Statistical Shape Analysis of Handwriting of Patients with Multiple Sclerosis

Multipl Sklerozlu Hastaların El Yazılarının İstatistiksel Şekil Analizi

Güven ÖZKAYA,[a]
Özlem TAŞKAPILIOĞLU,[b]
İlker ERCAN[a]

Departments of
[a]Biostatistics,
[b]Neurology,
Uludağ University Faculty of Medicine,
Bursa

Geliş Tarihi/*Received:* 30.04.2012
Kabul Tarihi/*Accepted:* 10.07.2012

Yazışma Adresi/*Correspondence:*
Güven ÖZKAYA
Uludağ University Faculty of Medicine,
Department of Biostatistics,
Bursa,
TÜRKİYE/TURKEY
ozkaya@uludag.edu.tr

ABSTRACT Objective: The aim of the present study was to determine the alterations in the handwriting characteristics of multiple sclerosis (MS) patients acquired along one year at three different time points by using statistical shape analysis. **Material and Methods:** The handwriting samples of multiple sclerosis patients and control subjects were taken at three different time points. Statistical shape analysis of handwriting characteristics was performed. Principal coordinate analysis was applied to tangent coordinate which derived from Procrustes analysis. **Results:** Analysis of the handwriting samples at different time points suggested that upper case letters, both in the same box and in separate boxes, showed more changes in MS patients. Lower case letters in the same box showed more changes in MS patients while lower case letters in separate boxes showed more changes in the control subjects. **Conclusion:** There are only a few studies about analysis of handwriting by statistical shape analysis. In recent years, it has been observed that there has been considerable interest in the statistical analysis of shape. This study has imaginative aspects as it analyzed the handwriting characteristics of MS patients by using statistical shape analysis for the first time. We hope that this study enables further studies using this method of application.

Key Words: Handwriting; statistical shape analysis; principal coordinate analysis

ÖZET Amaç: Bu çalışmanın amacı, multipl skleroz (MS)'lu hastaların bir yıl boyunca üç farklı zamanda alınan el yazısı karakteristiklerindeki değişimi istatistiksel şekil analizi ile incelemektir. **Gereç ve Yöntemler:** MS'li hastaların ve kontrol grubunun el yazısı örnekleri farklı üç zaman diliminde elde edildi. Toplanan bu el yazısı karakteristiklerine istatistiksel şekil analizi uygulandı. Procrustes analiz sonucunda elde edilen tanjant koordinatlarına temel koordinat analizi uygulandı. **Bulgular:** Üç farklı zaman noktasında toplanan büyük harfli el yazısı örneklerinin analiz sonucunda hem aynı kutu içerisinde hem de harflerin ayrı kutu içerisinde yer aldığı durumdaki değişim MS'li hastalarda daha fazla bulunmuştur. Aynı kutu içerisinde küçük harfli el yazısı karakteristikleri MS'li hastalarda daha fazla değişim gösterirken, ayrı kutulardaki küçük harfli el yazısı karakteristikleri kontrol grubunda daha fazla değişim göstermiştir. **Sonuç:** İstatistiksel şekil analizi ile el yazılarının incelendiği çalışma sayısı oldukça azdır. Son yıllarda istatistiksel şekil analizi giderek artan bir ilgi görmektedir. Bu çalışmanın yaratıcı olan yönü, MS'li hastaların el yazısı karakteristiklerinin ilk kez istatistiksel şekil analiziyle incelenmesidir. Çalışmamızda kullanılan yöntemin benzer çalışmalarda uygulanabileceğini düşünmekteyiz.

Anahtar Kelimeler: El yazısı; istatistiksel şekil analizi; temel koordinat analizi

Turkiye Klinikleri J Med Sci 2012;32(6):1702-9

Writing is there presentation of thoughts and emotions in a textual medium like paper, wood or stone with a set of symbols. The muscular movements involved in writing are controlled by the central nervous system (CNS).

doi: 10.5336/medsci.2012-30233

Handwriting requires voluntary acquisition. The learned configuration technique of a letter will lifelong stay the same.[1] Materials used during writing (paper, pen), environment (ground, illumination), loss of strength and coordination in the hand, arm, and shoulder due to aging, disease of CNS like multiple sclerosis (MS), traumatic complications, or alcohol use may cause permanent or transient alterations on handwriting.[2] There are few articles, based on empirical data such as "few" or "increased", about the influence of MS on handwriting characteristics.

There are very few studies about analysis of handwriting by statistical shape analysis. In recent years, it is observed that there has been considerable interest in the statistical analysis of shape.[3] Statistical shape analysis is a geometrical analysis of the statistics measured from sets of shapes that determines the features of similar shapes or of different groups comprising similar shapes. Distance between shapes, mean shape and shape variation can be predicted and obtained using statistical shape analysis.[4]

The aim of this study was to determine the alterations in the handwriting characteristics of MS patients acquired along one year at three different time points by using statistical shape analysis.

