HUMAN MOVEMENT
2010, vol. 11 (2), 114–118

KINEMATIC ANALYSIS OF SEATING MANEUVER: DIGITALIZATION OF MOVEMENT IN DAILY LIVING

doi:10.2478/v10038-010-0012-4

MAKI TAKEI [1, 2], HIDEKI SHIMIZU [1], MINORU HOSHIYAMA [1] *
[1] School of Health Sciences, Nagoya University, Nagoya, Japan
[2] School of Rehabilitation, Osaka Kawasaki Rehabilitation University, Osaka, Japan

ABSTRACT
Purpose. The objective of the present study was to digitally express a common daily movement of sitting down (seating maneuver), and to show an analytical example of normative indices of such a daily movement. **Basic procedures.** Sequential traces of moments and the center of pressure (COP) during the seating maneuver, approaching with steps to and sitting on a stool, were measured using two force plates, and we decided on normal ranges of parameters based on the vertical moment and lateral deviation of the COP. In addition to the normal data recorded from ten healthy subjects, a data set from a patient was plotted. **Main findings.** Normative indices to express the sequential movement were obtained. The patient showed abnormal values of the indices, which could be quantitative indicators to evaluate the normality and grade of abnormality. **Conclusions.** We introduced a method for the quantitative screening of a daily movement using force plates. The results showed normative values, and the method could be used to reveal abnormalities in a daily movement in a patient with mild movement disability.

Key words: force plate, sitting, pressure center, human

Introduction

The evaluation of basic movements in daily life is important to assess the disability level of patients, and devise a plan to support their daily living. Therapists evaluate ability and disability levels of patients employing various rating scales, such as the Barthel Index [1], Functional Independence Measure (FIM) [2], and International Classification of Functioning (ICF)-based assessment [3]. These scales are useful to understand the general condition of patients. However, for each movement, the range of variation in disability is marked. Although therapists observe and detect abnormal and disabled behaviors during each movement, it is not always easy to evaluate quantitative improvement/deterioration of the movement through visual observation. In addition, the reliability and variation in skill levels among therapists are marked [4–6].

In the present study, a common daily movement, sitting down on a stool (seating maneuver), was quantitatively measured and digitally expressed by representative indices. The values could be useful to evaluate to what extent movements deviate from the normal range, as well as to assess normal or abnormal behaviors. This is a pilot study to express a common daily movement by digitized indices and evaluate the movement. We assessed the seating maneuver to obtain indices for the movement in healthy subjects, and demonstrated abnormal patterns in a case showing disability.

We chose a sequential movement comprising the seating maneuver. Among various movements in daily life, the seating maneuver is a common movement at all ages. The maneuver included sequential movements, i.e., steps, turning, and sitting, which are basic components of body movements. To investigate the maneuver, two force plates (BP600900, AMTI, USA) were used. In addition to force plate recording, a 3-dimensional (3-D) movement analysis system (MAC 3D System, Motion Analysis, USA) was simultaneously employed to trace each subject's movements.

The main objective of the present study was not to analyze a daily movement, but to show that it was possible to express normal values of a daily movement. We proposed that abnormality in a daily movement could be detected on simple movement measurement using force plates. Such analysis could be potentially useful for screening the early stages of movement disorders on an annual health examination. Therefore, we generated a sample of representative kinematic indices to screen for abnormality in a daily movement. We did not analyze the 3-D data, but used them to trace the movement and identify movement components for the analyzed movement periods during the experimental maneuver.

* Corresponding author.

Material and methods

Subjects

Ten healthy volunteers (7 men and 3 women, aged 34.1 ± 12.4 years, range: 20–59 years) participated in the present study. The subjects had no history of neurological or orthopedic diseases. Written informed consent, based on the Declaration of Helsinki [7], to participate in the study, which was first approved by the Ethical Committee of Nagoya University, School of Health Sciences, was obtained from all participants prior to commencing the study.

Force plate setting

Two force plates were positioned in parallel on the floor next to each other. The recording area of each force plate was 900 × 600 mm (width × length); thus, the total recording area was 900 × 1,200 mm. The floor was on a level with the front force plate, plate-1. The edge of the rear force plate, plate-2, was flush against plate-1 (Fig. 1).

