



Forensic Examination of Effects of Diabetes Mellitus on Handwriting Characteristics

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Abstract

Diabetes mellitus is a long-term metabolic illness that affects people's social, physical, mental, and psychological health and can have a tremendous impact on the handwriting of an individual. Examining such handwriting specimens might be difficult for document examiners. This may have an effect on the reliability of their opinions on the subjects under consideration. As a result, the present study has been conducted to qualitatively and quantitatively determine the effects of diabetes mellitus on handwriting characteristics. A qualitative examination and comparative analysis of line quality errors in altered writings and writings copied by diabetes mellitus were also included in the study.

Keywords: Diabetes mellitus, handwriting characteristics, social, physical, mental, and psychological health.

1. Introduction

Handwriting is a neurophysiological technique for expressing thoughts and speaking in written form on the floor using a writing tool propelled by forearm movements. People's personalities and emotional states have long been described using handwriting (graphology). When we're writing, we make a lot of rapid movements. These motions are caught on paper and portray our constantly changing emotions. This recorded movement, handwriting, is like an open window into a person's psyche. The way we think is intricately linked to our handwriting, just as it is to how we express ourselves. It's also quite aware of the feelings like disappointment or excitement. During the writing process, we express our feelings on paper, and the words we come up with express those feelings. In truth, handwriting is so delicate that it may be used to measure one's emotional state. There are observable feelings such as excitement, nervousness, anxiety, impatience, and fury. That is why learning to write is so important. For instance, when writing under nervous conditions, the tension becomes apparent as a subtle tremor within the pen strokes of certain letters. It may not be evident at first glance (though this does occur on occasion), but it will almost surely be seen under a microscope. This phenomenon occurs because your handwriting reflects the internal passion and enthusiasm you possess.

Handwriting is always affected by physiological illness. Diabetes mellitus is also one of them. In recent years, the metabolic disease diabetes mellitus, which is hazardous and complex, has become increasingly prevalent. The International Diabetes Federation estimates that 382 million people worldwide have diabetes, and that number will rise to 592 million by 2035. In India, 65.1 million people between the ages of 20 and 79 suffer from diabetes.

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2. Background

Handwriting is a complex task that involves a high level of neuromuscular coordination. Physiological abnormalities such as diabetes mellitus may have a significant impact on the muscle control required for handwriting. According to the evidence, diabetes mellitus and its effects have a substantial impact on mental health problems. Among them are depression, bad eating practices, and a fear of hypoglycemia. According to study, diabetes patients endure high levels of emotional stress that is peculiar to diabetes. The goal of this study is to look at the effects of diabetes mellitus on handwriting characteristics, both qualitatively and quantitatively, and see if it's feasible to compare writings done under the influence of diabetes mellitus to writings done before the disease started. The study also involves a qualitative examination and comparative analysis of copied writings with handwriting samples from individuals with diabetes mellitus in order to identify and differentiate the features that may be utilized to identify and differentiate these writings.

3. Sample collection and Methodology

Table 1

Column1	Column2	Column3	Column4
Parameters	Groups	No of Subjects	%Age
Age	Below 40		
	41–50	2	20
	51–60	3	30
	61-70	2	20
	71-80	2	20
	81-90	1	10
Gender	Male	5	50
	Female	5	50
Educational qualification	Matric or below matric	2	20
	Higher secondary education	3	30
	Graduation or above	5	50
Occupation	Self-employed	3	30
	Job employee	5	50
	Not employed	2	2

Samples have been collected from 10 different individuals and everyone is having diabetes mellitus past 20 years. Samples of handwriting which is collected have been taken from writings of individuals before getting diabetes and writings are collected from individuals in a white A4 sheet paper of present form. Samples scripts are collected in both Malayalam and English. Samples which are collected before getting diabetic is mentioned as "Old Handwriting" (OH) and after getting diabetic as "Affected Handwriting" (AH). Samples were analyzed and compared using simple hand lens in natural daylight.

4. Analysis

The two handwriting samples, OH and AH, were compared against each other and then assessed for differences in various handwriting characteristics, including line quality features such as rhythm, tremor, pen lifts, retouching or overwriting, as well as letter formation, writing speed, omission of letters or parts, simplification or abbreviation of letters or parts, initial and terminal strokes, connecting strokes, overall size, slant, spacing, and alignment. These characteristics were coded and grouped into two categories, "0" and "1," based on their quality, and statistical analysis was conducted using IBM®SPSS® Statistics software. The handwriting samples with good line quality and consistency were categorized as "0," while those with poor or disrupted line quality and variation were categorized as "1."