MATERIAL AND METHODS

A total of 16 MS patients, diagnosed on the basis of McDonald's criteria and being followed up in the outpatient clinic of Neurology Department, Uludag University Medical Faculty, were included in the study. Seven of the patients were excluded due to nonattendance at 6th and 12th month follow ups. In addition, one of the patients was excluded because of having attached to study at the 12th month while taking handwriting sample. The rest of 8 MS patients (4 females, 4 males) were included in the study. Their ages were between 30-51 years (median= 36.00) with a disease duration of 1-19 years (median=10.50) and the Expanded Disability Status Scale (EDSS) of 2.5-6.5 (median=3.25). Five of them had relapsing-remitting MS while 3 of them were in the secondary progressive phase of MS. The median time from the onset of secondary progression was 2 (1-5) years. The control group consisted of 5 male and 11 female subjects, aged between 24 and 44 years (median=31.5). None of the MS patients had other major clinical illnesses, had a history of an MS attack, pseudo attack or corticosteroid use within 4 weeks preceding handwriting sample acquisition, a Beck Depression Rating Scale score more than 10, or a history of substance abuse. Informed consent was obtained from all participants, and the university ethics committee approved the study protocol.

The handwriting samples of MS patients and control subjects were taken at three different time points: At baseline, 6, and 12 months after. Each subject was asked to write the words: "BURSA" and "bursa" within a defined box as shown (Figure 1). The same numbers of landmarks were plotted on the letters each handwriting sample type. There were 10 and 9 landmarks on upper case and lower case letters, respectively. The studied landmarks were plotted on the digital images by using TPS-DIG 2.04 software.

Similar conditions such as a paper pad, a standard A4-sized paper and a medium ballpoint pen were maintained. The letters were written while seated at a table and chair appropriate for the height of the subject in a quiet room under adequate illumination and without distractions.

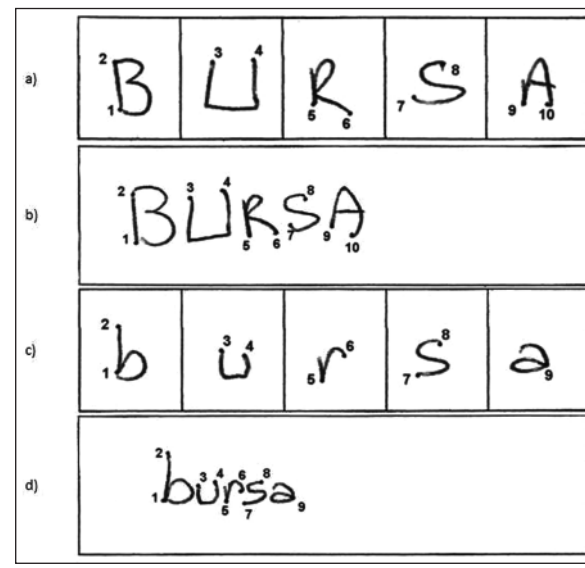


FIGURE 1: Landmarks on handwriting sample.

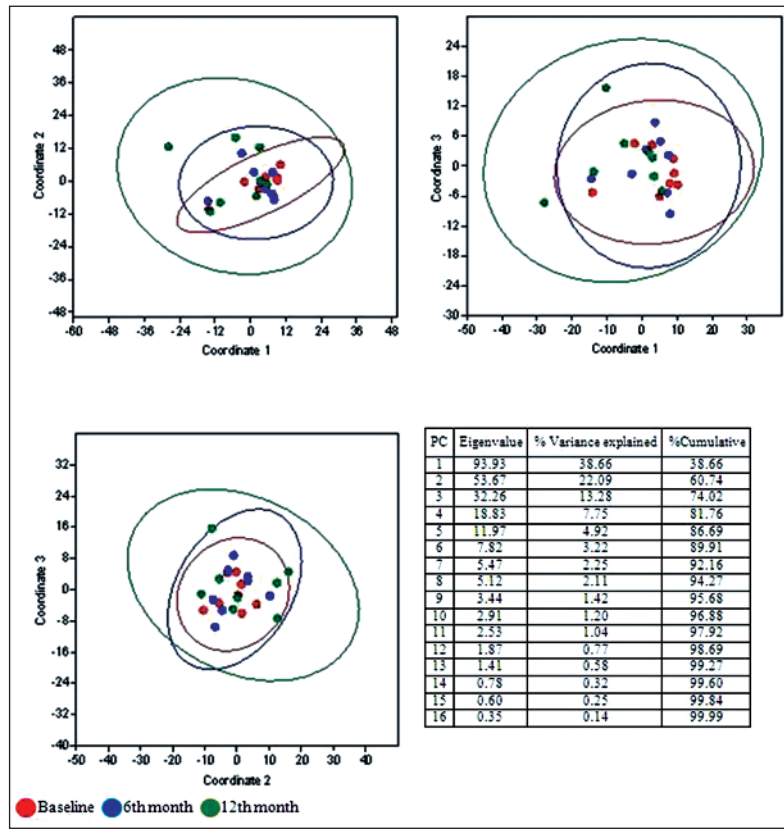
Statistical shape analysis of handwriting characteristics was performed. In statistical shape analysis, generalized Procrustes analysis was used for evaluating shapes of the letters. Procrustes analysis is known in shape analysis as the approach that obtains the minimum sum of squared differences between the landmarks. Procrustes analysis involves matching configurations with similarity transformations (translation, rotation, scaling) to be as close as possible according to Euclidean distance, using least squares techniques.[4] After using principal coordinate analysis, handwriting samples of classification and changes were examined for MS patients and control subjects at different time points. Principal coordinate analysis was applied to tangent coordinate which derived from Procrustes analysis. Euclidean distance is used in principal coordinate analysis. In this study, the R 2.11 and PAST 1.84 software were used for the statistical analysis.