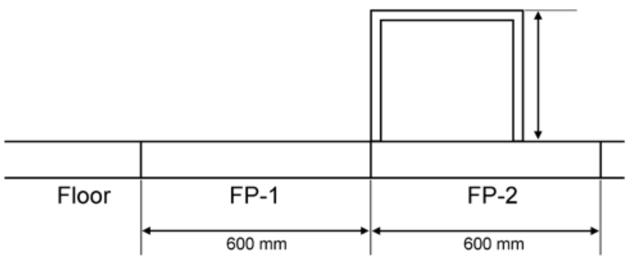

Figure 1. Placement of the two force plates and a stool. The subject approached the front force plate (FP-1) from the left side of the figure, and sat on the stool on the rear force plate (FP-2)

The force plates measured the orthogonal center of pressure (COP) along the X (anteroposterior) and Y (left and right) axes, vertical pressure (Z), and moment about three axes: Fx (anteroposterior), Fy (left and right), and Fz (vertical), producing a total of six outputs. The zero-point of the X-Y plane was the center of each force plate, and positive values showed on anterior and right direction for X and Y axes, respectively. Raw signals from the force plates were transferred via an analog-to-digital converter (National PCI-6071E) with a sampling rate of 120 Hz. All signals were collected online with software (EVaRT5.04).

A stool was fixed on force plate-2 with its two front legs placed at the front edge of the plate (Fig. 1). The stool was 43.0 cm high, with a seat area of 42.0 × 40.0 cm.

3-D movement analysis

The movement analysis system facilitated the recording of positions using up to thirty-five markers (Helen Hayes Set Marker) simultaneously along 3-D planes. The markers were attached to the subject's body, which enabled the monitoring of the 3-D movements of the subject's whole body and each body part. Fifteen markers were attached: top and back of the head, sacrum on the midline, and on the shoulder, elbow, wrist, knee, heel, and a toe on each side. Eight charge-coupled device (CCD) cameras (Eagle-4, NAC Image Technology, Tokyo, Japan) traced the positions of the markers. Raw signals from the kinematic system were transferred via an analog-to-digital converter (National PCI-6071E) with a sampling rate of 120 Hz. All signals were collected simultaneously with force plate recording online using software (EVaRT5.04).

Experimental design

Movement analysis involved the act of sitting on a stool (Fig. 1). The subjects stood 3 m away in front of the stool and were asked to approach it and sit on it in a natural way as they did in daily life. Thus, on the force plates, the movement of the subjects included the last step for approaching, turning, and sitting on the stool. Subjects repeated the seating maneuver ten times with a short rest after each maneuver.

Data analysis

Values from force plates

Since the objective of the present study was to express a daily movement using specific values, we first decided on a representative value obtained from the force plates. From the results of a preliminary study, we first chose the vertical direction of the force obtained from plate-1 and plate-2, Fz-1 and Fz-2, respectively, to express the movement. Although the Fz value depended on each subject's weight, the pattern of temporal change in the value was consistent among subjects, as shown in the results (Figs. 2 and 3).

The rising point of Fz-1 and Fz-2 was determined as the start of measurement, and the ten trials were averaged in each subject. For averaged waveforms, we defined values as follows:

Fz-1 from force plate-1 showed two major peaks in all subjects, and four phases of Fz-1 in its temporal change during the seating maneuver were identified. They were the onset to the initial peak (period-b), from the initial to the second peak (period-c), from the second peak to the following deflection (period-d), and from the second peak to the endpoint (period-e) (Fig. 3). The

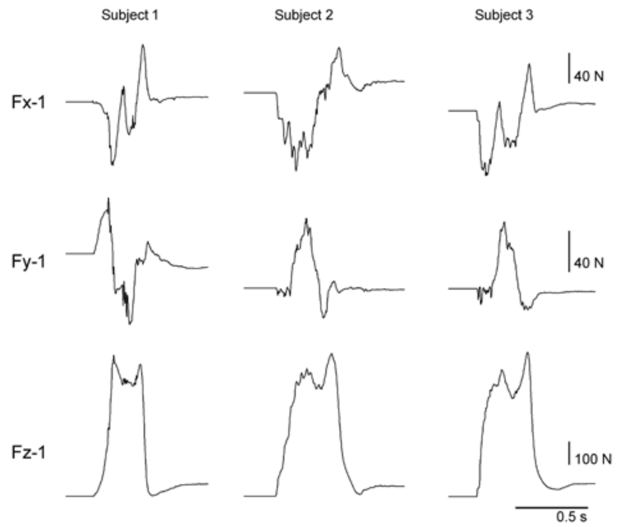

Figure 2. Averaged traces of moments recorded from force plate-1. Traces for three subjects are presented. There was a difference in the waveform of anteroposterior (Fx-1) and lateral (Fy-1) direction moments among the subjects, while vertical moment (Fz-1) showed relatively constant waveforms with two major upward peaks

