International Journal of Internet, Broadcasting and Communication Vol.13 No.2 260-266 (2021)
http://dx.doi.org/10.7236/IJIBC.2021.13.2.260

IJIBC 21-2-31

Comparison of dominant and nondominant handwriting with the signal of a three-axial accelerometer

Tae-Hoon Kim

Professor, Department of Occupational Therapy, Dongseo University, Korea, context@dongseo.ac.kr

Abstract

Handwriting using the dominant and nondominant arms was analyzed in 52 young adults with the aid of a three-axial accelerometer. We measured a signal vector magnitude (SVM) and the percentage of the total signal vector magnitude (%TSVM) for the metacarpophalangeal joint (MCP), radial styloid process (RSP), and lateral epicondyle (LE) of both arms. The SVM for the MCP was lower in the dominant arm than the nondominant arm, whereas that for the RSP was higher. %TVSM was lower for the MCP than for the RSP and LE in the nondominant arm, but higher for the MCP than for the LE in the nondominant arm. These findings suggest that controlling the MCP will improve the quality of handwriting, including when using the nondominant arm.

Keywords*: accelerometry, signal vector magnitude, handwriting, dominant arm*

1. Introduction

Handwriting is the most complex and also the most utilized motor skill. It took thousands of years for humans to develop tools with the precision of a pencil, which requires intricate fine motor skills. From a motor-skill perspective, a pencil is more difficult to use than the most useful computer [1]. Most healthy people use a pencil with their dominant arm. If they write with their nondominant arm, the efficiency of the movement would be relatively lower than that of the dominant arm during the performance. However, nondominant handwriting may have implications for clinical rehabilitation and highly specialized skill training that requires the use of the nondominant arm in complex tasks [2]. For example, a person with right hemiplegia after a cerebrovascular accident can dress, drive, or write themselves using their nondominant arm.

In other words, a patient with right hemiplegia, whose arm was right-dominant before the disease, often uses a left-nondominant arm to perform handwriting. Besides, the movement of the hemiplegic arm differs from that of the healthy arm and it shows a similar pattern in the sense that the movement of the nondominant arm is distinct from that of the dominant arm in healthy people [3]. Therefore, it can be assumed that analyzing the nondominant arm of the healthy maybe apply to that of hemiplegic patients in the further clinical study and we would need to find the patterns of the nondominant arm of

Manuscript Received: May. 2, 2021 / Revised: May. 6, 2021 / Accepted: May. 8, 2021
Corresponding Author: context@dongseo.ac.kr
Tel: +82-51-320-2718, Fax: +82-51-320-2721
Professor, Department of Occupational Therapy, Dongseo Unversity, Korea

the healthy in comparison with the dominant arm during handwriting.

A promising new area of research involves using a digitizer to record the position of the pen during handwriting, with the data transmitted as a Graphogram [4]. An accelerometer has previously been used to assess physical activity in traditional methods of motor analysis, and recent researches have shown that it facilitates high activity classification accuracies when using machine-learning models [5]. The objectives of this study were to compare dominant handwriting with nondominant handwriting using a three-axis accelerometer in young adults, so as to provide fundamental data for use in further clinical research.

2. Methods

2.1. Participants

From June 1 to June 30, 2020 we received ethical approval from two professional clinicians and three professors regarding the safety and clinical significance of this study. The 52 included subjects were aged 22.90±2.68 years (mean±SD) and they voluntarily agreed to participate after receiving information about the protocol and purpose of the study.

2.2. Apparatus

The Fitmeter (FitLife, Korea) is a three-axis acceleration motion sensor (3.5 cm × 3.5 cm × 1.3 cm, 13.7 g) that measures triaxial acceleration values in the x, y, and z directions, and applies a filter to reduce the effects of acceleration due to gravity (G) and internal errors. The times when acceleration changes are recorded as data is determined by pushing the button on the accelerometer. The maximum acceleration measurement range can be set from 2G to 8G (1G = 9.8 m/s^2): 2G (–61.25 cm/s^2 to +61.25 cm/s^2) is used for slow and precise motion measurements, 4G (–122.25 cm/s^2 to +122.25 cm/s^2) is used for routine movements, and 8G (–245 cm/s^2 to +245 cm/s^2) is used for rapid activities such as sports [6]. In the present study, 4G was set for measuring a task performed during the activities of daily living (Figure 1). To measure movements of the lower arm according to the International Biomechanics Association standard, markers were attached on the metacarpophalangeal joint (MCP), radial styloid process (RSP), and lateral epicondyle (LE) of both arms [7].

2.3. Experimental Procedure

The experiments were performed in a quiet environment. The subjects sat on chair with a backrest and no armrest, and then bent their hip joint, a knee joint, and an ankle joint at 90 degrees. Their arm rested comfortably on a table that was 10 cm from the torso. The researcher stood to one side of the subject while making the measurements.