RESULTS

Analysis of the written samples "BURSA" (each letter written in a separate box) (Figure 1a) showed variance explanation rates for the first three components considered in MS patients and control subjects as 74.02% and 53.07%, respectively (Figure 2, Figure 3).

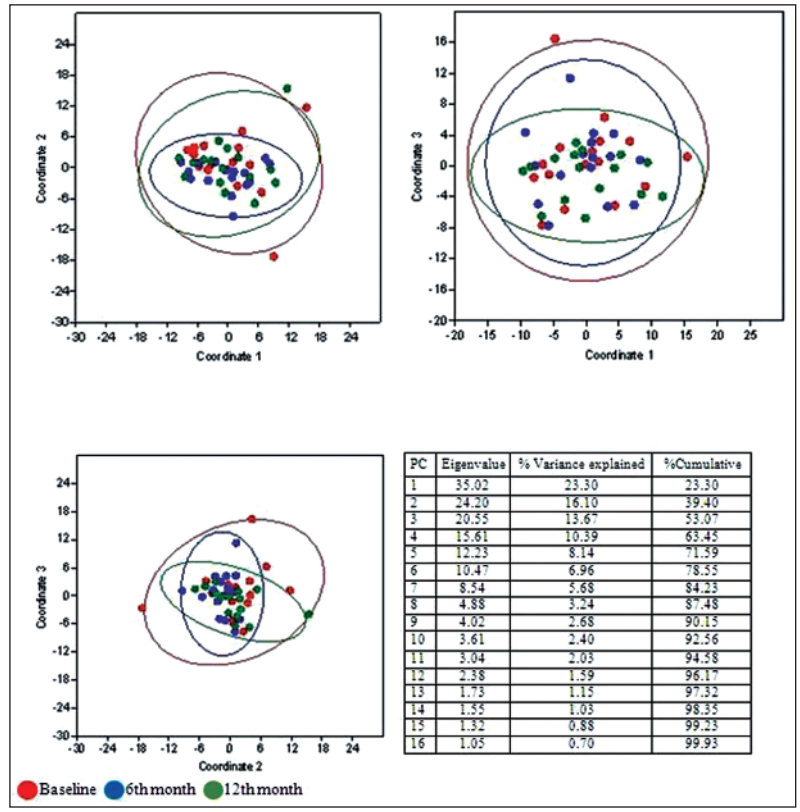
The variance explanation rates for the first three components of the written samples "BURSA" (the whole word written in the same box) (Figure1 b) were 62.89% and 61.05% in MS patients and control subjects, respectively (Figure 4, Figure 5).

According to the analysis results of the written samples "bursa" (each letter written in a separate box) (Figure1 c), variance explanation rates for the first three components considered in MS patients and control subjects were 54.98% and 59.60%, respectively (Figure 6, Figure 7).