A paired t-test was used to compare the two genuine writing samples, OH and AH. The null hypothesis (H_0) stated that there would be no significant difference in the handwriting features of the OH and AH samples ($H_0 = \mu_1 = \mu_2$), while the alternative hypothesis (H_1) stated that the true mean difference between the two paired samples would not be zero ($H_1 = \mu_1 \neq \mu_2$), where " μ_1 " represents the population mean for OH and " μ_2 " represents the population mean for AH. A p-value of less than 0.05 was chosen to determine statistical significance, with the rejection of H_0 indicating that diabetes mellitus would have a significant negative impact on the handwriting characteristics.

Table 2

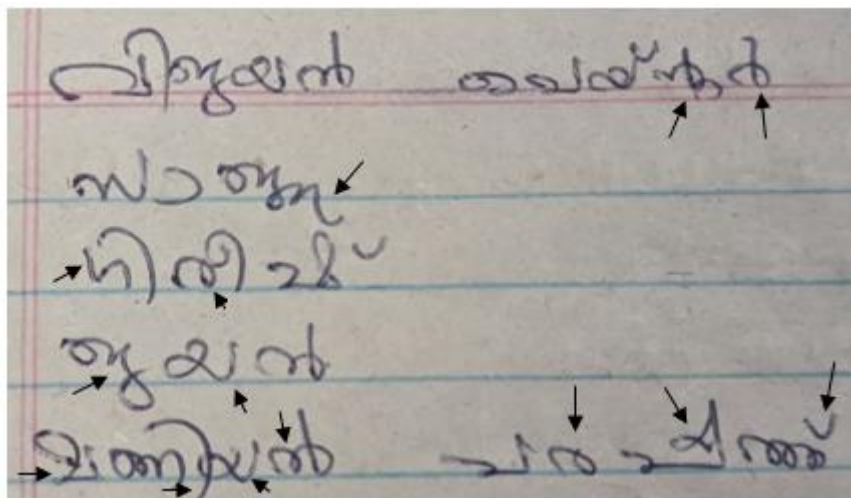
S. No	Handwriting Characteristics	Code	Codes along variables	Categorization of characteristics	
				Category 1 (0)	Category 2 (1)
1	Rhythm	RM	RM_OH/RM_AH	0 = Smooth	1 = Deteriorated
2	Tremors	TM	TM_OH/TM_AH	0 = Absent	1 = Present
3	Pen lifts	PN	PN_OH/PN_AH	0 = Absent	1 = Present
4	Retouching/overwriting	RO	RO_OH/RO_AH	0 = Absent	1 = Present
5	Letter formation	DL	DL_OH/DL_AH	0 = Absent	1 = Present
6	Overall writing speed	WS	WS_OH/WS_AH	0 = Fast	1 = Slow
7	Omission of letters/parts	OM	OM_OH/OM_AH	0 = Absent	1 = Present
8	Simplification/abbreviation	SM	SM_OH/SM_AH	0 = Absent	1 = Present
9	Initial and terminal strokes	IT	IT_OH/IT_AH	0 = Tapered	1 = Tremulous/blunt
10	Connecting strokes	NC	NC_OH/NC_AH	0 = Smooth/curved	1 = Tremulous/angular
11	Overall size	SI	SI_OH/SI_AH	0 = Constant	1 = Increase/decrease
12	Slant	SL	SL_OH/SL_AH	0 = Vertical/forward/backward/mixed	1 = Variation
13	Spacing	SP	SP_OH/SP_AH	0 = Narrow/wide/constant	1 = Variation
14	Alignment	AG	AG_OH/AG_AH	0 = Horizontal/uphill/downhill/mixed	1 = Variation
	Variables				
	Pre-condition (before DM) OH				
	Post-condition (after DM) AH				

5. Results

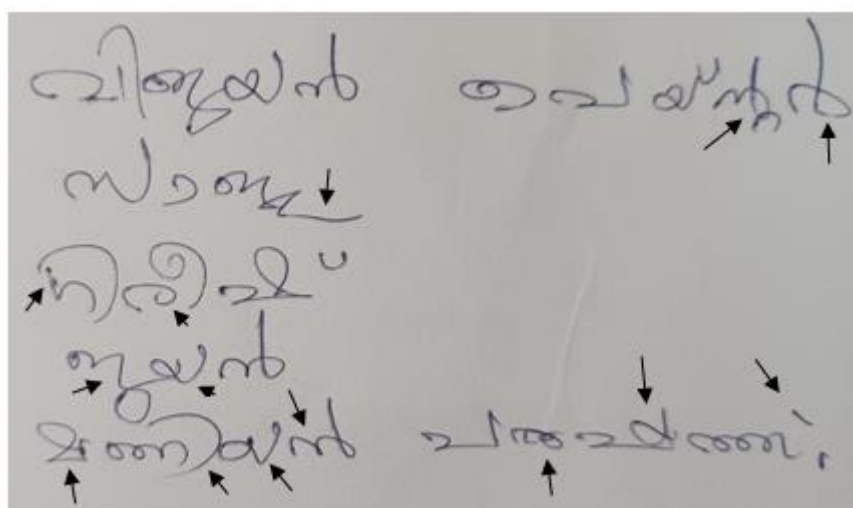
The findings of the qualitative analysis are discussed in the following section.