Based on the Jebsen-Taylor Hand Function Test [8], the participant was instructed to write a short Korean sentence “저 노인은 피곤해 보인다” (“That old man looks tired”) three times. A rest period of 1 minute was allowed between each trial.

(a) During writing (b) On the LE (c) On the MCP and RSP

Figure 1. Attachment locations of the accelerometers

2.4. Dependent Variables

2.4.1 Signal Vector Magnitude

We defined the signal vector magnitude (SVM) as follows [9]:

$$SVM = \sqrt{Ax^2 + Ay^2 + Az^2}$$

where *Ax*, *Ay*, and *Az* are the accelerations in the *x*, *y*, and *z* directions, respectively.

2.4.2 Percentage of the Total Signal Vector Magnitude

We defined the percentage of the total signal vector magnitude (%TSVM) as the value relative to the total SVM value, which is the sum of the values derived from the MCP, RSP, and LE of both arms.

2.5. Data Analysis

Fitmeter Manager (version 1.2) software was run on PC to analyze the data measured by the accelerometers. The accelerometers attached to both the upper and lower arms had a measurement interval of 1/32 sec for the three axes (*x*, *y*, and *z*), and the maximum acceleration measurement range was 4*G*. Six accelerometers (that were attached to subjects) and one accelerometer (that was used to allow the researcher to monitor the time) were synchronized, and then measured. The axial accelerations in the *x*, *y*, and *z* directions generated during the task were stored as a vector value with magnitude and direction [9]. IBM SPSS (version 23.0) software was used to statistically analyze the data. Movements were compared between the dominant and nondominant arms during the writing task using the independent-samples *t*-test, while one-way ANOVA was applied with an α level of .05 to compare the relative movements among the MCP, RSP, and LE.

3. Results

3.1. SVM

SVM was lower in the dominant arm than the nondominant arm for the MCP ($p < .05$), while it was higher in the dominant arm for the RSP ($p < .05$) and did not differ significantly between the dominant and nondominant arms for the LE ($p > .05$) (Table 1, Figure 2).

Table 1. Comparison of SVMs in the dominant and nondominant arms

	Dominant	Nondominant	*t*	*p*
MCP	3.56±5.37	5.19±1.91	2.06	.04*
RSP	5.44±2.23	4.62±1.61	2.14	.04*
LE	5.08±3.61	3.87±3.92	1.64	.11

Data are mean±SD values (*N* = 52) (*$p < .05$)

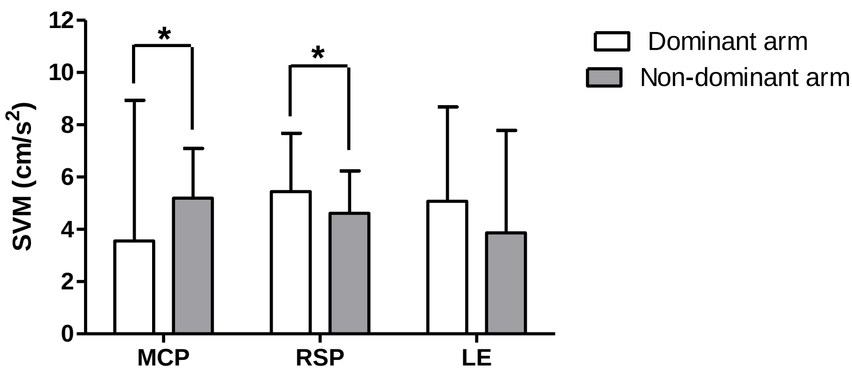

Figure 2. Comparison of SVMs in the dominant and nondominant arms. Data are mean and SD values (*$p < 0.05$)

3.2. %TSVM

A post-hoc analysis revealed that %TVSM in the dominant arm was lower for the MCP than for the RSP and LE ($p < .05$), with no significant difference between the RSP and LE ($p > .05$). In the nondominant arm, %TVSM was higher for the MCP than for the LE ($p < .05$), with no significant differences between the MCP and RSP ($p > .05$) or between the RSP and LE ($p > .05$) (Table 2, Figure 3).