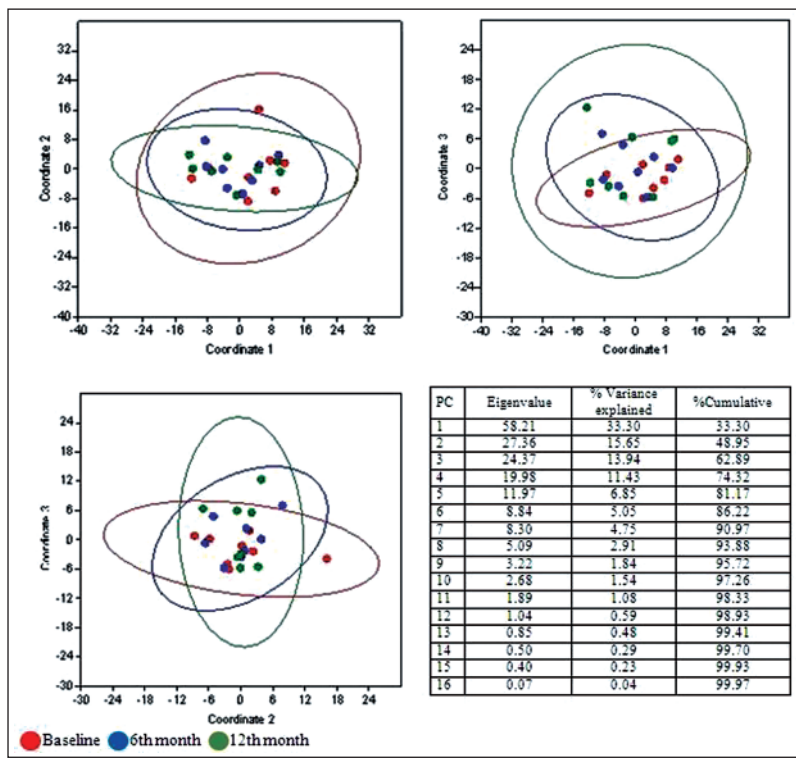
PC	Eigenvalue	% Variance explained	%Cumulative
1	93.93	38.66	38.66
2	53.67	22.09	60.74
3	32.26	13.28	74.02
4	18.83	7.75	81.76
5	11.97	4.92	86.69
6	7.82	3.22	89.91
7	5.47	2.25	92.16
8	5.12	2.11	94.27
9	3.44	1.42	95.68
10	2.91	1.20	96.88
11	2.53	1.04	97.92
12	1.87	0.77	98.69
13	1.41	0.58	99.27
14	0.78	0.32	99.60
15	0.60	0.25	99.84
16	0.35	0.14	99.99

FIGURE 2: Scatter graphs with 95% confidence ellipses and Principal Coordinate Analysis results of multiple sclerosis patients for B U R S A
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)



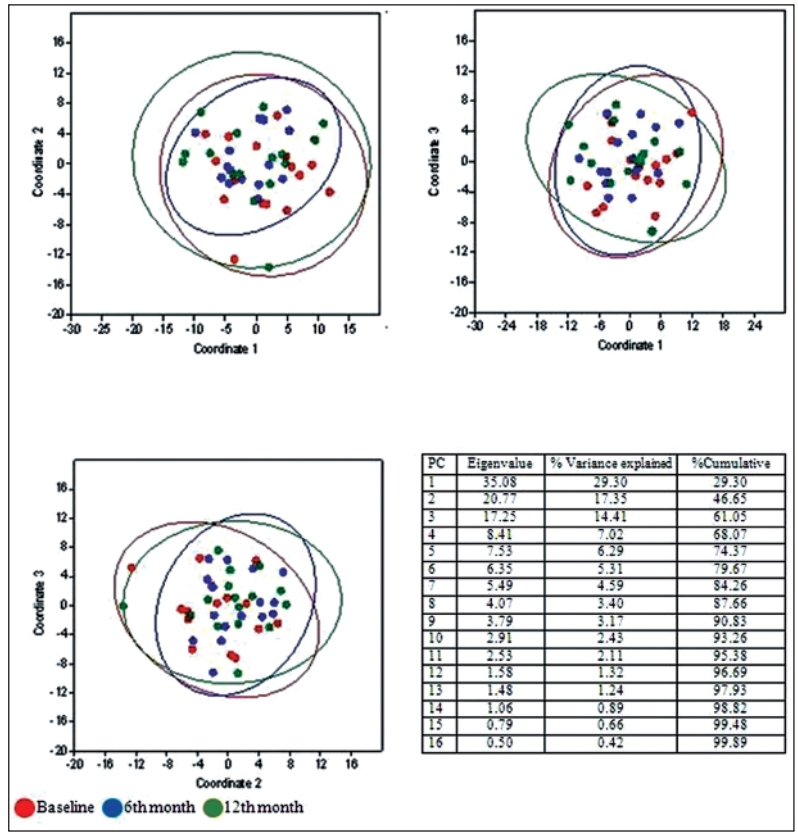
PC	Eigenvalue	% Variance explained	%Cumulative
1	35.02	23.30	23.30
2	24.20	16.10	39.40
3	20.55	13.67	53.07
4	15.61	10.39	63.45
5	12.23	8.14	71.59
6	10.47	6.96	78.55
7	8.54	5.68	84.23
8	4.88	3.24	87.48
9	4.02	2.68	90.15
10	3.61	2.40	92.56
11	3.04	2.03	94.58
12	2.38	1.59	96.17
13	1.73	1.15	97.32
14	1.55	1.03	98.35
15	1.32	0.88	99.23
16	1.05	0.70	99.93