Rhythm

Out of the 10 AH samples, 8 of them exhibited a decline in rhythm, which was evident from the letter strokes showing angularity and a change in stroke direction (as depicted in Fig 1a).



(a1)



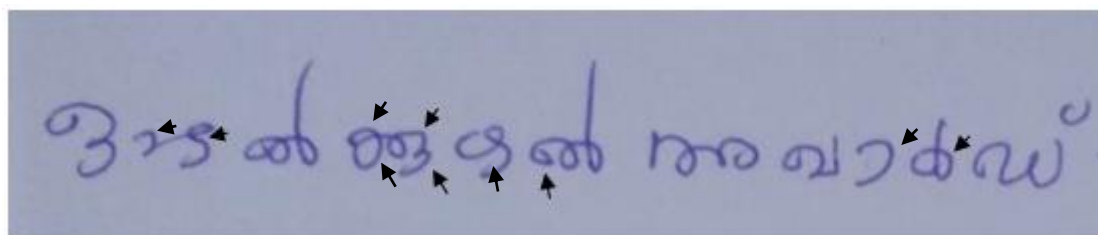
(a2)

Fig. 1. Rhythm. a1 Handwriting before the onset of diabetes mellitus with rhythmic strokes. a2 diabetes mellitus patient with non-rhythmic writing strokes.

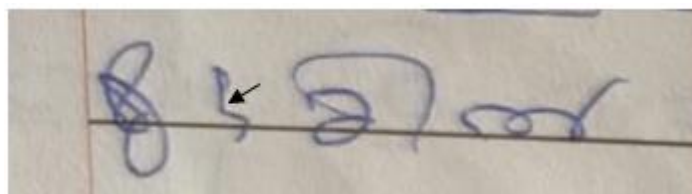
Line Quality defects

Tremor

Out of 10 handwriting samples from individuals with diabetes mellitus, 2 exhibited tremors characterized by slight variations in writing impulses to severe deteriorations to the point of illegibility. The tremors were identified through peculiar zigzag type of strokes and bunches observed on the strokes of a few letters (Fig. 2b). Additionally, only one of the 10 handwriting samples exhibited increased tremors. It should be noted that both of the samples exhibiting tremors were from elderly individuals, suggesting that age-related tremors may have contributed to their handwriting characteristics.



(a)



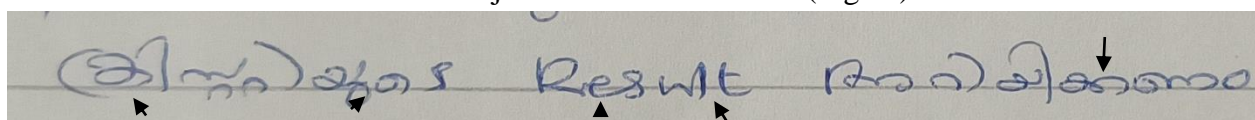
(b)

Fig. 2. Tremors. a Characteristic wavy stroke in the handwriting specimen of diabetes mellitus patient. b Sample of diabetes mellitus person depicting peculiar zigzag stroke.

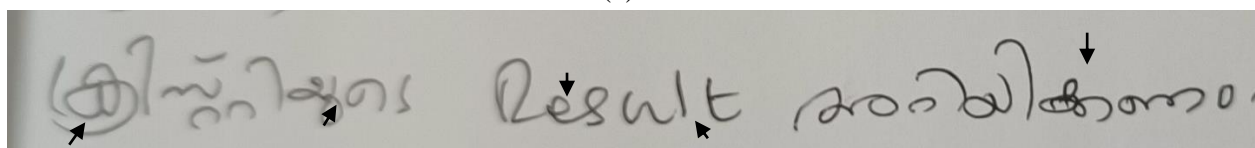
Tremor of age: Tremor arises in the elderly due to a poor neuromuscular state. In such circumstances, the writing will be slower and trembling, sometimes rhythmic, with wavering and broken strokes creating the letters of a writer writing that will diverge from regular writing. Despite all of these flaws, the writer's internal consistency remains unmistakable.