Table 2. Comparison of %TSVM among the three accelerometers

	MCP	RSP	LE	*F*	*p*
Dominant arm	10.06±11.52	20.35±7.69	17.39±6.10	19.07	.00**
Nondominant arm	19.87±6.20	18.03±7.07	14.27±14.00	4.47	.01*

Data are mean±SD values (*N* = 52) (*$p < .05$; **$p < .01$)

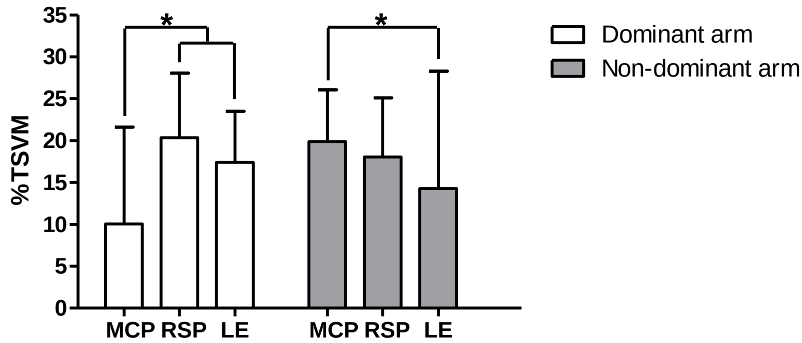

Figure 3. Comparison of %TSVM among the three accelerometers ($^{*}p < 0.05$)

4. Discussion

The purpose of this study was to compare dominant handwriting with nondominant handwriting by measuring SVMs using three-axis accelerometers in young adults. In our study, the SVM was lower in the dominant arm than the nondominant arm for the MCP, but higher for the RSP. This means that the wrist movement of the dominant arm is more stable than that of the nondominant arm, as is the writing fluency, which is characterized by rapid simultaneous movements of the forearms along the writing lines. Bunnell stated that the wrist is the key joint of the hand, and that limitations in movements of the wrist cannot be compensated for by any joint in the upper extremity [10]. [11] used electromyography to reveal that intrinsic muscles guide and grade the multiple movement patterns of the intermediate finger and thumb and control all rotatory movements of the thumb and MCP used in precision handling. Therefore, the wrist influences the position of the MCP, while the MCP influences the position of the proximal interphalangeal (IP) joint, which in turn influences the distal IP joint [12]. These anatomic principles provide a foundation to analyze the fine motor skills involved in the writing task [13].

%TVSM was lower for the MCP than for the RSP and LE in the dominant arm, and higher for the MCP than for the LE in the nondominant arm in the present study. This means that the stability of the MCP of the dominant arm—which is used to write with constant patterns—is higher than that of the nondominant arm. Moreover, excessive movements of the nondominant MCP cause the thumb IP joint to move with difficulty [14]. This results in nondominant handwriting being larger than dominant handwriting and characterized by inconsistent patterns, slowness, and illegibility [15]. The writing task involves a combination of acceleration and deceleration, which are determined by the ratio of the agonist and antagonistic muscles and show temporal and spatial motion characteristics [16]. A shift in muscular inhibition generates rapid movements associated with action and opposition activities increasing for agonist muscles relative to antagonistic muscles [17].

It has been suggested that accelerometers have various potential applications in conditions such as stroke and degenerative diseases of the central nervous system [18]. We suggest that the present results could be applied in rehabilitation clinics [19]. For example, patients with right hemiplegia often use the nondominant (left) arm to perform various activities of daily living, including handwriting. However, since the nondominant arm is characterized by abnormal movements in the MCP, RSP, and other joints, accelerometers could be used to quantitatively measure the movements of upper extremities and thereby allow objective data analyses. Accelerometers also have advantages of convenience and usability, and so could be useful tools for estimating the movements of the upper limb in individuals with neurogenic disorders.

5. Conclusion

The results obtained in this study suggest that controlling the MCP would improve the quality of handwriting, including when using the nondominant arm. Further research should be performed in rehabilitation clinics with the aim of facilitating the arm function of neurologic patients, including their handwriting

Acknowledgement

This work was supported by Dongseo University, "Dongseo Cluster Project" Research Fund of 2021 (DSU-20210004).

References

[1] E. Hamhuis, C. Glas, and M. Meelissen, Tablet assessment in primary education: Are there performance differences between TIMSS' paper - and - pencil test and tablet test among Dutch grade - four students?, British Journal of Educational Technology, Vol. 51, No. 6, pp. 2340-2358, Feb 2020. DOI: https://doi.org/10.1111/bjet.12914

[2] K. M. Farris, R. E. Fehrenbacher, E. L. Hayes, R. R. McEvoy, A. P. Smith, and R. S. McCulloch, The relationship between muscle activation and handwriting quality with non-native grip styles, Journal of Hand Therapy, Vol. 43, No. 1, pp. 1-34, Mar 2021. DOI: https://doi.org/10.1016/j.jht.2021.03.004

[3] M. Demers and M. F. Levin, Kinematic validity of reaching in a 2D virtual environment for arm rehabilitation after stroke, IEEE Transactions on Neural Systems and Rehabilitation Engineering, Vol. 28, No. 3, pp. 679-686, Mar 2020. DOI: https://doi.org/10.1109/TNSRE.2020.2971862

[4] M. Abazid, N. Houmani, and S. Garcia-Salicetti, Enhancing Security on Touch-Screen Sensors with Augmented Handwritten Signatures, Sensors, Vol. 20, No. 3, pp. 933-953, Feb 2020. DOI: https://doi.org/10.3390/s20030933

