Application of a tri-axial accelerometry-based portable motion recorder for the quantitative assessment of hippotherapy in children and adolescents with cerebral palsy

Tomoko Mutoh, BSc1)a, Tatsushi Mutoh, MD, DVM, PhD1, 2)a*, Makoto Takada, JD3), Misato Doumura, BSc4), Masayo Ihara, BSc4), Yasuyuki Taki, MD, PhD1), Hirokazu Tsubone, DVM, PhD5), Masahiro Ihara, MD, PhD6)

1) Department of Nuclear Medicine and Radiology, Institute of Development, Aging and Cancer, Tohoku University: 4-1 Seiryo-machi, Aoba-ku, Sendai 980-8575, Japan
2) Department of Surgical Neurology, Research Institute for Brain and Blood Vessels-AKITA, Japan
3) LSI Medience Corporation, Japan
4) Holistic Betterment and Wellness Through Riding PIROUETTE, Japan
5) Research Center for Food Safety, Graduate School of Agricultural and Life Sciences, The University of Tokyo, Japan
6) Teikyo University Faculty of Medical Technology, Japan

Abstract. [Purpose] This case series aims to evaluate the effects of hippotherapy on gait and balance ability of children and adolescents with cerebral palsy using quantitative parameters for physical activity. [Subjects and Methods] Three patients with gait disability as a sequela of cerebral palsy (one female and two males; age 5, 12, and 25 years old) were recruited. Participants received hippotherapy for 30 min once a week for 2 years. Gait parameters (step rate, step length, gait speed, mean acceleration, and horizontal/vertical displacement ratio) were measured using a portable motion recorder equipped with a tri-axial accelerometer attached to the waist before and after a 10-m walking test. [Results] There was a significant increase in step length between before and after a single hippotherapy session. Over the course of 2 year intervention, there was a significant increase in step rate, gait speed, step length, and mean acceleration and a significant improvement in horizontal/vertical displacement ratio. [Conclusion] The data suggest that quantitative parameters derived from a portable motion recorder can track both immediate and long-term changes in the walking ability of children and adolescents with cerebral palsy undergoing hippotherapy.

Key words: Cerebral palsy, Hippotherapy, Gait analysis

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INTRODUCTION

Cerebral palsy (CP) is a permanent motor disorder caused by a nonprogressive lesion that occurs in the immature brain1). Various movement and postural impairments can occur and can limit physical activity and daily life of children and adolescents with CP2).

Hippotherapy is thought to be a useful method for improving trunk balance and gait ability in children with CP. It is believed that improvements in balance and sensory integration are mediated by improvements in muscle tone and control of movement patterns caused by sitting on a horse1, 3). In recent years, the potential for hippotherapy to promote gross motor
function in children with CP of various functional levels has been demonstrated in randomized controlled trials\textsuperscript{5–8}. However, the scoring systems used in these trials can provide only a rough quantitative estimate of motor function\textsuperscript{9, 10}\textsuperscript{16, 17}, with a significant decrease from basal level detected at 2 years.

**RESULTS**

Characteristics of the participants are described in Table 1. In all participants, there was an improvement in GMFCS level after the 2-year intervention. There was a significant increase in step length between before and after a single hippotherapy session (Table 2). An improvement in horizontal and vertical displacement was recognized qualitatively by the symmetric reproducibility of the acceleration curve, with an increase in the amplitude of displacement after a single hippotherapy session (Fig. 1).

Over the course of the 2-year intervention, there was a gradual but significant increase in step rate, gait speed, step length, and mean acceleration (p<0.05). Step rate significantly increased from baseline to the 18-month time point, and this may have been related to an increase in gait speed and/or mean acceleration (Table 3). The horizontal/vertical displacement ratio gradually improved to close to the normal level (approximately 1.5 during normal gait)\textsuperscript{16, 17}, with a significant decrease from the baseline value detected at 2 years.

**DISCUSSION**

Hippotherapy is a form of physical, occupational, and speech therapy in which a therapist uses the characteristic movements of a horse to provide passive motor and sensory input to the patient in order to obtain functional improvements. Studies have shown improvements in motor function and sensory processing following hippotherapy in patients with a variety of neuromotor disabilities, developmental disorders, and skeletal impairments\textsuperscript{18}. This is the first case series to describe the...
clinical importance of quantitative assessment of gait and balance ability in tracking immediate and long-term effects related to hippotherapy in patients with CP.