Figure 3. Averaged traces of moments recorded from force plate-2. Traces for three subjects are presented as in Fig. 2. There was a difference in the waveform of anteroposterior (Fx-2) and lateral (Fy-2) direction moments among the subjects, while vertical (Fz-2) moment also showed relatively constant waveforms with two major upward peaks

values of the periods were divided by the total period of the phases, i.e., from the onset to endpoint (period-a), to obtain standardized values, %-b, %-c, %-d, and %-e. Similarly, we determined two periods (period-g to -h) in Fz-2 obtained from force plate-2 (Fig. 3), and they were divided by period-f (Fig. 3) to obtain standardized values, %-g and %-h.

Another parameter we chose was the lateral deviation of the COP. The Y values obtained from each plate, Y-1 and Y-2, indicated the COP during the maneuver. Since the waveform of the Y value showed large inter-individual variation, we measured the maximal lateral deviation of COP during the maneuver. First, we decided on the baseline based on the plateau level of the latter part of the waveform. Excluding the initial lateral deviation caused by the first step, we measured values for the maximum lateral deviation of the COP to the left (YL-1 and YL-2) and right (YR-1 and YR-2) for Y-1 and Y-2, respectively (Fig. 4). The total lateral deviation of the COP (YD), i.e., YD-1 = YL-1 + YR-1, YD-2 = YL-1 + YR-1, was also measured. From the 3-D motion monitor, each period corresponded to the movement components during the seating maneuver, as shown in Table 1.

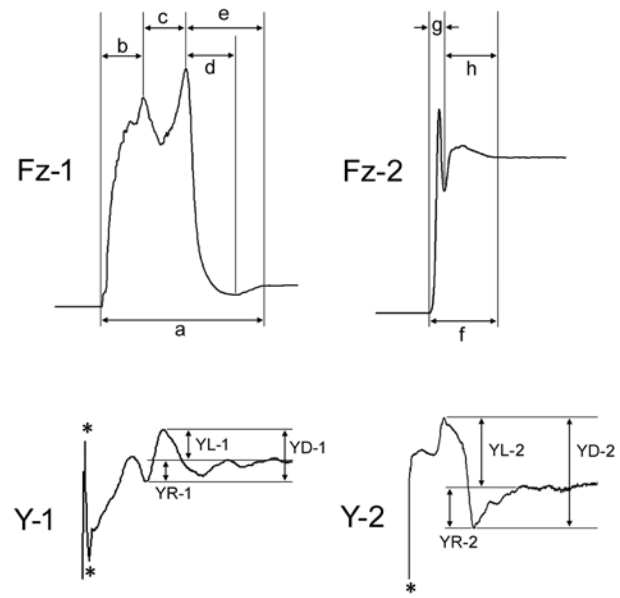

Figure 4. Definition of the analyzed values obtained from the force plates (see text and Table 1). For lateral deviation of the center of pressure (Y) and vertical moment (Fz) recorded from the front force plate, FP-1, (Y-1 and Fz-1) and the rear force plate, FP-2, (Y-2 and Fz-2) values, the initial lateral deviation of the center of pressure caused by the initial step (*) was excluded

Table 1. Movement periods and components during the seating maneuver

Period	Movement component during seating maneuver.
Period-b	From putting a foot on plate-1 and moving forward until turning.
Period-c	From the beginning of turning the body until bending the knees.
Period-d and -g	From bending the knees until contacting the stool.
Period-e and -h	From contacting the stool until a fully seated position.

Case report

We recorded kinematic values in a case showing disability in daily movement. The case was a 54-year-old male who had suffered from polio-myelitis in childhood. He showed mild weakness in the right leg muscles innervated by L3-S1. He did not require any support for daily living, and could perform most movements independently in his daily life. However, his motor performance was somewhat abnormal and unstable in each movement. The values recorded from the patient were compared with data from the normal subjects by employing the one-sample t-test.