Pen lift

Pen lifts were found in 5 out of 10 diabetes mellitus samples. Pen lifts were inconsistent in the majority of afflicted writings, as evidenced by the appearance of pen lifts in certain areas and the absence of pen lifts in the same writing. During construction of loops, the specimens written in Malayalam script showed considerably higher pen lifts. Some of the new diabetes mellitus manuscripts exhibited forceful rejoining of strokes at areas of pen lifts, whereas others showed little extra effort to rejoin the residual strokes (Fig 3b).



(a)

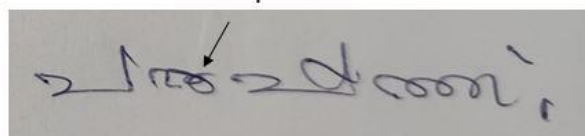


(b)

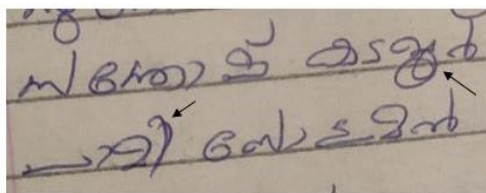
Fig. 3. Pen lifts. a Consistency of stroke in Handwriting before onset of diabetes mellitus. b Handwriting with inconsistent pen lifts in diabetes mellitus patient

Retouching

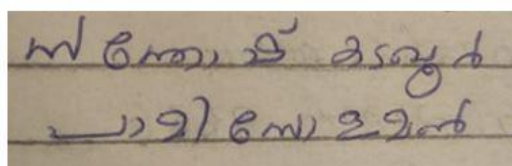
Among the 10 handwriting samples from individuals with diabetes mellitus, 5 samples exhibited retouching in the form of additional strokes and bold overwriting. This retouching aimed to enhance legibility, sometimes resulting in the duplication or overwriting of the same strokes. These characteristics were not observed in the individuals' earlier writings. Interestingly, in one particular sample, retouching was observed in the earlier handwriting but was absent in the more recent sample (Fig 4 b2).



(a)



(b1)



(b2)

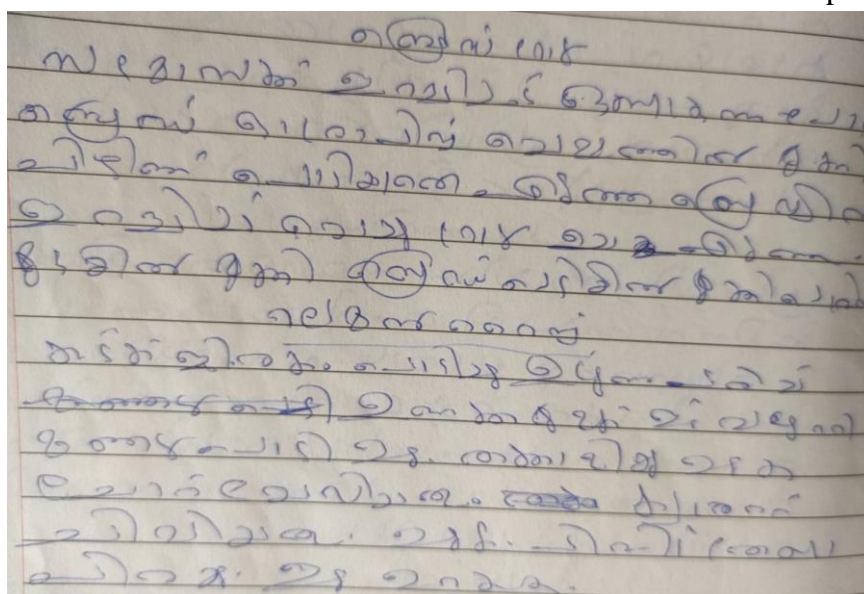
Fig. 4. Retouching's a sample of diabetes mellitus subject showing overwriting type of retouching, b1 earlier sample showing extra stroke retouching, b2 no retouching is observed in newer sample