[5] A. Narayanan, F. Desai, T. Stewart, S. Duncan, and L. Mackay, Application of raw accelerometer data and machine-learning techniques to characterize human movement behavior: a systematic scoping review, Vol. 17, No. 3, pp. 360-383, Mar 2020. DOI: https://doi.org/10.1123/jpah.2019-0088

[6] D. Y. Kim, I. H. Hwang, S. H. Jeon, Y. H. Bae, and N. H. Kim, Estimating algorithm of physical activity energy expenditure and physical activity intensity using a tri-axial accelerometer, Rehabilitation Engineering and Assistive Technology Society of Korea, Vol. 5, No. 1, pp. 27-33, Dec 2011.

[7] G. Wu et al, ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand, Journal of Biomechanics, Vol. 38, No. 5, pp. 981-992, May 2005. DOI: https://doi.org/10.1016/j.jbiomech.2004.05.042

[8] K. B. Lynch, and M. J. Bridle, Validity of the Jebsen-Taylor Hand Function Test in predicting activities of daily living, The Occupational Therapy Journal of Research, Vol. 9, No. 5, pp. 316-318, Sep 1989. DOI: https://doi.org/10.1177/153944928900900505

[9] P. Pan, M. A. Peshkin, J. E. Colgate, and K. M. Lynch, Static single-arm force generation with kinematic constraints, Journal of Neurophysiology, Vol. 93, No. 5, pp. 2752-2765, May 2005. DOI: 10.1152/jn.00799.2004

[10] A. Peljovich, Hand Reconstruction in Children with Spinal Cord Injury, Physical Medicine and Rehabilitaion Clinics of North America, Vol. 31, No. 3, pp. 471-498, Aug 2020. DOI: https://doi.org/10.1016/j.pmr.2020.04.008

[11] A. Buniya, A. H. Al-Timemy, A. Aldoori, and R. N. Khushaba, Analysis of Different Hand and Finger Grip Patterns using Surface Electromyography and Hand Dynamometry, Al-Khwarizmi Engineering Journal, Vol. 16, No.

2, pp. 14-23, Jun 2020. DOI: https://doi.org/10.22153/kej.2020.05.001
[12] M. Domalain, P. J. Evans, W. H. Seitz Jr, and Z. M. Li, Influence of Index Finger Proximal Interphalangeal Joint Arthrodesis on Precision Pinch Kinematics, The Journal of Hand Surgery, Vol. 36, No. 12, pp. 1944-1949, Dec 2011. DOI: https://doi.org/10.1016/j.jhsa.2011.09.010
[13] K. Feder, A. Majnemer, and A. Synnes, Handwriting: Current Trends in Occupational Therapy Practice, Canadian Journal of Occupational Therapy, Vol. 67, No. 3, pp. 197-204, Jun 2000. DOI: https://doi.org/10.1177/000841740006700313
[14] X. Li, W. He, C. Li, Y. C. Wang, B. A. Slavens, and P. Zhou, Motor unit number index examination in dominant and non-dominant hand muscles, Laterality, Vol. 20, No. 6, pp. 699-710, Jul 2015. DOI: https://doi.org/10.1080/1357650X.2015.1041971
[15] S. R. Min, Y. J. Jung, T. H. Yoon, N. H. Jung, and T. H. Kim, Comparison of Muscle Activity Between Handwriting and Touchscreen Use in Younger Adults and the Elderly, The Korea Contents Association, Vol.16, No. 1, pp. 57-64, Mar 2020. DOI: https://doi.org/10.5392/IJoC.2020.16.1.057
[16] R. Plamondon, A kinematic theory of rapid human movements, Biological cybernetics, Vol. 72, No. 4, pp. 295-307, Mar 1995. DOI: https://doi.org/10.1007/BF00202785
[17] A. R. E. Potgieser and B. M. de Jong, Different distal-proximal movement balances in right-and left-hand writing may hint at differential premotor cortex involvement, Human Movement Science, Vol. 30, No. 6, pp. 1072-1078, Dec 2011. DOI: https://doi.org/10.1016/j.humov.2011.02.005
[18] C. E. Lang, K. J. Waddell, J. W. Klaesner, and M. D. Bland, A method for quantifying upper limb performance in daily life using accelerometers, Journal of Visualized Experiments, Vol. 122, pp. 1-8, Apr 2017. DOI: https://doi.org/10.3791/55673
[19] H. U. Nam et al, Effect of Dominant Hand Paralysis on Quality of Life in Patients with Subacute Stroke, Annals of Rehabilitation Medicine, Vol. 38, No. 4, pp. 450-457, Aug 2014. DOI: https://doi.org/10.5535/arm.2014.38.4.450