Results

All subjects performed the sequential seating maneuver. Total periods of movement recorded from the force plates, i.e., period-a and period-h, were 377.5 ± 113.0 and 170.0 ± 49.6 ms, respectively. The standardized values of the periods are shown in Figure 5.

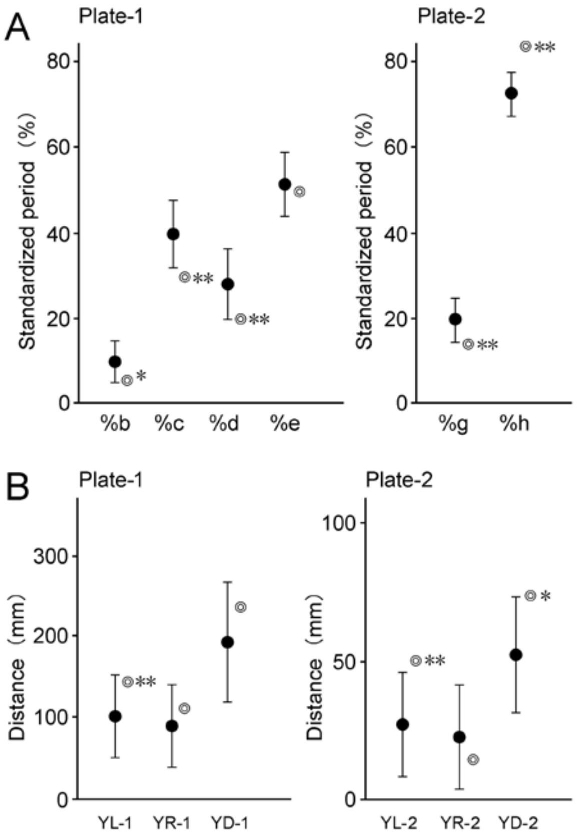

Figure 5. Standardized periods of movement components (A) and lateral deviation of the center of pressure (B). Vertical bars indicate standard deviations. Refer to the text and Fig. 4 for abbreviations. Values for the patient were plotted (◎), showing a significant difference from the range in normal subjects (* $p < 0.03$, ** $p < 0.01$)

The lateral deviation during the movement is also presented in Figure 5. Data obtained from the patient are plotted in Figure 5. There was no significant difference in the values of %-e, YL-1, YD-1, and YL-2. However, other values were out of the range of the normal subjects, showing a significant difference ($p < 0.05$).

Discussion

We measured kinematic values during sitting on a stool using two force plates. We chose two factors from recorded values, Fz and Y, which expressed the components of the movement. Although the selection of factors is variable, the present study demonstrated a strategy to evaluate a sequential daily movement.

There are several ways to observe and evaluate a sequential movement. The time required to complete a movement is the most simple and conventional method to evaluate disability. However, the time to perform a movement depends on the effort of the subjects, and the same time does not always indicate the same level of ability to perform a movement [8]. Healthy subjects are easily able to perform such a movement, while persons with disabilities may require a marked effort to complete time-restricted movements. Recently, 3-D monitoring and electromyographic (EMG) techniques to analyze sequential movements have become popular in the field of kinesiology. Previous studies analyzed normative and pathological conditions in daily movements in detail, such as gait [9–12]. However, most of the kinematic and neurophysiological techniques, such as EMG, 3-D motion analysis, and arthrokinematic studies, are usually complex in terms of preparation and analysis, although these techniques are certainly powerful to analyze components of movements. On the other hand, as mentioned in Introduction, several rating scales to evaluate the general condition of patients are not suitable to express disability in a movement.

In the present study, we used data from force plates to digitize a movement. One of the most important advantages of force plate recording is that there is no requirement for subjects to measure the movement, but just perform the movement on the plates. We also used a 3-D movement analysis system to trace the movement, but a 3-D monitor analysis was not essential to define the force plate values to be analyzed. It was important to identify a sequential pattern of values, which could be recorded consistently in the subjects during a movement, as the Fz value in the present study.