FIGURE 3: Scatter graphs with 95% confidence ellipses and Principal Coordinate Analysis results of the controls for B U R S A
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)



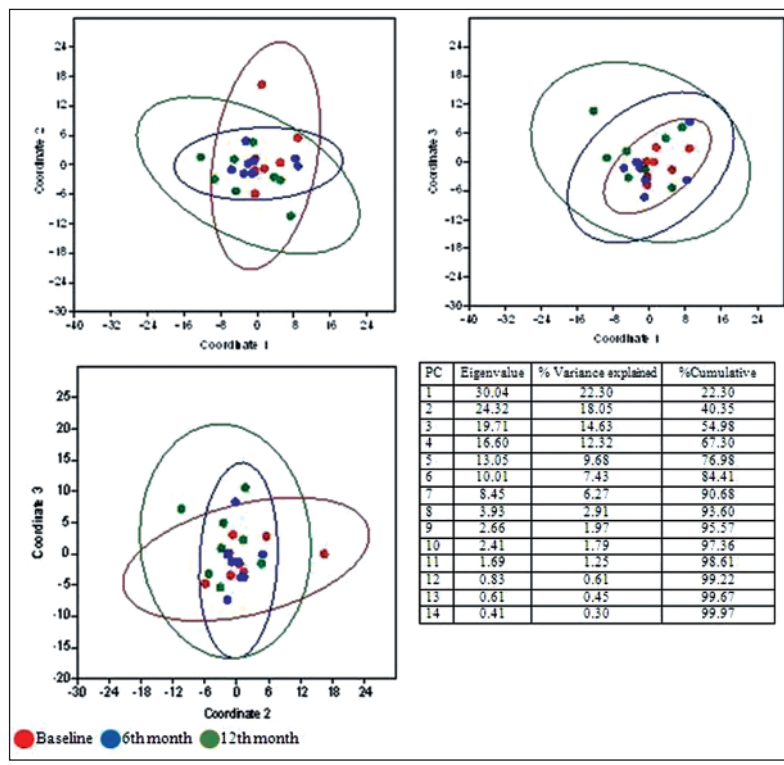
PC	Eigenvalue	% Variance explained	%Cumulative
1	58.21	33.30	33.30
2	27.36	15.65	48.95
3	24.37	13.94	62.89
4	19.98	11.43	74.32
5	11.97	6.85	81.17
6	8.84	5.05	86.22
7	8.30	4.75	90.97
8	5.09	2.91	93.88
9	3.22	1.84	95.72
10	2.68	1.54	97.26
11	1.89	1.08	98.33
12	1.04	0.59	98.93
13	0.85	0.48	99.41
14	0.50	0.29	99.70
15	0.40	0.23	99.93
16	0.07	0.04	99.97

FIGURE 4: Scatter graphs with 95% confidence ellipses and Principal Coordinate Analysis results of multiple sclerosis patients for BURSA
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)



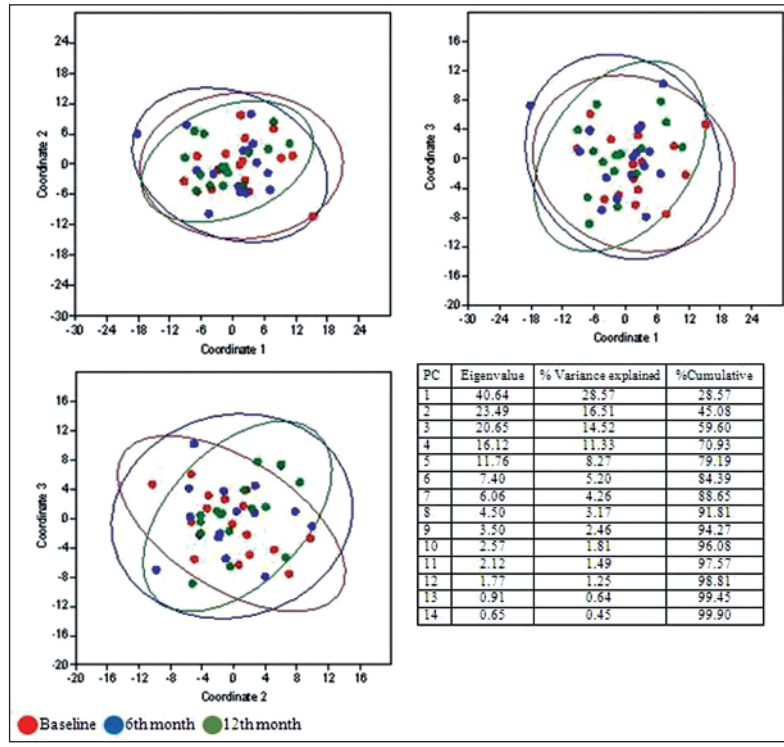
PC	Eigenvalue	% Variance explained	%Cumulative
1	35.08	29.30	29.30
2	20.77	17.35	46.65
3	17.25	14.41	61.05
4	8.41	7.02	68.07
5	7.53	6.29	74.37
6	6.35	5.31	79.67
7	5.49	4.59	84.26
8	4.07	3.40	87.66
9	3.79	3.17	90.83
10	2.91	2.43	93.26
11	2.53	2.11	95.38
12	1.58	1.32	96.69
13	1.48	1.24	97.93
14	1.06	0.89	98.82
15	0.79	0.66	99.48
16	0.50	0.42	99.89