Patients with CP have poorer balance ability than healthy subjects and thus have a higher risk of falls. Mobility declines with increasing age\textsuperscript{19}. A shorter step length and slower step rate in these patients can cause instability (e.g., reduced mean acceleration) and falls. By using the portable gait monitoring device, we have successfully recorded an increase in step length, indicating an improvement in balance control (Table 2 and Fig. 1). This means that, as the center of gravity moves during gait and causes instability, balance can be recovered from larger angles\textsuperscript{20}. An increase in gait speed can be regarded

Table 1. General characteristics of the subjects

| Participant | Age (years) | Gender | Diagnosis                              | GMFCS level before hippotherapy | GMFCS level after 1 year of hippotherapy | GMFCS level after 2 years of hippotherapy |
|-------------|-------------|--------|----------------------------------------|---------------------------------|------------------------------------------|------------------------------------------|
| Participant 1 | 5           | Male   | Spastic CP                            | III                             | II                                       | II                                       |
| Participant 2 | 12          | Female | Spastic CP                            | III                             | III                                      | II                                       |
| Participant 3 | 25          | Male   | Spastic CP with cognitive impairment  | IV                              | III                                      | II                                       |

CP: cerebral palsy; GMFCS: Gross Motor Function Classification System

Table 2. Comparison of gait and balance measurements before and after a hippotherapy session

| Measurement                                | Before | After |
|--------------------------------------------|--------|-------|
| Step rate (step/min)                       | 117 ± 17 | 119 ± 19 |
| Step length (cm)                           | 39 ± 11  | 42 ± 10* |
| Gait speed (m/min)                         | 45.9 ± 11.7 | 48.6 ± 12.2 |
| Mean acceleration (G)                      | 0.41 ± 0.08 | 0.44 ± 0.11 |
| Horizontal/vertical displacement ratio     | 2.6 ± 0.8  | 2.4 ± 0.8 |

Values are expressed as the mean ± SD and were measured at 6-month intervals until 24 months

* Significant difference from the value before hippotherapy \( (p<0.05) \)

Fig. 1. Representative data showing improvements in horizontal and vertical displacement after a hippotherapy session

Data are from participant 2 and were obtained 18 months after the start of the hippotherapy intervention. The left and right panels indicate vertical (Y-axis, vertical plane; X-axis, horizontal plane) and horizontal (Z-axis, anterior-posterior direction; X-axis, mediolateral direction) trunk displacement, respectively. Note the irregular trunk movement before the hippotherapy session (upper panels), and the improvements in symmetry, with reproducible figures-of-eight visible in the traces, after the hippotherapy session (lower panels).
as a response to control balance. Therefore, increases in step length and gait speed increase the ability to cope with the risk of falls when balance has been lost. We clearly demonstrated increased step length and balance control immediately after a single hippotherapy session, and a gradual improvement in all functional parameters over the course of the 2 years of hippotherapy. Beneficial effects of hippotherapy on gait parameters (except for balance indicators) have also been reported using a walkway-type gait analysis system (GAITRite, CIR Systems, Franklin, NJ, USA) in elderly patients with stroke. However, no other data is available with respect to clinical application of accelerometry-based handy motion detectors for quantitative gait assessment following hippotherapy.

In children with CP, the most rapid improvements in gross motor function occur during the first 4 years of life, with children reaching a plateau between 5 and 6 years, depending on the severity of their disability. In the present study, we observed significant improvements in GMFCS level after 1–2 years of hippotherapy (30 min, once a week) in three participants with a wide age range (2 to 25 years), supporting the beneficial effects of hippotherapy on gross motor function. Our results are consistent with a recent systematic review, suggesting that hippotherapy sessions of 30-min duration, once or twice a week for 8–10 weeks were correlated with positive effects on gross motor function in patients with CP aged 4 to 10 years. Although the device used to evaluate gait in the current study is simple to use and user-friendly, it cannot give in-depth quantitative details concerning how muscles activate or how acceleration converts into weight loads, but it can provide sufficient data to compare functional outcomes across time.

A limitation of this study is the small number of participants, which means that the results cannot be extrapolated to all types and severity levels of CP. In addition, the length of time over which the improvements in balance and gait abilities can be maintained after 2 years of hippotherapy is uncertain. These issues need to be examined in future studies with a larger sample size.

In conclusion, the quantitative evaluation of gait and balance parameters using the portable motion recorder can detect both immediate and long-term changes in the walking ability of individuals undergoing hippotherapy, and the results of the present study support the therapeutic benefits of hippotherapy in children and adolescents with CP.

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