Letter Formation

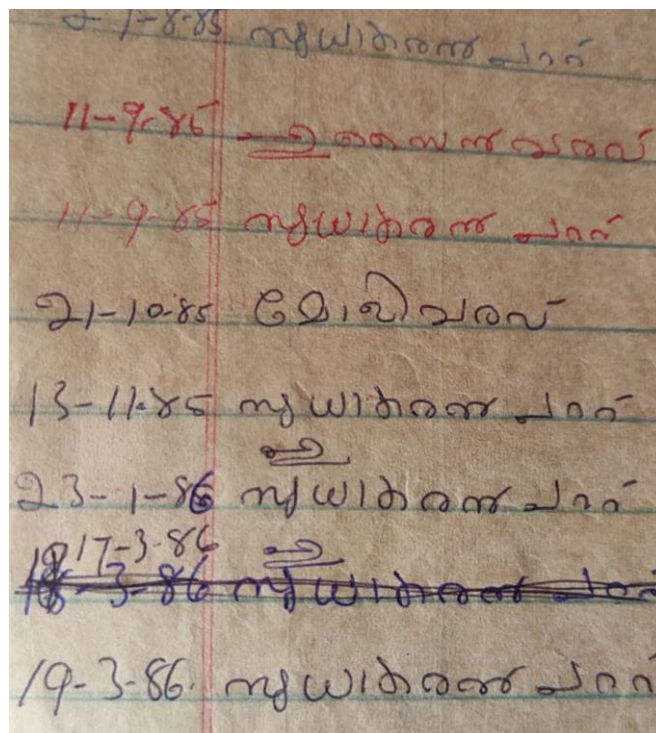
Alterations in letter formations were identified in 8 out of 10 handwriting samples from individuals with diabetes mellitus. In 4 of these samples, entire words or substantial portions of words exhibited a complete transformation in letter formation. One sample displayed a shift towards more angular letter formations compared to their previous writings. Only minimal changes in letter formation were observed in 3 of the samples.

Overall Writing speed

Among the handwriting samples of individuals with diabetes mellitus, a decrease in writing speed was noticed in 6 out of 10 samples when compared to their previous writings. This decrease was evident from hesitations observed in the final strokes of each alphabet.



(a)

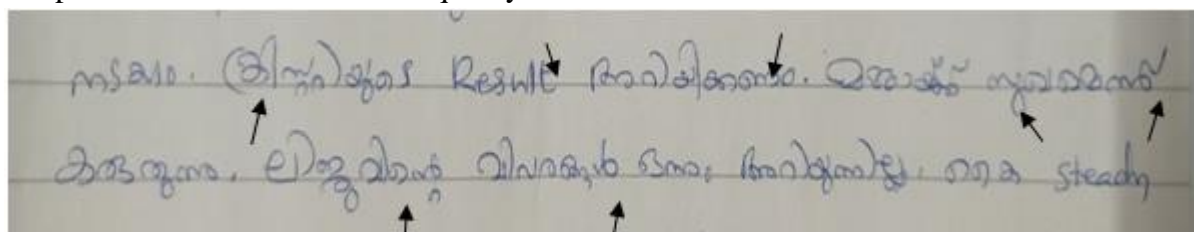


(b)

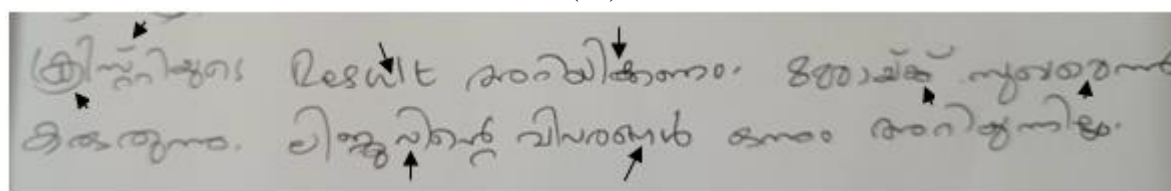
Fig. 4. Writing Speed. (a) Handwriting specimen of a diabetes mellitus patient demonstrating a decrease in writing speed as compared to a pre-disease handwriting sample(b).

Omission of letters/parts and words

Four AH samples revealed the omission of some letters or fragments of a few letters, indicating difficulties in the production of some specific letters (Fig. 6a). All the writing samples from the OH lacked this quality.



(a1)



(a2)

Fig. 5. Omission of letters and words. a1 Handwriting executed before onset of diabetes mellitus. a2 Omission of entire words and the presence of bold overwritten strokes in handwriting of diabetes mellitus individual.

Simplification/abbreviation of letters or parts of letters

No Simplification/abbreviation of letters were observed in the samples as they are in Malayalam script.

Nature of initial and terminal strokes

Blunt initial and terminal strokes were observed in 4 samples, while a mixed type of initial and terminal strokes was observed in 2 samples out of the total 6 AH samples (Fig 7b).