FIGURE 5: Scatter graphs with 95% confidence ellipses and Principal Coordinate Analysis results of the controls for BURSA
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)



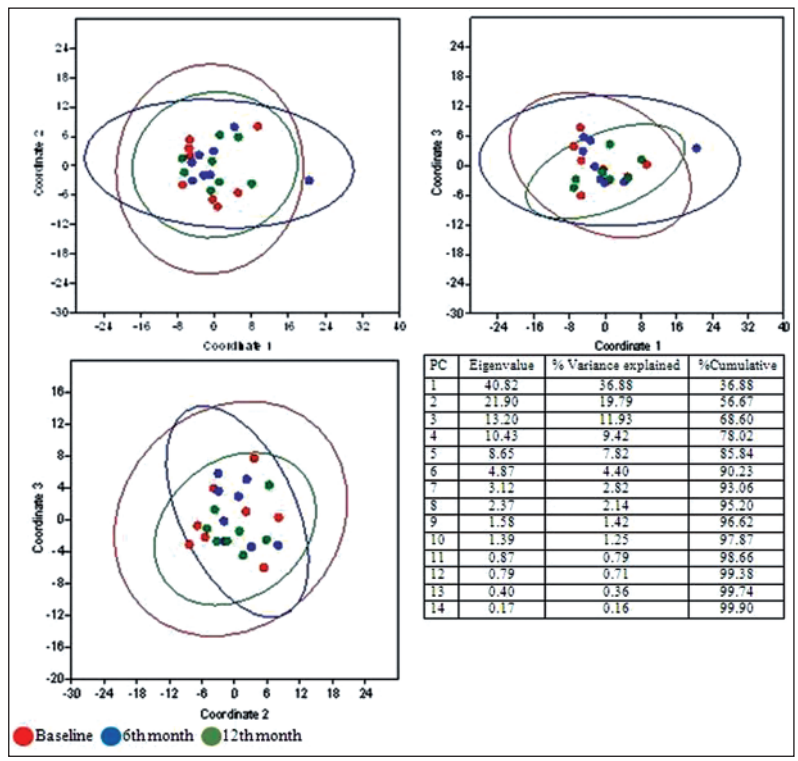
PC	Eigenvalue	% Variance explained	%Cumulative
1	30.04	22.30	22.30
2	24.32	18.05	40.35
3	19.71	14.63	54.98
4	16.60	12.32	67.30
5	13.05	9.68	76.98
6	10.01	7.43	84.41
7	8.45	6.27	90.68
8	3.93	2.91	93.60
9	2.66	1.97	95.57
10	2.41	1.79	97.36
11	1.69	1.25	98.61
12	0.83	0.61	99.22
13	0.61	0.45	99.67
14	0.41	0.30	99.97

FIGURE 6: Scatter graphs with 95% confidence ellipses and Principal Coordinate Analysis results of multiple sclerosis patients for b u r s a
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)



