Fig-9].

Form the tables it is clear that the mean pastiosity count of the writing increases proportional to the degree of myopia induced. The mean pastiosity count at normal vision was 2.16 times and at induced myopia of 4D it was 3.87 times. Blurring of vision could lead to decreased speed of writing and maneuvering curved letters leading to increased pastiosity. We could not find any significant literature showing similar find in writing except for suggestions by Huber et al about increase in the pastiosity with visual impairment [7].

CONCLUSION

From the findings of the study it can be concluded that myopia significantly influence the handwriting and any change in visual acuity would induce corresponding changes in the handwriting characters.

There is increase in letter size, pastiosity where as the ability to stay on line and space between the lines decrease in different grades of myopia. The changes are not linear and can't be used to predict the grade of myopia but can be used as parameters suggestive of refractive error. These findings or parameters in children with myopia after assessment may help in overall development of children with myopia and improve their performance in school

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