(a)



(b)

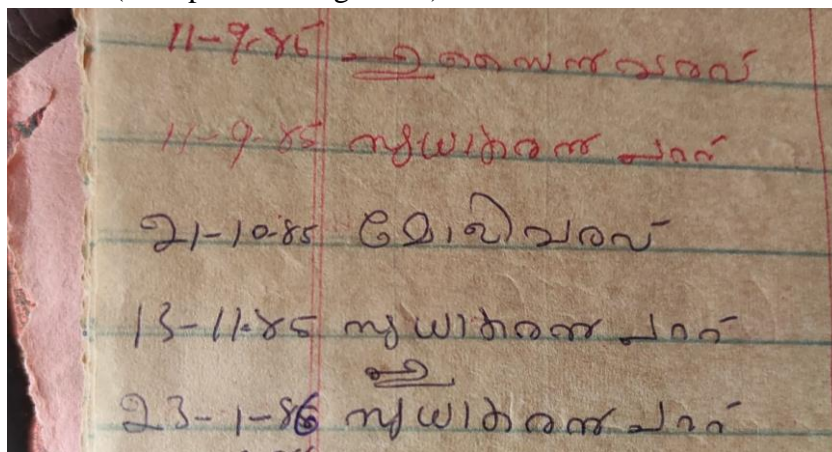
Fig. 6. Initial and terminal strokes. a Handwriting sample prior to the onset of diabetes mellitus exhibited excellent quality of initial and terminal strokes. b Handwriting of diabetes mellitus patient with blunt initial and terminal strokes, as well as tremulous connecting strokes.

Nature of connecting strokes

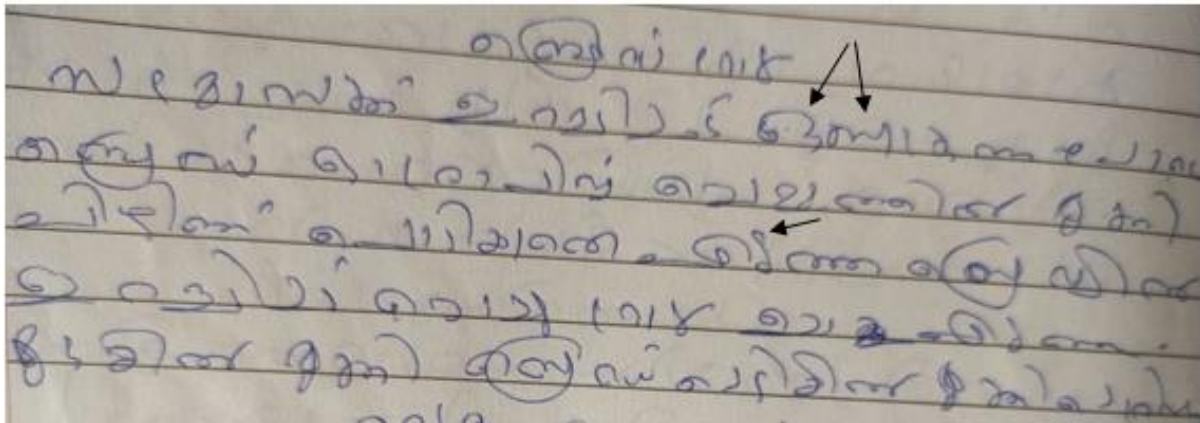
The connection between the letters was found to have changed noticeably in 6 of the handwriting samples of people with diabetes mellitus, as evidenced by ill-defined and tremulous strokes. In the handwriting samples of individuals with diabetes mellitus, the connecting strokes occasionally exhibited overwriting, overlapping, and pen lifts, as illustrated in Figure 7b. However, two of the samples showed significantly less tremor, and the connecting strokes demonstrated reduced instances of pen lifts.

Overall size

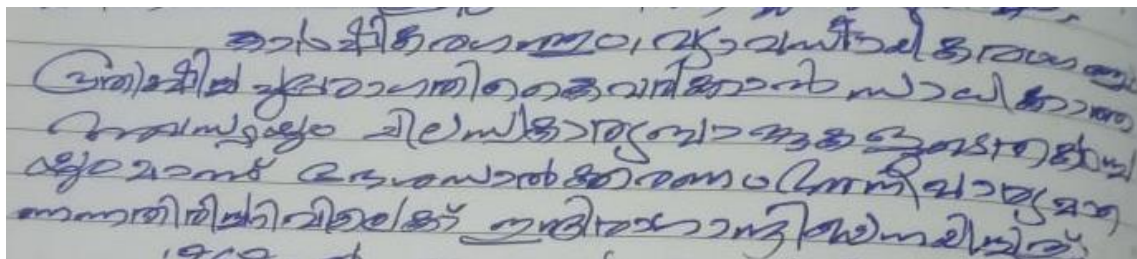
Among the 10 AH samples, changes in the overall size of the handwriting were observed in 6 samples. In 4 samples from individuals with diabetes mellitus, there was a general increase in the size of the writings. Notably, one sample displayed letters that were double the usual size (as shown in Figure 8a). In one instance, the size of letters from the same writer was inconsistent. These changes were not present in the individual's earlier writings. Conversely, a decrease in the overall size of the handwriting was observed in 2 samples of individuals with diabetes mellitus (as depicted in Figure 8b).