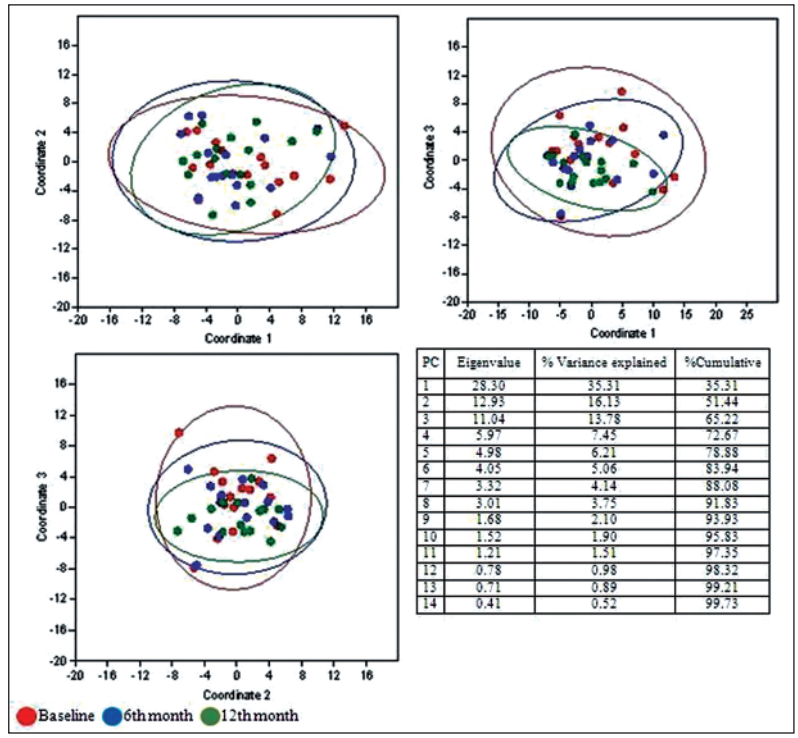
PC	Eigenvalue	% Variance explained	%Cumulative
1	40.64	28.57	28.57
2	23.49	16.51	45.08
3	20.65	14.52	59.60
4	16.12	11.33	70.93
5	11.76	8.27	79.19
6	7.40	5.20	84.39
7	6.06	4.26	88.65
8	4.50	3.17	91.81
9	3.50	2.46	94.27
10	2.57	1.81	96.08
11	2.12	1.49	97.57
12	1.77	1.25	98.81
13	0.91	0.64	99.45
14	0.65	0.45	99.90

FIGURE 7: Scattergraphs with 95% confidence ellipses and Principal Coordinate Analysis results of the controls for b u r s a
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)



PC	Eigenvalue	% Variance explained	%Cumulative
1	40.82	36.88	36.88
2	21.90	19.79	56.67
3	13.20	11.93	68.60
4	10.43	9.42	78.02
5	8.65	7.82	85.84
6	4.87	4.40	90.23
7	3.12	2.82	93.06
8	2.37	2.14	95.20
9	1.58	1.42	96.62
10	1.39	1.25	97.87
11	0.87	0.79	98.66
12	0.79	0.71	99.38
13	0.40	0.36	99.74
14	0.17	0.16	99.90

FIGURE 8: Scatter graphs with 95% confidence ellipses and Principal Coordinate Analysis results of multiple sclerosis patients for bursa
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)



PC	Eigenvalue	% Variance explained	%Cumulative
1	28.30	35.31	35.31
2	12.93	16.13	51.44
3	11.04	13.78	65.22
4	5.97	7.45	72.67
5	4.98	6.21	78.88
6	4.05	5.06	83.94
7	3.32	4.14	88.08
8	3.01	3.75	91.83
9	1.68	2.10	93.93
10	1.52	1.90	95.83
11	1.21	1.51	97.35
12	0.78	0.98	98.32
13	0.71	0.89	99.21
14	0.41	0.52	99.73

FIGURE 9: Scatter graphs with 95% confidence ellipses and Principal Coordinate Analysis results of the controls for bursa
(See for colored form http://tipbilimleri.turkiyeklinikleri.com/)

The variance explanation rates for the first three components of the written samples "BURSA" (the whole word written in the same box) (Figure 1d) were 68.60% and 65.22% in MS patients and control subjects, respectively (Figure 8, Figure 9).

DISCUSSION

In the last two decades, a growing interest has been observed in the use of statistical shape analysis in the field of medicine. The main reasons for use of statistical shape analysis widely in medicine are advances in imaging technology and tendency to investigate the effects of diseases and the environmental factors' effects on the structure of the organ or organism.[5]

There are studies about handwriting changes in neurological disorders, but most of them were concentrated on dystonia, stroke, Parkinson's or Huntington's disease.[6-9] Despite common occurrence of handwriting deficits in MS, there are a limited number of manuscripts on this aspect of MS in the literature. Some of them were done in MS patients with tremor; some in MS with a motor disorder of handwriting. All of them used different methods to analyze the handwriting samples.[10-14]

Analysis of the handwriting samples at different time points suggested that upper case letters, both in the same box and in separate boxes, showed more changes in MS patients. Lower case letters in the same box showed more changes in MS patients while lower case letters in separate boxes showed more changes in the control subjects. Changes in the upper case letters being more prominent in MS patients may be the result of the difficulty attributed to their longer straight lines and more difficult perpendicular angles.

None of MS patients, except one, showed progression during the study. EDSS of the patient with disease progression increased from 4.0 to 5.5 without any attack. Therefore the changes in upper case letters written by the same MS patient at different time points may be attributed to vulnerability of fine motor control system in MS patients in time.

Application of statistical shape analysis of organ and organism are very common. However, there are very few studies about analysis of hand-

writing by statistical shape analysis.[15-19] Only Arslan and Guney examined shape changes between characters written by left-handed and right-handed persons and females and males.[20]

The novelty of this study is due to rarity of handwriting analysis in patients with MS, follow-up of MS patients for one year, and use of statistical shape analysis for handwriting analysis. One limitation of the study is its short duration and small numbers of participants. It would be valuable to perform a longer study with more MS patients taking the long duration of MS into consideration.