An important finding in the present study was that the digitized value could indicate the "normality" of a movement. When we see a patient showing a somewhat abnormal movement on sitting, it may not be easy to point out how and what is abnormal about it. In addition, the evaluation of normality may vary among investigators [4–6]. Distinguishing between normal and pathologic movements is often difficult, and it is not easy to decide what is normal for a daily movement [13]. In fact, it is not rare in clinical situations for a patient to think his/her movement is impaired, while the investigator judges the movement to be within the normal range. Thus, we considered it important to identify simple and reliable digitized values to evaluate the normality of a movement. We think that the test movement should not be an experimental but a natural movement performed in daily life, since patients do not feel disabilities in movements in a laboratory but in their daily lives.

The method in the present study facilitates the quantitative expression of the normality of a daily movement. Since the method involved several indices, they may be applied to identify minor movement abnormalities in the early stage of diseases, as well as to evaluate improvement in a movement during rehabilitation. We considered that a combination of simple indices for screening with further kinematic studies for detailed examination would be practically useful.

We conclude that this pilot study successfully introduced a method for the screening of a daily movement using force plates. Our results showed normative values, facilitating the identification of abnormality in a daily movement performed by patients with mild movement disability.

References

1. Sainsbury A., Seebass G., Bansal A., Young J.B., Reliability of the Barthel Index when used with older people. *Age Ageing*, 2005, 34, 228–232. doi:10.1093/ageing/afi063.
2. Gabbe B.J., Sutherland A.M., Wolfe R., Williamson O.D., Cameron P.A., Can the modified functional independence measure be reliably obtained from the patient medical record by different raters? *J Trauma*, 2007, 63, 1374–1379. doi:10.1097/01.ta.0000240481.55341.38.
3. Farin E., Fleitz A., Frey C., Psychometric properties of an International Classification of Functioning, Disability and Health (ICF)-oriented, adaptive questionnaire for the assessment of mobility, self-care and domestic life. *J Rehabil Med*, 2007, 39, 537–546. doi:10.2340/16501977-0083.
4. Swinkels R.A., Oostendorp R.A., Bouter L.M., Which are the best instruments for measuring disabilities in gait and gait-related activities in patients with rheumatic disorders. *Clin Exp Rheumatol*, 2004, 22, 25–33.
5. Spanjer J., Krol B., Brouwer S., Groothoff J.W., Inter-rater reliability in disability assessment based on a semi-structured interview report. *Disabil Rehabil*, 2008, 30, 1885–1890. doi:10.1080/09638280701688185.
6. Quinn T.J., Dawson J., Walters M.R., Lees K.R., Exploring the reliability of the modified Rankin Scale. *Stroke*, 2009, 40, 762–766. doi:10.1161/STROKEAHA.108.522516.
7. Rickham P.P., Human Experimentation. Code of ethics of the world medical association. Declaration of Helsinki. *Br Med J*, 1964, 18 (5402), 177.
8. Graham J.E., Ostir G.V., Fisher S.R., Ottenbacher K.J., Assessing walking speed in clinical research: a systematic review. *J Eval Clin Pract*, 2008, 14, 552–562. doi:10.1111/j.1365-2753.2007.00917.x.
9. Hreljac A., Marshall R.N., Algorithms to determine event timing during normal walking using kinematic data. *J Biomech*, 2000, 33, 783–786.
10. Watelain E., Barbier F., Allard P., Thevenon A., Angué J.C., Gait pattern classification of healthy elderly men based on biomechanical data. *Arch Phys Med Rehabil*, 2000, 81, 579–586. doi:10.1053/mr.2000.4415.
11. Chester V.L., Biden E.N., Tingley M., Gait analysis. *Biomed Instrum Technol*, 2005, 39, 64–74.
12. Hodgins D., The importance of measuring human gait. *Med Device Technol*, 2008, 42, 44–47.
13. Lim M.R., Huang R.C., Wu A., Girardi F.P., Cammisa F.P. Jr., Evaluation of the elderly patient with an abnormal gait. *J Am Acad Orthop Surg*, 2007, 15, 107–117.

Paper received by the Editors: August 25, 2009.
Paper accepted for the publication: February 24, 2010.

Address for correspondence
Minoru Hoshiyama Ph.D. Professor
School of Health Sciences, Nagoya University
1-1-20 Daiko-minami, Higashi-ku
Nagoya 461-8673, Japan
e-mail: hosiyama@met.nagoya-u.ac.jp