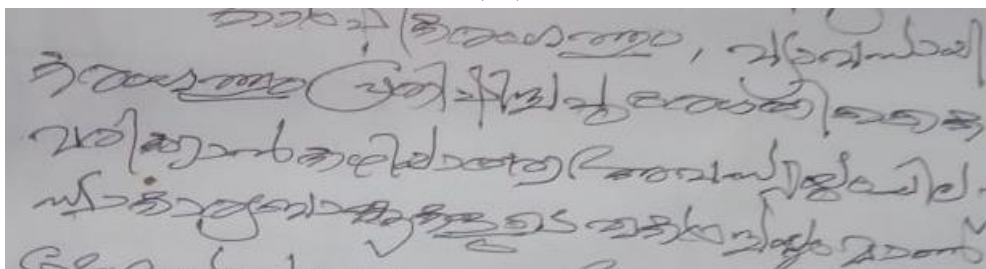
(a1)



(a2)



(b1)

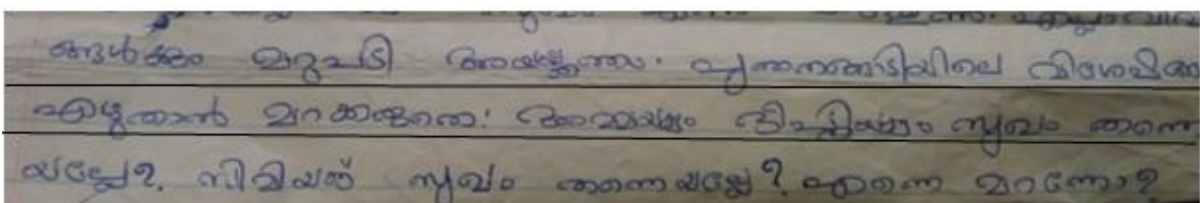


(b2)

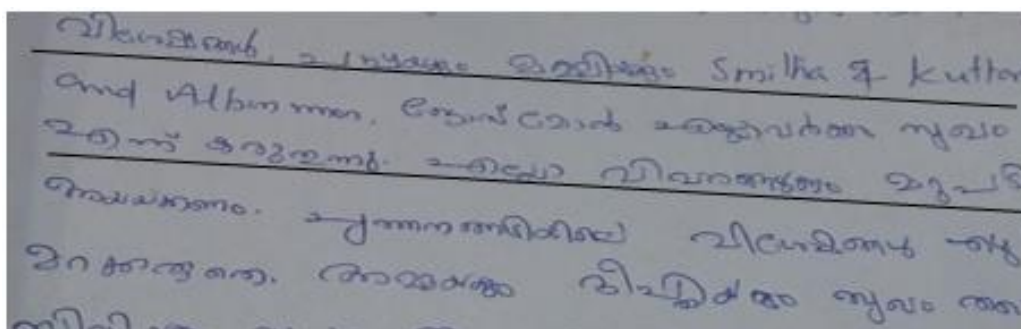
Fig. 7. Size of writing. (a1) Old handwriting specimen of a diabetes mellitus individual. (a2) Handwriting specimen of diabetes mellitus individual depicting increase in size as compared to handwriting executed during earlier period of time(a1). (b1) Old handwriting specimen of a diabetes mellitus individual. (b2) Handwriting sample of diabetes mellitus individual revealing decrease in size as compared to handwriting sample written during earlier period of time(b1).

Slant, Spacing and Alignment

In comparison to their OH samples, 8 AH samples exhibited a consistent slant similar to their previous writings. Additionally, 7 affected writings displayed narrow spacing between words, while 6 of the total affected writings demonstrated variations in the alignment of the overall writing (as shown in Figure 9).



(a)



(b)

Fig. 8. Alignment. (a) Handwriting before onset of diabetes mellitus depicting mixed alignment. (b) A shift in overall alignment along the downward direction in handwriting of diabetes mellitus patient.