This study has imaginative aspects as it analyzed the handwriting characteristics of MS patients by using statistical shape analysis for the first time.

CONCLUSION

This study showed the presence of changes in the handwritings of MS patients compared to control subjects within one year period by using statistical shape analysis. We hope that this study enables further studies using similar methods of application.

REFERENCES

1. Seçkin Ç, Kurtaş Ö, Çakır İ, Aşıcıoğlu F, Birincioğlu İ, Alkan N, et al. [Handwriting examination techniques and principles by examples]. Aşıcıoğlu F, editör. Adli Bilimlerde Elyazısı ve İmza İncelemeleri. 1. Baskı. İstanbul: Öner Matbaacılık; 2007. p.122-47.
2. Aşicioğlu F, Turan N. Handwriting changes under the effect of alcohol. Forensic Sci Int 2003;132(3):201-10.
3. Amaral GJA, Dryden I, Wood ATA. Pivotal bootstrap methods for k-sample problems in directional statistics and shape analysis. J Am Stat Assoc 2007;102(478):695-707.
4. Dryden IL, Mardia KV. Statistical Shape Analysis. Volume 4. 1st ed. Chichester: John Wiley & Sons; 1998. p.1-107.
5. Ercan İ, Ocakoğlu G, Sığırlı D, Özkaya G. Statistical shape analysis and usage in medical sciences. Turkiye Klinikleri J Biostat 2012;4(1):27-35.
6. Phillips JG, Bradshaw JL, Chiu E, Bradshaw JA. Characteristics of handwriting of patients with Huntington's disease. Mov Disord 1994;9(5):521-30.
7. Walton J. Handwriting changes due to aging and Parkinson's syndrome. Forensic Sci Int 1997;88(3):197-214.
8. Van Gemmert AW, Teulings HL, Contreras-Vidal JL, Stelmach GE. Parkinson's disease and the control of size and speed in handwriting. Neuropsychologia 1999;37(6):685-94.
9. Contreras-Vidal JL, Teulings HL, Stelmach GE, Adler CH. Adaptation to changes in vertical display gain during handwriting in Parkinson's disease patients, elderly and young controls. Parkinsonism Relat Disord 2002; 9(2):77-84.
10. Scolding NJ, Lees AJ. Micrographia associated with a parietal lobe lesion in multiple sclerosis. J Neurol Neurosurg Psychiatry 1994; 57(6):739-41.
11. Alusi SH, Worthington J, Glickman S, Findley LJ, Bain PG. Evaluation of three different ways of assessing tremor in multiple sclerosis. J Neurol Neurosurg Psychiatry 2000;68(6):756-60.
12. Schenk T, Walther EU, Mai N. Closed- and open-loop handwriting performance in patients with multiple sclerosis. Eur J Neurol 2000;7(3): 269-79.
13. Varley R, Cowell PE, Gibson A, Romanowski CA. Disconnection agraphia in a case of multiple sclerosis: the isolation of letter movement plans from language. Neuropsychologia 2005;43(10):1503-13.
14. Rosenblum S, Tamar Weiss PL. Evaluating functional decline in patients with Multiple Sclerosis. Res Dev Disabil 2010;31(2):577-86.
15. Sonat F, Ercan I, Ozdemir ST, Ozkaya G, Noyan B. Statistical shape analysis of the rat hippocampus in epilepsy. Anat Sci Int 2009;84(4):298-304.
16. Ercan I, Ozdemir ST, Etoz A, Sigirli D, Tubbs RS, Loukas M, et al. Facial asymmetry in young healthy subjects evaluated by statistical shape analysis. J Anat 2008;213(6):663-9.
17. Ozdemir ST, Ercan I, Sevinc O, Guney I, Ocakoglu G, Aslan E, et al. Statistical shape analysis of differences in the shape of the corpus callosum between genders. Anat Rec (Hoboken) 2007;290(7):825-30.
18. Colak C, Ercan I, Dogan M, Ozdemir ST, Sener S, Alkan A. Detecting the shape differences of the corpus callosum in Behçet's disease by statistical shape analysis. Anat Rec (Hoboken) 2011;294(5):870-4.
19. Başkan EB, Ercan İ, Özdemir ST, Özkaya G, Yılmaz M, Özgenel Y, et al. A case of Parry-Romberg syndrome: examining efficacy of lipofilling by statistical shape Analysis. Turkiye Klinikleri J Med Sci (doi: 10.5336/medsci.2011-27004).
20. Arslan E, Guney I. Analyzing the S character with thin plate spline. Journal of Analysis and Computation 2007;3(2):109-14.