6. Statistical Analysis

The paired t-test results revealed that Diabetes mellitus had an overall significant effect ($p < 0.05$) on several handwriting characteristics (Table 3) including rhythm ($t=-6.000$, $p=.000$), pen lift ($t=-3.000$, $p=.015$), retouching's ($t=-3.000$, $p=.015$), letter formation ($t=-6.000$, $p=.000$), writing speed ($t=-3.674$, $p=.005$), initial and terminal strokes ($t=-3.674$, $p=.005$), connecting strokes ($t=-3.674$, $p=.005$), overall size ($t=-3.674$, $p=.005$), spacing ($t=-4.583$, $p=.001$) and alignment ($t=-3.674$, $p=.005$). On the other hand, handwriting characteristics of tremor ($t=-1.500$, $p=.168$), omission of letters/parts ($t=-2.449$, $p=.037$), slant ($t=-1.500$, $p=.168$) and simplification/abbreviation did not show a statistically significant difference between the two groups ($p>0.05$).

Table 3

Pair	Variables	Mean	Std. deviation	t (test statistic)	df (degree of freedom)	Sig. (two-tailed) (p-value)
Pair 1	RM_OH/RM_AH	-0.8	0.422	-6	9	0
Pair 2	TM_OH/TM_AH	-0.2	0.422	-1.5	9	0.168
Pair 3	PN_OH/PN_AH	-0.5	0.527	-3	9	0.015
Pair 4	RO_OH/RO_AH	-0.5	0.527	-3	9	0.015
Pair 5	DL_OH/DL_AH	-0.8	0.422	-6	9	0
Pair 6	WS_OH/WS_AH	-0.6	0.516	-3.674	9	0.005
Pair 7	OM_OH/OM_AH	-0.4	0.516	-2.449	9	0.037
Pair 8	SM_OH/SM_AH	-	-	-	9	-
Pair 9	IT_OH/IT_AH	-0.6	0.516	-3.674	9	0.005
Pair 10	NC_OH/NC_AH	-0.6	0.516	-3.674	9	0.005
Pair 11	SI_OH/SI_AH	-0.6	0.516	-3.674	9	0.005
Pair 12	SL_OH/SL_AH	-0.2	0.422	-1.5	9	0.168
Pair 13	SP_OH/SP_AH	-0.7	0.483	-4.583	9	0.001
Pair 14	AG_OH/AG_AH	-0.6	0.516	-3.674	9	0.005

7. Discussion

Diabetes mellitus is a metabolic illness that affects people's social, physical, mental, and psychological well-being. Depression, poor eating habits, emotions, stress play a very

important part in handwriting and these factors are mostly characterized by people suffering from diabetes mellitus.

From the qualitative study we have found that the rhythm of writings after the onset of disease has a significant change. No significant tremor is observed in affected writings. Half of the samples showed pen lifts at certain strokes, particularly at letter turning positions and in words with larger letter formations, which may be mostly the result of muscle soreness. As a result, the position of the pen lifts can indicate the writer's genuine state of health. Retouching in affected works has been discovered to be bold in character and produced carelessly, which denotes a lack of effort to precisely link the strokes.

In the majority of the affected writings, varied degrees of deterioration in letter formation have been noted. Due to the tightness of the muscles brought on by diabetes mellitus, it has been discovered that the letter strokes are not smooth. Additionally, it might have prevented the proper hand motion needed to create some letters.

Moreover, a consistent observation in the affected handwriting samples was a decrease in writing speed. While a few examples exhibited challenging execution with blunt initial and terminal strokes, the majority of the samples displayed a combination of tapered and blunt strokes. Furthermore, the connecting strokes in most of the affected writings exhibited tremor in an angular and zigzag style.

The findings indicated that the size of the affected writing underwent both increases and decreases. However, the slant of the writing remained relatively unchanged in the AH samples. The slant is considered a consistent writing characteristic, and even minor deviations in a few strokes can indicate potential lack of authenticity. Furthermore, a shift in the alignment of the handwriting was observed, possibly due to variations in the movement and positioning of the writing arm relative to the writing line. Most of the affected writings exhibited a decrease in spacing, which may be attributed to the difficulty experienced in moving the writing instrument.

Lastly, the statistical comparison of the two authentic writes, OH and AH, has shown statistical significance for the majority of handwriting traits. This suggests that there is a distinct difference between texts created under two separate circumstances, namely before and after the onset of disease.

8. Conclusion

It can be concluded that diabetes mellitus brings about considerable effects on the handwriting of an individual owing to the mental stress and psychological nature of disease. Through comparison between handwritings of before getting affected and after getting affected by the disease has a considerable variation in them. This study may help forensic document experts to analyze between the handwriting sample of a person before and after getting with diabetes mellitus.

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